



ITS

***INVENTING THE
FUTURE OF MOBILITY***

*Institute of Transportation Studies
University of California, Berkeley*

```

33     """create geojson LineString features f
34     generated in data_import.py"""
35     out = ''
36     out += begin
37     for user_id in df.index.levels[0][: -1]:
38         out += extract_one_trajectory(df, u
39         out += end_prop(True)
40     out += extract_one_trajectory(df, df.in
41     out += end_prop(False)
42     return out
43
44
45 def extract_one_trajectory(df, user_id, cal
46     """create geojson LineString features f
47     generated in data_import.py"""
48     print 'convert trajectory for user {} t
49     out = ''
50     if not called_by_extract_all_trajectory
51     out += begin_feature("LineString")
52     length, duration = 0., 0.
53     for i in range(len(df.loc[user_id])):
54         row = df.loc[user_id].loc[i]
55         if i > 0:
56             length += row['dist_to_prev']
57             duration += row['time_to_prev']
58         out += coord(row['lat'], row['lon']
59     out += begin_prop
60     out += prop('distance', length)
61     out += prop('duration', duration)
62     out += prop('user_id', user_id)

```

***INVENTING THE
FUTURE OF MOBILITY***

*Institute of Transportation Studies
University of California, Berkeley
Decadal Report, 2005–2015*

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Map: Estimated afternoon peak bicycle volumes in San Francisco. In order to evaluate bicycling risk, ITS researchers fused information from the Metropolitan Transportation Commission's regional travel demand model, the bike-trip crowdsourcing application Strava, Bay Area Bikeshare, and on-the-ground traffic counts. Courtesy of SafeTREC graduate student Frank Proulx



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PREFACE



“As California goes, so goes the nation.” The political aphorism coined for New Hampshire’s election influence has long been adapted to recognize the nation’s most populace state for our innovative spirit and unflagging leadership. In today’s global society, California’s influence is felt not just the by nation, but across the world, from agricultural exports valued at

more than \$21 billion to technology born here that travels across borders at light-speed. The state’s aggressive greenhouse gas emission standards have impacts far beyond U.S. borders, as models for aggressive and effective action.

Changing that aphorism to “how California goes, so goes the world” alludes to a key component of our vision and leadership. From moving food to technology to people, efficient and sustainable transportation is central to keeping our economy healthy and productive. California’s revolutionary vision recognizes this critical relationship, with support for clean-energy vehicles and infrastructure, as well as for the research that supports these endeavors. Moreover, our technology boom’s ever-growing mobility sector is reinventing the very notion of transport.

The University of California’s flagship campus has a long and distinguished record of working with the state to address changes and challenges in the transportation sector. With our state’s broad and far-reaching influence, UC Berkeley’s research contributions to advancing mobility have been constant, and with today’s complexity of technology and the growing interaction between disciplines, they have never been more relevant.

Congressman Mark DeSaulnier





PARIS

The Institute

CHANCELLOR'S MESSAGE



The study of transportation has come a long way from its start as an engineering discipline. Today, what is known as the mobility sector is associated with numerous fields of study and has an impact on just about every facet of modern society. Yet, even in today's interconnected, interdisciplinary world, an engineer's pragmatism remains the essence of the field. "Engineering is the art or science of making practical application of the knowledge of pure sciences," author Samuel Florman said in his 1976 book, *The Existential Pleasures of Engineering*.

UC Berkeley is uniquely positioned to bring both the art and science of engineering — and many other disciplines — to bear on the practical challenges and opportunities we face in this arena. Transportation accounts for close to one-third of global greenhouse gas emissions. There are public health issues pertaining to air quality as well as to safety for pedestrians, cyclists, and motorists. The economy at the local, national, and global level is dependent on both goods movement and human mobility to flourish. And, as people move to cities in unprecedented numbers, the impacts on the transportation system multiply as gridlock increases and infrastructure ages.

One of this University's defining attributes is our shared interest in and commitment to building a better, more sustainable future. That ethos is amplified when it is joined with Berkeley's academic excellence and an atmosphere that fosters innovation across the disciplines. The Institute of Transportation Studies' ability to tap into and harness all that Berkeley has to offer is what enables it to lead the way in addressing the rapidly evolving challenges in the 21st century mobility sector. I am looking forward to the next decade of the Institute's work and its contributions to the greater good.

Nicholas B. Dirks

Chancellor, University of California, Berkeley
Professor of History
Professor of Anthropology

UC Berkeley campus skyline

Photo: Courtesy of the Atkinson Photographic Archive

Previous page: Pedestrian traffic flow
on the UC Berkeley campus

Photo illustration: Courtesy of Paul Kirchner Studios



DIRECTOR'S MESSAGE



It is a privilege to assemble the first book about the Institute of Transportation Studies (ITS) since it began operations in 1948. The Institute's history, leadership, and administration are covered in some of the pages that follow, but the goal of this decadal report is mainly to look at the future of transportation through the various initiatives currently under way at ITS, and to present our vision for helping society address the transportation challenges of the 21st century.

The Institute is UC Berkeley's transportation nucleus. Collectively, our faculty, research centers, projects, programs, initiatives, groups, seminars, alumni, and students have made a permanent impact on the mobility sector. Numerous technologies now in common use were born here, including bridge-ramp metering schemes in the 1970s, platooned and automated cars in the 1990s, and GPS-enabled traffic information smartphone apps in the 2000s.

Today, our numerous, increasingly interwoven fields of study address contemporary challenges — safety, energy consumption, an aging infrastructure, and a lack of reliability, resilience, and sustainability — in our systems. As an institution that spans nine departments and four colleges within UC Berkeley and two divisions at the Lawrence Berkeley National Laboratory, ITS is a unique environment where the entire pipeline from science and technology inception to deployment can be brought to bear on these challenges, working directly with transportation practitioners and the worlds of policy and governance in which they must function. Our researchers work in a wide range of fields, including robotics and machine learning, behavioral economics, policy, and urban planning.

To effectively harness that expertise, our plan for the future focuses on four growth areas that will allow us to advance the knowledge base in key fields such as self-driving cars, airspace governance for the coming drone revolution, and a clean-energy infrastructure. With our mission of service to the state of California, and with our San Francisco Bay Area location — ground zero for the extraordinary data-rich, technologically advanced era in which we live — ITS aims to be the inventor of the smart cities of tomorrow, contributing to an always more efficient and sustainable transportation system.

Alexandre M. Bayen

Director, Institute of Transportation Studies
Liao-Cho Innovation Chair, College of Engineering
Professor of Civil and Environmental Engineering
Professor of Electrical Engineering and Computer Science



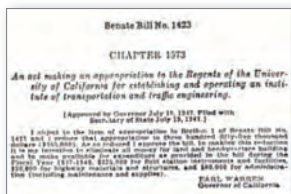
A BRIEF HISTORY



In the aftermath of World War II and years of fuel rationing, America was on the move. People were buying cars, the population was shifting from urban to suburban, trucks were becoming a more common way to transport goods, and air travel was on the rise. Yet the highways and runways to accommodate these changes, and the trained professionals to plan and design them, were lacking. California's economy and populace were rapidly expanding, and the war had left the state's roads with years of deferred maintenance.

In response to the lack of transportation investment during the war years, the state legislature approved Senate Bill 1423 in 1947 to establish the Institute of Transportation and Traffic Engineering at the University of California, now known as the UC Berkeley Institute of Transportation Studies (ITS). With a starting budget of \$710,000, UC Berkeley President Robert Sproul asked Harmer E. Davis, a Berkeley professor of civil engineering and well-known transportation policy expert, to establish the new organization, the first of its kind to address the interdisciplinary nature of transportation. This then-novel approach still frames ITS's philosophy of recognizing the complex interplay of disciplines — including engineering, the physical sciences, social sciences, and humanities — in addressing transportation problems and solutions.

The fledgling teaching and research institute offered a robust academic program that included undergraduate, master's, and doctoral programs, eventually focusing on graduate programs. From the beginning, the Institute has maintained close ties with the California Department of Transportation, or Caltrans, and over the years has trained many engineers who went on to work for the state.



California state legislature approves SB 1423 to establish the Institute of Transportation and Traffic Engineering.

Harmer E. Davis is appointed the first director.

Soil Mechanics and Bituminous Materials Laboratory was established at the Richmond Field Station to develop pavement technology. The Asphalt Research Program resulted from a Strategic Highway Research Program, and in 1994, Caltrans supported the launch of the Pavement Research Center.

ITTE is renamed Institute of Transportation Studies to reflect a broader approach encompassing multi-modal transport, energy sources, environmental impacts, and new technologies that are reshaping traffic control, safety, and transportation.

PATH, created to research and develop technological solutions to improve traffic flow and safety, has pioneered Intelligent Transportation Systems solutions such as automated and connected vehicles, traffic detection systems, and wireless communications.



The National Center of Excellence in Aviation Operations Research, or NEXTOR, a multi-university consortium headquartered at UC Berkeley, is launched.

1947

1948

1954

1973

1976

1983

1986

1988

1996

1997

Over 1,000 people enroll in the new Extension Program, which provides professional development and ongoing training in the developing field of traffic engineering.

Founding librarian Beverly Hickok (right, with Harmer E. Davis and assistant Norene Jordan) begins growing the nation's first comprehensive transportation library, renamed Harmer E. Davis Transportation Library in 1996.



Harmer E. Davis retires. William L. Garrison is appointed director.



Extension Program renamed Technology Transfer Program, reflecting the broader range of challenges and innovations that the transportation workforce faces.

Adib Kanafani becomes director, after serving as acting director since 1981.



U.S. DOT headquarters the multi-campus University of California Transportation Center at UC Berkeley.

PATH's pioneering connected-automated vehicle research culminates with a demo of eight automated, platooned cars on I-15 in San Diego, launching the era of self-driving cars.





From its inception, the Institute has transformed transportation in California, the country, and the world. The early years of expanding the state's transportation network introduced advancements in lighting, skid-resistant pavement, runway design, accident-reducing signage, and vehicle safety. In the 1960s, the national highway program adopted the results from these California safety studies.

The late 20th century saw a waning of new road building and a growth of congestion, changing the 21st century focus to using innovative, technological solutions to make transportation smarter and broaden mobility options.

Today, ITS leads research advancements in alternative fuel vehicles, wireless networking, automated vehicles, computer science, urban data analysis, and geolocation to produce such innovations as real-time traffic monitoring, autonomous vehicles, intermodal coordination, and connected corridors to relieve congestion, increase safety, bring economic vitality to urban centers, and sustainably enhance mobility. Our faculty, researchers, and students are active in research that frames government policy, analyzes human behavior, and addresses infrastructure. Our alumni work around the world in industry, academia, and the public sector, contributing to the economies of California and the United States and leading the broad field of transportation across the globe.



The California Center for Innovative Transportation launches to accelerate deployment of Caltrans research results that

improve the safety and efficiency of surface transportation, such as a project on Highway 101 that used information to encourage drivers to switch to transit.

Martin Wachs is named director.



The Transportation Sustainability Research Center is established to study and foster the adoption of sustainable transportation fuels, innovative mobility strategies, and environmentally supportive policies.



Tech Transfer's Silicon Valley Innovation and Entrepreneurship Program, Learn2Launch, welcomes its first class.

ITS and Lawrence Berkeley National Laboratory (LBNL) jointly launch the Sustainable Transportation Initiative in cooperation with the Department of Energy.

1999 **2000** **2001** **2004** **2006** **2012** **2013** **2014** **2015** **2016**

Traffic Safety Center, now called SafeTREC, was established with a grant from the California Office of Traffic Safety to reduce transportation-related injuries and fatalities.



Volvo Research and Educational Foundations establishes the UC Berkeley Center for Future Urban Transport to study the interdependence of urban transportation policy and technology. Volvo completed its mission in 2012.



Samer Madanat becomes director after serving as acting director from 2002 to 2003.

U.S. DOT selects UC Berkeley to lead the consortium UCONNECT, a new University Transportation Center focusing on the connections between transportation, environmental sustainability, and the design of livable urban and suburban communities.

Alexandre Bayen becomes director.



ITS and LBNL jointly launch the Smart Cities Research Center.

LEADERSHIP PERSPECTIVES

Q&A with ITS Directors Past and Present



Alexandre Bayen

July 2014–present

Liao-Cho Innovation Chair, College of Engineering;

Professor, Civil and Environmental Engineering and Electrical Engineering and Computer Science

Top achievements during your tenure?

After one year, and looking ahead, one initiative I am very excited about is the new Smart Cities Research Center in the field of energy-efficient transportation (see page 54), to be launched in partnership with the Lawrence Berkeley National Laboratory (LBNL) — the first center to be jointly operated by our two organizations. LBNL has terrific potential in the field of transportation, and their expertise truly complements the assets of ITS, in particular in the fields of electrification grid–vehicle interaction, fuels, batteries, and GHG emission reduction. The Department of Energy has seeded the new center through a research and development grant. In addition, the new entrepreneurship programs within the Technology Transfer Program (see page 31) have grown steadily, raising ITS’s international profile and enabling the launch of several successful companies in the field of transportation and beyond.

Biggest organizational challenges?

In the context of shrinking budgets and tighter financial constraints, the diversification of funding for ITS becomes

a more pressing matter each day. This is a major financial sustainability problem we must address now by revisiting our core funding from California (unchanged since 1947) as well as our support from campus and the UC system.

Solutions?

Readjusting the state contribution is a top business priority for ITS, and we are including an inflation framework to protect future generations’ leaders from having to solve the same problem. In addition, we must change our strategic approach with the changing times. Thanks to previous leadership, ITS not only survived the global economic downturn, but we thrived. However, now that the world is changing again, we will be most effective by identifying and focusing on topics that have the most impact on the global transportation network (see page 58).

Biggest transportation challenges?

A few burning questions in the transportation landscape include: How will the sharing economy change demand management for mobility in large urban cities? How does urban data analytics enable researchers to reveal previously

unobservable, but suspected phenomena such as gentrification, inequities with relation to travel time and pricing, hyper-local contributions to GHG emissions, and robustness of the transportation network? How will electrification, automated driving, and connected vehicles change mobility, and at what scale?

Technology crystal ball?

The next big thing in transportation technology is the third dimension: drones, or UAVs — unmanned aerial vehicles. The time is not far off for pizza or mail delivery by UAVs to people’s skyscraper terraces and first aid by flying robots on the scene of accidents on freeways, and it will affect our lives in unprecedented ways. As mobility becomes automated, so will the logistics underlying our daily lives. The number of drones sold is already over 200,000 units per month, rapidly increasing, which will lead to a revolution in how aerial traffic needs to be managed.

Map: Data visualization from the Smart Cities Research Center’s SmartBay project, which shows multimodal transportation in real time



Samer Madanat

2005–2014; Acting Director, 2002–2003

Xenel Distinguished Professor, UC Berkeley; Dean of Engineering, New York University–Abu Dhabi

Top achievements during your tenure?

Three notable ITS achievements during my tenure are the 2006 establishment of the Transportation Sustainability Research Center (see page 38) in collaboration with the Energy and Resources Group; the 2005 establishment of the Volvo Center of Excellence on Future Urban Transport (see page 46), which was won after an international competition; and the 2009 establishment of the ITS Multi-campus Research Program on Transport Sustainability.

Biggest organizational challenges?

There was large dependence on funding from Caltrans and insufficient diversification of research funds. As the state budget situation worsened, leading to a reduction of available research funding, this jeopardized ITS's ability to maintain our usual level of research productivity. This also put our research staff, who are funded primarily on state contracts, in a stressful and uncertain environment.

Resolution?

We were successful in diversifying our research funds through winning grants from international foundations, the federal

government, and private sponsors. Furthermore, we managed to strengthen our partnership with Caltrans by restructuring some of our centers to align ITS research more closely with the state's mission and priorities.

Biggest transportation challenges?

Climate change is a challenge that touches on all aspects of transportation. In the United States, and especially California, transportation is a major emitter of CO₂, which places the onus on the transport industry to reduce its carbon footprint significantly. The consensus in the research community is that this should be done through three tracks:

- Improved vehicle fuel economy, or adoption of low-carbon fuel standards that necessitate a shift in the fleet toward electric vehicles (EVs)
- Improved freeway operation (for example, by better mitigating bottlenecks to reduce congestion) and better management of infrastructure, such as optimizing pavement resurfacing for GHG reduction benefits
- Increased urban density to reduce vehicle miles traveled (VMT) by cars and also enable a shift from low-occupancy vehicles to high-occupancy public transportation, thus further reducing VMT

Technology crystal ball?

I don't believe technology alone can solve the major problems in the field of transportation. For example, to effectively reduce transportation's carbon footprint as I outline above, most solutions require the use of existing technologies combined with policy regulation or market incentives, as well as transformation in the way we live — favoring higher density urban living with a reduced dependence on the automobile. One area where technology can play a role is in the development of better fuel cells to increase the range of hydrogen vehicles. Such advances still need to be combined with government investment in creating the fueling infrastructure to make EVs real alternatives to the combustion engine. This investment will be needed before the market share of alternative fuel vehicles can climb high enough to attract the private sector to invest in such infrastructure.



Martin Wachs

1999–2006

Distinguished Professor Emeritus, Civil and Environmental Engineering and City and Regional Planning, UC Berkeley; Distinguished Professor Emeritus, Urban Planning, UCLA

Top achievements during your tenure?

The establishment of SafeTREC — the Safe Transportation Research and Education Center, a multidisciplinary center in cooperation with the School of Public Health — was especially satisfying for me. Another major accomplishment was strengthening the transportation library. I also was particularly proud of our effort to strengthen ties between the Institute and academic departments in which there were curricular offerings in transportation.

Biggest organizational challenges?

The Institute had a rich history of accomplishment in traditional areas of transportation engineering, including pavement and traffic engineering. Prior directors had worked to broaden the mission of the Institute to include social

science analysis, the study of human behavior, and information technology as the nature of travel and transportation systems changed. My challenge was to continue to be strong in traditional areas, to remain loyal to our longstanding constituents around the state, and to broaden our programs in a time of budgetary reductions.

Resolution?

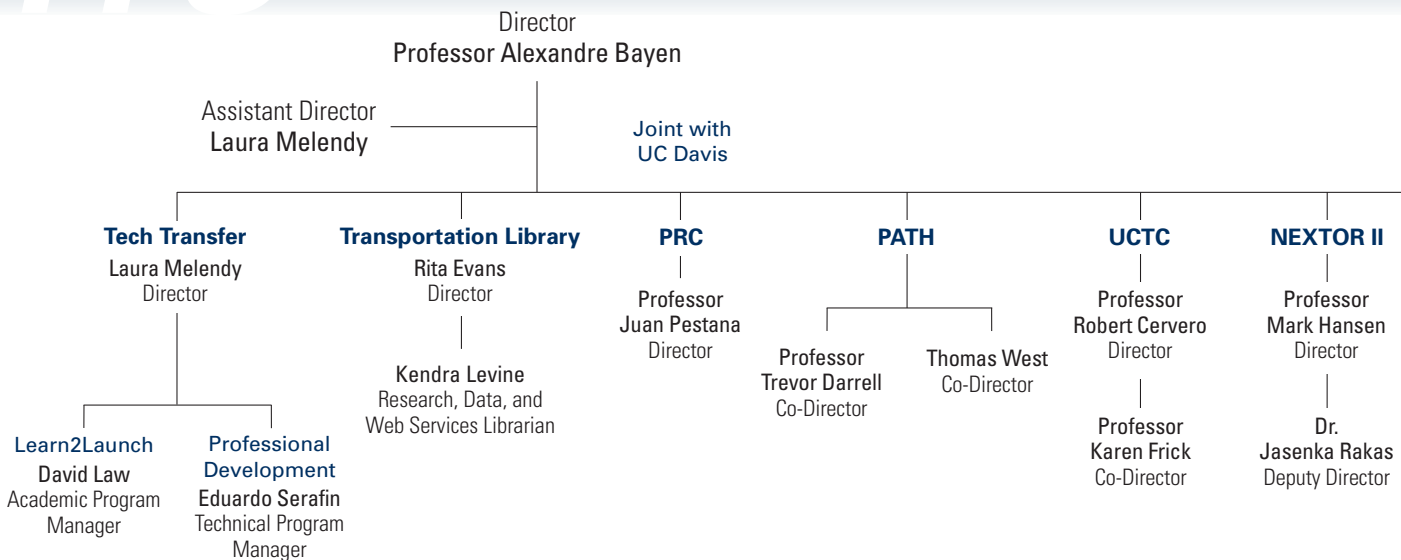
The challenges had intensified and the cost of the research enterprise was growing. While we accomplished a great deal, it was clear that the Institute had to specialize to a greater degree while reaching out to engage the larger university community more actively in transportation.

Biggest transportation issues now?

Transportation infrastructure is costly and needs to be entirely renewed to reflect the changing nature of travel and the changing technology by which it is produced. America has been unable to maintain its existing transportation systems, much less address their adaptation to the new technological realities.

Technology crystal ball?

While many see the biggest challenges to be technology, I think engineers are far more ready to advance technology than is our society ready to accept it into daily life. The greatest challenges relate to social and economic changes and governance that will enable us to use technology effectively to benefit society.





Adib Kanifani

1983–1997

E. G. & J. R. Cahill Professor of Civil Engineering Emeritus;
Professor of the Graduate School, Civil and Environmental Engineering

Top achievements during your tenure?

Probably the most profound achievement was the Institute's leadership in transforming the paradigm of transportation research along two dimensions: the introduction of automation in road transport, and the role of information technology in the use and performance of transportation systems. The PATH program (see page 36) was established in 1986 to lead the research in Intelligent Transportation Systems *avant le mot*.

Another achievement was the Institute's leadership in fostering the creation of centers of research excellence, which focused on important topics of interest in transportation and brought together a far broader group of faculty from around the campus than ever before. The creation of

NEXTOR (see page 52) with its focus on aviation and UCTC (see page 40) with its focus on planning and policy are just two examples from that period.

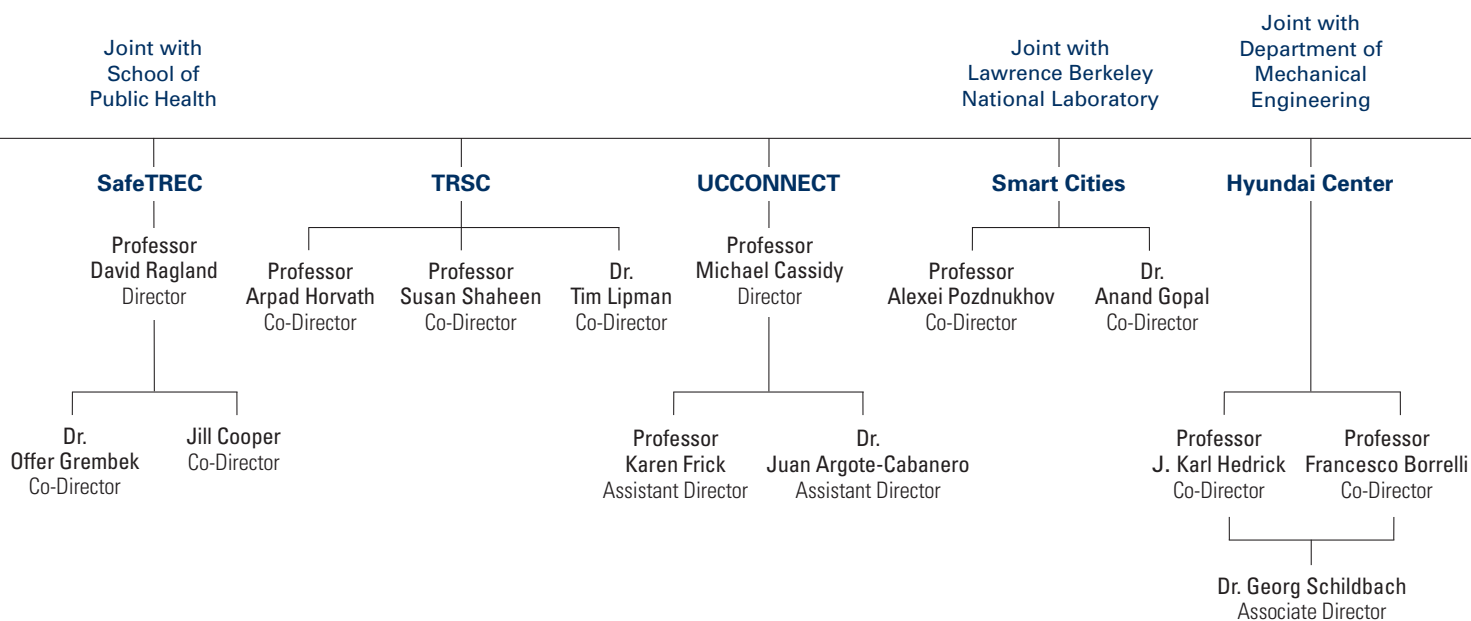
Biggest transportation issues now?

Transportation engineers represent but a segment of the ITS research landscape, which encompasses a broad community of scholars in the physical sciences, social sciences, and humanities. The biggest intellectual challenges are probably in this broader ecology of transportation, including societal and environmental concerns. The big challenges have been with us for decades — environmental impacts, safety, and equitable and efficient management of transportation systems. Automation and new forms of clean, renewable energy for transportation are

promising answers to these challenges, provided the political decision-making process does not stand in the way. Efficient management of transportation systems continues to be elusive. But the next big thing in transportation may be the solution.

Technology crystal ball?

I think that the big thing in transportation is the totally connected traveler and vehicle. The combination of total connectivity and personal-level computing and decision making will open up new avenues for efficient and equitable use of transportation resources and will enable new ways of life with a completely different meaning of mobility — a new mobility to access processes and services rather simply moving from place to place.



FINANCES

The many research initiatives and programs at the Institute of Transportation Studies are supported by a combination of funding that includes federal, state, and industry support, revenue generation, and gifts. The Institute's annual budget averages between \$20 and \$25 million and is growing.

SPONSORED RESEARCH

The Institute receives approximately \$20 million in sponsored research funding each year from federal, state, regional, and local governments, privately funded research foundations, and industry.

FEDERAL AGENCIES. Significant federal sponsors include the U.S. Departments of Transportation, Energy, and Defense, the National Aeronautics and Space Administration, and the National Science Foundation.

One important federal program for supporting faculty and graduate student research is the University Transportation Center (UTC) housed at UC Berkeley. The Institute has competed successfully for the Federal Region 9 University Transportation Center every four years since the inception of the program in 1988. To administer the University of California Transportation Center (see page 40), ITS has received up to \$3 million annually in federal funding, which has been fully matched by Caltrans funds. In addition, in 2015, ITS was awarded a new federally funded UTC: the Regional Center on Economic Competitiveness (see page 42), also with significant match from Caltrans.

STATE AGENCIES. Significant state agency sponsors include the California Department of Transportation (Caltrans), the California Energy Commission, the California Air Resources Board, and the California Office of Traffic Safety. Caltrans is the single largest state sponsor of research at ITS. This longstanding partnership between California's transportation operating agency and its largest public research university is one of the historic strengths in UC Berkeley's transportation research program.

PRIVATE SECTOR AND FOUNDATIONS. Industry and foundation sponsored-research partners span the automotive, mobility, information, and technology sectors (see page 28). Private sector companies sponsor research at ITS through a variety of mechanisms, including contracts, grants, partnerships, technology licensing, and monetary and in-kind donations. The Institute's industry partnerships include leading Silicon Valley companies involved in mobility and related technology, as well as international organizations working globally on transportation, such as airlines, infrastructure companies, and service providers.

UNIVERSITY OFFICE OF THE PRESIDENT. The University of California Multi-Campus Research Program includes UC Berkeley, UC Davis, UC Irvine, UCLA, UC Riverside, and UC Santa Barbara. The collaboration focuses the capabilities and efforts of dozens of UC faculty and researchers working on sustainable transportation, leading to rapid advances and major contributions — and similarly large leveraging of funds.



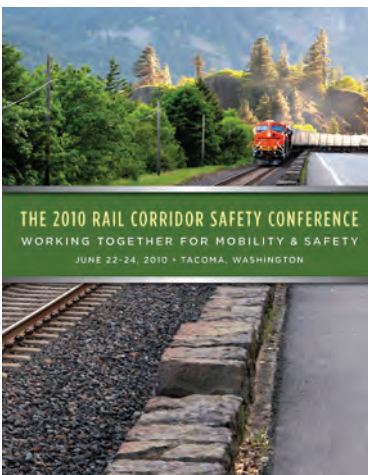
State capitol building in Sacramento, California



Toyota is one of many industry affiliates working with ITS researchers. Above: The company's first plug-in hybrid electric vehicles arrive at the Transportation Sustainability Research Center for a major study on driver behavior.

CORE FUNDING

ITS receives approximately \$700,000 per year of core, baseline funding from the state of California, provided by a line item in the budget. It is used to support administrative services, communications and outreach activities, weekly seminars, student activities, and the Transportation Library (see page 21).



Conferences and trainings like this 2010 rail conference support themselves through revenue generation while they contribute critical technology transfer across a variety of modes.

INDUSTRY AFFILIATE PROGRAMS

ITS has a long history of successful industry partnerships and affiliate programs. Numerous industries work with ITS as research partners, research sponsors, and donors (see page 28).

In late 2015, ITS launched its newest industry affiliates program, Berkeley DeepDrive (see page 29). This initiative, focused on deep learning for assisted and automated driving, is projected to generate \$1.2 million in its first year and up to \$3 million annually in future years.

REVENUE GENERATION

A number of the research units host conferences or workshops and generate revenues through participant registration fees. The Technology Transfer Program (see page 22) is by far the largest revenue-generating unit within ITS, producing over \$2 million in revenues each year from professional development, training, and conference activities, including its Learn2Launch entrepreneurship program (see page 31).

GIFTS

ITS research centers and the ITS Library together receive approximately \$800,000 per year in monetary and in-kind donations. Donors include automotive and energy companies, nonprofit foundations, and private individuals making personal contributions ranging from \$50 to tens of thousands of dollars.

Hyundai is providing financial support for graduate student researchers and has also provided vehicles for use in research. Left to right: Mechanical engineering professors J. Karl Hedrick and Francesco Borrelli, along with College of Engineering dean Shankar Sastry and Woongchul Yang of Hyundai, dedicate UC Berkeley's new Hyundai Center of Excellence.





COMMUNICATIONS AND OUTREACH

COMMUNICATION VEHICLES

ITS is committed to communicating with its students, faculty, and staff; the university community; transportation industry; federal, state, and other interested stakeholders; and the general public. Several channels are being used to reach these diverse audiences.

BERKELEY TRANSPORTATION LETTER. ITS's flagship communication is distributed to students, faculty and staff, industry and government leaders and partners, and alumni. It features stories about faculty, staff, students, and alumni who are making an impact on transportation. its.berkeley.edu/btl

DIRECTOR'S LETTER. The Director's Letter has traditionally gone out at the start of each semester to keep the ITS community connected and set the tone for the academic term; it is currently going out monthly to keep pace with exciting changes at the Institute. It highlights news, important events, initiatives, operations, and people.

WEBSITE. ITS's website is a vital tool that serves as a hub for news and events; faculty information and publications; and resources for faculty and staff. It's a portal to the Institute's research centers, a recruitment tool for students and faculty, and a connection to our social media channels.

SOCIAL MEDIA. ITS has a strong presence on social media through Facebook (/ITSBerkeley) and Twitter (@BerkeleyITS). These channels build community with photo-rich postings of campus events, seminars, students, ITS members, and alumni across the country and in the news. Our Facebook page is aimed primarily at creating an opportunity for alumni interaction, while Twitter is used as an outreach tool to connect with the broader transportation community in both the public and private sectors.

EVENTS. A weekly academic seminar features renowned faculty speakers from around the world lecturing on timely, relevant topics. ITS is also active at the Transportation Research Board Annual Meeting. In addition to the many presentations, committee positions, and leadership roles ITS takes on at this high-profile industry gathering, our annual reception brings together past, current, and future partners, colleagues, and students, helping to build lasting professional relationships.

Above: Media and transportation professionals crowd the press conference at the command center of the February 2008 Mobile Century field test.

MEDIA RELATIONS

Transportation research and expertise are central to the workings of society, so it's no surprise that ITS research findings have been featured in local, state, national and international news stories, and that our faculty are routinely sought after as expert commentators across numerous topic areas, including traffic-flow theory, pedestrian safety, carsharing, and automation. Just a few highlights of media coverage in the past decade are featured here.



Paul Brubaker, then-Administrator of the U.S. Department of Transportation's Research and Innovative Technology Administration, joined a 2008 press conference on Safe-Trip 21, a public-private partnership with UC Berkeley, the U.S. and California DOTs, and NAVTEQ that integrated two high-tech research efforts at ITS to advance gains in safety and efficiency. The event, held at the Bay Bridge in Oakland, California, drew media from around the Bay Area.

“The first- and last-mile problem has been growing steadily during the last 50 years as cities expanded. It’s often just too far to walk to a mass-transit station.”

“I think the question for now is, do they hold promise to achieve some of society’s social and environmental goals? I think they show strong potential.”

“These results suggest that the law banning handheld cellphone use while driving had a positive impact on reducing traffic fatalities and injuries.”

“The report is the most comprehensive so far on the true cost of flight delays because of the method used to calculate the costs. [It shows that the] ripple effects ... can be far worse for passengers.”

“[Our model shows] where people work, where they go for shopping, where they go for leisure, and how they choose to get there.”

City and regional planning professor emerita Elizabeth Deakin comments in a *New York Times* story about transit parking on July 13, 2012. ITS-affiliated faculty in urban and regional planning — including Deakin, Karen Frick, Daniel Chatman, and Robert Cervero — are frequently in the news as experts on major urban issues. Recent outlets include the *San Francisco Chronicle*, *The Economist*, and NPR.

TSRC co-director Susan Shaheen is quoted in an August 8, 2015 *Forbes* article on carsharing. Shaheen’s research results and expertise are sought across the media spectrum. The *New York Times*, *Time*, *National Geographic*, and *USA Today* are just a few of the national outlets where her comments have appeared.

SafeTREC director David Ragland remarks on his research results, covered in “PolitiCal,” a *Los Angeles Times* column and blog, on March 5, 2012. Ragland’s comments on traffic safety issues have appeared in numerous other outlets, including the PBS NewsHour, the *San Francisco Chronicle*, and Bay Area television.

NEXTOR II director Mark Hansen is quoted in a *Washington Post* story on a landmark FAA study he led about the true costs of flight delays. The story was picked up by the Associated Press and ran in newspapers around the United States and the world. Hansen’s aviation research has also been covered in the *The Economist* and Bay Area television.

Smart Cities Research Center co-director Alexei Pozdnukhov comments in an October 15, 2015 *Fortune* article covering the Connected Corridors collaboration between UC Berkeley, AT&T, and Caltrans.



This self-driving bus, on the first street test of a transit vehicle using an automated guidance system, was covered in a Wired article on September 9, 2008. The California PATH-based project, led by research engineer Wei-Bin Zhang, was featured in national media outlets, including several major television networks.

The ITS-based Mobile Century and Mobile Millennium projects were covered worldwide in thousands of media outlets, including Forbes, The Economist, Die Welt, Wired, New Scientist, and radio and television. Below: An ITS student (left) staffing the “tech bar” at the November 2008 Mobile Millennium software download event is filmed by a CNET news crew. Dan Work (right), the lead graduate student on the projects, earned numerous honors for his work, including the IEEE Intelligent Transportation Systems Society’s Best Dissertation Award, UCTC Student of the Year, and Eisenhower and Eno fellowships.



FACILITIES

The main offices of ITS are located on the first floor of McLaughlin Hall, a mainstay of the College of Engineering complex on the UC Berkeley campus. In addition, our affiliated research centers, faculty, and researchers have offices, labs, and facilities across campus, off campus in locations around Berkeley, at the Lawrence Berkeley National Laboratory, and at the Berkeley Global Campus at Richmond Bay (BGC), formerly called the Richmond Field Station.



Research engineer Angela Fan Liu runs the BGC-based Pavement Research Center's shear machine, which allows researchers to measure how pavement deforms — cracks and ruts — when a load is applied.



Left top: Sutardja Dai Hall opened in 2009 as the new home of CITRIS, the Center for Information Technology Research in the Interest of Society. The building houses numerous ITS-affiliated faculty, and CITRIS supports a variety of ITS research collaborations.
Left bottom: McLaughlin Hall

Above: The high-pressure hydrogen fueling station at the Transportation Sustainability Research Center, located at BGC, was the first in Northern California and serves numerous research projects and public agencies.

ITS'S LIBRARY GEM GOES VIRTUAL

Physical space and people — two valuable resources for any organization to conduct its business. In the past, ITS's transportation library used those resources to support the business of information services, building the collection to over 200,000 volumes to become one of the top two transportation libraries in the United States.

As the library science field has evolved with the digital age, ITS has modernized its library to increase access to information while decreasing costs and space demands. "We've shifted emphasis from the number of volumes we house to the information services we provide," said library director Rita Evans.

Research librarian Kendra Levine says librarians are now curators and guides for the ever-growing mass of data available online, helping students and researchers navigate the maze of terabytes to find information that is most accurate and most relevant to their work. "The present and future of libraries is data services," she says. Levine is leading the Institute's efforts to digitize the collection, create open access, manage data, and connect people and data.

Looking ahead, the library is focusing on using more specialized data and social media tools — like Web of Science and TRID, the Transport Research International Documentation database, which are purpose-built for librarians to share information — leveraging virtual "facilities" as it optimizes the limited physical space that is inherent in life at UC Berkeley. "These tools will yield information exponentially greater than what we could ever provide on our shelves," Levine says.



When librarians Kendra Levine (left) and Rita Evans assist researchers, they use more databases than books. But the transportation library in McLaughlin Hall continues to be the "living room of ITS," where students come to study and socialize.

"We've shifted emphasis from the number of volumes we house to the information services we provide."



THE TECHNOLOGY TRANSFER PROGRAM

MISSION: Prepare today's transportation workforce for tomorrow's challenges by providing training, workshops, conferences, and technical assistance in the transportation-related areas of planning and policy, traffic engineering, project development, infrastructure design and maintenance, safety, environmental issues, complete streets, multimodal transportation, railroad, and aviation.

The Technology Transfer Program was established in 1948 by the California Legislature to "extend" highway research generated at the UC Berkeley Institute of Transportation Studies to the California workers who designed, built, and maintained the state's transportation system. From 1948 to 1983, the program was known as "ITS Extension." In 1983, it was renamed the Technology Transfer Program, a change that signaled expansion to a broader range of activities supporting professional development.

Today the program is well established as California's source for transportation-related training for professionals and practitioners. The program has a robust communication network, reaching over 16,000 transportation professionals statewide. Tech Transfer hosts over 80 transportation-related training events annually, including live classes, distance learning, hosted training, seminars, symposia, workshops, and conferences. In 2014, more than 3,000 transportation professionals attended Tech Transfer events, and program staff visited more than two dozen local agencies to provide on-site technical assistance to improve traffic, pedestrian, and bicycle safety.

The Technology Transfer Program is fully self-supporting through a combination of sponsored projects, training contracts, grants, and revenue-generating activities. A full-time staff of seven and a team of over 100 faculty and affiliates provide instruction and technical expertise in all modes of transportation.

techtransfer.berkeley.edu

Above: ITS assistant director Laura Melendy also directs the Technology Transfer Program. Classes for Tech Transfer's Learn2Launch program are held in Hearst Mining Building on campus, pictured above.

CAPABILITIES

Course Development: Tech Transfer's team of highly specialized, highly qualified, in-house engineering and planning professionals lead the development of new courses for the public and customized training programs for agency clients. We closely track legislative, funding, and technical developments affecting transportation practice, and we engage a pool of more than 100 experts from academia, government, and industry to develop course materials and teach our classes.

Event Planning: Tech Transfer staff routinely host over 80 events each year, ranging from online short courses to one-to-four day classes held around the state, semester-long programs, and large international conferences with sponsors, exhibitors, and concurrent sessions. Capabilities include online registration and direct revenue capture, telephone customer service, event planning and logistics services for events large and small, and a full-time instructional designer and training coordinator specifically for online class delivery.

TRAINING HIGHLIGHTS

Standards, regulations, and technology advancements force change that people need to understand to do their jobs. Tech Transfer partners with government and industry to develop customized training for those workforces and convenes conferences to connect professionals with the latest knowledge — and with each other.

COURSE HIGHLIGHTS

- Multimodal Transportation Impact Analysis
- Adaptive Traffic Control Systems
- Complete Streets Planning and Design
- Multimodal Level-of-Service Analysis
- Traffic Flow Principles for Practitioners
- Funding and Programming Transportation Projects

STAPLES AND FUNDAMENTALS

- Traffic Engineering
- Geometric Design
- Airport Systems Planning and Design

Right: Jenny Smith manages Tech Transfer's online learning courses, which serve hundreds of students each year. This time- and cost-effective platform is conducted live, allowing for two-way, real-time communication between instructors and students, just like in the classroom.

CONFERENCES

- Shared Use Mobility Summit, 2013
- 19th International Symposium on Transportation and Traffic Theory, 2011
- International Conference on Pavement Preservation, 2010
- Western Regional Rail Corridor Safety Conference, 2005, 2006, 2008, 2010
- California Pavement Preservation Conference, 2006, 2007, 2008, 2009
- World Conference on Transportation Research, 2007



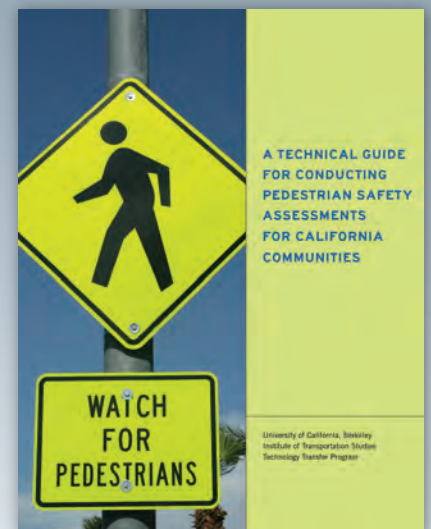
REACHING OUT ACROSS CALIFORNIA

Safety assessments have helped more than 300 California communities create safer, more thriving neighborhoods. The award-winning *Pedestrian Safety Assessment Guidebook*, and the program on which it is based, have been recognized as best practices at the local, regional, and national levels, including by the Institute of Transportation Engineers and the American Planning Association. *The Bicycle Safety Assessment Guidebook* and its program help communities improve bicycle safety, accessibility, and infrastructure.

Pavement Technology Updates describe practical applications of pavement technology innovations from the Pavement Research Center (see page 50). Launched in 2009 as a newsletter insert and funded by Caltrans, *Updates* are now distributed electronically.

Tech Transfer was a quarterly newsletter featuring timely articles on innovation, practical applications of research, and best practices relevant for transportation professionals. It was published through Spring 2011 and distributed to more than 18,000 readers in California and the United States through the Local Technical Assistance Program, with funding from the Federal Highway Administration and Caltrans.

Tech Topics was a periodical aimed at providing a link between innovative developments in technology and practical engineering applications. It was distributed as a newsletter supplement from 1998 to 2007.



ACADEMIC LEADERSHIP



The Institute of Transportation Studies is a research organization that comprises 35 faculty members from nine UC Berkeley academic departments or schools. Approximately 50 additional researchers are associated with the Institute and its various research centers or projects.

ACADEMIC DEPARTMENTS

- Civil and Environmental Engineering
- City and Regional Planning
- Energy and Resources Group
- Electrical Engineering and Computer Science
- Industrial Engineering and Operations Research
- Mechanical Engineering

SCHOOLS AND COLLEGES

- College of Engineering
- College of Environmental Design
- College of Natural Resources
- Goldman School of Public Policy
- Haas School of Business
- School of Public Health

LAWRENCE BERKELEY NATIONAL LABORATORY

- Energy Analysis and Environmental Impacts Division
- Energy Storage and Distributed Resources Division

HONORS

ITS faculty members have earned numerous academic, industry, and teaching honors for their research and mentorship. Among our ranks we proudly count six National Academy of Engineering members as well as fellows of the Institute of Electrical and Electronics Engineers (IEEE), the American Society of Civil Engineers, and the American Society of Mechanical Engineers (ASME). Our faculty includes six National Science Foundation (NSF) Faculty Early Career Development Program awards and two winners of the NSF's Presidential Early Career Award for Scientists and Engineers (PECASE). Transportation was both the impetus and the validation model for Berkeley economics professor Daniel McFadden's Nobel Prize-winning work in discrete choice modeling, and former Transportation Sustainability Research Center director Dan Kammen was part of the Nobel Prize-winning Intergovernmental Panel on Climate Change.

Our faculty have authored papers, articles, and books seminal to the advancement of transportation around the world. Publications over the past 10 years include more than 20 books, 40 book chapters, 300 conference papers, and 700 journal articles.

AWARDS

Faculty have received awards and prizes from professional societies, governments, industry, technology, and academia, including more than 20 "Best Paper" awards.

Just a few of the many distinctions include four Walter L. Huber Civil Engineering Research Prizes (Adib Kanifani, Juan Pestana, Arpad Horvath, and Alexandre Bayen), the Dale Prize for Excellence in Urban Planning (Robert Cervero), the Laudise Prize from the International Society for Industrial Ecology (Horvath), the Transportation Research Board's Francis X. McKelvey Award (Mark Hansen), the Robert Herman Lifetime Award in Transportation Science from the Institute for Operations Research and the Management Sciences (Carlos Daganzo), and the ASME Dynamic Systems and Controls Division's Charles Stark Draper Award for Innovative Practice (Steven Shladover) and Henry M. Paynter Outstanding Investigator Award (Roberto Horowitz).

ITS faculty members Joan Walker and Alexandre Bayen are both PECASE award recipients. Above: President Obama with the 2010 PECASE class. Official White House photo: Pete Souza

TRANSPORTATION THROUGH DIFFERENT LENSES

The ITS faculty is enormously diverse in what they study. We see this interdisciplinary approach as a strength and, in fact, a necessity to understanding the complexities of society's transportation challenges. The following research profiles highlight just a few faculty approaching transportation problems from different angles.



Q&A *Joan Walker: Travel Behavior*

Associate Professor, Civil and Environmental Engineering; Co-Director, Global Metropolitan Studies Initiative

PROBLEM: The future of shared, connected, autonomous, clean, app-driven vehicles and services promises to transform mobility. Yet over the coming decades, this evolution could play out in heaven or hell scenarios and anywhere in between. How travelers modify their behaviors in light of these new services is a critical ingredient driving outcomes. My work focuses on behavioral analysis approaches to model and influence travel behavior with an objective of developing tools to guide this transformation toward a more sustainable, efficient, and equitable system.

RESEARCH: I blend statistical models with behavioral models. Research has shown that softer variables such as attitudes and social influences are important drivers of behavior. However, incorporating such variables in statistical models for analysis and prediction has proven difficult and requires innovation in the methods, data collection, and behavioral formulations. For example, we have developed travel behavior models that focus on a higher-order modal orientation or travel lifestyle choice. That is, some people are going to drive no matter what, and others are more multimodal in their transportation decisions. This higher-level choice is most influential in determining the aggregate travel demand. Modality style is a natural concept that is very different from the structure of traditional travel demand models. Our modality style models have shown that in 2000, 42 percent of the San Francisco Bay Area's population exclusively considered driving. The good news is that we also found that this share has reduced to 22 percent in 2012.

WHAT'S NEXT: The quality and quantity of our data is steadily improving using the latest developments in mobile communications. We are working toward collecting data from individuals over longer periods of time to be able to model behavioral trends. We are working to understand the impact that services such as Zipcar, Uber, and Lyft have on modality styles, and are extending our methodologies to model the impact of autonomous vehicles. By better understanding the dynamics of such attitudes and behaviors, we expect to be more effective in planning and managing future transportation systems.

Q&A *Ruzena Bajcsy: Autonomous Driving*

NEC Distinguished Professorship; Professor, Electrical Engineering and Computer Science



Photo: Courtesy of CITRIS

PROBLEM: Humans interact with cyber-physical systems on a daily basis. Consider the use of smartphones, computers, monitoring systems at home, GPS systems in the car, and so on. Scenarios span many levels of complexity, from simple tasks of specific communication to complex dynamic interactions.

RESEARCH: We wish to understand the mechanics of these interactions and design algorithms for control-sharing between humans and autonomous systems while taking into consideration the physical (and cognitive) capabilities and constraints of an individual. This interaction is especially pertinent in driving situations when a human driver interacts with a semi- or fully autonomous car on the road. We must understand how the human driver communicates with a semi- or fully autonomous vehicle, i.e., how each informs the other about intentions, such as changing lanes and unexpected stopping. The critical part of these studies will be the guarantees of safety and the robustness of decision making under various environmental conditions, including road and weather conditions.

WHAT'S NEXT: Modeling of the dynamics and kinematic capabilities — the motion mechanics — of the human driver will be of utmost importance since those physical capabilities, together with cognitive abilities, will determine the reaction time of the driver, especially in stressful situations. By incorporating individualized models into the shared control, the decision-making algorithm can perform more robustly and adapt to the driving style of the individual.

Q&A *Robert Cervero: Sustainable Transportation Policy and Planning*

Carmel P. Friesen Chair in Urban Studies; Professor and Chair, Department of City and Regional Planning

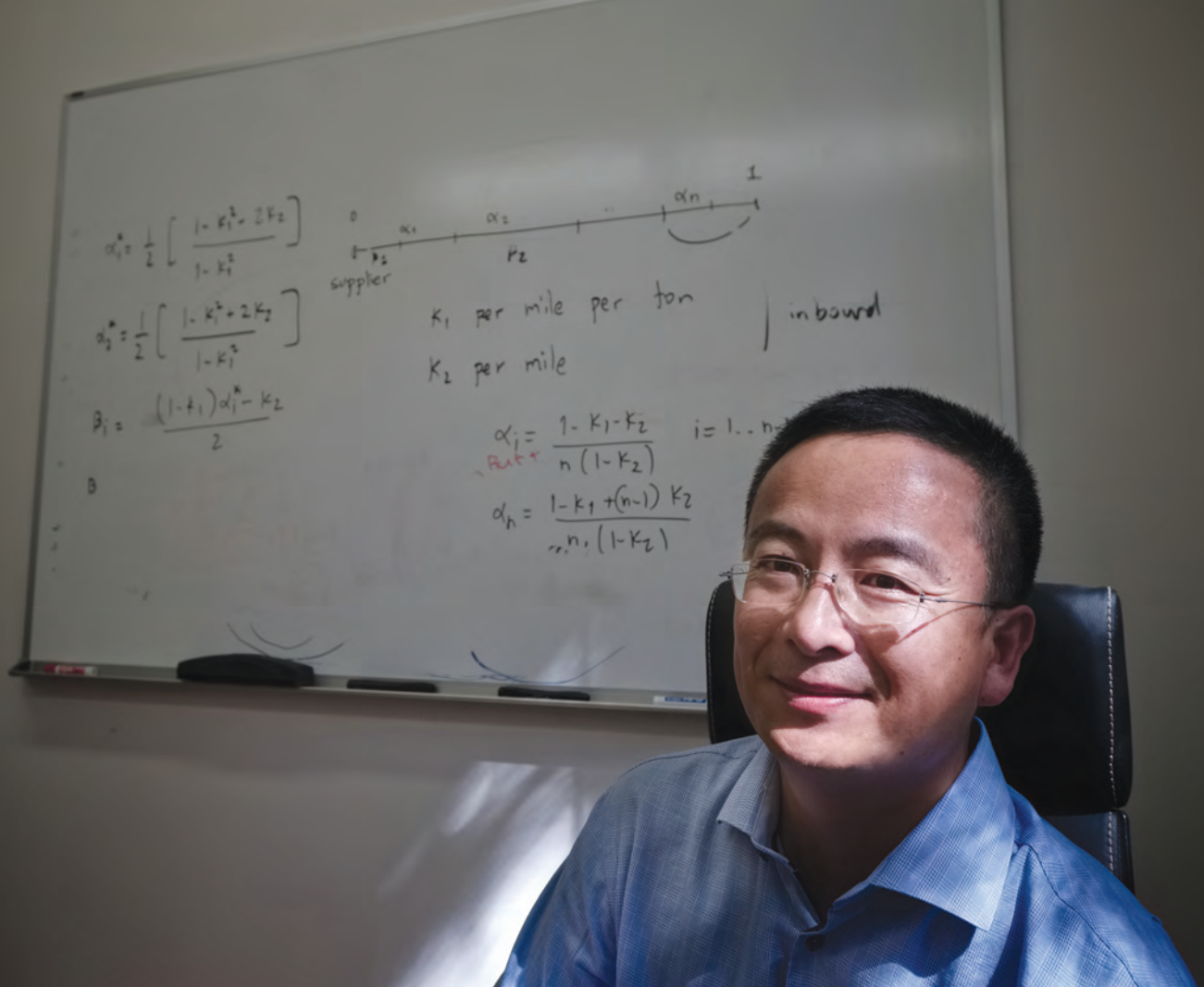


Photo: Courtesy of the College of Environmental Design

PROBLEM: The advancement of sustainable forms of mobility and urban development patterns that support them must strike a balance between mobility planning and place-making. This often requires adapting transportation programs and settlement patterns to shift more travel to green, active modes, such as cycling and walking. Related questions concern the service, institutional, and regulatory reforms needed to cost-effectively integrate “micro-transit” modes — such as minibuses, motorcycle taxis, three-wheelers, and ride-hail services — with bus rapid transit (BRT) investments, particularly in developing cities in the Global South.

RESEARCH: Mixed methods that draw from both quantitative modeling and qualitative case-based work are best suited to my research and, importantly, to communicating the results to policymakers and wider audiences. In addition to comparative case studies, I also often study land-market performance. Real-estate markets reflect the quality of urban environments as well as transportation services, in the form of rent premiums, rapid absorption of leasable space, and other performance indicators. Other work includes comparing statistics on changes in average travel time before and after coordinated microtransit-BRT service reforms, supplemented by case examples. I’ve also used detailed geo-referenced data to study the influences of network designs and various connectivity metrics on bicycle commuting.

WHAT'S NEXT: We’re all interested in what the future might hold with the introduction of self-driving, autonomous vehicles — in terms of transportation system performance but also larger societal concerns. Such technological advances raise a host of public-policy questions, such as needed reforms to parking codes to handle driverless cars seeking low-cost peripheral locations to park themselves. What interests me even more are how shifts toward the sharing and rating economies and “vehicle-sourcing” in general are giving rise to niche-market forms of urban mobility, such as dynamic rideshare services like Uberpool, route-deviation private minibus services such as Chariot in San Francisco, and even package-and-meal delivery services like Via. Diversification of travel choices is, on balance, a positive step given the increasingly heterogeneous nature of urban travel. What such niche-market services will mean in terms of future travel behavior, vehicle ownership patterns, and long-term costs of travel will keep transportation researchers busy for years to come.



Q&A Zuo-Jun Max Shen: EV Infrastructure

Chancellor's Professor, Industrial Engineering and Operations Research and Civil and Environmental Engineering

PROBLEM: The successful mass adoption of electric vehicles (EV) hinges on the accessibility of supporting infrastructure.

RESEARCH: I have been working on designing effective models and systems for the electric vehicle infrastructure industry, with the eventual goal of facilitating mass adoption of EVs and creating a sustainable green transportation sector. I am also very interested in public transportation system design and optimization.

My research focuses on the EV infrastructure industry from a logistics and economics angle, and on providing effective optimization models and systems that can be applied to assist complicated decision making, evaluate the effectiveness of policies, and provide real-time operations control. For example, cities need to know where to locate recharging stations to maximize their return on investment, so the dollars they spend installing the station support the most drivers both now and in the future. The more convenient and accessible the stations, the more EV use will spread, so good decisions are critical to the adoption process.

WHAT'S NEXT: To reduce greenhouse gas emissions and temper oil dependence in the transportation sector, EV sharing is a promising alternative for customers — that is, to drive EVs without ownership. Furthermore, thoughtful planning and implementation of public transportation systems, including high-speed rail and fleets of electric buses, will facilitate the revolution of a sustainable, green-transportation future.

PARTNERS

By its very nature, transportation research is collaborative. Mobility is an integral part of urban and regional activity that is subject to governance, dependent on private companies for invention and investment, and reliant on experienced practitioners to help mentor a new generation of professionals. The Institute works with countless partners from across the public and private sectors in our effort to advance the future of the transportation sector.

PUBLIC SECTOR

From running tests on public roads to conducting full-scale research operations, ITS works closely with governmental agencies at the local, state, regional, and federal levels. Here are just some of the agencies we've partnered with in recent years.

- AC Transit
- California Air Resources Board
- California Department of Transportation
- California Energy Commission
- California Office of Traffic Safety
- Centers for Disease Control
- Contra Costa Transportation Authority
- Defense Advanced Research Projects Agency
- Federal Aviation Administration
- Federal Highway Administration
- LA Metro
- Lane Transit (Eugene, Oregon)
- Metropolitan Transportation Commission (San Francisco Bay Area)
- NASA
- National Science Foundation
- San Diego Association of Governments
- San Francisco International Airport
- University California Office of the President
- Southern California Association of Governments
- U.S. Department of Defense
- U.S. Department of Energy
- U.S. Department of Transportation

PRIVATE INDUSTRY

Private companies are critical stakeholders in the fast-paced world of transportation-related technology and analytics advances. Partners include automotive, engineering, information, and technology companies.

- BMW
- Car2Go
- DaimlerChrysler
- Delta Airlines
- Dynatest
- Ericsson
- Ford
- General Motors
- Google
- HERE
- Honda
- Hyundai
- IBM
- INRIX
- ITERIS
- ITRI
- Mercedes Benz
- Microsoft
- NAVTEQ
- Nissan
- Nokia
- Parsons Brinckerhoff
- Peugeot
- Powertech Labs
- Renault
- Siemens
- Telenav
- Toyota
- Volvo
- VW/Audi
- Waze
- Zipcar



Above, left to right: SafeTrip-21 partners Gary Ritter of the U.S. Department of Transportation, Greg Larson of Caltrans, and Harry Voccola of NAVTEQ speak with Melanie Crotty of the Metropolitan Transportation Commission at the 2008 launch of the Mobile Millennium pilot. Left: A map of GPS probe data in San Francisco, collected through the pilot Mobile Millennium system, a SafeTrip-21-supported project.

NEXT-GEN DRIVING TECHNOLOGY: DEEP LEARNING

The success of automated driving technology hinges on rapid and accurate awareness of the surrounding environment to assess risk and anticipate people's behavior. The still-developing field of automotive perception is about to jump into the fast lane with the application of machine-learning technology called deep learning. Trevor Darrell, professor of electrical engineering and computer science and the new co-director of California PATH, has formed the PATH-based Berkeley DeepDrive Industry Consortium, a multidisciplinary research alliance focused on applying state-of-the-art computer vision and machine-learning technologies for automated and assisted driving systems.

"When computers can recognize their surroundings, it makes everything safer," says Darrell. "This research makes cars safer for people on the inside and for pedestrians on the outside." Darrell is an early leader in the field whose code Caffe is one of the most widely used deep-learning frameworks for vision and has been broadly adopted by major Internet companies, startups, and in academia. The consortium will focus on deep-learning research using minimal computation resources to quickly and accurately recognize pedestrians, anticipate pedestrian behavior, and detect and classify objects, surfaces, and signage. The group's emphasis will be on research, implementation, and real-world demonstrations.

In addition to PATH, the consortium includes faculty and researchers from the Department of Electrical Engineering and Computer Science, the Center for Information Technology Research in the Interest of Society, and the Berkeley Vision and Learning Center. Berkeley DeepDrive also has support from numerous automotive industry manufacturers and suppliers, who will have early access to the technology.

Deep-learning expert Trevor Darrell was appointed co-director of PATH in 2015. He's a professor of electrical engineering and computer science, with a robotics and artificial intelligence focus.



ENTREPRENEURSHIP

Cutting-edge research in the highly applied field of transportation often leads ITS faculty and students to ideas with commercial potential — giving individuals with an entrepreneurial edge both inspiration and a deep understanding of the market. Below are just a few of the companies that were incubated or launched through ITS-based research or its Technology Transfer Program’s Learn2Launch (see page 31), which provides access to connected UC Berkeley entrepreneurship programs, including SkyDeck and the Sutardja Center for Entrepreneurship and Technology.

AUTOMATIC is a connected-car platform that assists drivers with eco-driving, car location, and emergency services. Formed in 2011 and launched publicly in 2013, Automatic works with a small plug-in device that connects a driver’s phone to a car’s onboard computer. It helps save gas, reminds drivers where they parked, and calls for help in the event of a crash. The companion smartphone app scores a customer’s driving and tracks fuel costs.

“This product really grew out of my thesis, which was about providing feedback for people about their travel choices — how much time it took to travel, how many calories were used, how much CO₂ was emitted,” said Jerry Jariyasunant, an Automatic co-founder with fellow Berkeley alumnus Thejo Kote. “Automatic is similar, but it’s for vehicles,” he said. Jariyasunant received his Ph.D. from ITS in 2012. Working with advisers Joan Walker and Raja Sengupta, he used open-source code developed for Sengupta’s Quantified Traveler project, part of the ITS-based SafeTrip-21, a federally funded public-private research collaboration. The growing California-based company is now leveraging that research investment with job creation. automatic.com

Automatic, a connected-car platform, grew out of the ITS-based public-private partnership SafeTrip-21. Photo: Courtesy of Automatic



SENSYS NETWORKS provides wireless vehicle-detection solutions that allow transportation agencies to obtain and utilize accurate, real-time data on traffic movement. Unlike inductive loops — sensors embedded in roadway pavement — Sensys Networks’ next-generation technology uses wireless magnetic vehicle detection systems that can be installed wherever detection is needed without digging up pavement. And, unlike video detection, the sensors perform in all weather and lighting conditions.

Pravin Varaiya, emeritus professor of electrical engineering and computer science (EECS), founded Sensys in 2003 with fellow EECS alumni Robert Kavaler and Amine Haoui, based on research from his lab on improving the quality of loop-detector data. It took the team five years to bring the product to market, supported by “sweat and venture funding,” said Varaiya. In 2015, the Berkeley-based company employed 80 people and had 200 customers spanning 40 states and 10 countries. The Intelligent Transportation Society of America recognized Sensys Networks’ VDS240 wireless vehicle-detection system as the “Best Innovative Technology for 2008.” sensysnetworks.com

Above: Sensys Networks’ microradar sensor is one product that helped make the ITS-born company the leader in its industry. Photo: Courtesy of Sensys Networks

URBANCANVAS is a powerful software-based simulator for planning and analyzing urban development. It was developed by Synthicity, a Berkeley-based software company founded and led by ITS-affiliated city and regional planning professor Paul Waddell. UrbanCanvas uses a “SimCity”-style 3D digital model as an interactive backdrop to help city planners collaboratively edit and share urban data about complex city phenomena, including tracking buildings from plan to construction. Last year, the program was acquired by 3D software giant Autodesk and is slated for wide release.

“We’re very excited to be releasing UrbanCanvas as an Autodesk product,” Waddell said. “This kind of rapid prototyping solution that integrates design, analysis, and visualization in one application empowers planners to design and evaluate many more alternative proposals and plans rapidly, allowing them to engage stakeholders in a more meaningful way.” Synthicity grew out of Waddell’s 1990s development of UrbanSim, a software-based simulation system supporting planning and analysis of urban development, now widely used by metropolitan planning organizations and other local and regional agencies around the world. synthicity.com/urbancanvas

Above: Urban development is simulated using city and regional professor Paul Waddell’s UrbanCanvas software, now an Autodesk product. Image: Courtesy of Synthicity, an Autodesk company

PRYNT is a smartphone case that prints photos instantly without ink or batteries. It was developed by Clément Perrot and David Zhang, two alumni of the inaugural class of Tech Transfer's Learn2Launch program (see below). After using a friend's Polaroid camera, the pair were inspired to reinvent printed photos for the smartphone age. The seven-person company is based in San Francisco and Paris. Their debut product, the Prynt Case, is shipping its first orders by early 2016, supported by a Kickstarter campaign that raised over \$1.5 million. In a promising debut, the startup has already been written up in Tech Crunch, CNET, Gizmag, and numerous other tech blogs. pryntcases.com

The Prynt Case, which turns smartphones into instant photo printers, becomes available by early 2016. The company's founders are Learn2Launch alumni. Photo: Courtesy of Prynt

Learn2Launch's "birth story" rivals any Silicon Valley startup.

LEARNING TO LAUNCH STARTUPS



Learn2Launch alum Yann Fleureau (left), founder of the startup CadioLogs, explains the concept of his company to French President François Hollande. Photo: Courtesy of Bruno Martinaud

Necessity was the mother of invention in the case of Learn2Launch, an ITS-based training program hosting intensive entrepreneurship education for students from around the world. "A calculated five-year plan couldn't have yielded any more success than this model born of troubleshooting a genuine need," said ITS assistant director Laura Melendy of the growing program.

Learn2Launch's "birth story" rivals any Silicon Valley startup. In 2013, Melendy received a request from a cohort of expertise-hungry French engineers and business students who wished to train with Berkeley engineering, design, and business faculty, and immerse themselves in the Silicon Valley entrepreneurship ecosystem. With her deep educational-programming experience as director of ITS's Technology Transfer Program (see page 22) and an entrepreneurial attitude, Melendy set to work. She developed a budget, recruited faculty from across campus and industry, shaped the curriculum, and smoothed the administrative path for the international visitors. The program for the group of 17 was a huge success, with multiple teams going on to raise millions of dollars in capital. Just one notable example: Within a year of completing the training, two students started Prynt (see above), and in the process held the highest-grossing campaign for a French startup in Kickstarter's history.

Since that initial training, the demand kept coming. In 2015, the program hosted 38 students and it now supports a full-time manager. "We didn't set out to be entrepreneurs," Melendy says, "but we were bootstrapping, iterating, launching, and scaling just like any startup, so right in front of our students, we were role models for the very skills we were teaching." learn2launch.berkeley.edu

STUDENTS AND ALUMNI

MAPPING THE INSTITUTE'S INFLUENCE

The Institute's alumni are in demand. In the academic sector, more than 100 alumni are teaching in private and public universities, including top engineering and transportation programs around the world. The list below includes just a portion of the universities where we can track our graduates.

ITS alumni also work in leading private sector companies that are advancing transportation through engineering, computer science, and other avenues. Just a few organizations currently employing ITS graduates include Uber, Google, Tesla, Genentech, IBM, Facebook, eRide Inc, Applied Materials, Cambridge Systematics, Human Intellect Lab, and the World Bank. The U.S. and California Departments of Transportation and the San Francisco Bay Area's Metropolitan Transportation Commission are just a few of the government agencies where our alumni serve the public sector.

ALUMNI IN ACADEMIA

American University of Beirut (Lebanon)
 Arizona State University
 Boston University
 Bucknell University
 California Polytechnic State University
 California State University—San Diego
 California State University—San Jose
 Chalmers University of Technology
 (Gothenburg, Sweden)
 City University of Hong Kong (China)
 Cornell University
 Dallhousie University (Nova Scotia, Canada)
 École Polytechnique Federale de Lausanne
 (Switzerland)
 Embry-Riddle Aeronautical University
 ETH-Zurich, Zurich, Switzerland
 Feng Chia University (Taichung, Taiwan)
 George Mason University
 Georgia Institute of Technology
 Georgia State University
 Hong Kong Polytechnic University (China)
 Hongik University (Seoul, South Korea)
 Ibmec Business School (Rio de Janeiro, Brazil)
 Iowa State University
 King Abdullah University of Science and
 Technology (Thuwal, Saudi Arabia)
 Korea Advanced Institute of Science and
 Technology (Daejeon, South Korea)
 Massachusetts Institute of Technology
 Michigan Technological University
 MingDao University (Changhua, Taiwan)
 Morgan State University
 Myongji University, Seoul (South Korea)
 Nanyang Technological University (Singapore)

North Carolina State University
 National Chiao-Tung University (Hsinchu, Taiwan)
 National Taiwan University (Taipei, Taiwan)
 Naval Postgraduate School
 Northwestern University
 Ohio State University
 Oregon Institute of Technology
 Oregon State University
 Pardee RAND Graduate School
 Penn State
 Pontificia Universidad Católica de Chile
 (Santiago, Chile)
 Portland State University
 Purdue University
 Rutgers University
 Ryerson University
 Stanford University
 State University of New York at Buffalo
 Technical University of Catalonia (Barcelona, Spain)
 Technical University of Munich (Germany)
 Technion-Israel Institute of Technology
 (Haifa, Israel)
 Temple University
 Texas A&M
 Tsinghua University (Beijing, China)
 Universidad Católica (Buenos Aires, Argentina)
 Universidad de los Andes (Bogotá, Columbia)
 Universidad Nacional de Córdoba (Argentina)
 Universidad Politecnica de Madrid (Spain)
 Universidade Federal do Rio Grande do Sul
 (Porto Alegre, Brazil)
 Universita degli studi di Trieste (Italy)
 University of Alberta (Edmonton, Canada)
 University of Auckland (New Zealand)
 University of Belgrade (Serbia)
 University of British Columbia (Vancouver, Canada)
 University of Calgary (Canada)

University of California—Berkeley
 University of California—Davis
 University of California—Irvine
 University of California—Los Angeles
 University of California—Riverside
 University of Central Florida
 University of Costa Rica
 (San Pedro, Costa Rica)
 University of Florida—Gainesville
 University of Hawaii at Manoa
 University of Hong Kong (China)
 University of Illinois at Chicago
 University of Illinois at Urbana—Champaign
 University of Maryland—College Park
 University of Massachusetts—Amherst
 University of Melbourne (Australia)
 University of Michigan
 University of Minnesota
 University of Missouri—Rolla
 University of Nevada—Reno
 University of North Carolina at Chapel Hill
 University of Oklahoma
 University of Pennsylvania
 University of Pretoria (South Africa)
 University of South Florida
 University of Southern California
 University of Tennessee—Knoxville
 University of Texas—Arlington
 University of Texas—Austin
 University of Tokyo (Japan)
 University of Toronto (Canada)
 University of South Australia
 University of Virginia
 University of Washington
 University of Wisconsin—Madison
 University of Wisconsin—Milwaukee
 VIA University College (Horsens, Denmark)
 Yale University



AWARDS

ITS students have an impressive track record with the Dwight David Eisenhower Transportation Fellowship award, boasting more than 20 Eisenhower fellowships over the past decade. A sampling of additional recent ITS student honors include the University Transportation Center's Best Ph.D. award at the state and national level, the Institute of Electrical and Electronics Engineers (IEEE) Intelligent Transportation Systems Society's Best Dissertation Award, the Eno Transportation Foundation Fellowship Award, the Women's Transportation Seminar Award, the new MIT Rising Star Award, and numerous "Best Paper" awards, including from the Transportation Research Board and IEEE.

Below: Frank Proulx, Jesus Barajas, and Lisa Rayle are three recent winners of the highly competitive Eisenhower Fellowship, which provides support for promising students in the transportation field. Photo: Courtesy of ITS



BUILDING THE ROAD TO PROGRESS

As she stood at the podium at the College of Engineering graduation ceremony, ITS student Patricie Uwase Mavubi conjured memories of visits to the Botanical Gardens, reading on Memorial Glade, and long nights of studying at the ITS Library. Mavubi, who graduated in May 2015 with a master of science in civil engineering with a focus on transportation and planning, won the high honor of graduation speaker for her exceptional achievements, unique story, and profound commitment to use transportation to improve people's lives.

Mavubi grew up in genocide-ravaged Rwanda. One afternoon in 1997, she watched a documentary about a prestigious U.S. university. At that moment, "I had a dream to attend a school like the one in the movie, a school just like Cal, which would equip me with skills to be able to rebuild our devastated nation," she recounted in her speech. In her conflict-weary nation, accessing markets and hospitals was impossible because there were no proper roads.



Mavubi and students from her 100 Women Who Will Impact Rwanda program. Photo: Courtesy of 100 Women Who Will Impact Rwanda

Already struggling to afford primary school fees, it was an ambitious goal, she said, "but dreams are powerful." She got through school on scholarships, and was inspired by a Rwandan woman, a city engineer, who spoke at her school about engineering. "I already had a desire to improve . . . access to my hometown, and now I knew the way to really have an impact," she said. She attended UC Berkeley as part of The MasterCard Foundation Scholars Program, which provides comprehensive support for bright but economically marginalized young Africans who have a "give-back" ethos.

Just months after graduation, Mavubi, 25, was already giving back. She established and ran 100 Women Who Will Impact Rwanda, a mentoring camp for young Rwandan women, and she now works on transportation issues in the Ministry of Infrastructure. "I have learned that when you mean well and want to do good for others, the whole universe will get up to help you," Mavubi said in an article on the Nigeria-based website *Edufrica.com*. "I have also learned that when you dare to dream big, anything is possible."

INTRINSICALLY SAFE WIRING

INTRINSICALLY SAFE WIRING

EP
ELECTRICAL

EP
ELECTRICAL





PAR

The Research Centers



CALIFORNIA PARTNERS FOR ADVANCED TRANSPORTATION TECHNOLOGY

MISSION: Develop transformative ideas and deploy advanced technologic solutions that address California's multitude of economic, environmental, and transportation challenges, while developing the next generation of transportation professionals.

Since its founding in 1986, California Partners for Advanced Transportation Technology (PATH) has been a leader in intelligent transportation systems (ITS) research. PATH has pioneered new technologies and continually advocated for the use of innovation to improve transportation safety and mobility, executing a diversified portfolio of multi-disciplinary transportation research projects with our staff, UC Berkeley faculty, and students, and with partners in the public and private sector, including state, federal, and local government entities; automakers; and technology companies.

California's entrepreneurial spirit and innovative culture, together with the technical prowess of the UC Berkeley community, give California PATH the unique ability to conceive transformative ideas and then implement them in small and large-scale demonstrations. For this reason, PATH has been a key participant in nearly every major national effort to develop and apply emerging ITS technologies to all aspects of surface transportation.

In 2011, the current incarnation of PATH emerged through the consolidation of two high-profile UC Berkeley programs: the California Partners for Advanced Transit and Highways and the California Center for Innovative Transportation (see page 47). This new organization, with deep expertise in research and deployment, is defining ITS concepts that address the societal need for mobility, people and goods movement, and improvements in safety and emissions reduction.

path.berkeley.edu

RESEARCH THRUSTS

- Transportation safety
- Traffic operations
- Sustainability
- Modal applications
- Integrated corridor management
- Automated and connected vehicles
- Advanced decision support

CAPABILITIES

Intelligent Intersection: This four-way traffic signal includes advanced detection systems to identify approaching vehicles and pedestrians, as well as new and emerging connected-vehicle communications technology.

Automated Test Track: A series of protected and paved roadways is used for testing large-scale prototype technologies, such as autonomous vehicles, transit bus guidance, highway-vehicle electrification, and truck platooning.

Laboratories: Facilities include vehicle instrumentation spaces for both cars and large vehicles, including trucks, buses, and snowplows; a research engineering and testing facility; and two electronic labs, one focused on traffic management simulations and another on the experimental development of wireless communication technology.

Test Beds: The first Connected Vehicle Testbed in the United States was developed and is managed by PATH for use by researchers in both academia and industry. The Palo Alto facility boasts sophisticated communication technology across 11 consecutive intersections, allowing for the advanced testing of vehicle and traffic intersection communication in a real-world environment. Similar facilities located at the Berkeley Global Campus at Richmond Bay allow for protected and off-system testing of newly developed tools and techniques.

Above: PATH's Connected Corridors project is a major effort developing the framework for robust transportation system management within California, to be implemented at multiple separate corridors across the state, including a pilot on I-210 in Los Angeles. This image from PATH's Traffic Lab shows aggregate traffic information from multiple sources, with technical lead Greg Merritt at the helm.

Previous page: The compressor room of the hydrogen fueling station at the Transportation Sustainability Research Center

LEADERSHIP

- Trevor Darrell, Co-Director; Professor, Electrical Engineering and Computer Science; Head of the Computer Vision Group at the International Computer Science Institute
- Thomas West, Co-Director



Thomas West
Photo: Courtesy of PATH



Trevor Darrell

A PATH faculty Advisory Board includes experts in transportation and the diverse areas of electrical, mechanical, and civil engineering, computer science, and city and regional planning.



Roberto Horowitz (left), James Fife Chair and chair of the Department of Mechanical Engineering, was PATH co-director from 2011 to 2014. Alex Skabardonis, professor-in-residence in the Department of Civil and Environmental Engineering, was PATH director from 2005 to 2010.

“PATH is entering an exciting phase in its research trajectory and will be focusing increasingly on the interplay of methods, including deep learning, to transform transportation research. We will be growing and extending our efforts in several key areas, including autonomous perception for smart vehicles with varying levels of driver assistance, and in deep analytics of transportation infrastructure.”

— Darrell



Above: Lane Transit in Eugene, Oregon, ran a six-month pilot of the PATH-developed automated guidance system for buses, which gave buses the efficiency of a light-rail system. Photo: Courtesy of PATH



PATH’s research in vehicle automation, a field it pioneered in the 1990s, includes truck platooning, which can lower GHG emissions and increase safety for all drivers on the road.

TRANSPORTATION SUSTAINABILITY RESEARCH CENTER

MISSION: Develop knowledge and decision-support tools to foster the introduction and adoption of sustainable transportation fuels, technologies, systems, policy, and planning.

Since its founding in 2006, the Transportation Sustainability Research Center (TSRC) has employed a diverse array of perspectives to conduct timely research on innovative, real-world solutions for a more sustainable transportation future. TSRC also engages in education and outreach to promote its core values of sustainability and equity, to ensure that California and society at large can meet the mobility needs of the present without compromising future generations. TSRC research incorporates transportation technology, infrastructure, and human behavior. The center emphasizes undergraduate, graduate, and postgraduate research, learning, and mentorship opportunities.

The center was formed to combine the research forces of six UC Berkeley-based groups: ITS, the University of California Transportation Center, the University of California Energy Institute, the Energy and Resources Group, the Center for Global Metropolitan Studies, and the Berkeley Institute of the Environment. Professors Samer Madanat, William Nazaroff, and Alex Farrell founded the center along with researcher Timothy Lipman.

tsrc.berkeley.edu

Above: TSRC co-director Tim Lipman uses the center's hydrogen refueling station, the first in Northern California.

CAPABILITIES

Hydrogen Fueling Station: The first high-pressure hydrogen fueling station to become operational in Northern California opened in 2011 at Berkeley Global Campus at Richmond Bay (BGC). Built with support from Toyota, Powertech Labs, and Linde North America, it provides fast (8–12 minute) fills of pressurized hydrogen gas for TSRC's ongoing fuel cell vehicle (FCV) test program, and is also available to the California Air Resources Board, the California Energy Commission, and California Fuel Cell Partnership (CaFCP), and other Bay Area FCV test drivers.

NorthCAT: The Northern California Center for Alternative Transportation Fuels and Advanced Vehicle Technologies will develop outdoor exhibit kiosks, enhanced learning classrooms, and demonstration spaces at BGC and in San Jose, West Sacramento, and Arcata locations. The project is funded by the California Energy Commission.

RESEARCH THRUSTS

- Advanced vehicles and fuels
- Energy and infrastructure
- Innovative (shared-use) mobility
- Goods movement
- Mobility for special populations
- Transportation and energy systems analysis

LEADERSHIP

- Arpad Horvath, Co-Director; Professor, Civil and Environmental Engineering
- Susan Shaheen, Co-Director; Adjunct Professor, Civil and Environmental Engineering; Director, Innovative Mobility Research
- Timothy Lipman, Co-Director; Lecturer, Civil and Environmental Engineering



Arpad Horvath

TSRC has an Advisory Board comprising leading sustainable transportation experts who represent a range of different subsectors, both public and private.



As TSRC's first director, Dan Kammen helped connect the Energy and Resources Group (ERG) with ITS. Kammen is the Class of 1935 Distinguished Professor of Energy, and holds appointments in ERG, public policy, and nuclear engineering.

"Sustainability is the new lens through which all transportation fields are studied, so the center has never been more relevant. Life-cycle assessments have increased our understanding of everything from designing infrastructure to quantifying GHG emissions."

— Horvath

MOBILITY AND THE SHARING ECONOMY



Susan Shaheen

"Transportation hasn't changed much for over 100 years, and now we're looking at changes that will most likely be transformative."

When TSRC co-director Susan Shaheen published her 1999 dissertation "Smart Car Sharing," the dominant model in that fledgling industry was a now- quaint system involving a lockbox full of keys, a manually maintained schedule, and a pager for phone reservations. "Smart" referred to innovations like using an electronic lockbox and radio frequency to locate vehicles. Shaheen, an adjunct professor of civil and environmental engineering, was riveted by the associated lower vehicle miles traveled and declining car ownership numbers, and, despite funding challenges with the little-known new discipline, she grittily — and presciently — stuck with the topic, with support from ITS, PATH, and, since 2008, TSRC.

Then she watched the field of "mobility and the sharing economy" explode. Between 2010 and 2015, carsharing numbers grew, along with innovative models like peer-to-peer and one-way carsharing. On-demand ride services like Uber and Lyft appeared; "microtransit" — app-driven shuttle systems — launched; and there was growth in bikesharing throughout North America, including San Francisco. Scooter sharing and goods-delivery "courier network services" appeared on the horizon.

Shaheen has been along for the ride, documenting, analyzing, and classifying each new endeavor. But she avoids using the word "new." "Sharing is not new," she says, citing examples like carpools and jitneys. "Having electronic, wireless, or intelligent transportation systems applied to sharing — that was the big innovation."

Innovation continues to broaden the field. The 2013 UC Berkeley–led, sold-out Shared Mobility Summit in San Francisco, organized by Shaheen, was the first U.S. gathering of all the players in the sector. Then in 2015, Berkeley, MIT, and the London School of Economics co-presented the Disrupting Mobility Summit, an event examining how automated, electric, and shared transportation can work together to create the greatest social, environmental, and sustainability benefits.

UNIVERSITY OF CALIFORNIA TRANSPORTATION CENTER

MISSION: *Serve as Region 9 University Transportation Center (UTC) of the U.S. Department of Transportation, which includes Arizona, Hawaii, Nevada, Guam, and California, and serve the mobility needs of the state of California. Provide excellence in transportation education, cutting-edge transportation research, and a vibrant network of transportation professionals who will put their education and research findings into practice.*

The University of California Transportation Center (UCTC) is a six-campus consortium comprising UCs at Berkeley, Davis, Irvine, Los Angeles, Riverside, and Santa Barbara, as well as partners at four California State Universities — Pomona, San Bernardino, San Luis Obispo, and Sacramento. The federal UTC program launched in 1987 under the Surface Transportation and Uniform Relocation Assistance Act, which authorized the establishment and operation of transportation centers in each of the 10 standard federal regions.

UCTC recognizes that California, Region 9, and the nation face important transportation challenges now and in coming years and that the center's key charge is to address these challenges through three core programmatic endeavors: research, education/workforce development, and technology transfer. U.S. Department of Transportation funding supports student fellowships, tuition, and dissertation research grants. Caltrans dollars that match federal funds are used for faculty research grants, technology transfer, and select educational and workforce development activities.

uctc.net



RESEARCH THRUSTS

- Environmental sustainability
- Economic competitiveness
- Livability

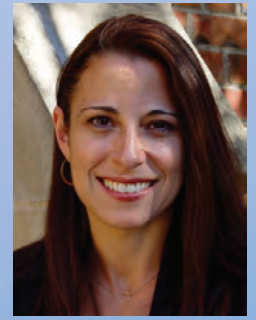
LEADERSHIP

- Robert Cervero, Co-Director; Carmel P. Friesen Chair in Urban Studies; Professor of City and Regional Planning
- Karen Trapenberg Frick, Co-Director; Assistant Adjunct Professor of City and Regional Planning



Robert Cervero

Photo: Courtesy of the College of Environmental Design



Karen Trapenberg Frick

UCTC has two boards. The Executive Committee is a faculty committee that sets the overall policy direction and ensures coordination across campuses. The Advisory Committee is composed of leading transportation experts who help the center identify key areas of research for its annual faculty research call for projects, and advise on research, education, and tech transfer needs.

ALUM WINS NATIONAL HONOR



Photo: Courtesy of Jack Reilly

ITS graduate Jack Reilly received the Council of University Transportation Center's Milton Pikarsky Memorial Award in Science and Technology, which names the best dissertation in the United States in science or transportation. Reilly completed his Ph.D. in 2014 in civil systems engineering. His dissertation focuses on new methods for coordinated, predictive, and decentralized freeway traffic control to help connect related corridors and increase traffic flow.

Reilly took full advantage of the range of projects and disciplines in his department, including creating crowd-sensing platforms, creating pollution maps from traffic, studying game theory as applied to freeway route-choices, and developing novel traffic-routing engines. "I don't think I could have run into so many cross-disciplinary fields with direct impact on civil engineering at any other school," says Reilly, who graduated from the Civil and Environmental Engineering department's still-young Civil Systems program. In addition, Reilly was able, and encouraged, to implement his theory on large, real-world systems as a part of his program. "Knowing that your research has real-world impact gives much more weight and longevity to your work," he says.

Reilly's work continues to have real-world impact. Now at Google, he is part of the Ground Truth team at Google Maps, which leverages the company's vast resources to develop the underlying map data that powers location-aware products like navigation and traffic. The team also works on algorithms that help improve the quality of map data.

"STUDENT OF THE YEAR" PROMOTES UC SCHOLARS



Photo: Courtesy of UCTC

Each year, UCTC (and now, UCCONNECT — see page 42) names a Student of the Year, an award honoring an outstanding graduate student. ITS alumnus Sebastian Guerrero, the 2014–15 honoree, wrote his doctoral thesis on the effectiveness of governmental interventions in the U.S. trucking sector to improve energy efficiency and reduce GHG emissions. Guerrero currently works as a consultant on freight transportation and logistics for Parsons Brinckerhoff. Other recent awardees include Stephen Spears of UC Irvine in 2013, and Vikash Gayah of ITS Berkeley in 2012. Spears is now an assistant professor at the University of Iowa. Gayah is an assistant professor at Penn State University. "We judge from a pool of the most talented minds working in transportation research today," said UCTC co-director Karen Trapenberg Frick. "Through this award, we are serving UCTC's mission to advance the workforce by making our accomplished scholars more visible to the broader transportation community."

UNIVERSITY OF CALIFORNIA CENTER ON ECONOMIC COMPETITIVENESS IN TRANSPORTATION

MISSION: Serve as the new University Transportation Center for federal Region 9, which includes Arizona, Hawaii, Nevada, Guam, and California, through its activities in three main areas: research, education, and workforce development.

The University of California Center on Economic Competitiveness in Transportation, known as UCONNECT, supports faculty within its consortium of five UC campuses (Berkeley, Irvine, Los Angeles, Riverside, and Santa Barbara) and its affiliate, California State University at Pomona (Cal Poly), to pursue research aligned with our new center's broad theme of promoting economic competitiveness by enhancing multimodal transport for California and the region.

UCONNECT is dedicated to the proposition that economic competitiveness comes by mobilizing society in general, and the workforce in particular; and by delivering goods and services in the most efficient ways possible. Our center recognizes that achieving these aims requires innovative ideas for combating transport congestion and its attendant costs. These costs not only entail monetary, out-of-pocket expenses, but also include lost time, lost opportunities, and environmental externalities.

In view of these challenges, UCONNECT fosters varied activities aimed at finding new ways to enhance mobility by battling congestion and the attendant costs. These activities are collaborative and multidisciplinary and present three main thrusts: research, education, and workforce development. They bring to the table the scholarship to be found in varied, top-ranked academic departments together with the breadth of knowledge and experience to be found in transport agencies throughout Region 9, and in Caltrans in particular, in an effort to provide modern multimodal solutions to enhance the economic competitiveness of the region.

uconnect.berkeley.edu

RESEARCH THRUSTS

- Promoting economic competitiveness by enhancing multimodal transport for California and the region
- System planning and management
- Data collection and use
- Transport models, funding, and finance
- Institutional culture and relationships

CAPABILITIES

The UCONNECT Summer Program at Cal Poly Pomona seeks to attract both undergraduate and graduate students — especially those from underrepresented demographics — with an interest in transportation research to directly collaborate with faculty members in the completion of an independent study. The final goals of the program are to create opportunities to assist Region 9 students in their transition from academia to industry practice and to incentivize students to choose transportation as their specialty field during their graduate-level studies.

Access Magazine reports on research at UCONNECT. The goal is to translate academic research into readable prose that is useful for policymakers and practitioners, to catapult academic research into debates about public policy, and to convert knowledge into action. accessmagazine.org



LEADERSHIP

- Michael Cassidy, Director; Robert Horonjeff Professor in Civil Engineering
- Juan Argote-Cabanero, Ph.D., Assistant Director
- Karen Trapenberg Frick, Assistant Director; Assistant Adjunct Professor of City and Regional Planning

An Executive Committee is composed of representatives from the five core universities in the consortium. An Advisory Board is composed of a representative from our consortium's affiliate, Cal Poly Pomona, along with other transportation experts drawn from academia and the public and private sectors.

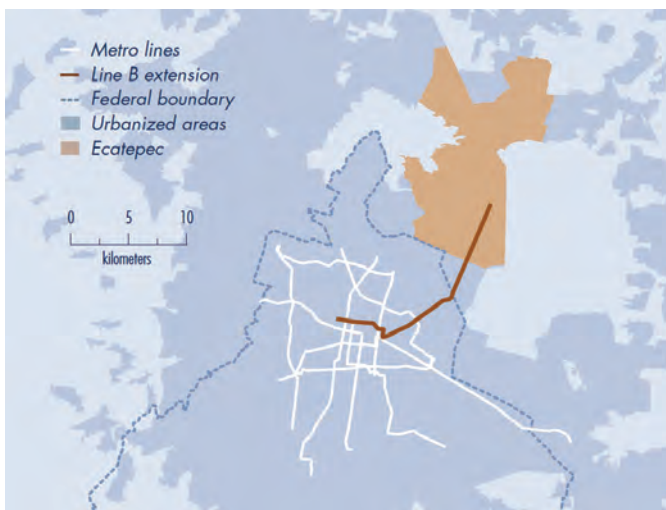


Michael Cassidy

“Our center’s aspirations can be distilled in a simple way: we aim to carry on in the tradition of our forebearer, the University of California Transportation Center (UCTC), to serve California and the larger region through research, education, and workforce development in the realm of surface transport. In that our new center was formed through a grant from the new federal program MAP-21, and that we will for a time exist side by side with UCTC, we have a new name, a sharpened focus on economic competitiveness, and a streamlined consortium of five UC campuses and one Cal State University affiliate.”

— Cassidy

A recent Access Magazine article by Erick Guerra covers suburban transit in Mexico City. Guerra received his Ph.D. in city and regional planning through ITS and is now an assistant professor of city and regional planning at the University of Pennsylvania.



HYUNDAI CENTER OF EXCELLENCE IN INTEGRATED VEHICLE SAFETY SYSTEMS AND CONTROL

MISSION: *Improve safety, handling, fuel efficiency, and driving dynamics for future vehicles.*

The Hyundai Center of Excellence launched in September of 2012, and became affiliated with PATH in 2013. The collaboration brings together the best of Hyundai senior research engineers, who spend six months to two years immersed at the center, working with Berkeley's leading experts in the field. Hyundai is providing financial support for graduate student researchers and has also provided a fuel-cell electric vehicle for use in research.

mpc.berkeley.edu
vehicle.me.berkeley.edu

Francesco Borrelli sits in a 2014 Hyundai Genesis outfitted with the most powerful GPS available. The technology is central to the center's cutting-edge guidance-system research.

RESEARCH THRUSTS

- Control theory
- Control systems technology

The center showcases the importance of university research for industry while offering students the opportunity to collaborate on cutting-edge science.

LEADERSHIP

- J. Karl Hedrick, Co-Director; Professor and James Marshall Wells Academic Chair in Mechanical Engineering
- Francesco Borrelli, Co-Director; Associate Professor and Howard P. Brown Chair in Mechanical Engineering
- Georg Schildbach, Ph.D., Associate Director

REVOLUTIONIZING THE DRIVER EXPERIENCE

In a garage at PATH, a late model Hyundai Azera with Michigan manufacturer plates is undergoing a radical transformation. A UC Berkeley control theory researcher is installing laser sensors — lidar, radar, cameras, and an extraordinarily accurate GPS — in its silver-gray body, neatly packaging more than a kilometer of wiring inside the vehicle. The hardware and software with which he's equipping the Hyundai sedan will provide vital information needed to develop control systems that will revolutionize the safety and driver experience of future vehicles.

The project is part of the Hyundai Center of Excellence in Integrated Vehicle Safety Systems and Control, a center — created in 2012 with support and funding from Hyundai — that showcases the importance of university research for industry while offering students the opportunity to collaborate on cutting-edge science. Hyundai vehicles at UC Berkeley are used as a platform to demonstrate the effectiveness and the value of state-of-the-art control theory and control technology. “The center is a great asset for our researchers and our collaboration,” said Francesco Borrelli, who, with fellow mechanical engineering professor J. Karl Hedrick, co-directs the center.

Several Hyundai engineers visit the university each year for training and to work closely with the Center of Excellence scholars on research projects under the guidance of experts like Hedrick and Borrelli. “These visiting Hyundai engineers already have either their master’s or doctoral degrees, but here they have the opportunity to learn about new developments in the area of control and optimization of dynamic systems,” explains Hedrick. In addition, Borrelli and Hedrick regularly visit Seoul to meet the company’s research engineers, review research projects, and choose research directions that will most benefit both UC Berkeley graduate students and Hyundai. Examples of such projects include advanced vehicle dynamics controllers, self-parking vehicles, and control of four-wheel drive electric vehicles.

“This center is not only training our engineers but also spurring the excitement and passion of engineering students at UC Berkeley by giving them exposure to industry,” said Woongchul Yang, vice chairman of Hyundai Motor Group and head of the R&D division. “I have no doubt that the best control engineers will be produced through this joint effort — engineers who will take great leadership in developing more intelligent and safer vehicles.”

J. Karl Hedrick and Georg Schildbach at the Hyundai Center for Excellence’s research facility at PATH, located at the Berkeley Global Campus at Richmond Bay.



UC BERKELEY CENTER FOR FUTURE URBAN TRANSPORT

A Volvo Center of Excellence 2004–2012

MISSION: Study the mutual interdependence of urban transportation policy and technology and use the understanding of that concept to devise sustainable transportation strategies for the world's cities.

The UC Berkeley Center for Future Urban Transport was established in 2004 after the Volvo Research and Educational Foundations designated it as a Volvo Center of Excellence in a competition involving a large field of international candidates. It focused on the “three-legged stool” of how cities work: technology, policy, and physics. The original funding cycle was five years. The center received funding renewals for three years, and, having fulfilled its mission, closed in 2012.

RESEARCH THRUSTS

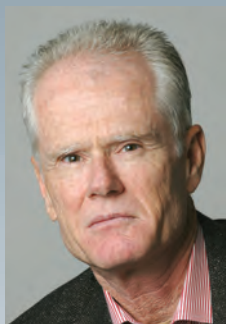
- Policy
- The physics, mechanics, and engineering of urban transportation
- Sustainability and life-cycle analysis
- Traffic engineering
- Enabling technologies in electrical engineering and computer science

LEADERSHIP

- Carlos Daganzo, Director; Chancellor's Professor of the Graduate School; Professor Emeritus of Civil and Environmental Engineering
- Michael Cassidy, Co-Director; Robert Horonjeff Professor in Civil Engineering; Director, UCONNECT
- Weihua Gu, Deputy Director; Assistant Researcher at ITS Berkeley
(at center closing)

Above: Civil engineering (CE) professor Joan Walker commutes on her e-bike to campus every day. Walker's collaborative research with fellow CE professor Raja Sengupta on tracking multimodal transportation behavior and technology was seeded by the Volvo Center.

AN INCUBATOR'S FAR-REACHING INFLUENCE



Carlos Daganzo

Carlos Daganzo talks about ITS's Volvo Center for Excellence like a parent who raised a bright, capable child and then confidently released her into the world. After eight years partnering on public- and private-sector projects both domestically and internationally, the center, named the UC Berkeley Center for Future-Urban Transport, fulfilled its purpose, Daganzo says. “We seeded the ideas, and the professors continued the work on their own — we didn't need the center anymore.”

The center seeded faculty research on promising early-stage ideas. Concepts that incubated at Volvo include the Connected Corridors Project, which arose from Michael Cassidy's research on the physics of traffic with special lanes; Alexandre Bayen's mobile sensor-based work; Arpad Horvath and Samer Madanat's collaborative life-cycle analyses on transit systems; and a behavior-tracking collaboration between Raja Sengupta and Joan Walker. Other influential achievements include Robert Cervero's policy contributions in Los Angeles and China, and Daganzo's own work on the design of a bus rapid transit system now in use in Barcelona. The center also supported 10 to 20 Ph.D. students at any given time, many of whom went on to university faculty positions.

One of the Volvo Center's impacts was personal for Daganzo. “The center transformed me from a person who did logistics and traffic to a person who is interested in the whole of transportation,” he said. “I became passionate about public transportation — understanding what type of transit system is right for a particular city, and how to control it so it's reliable.” He adds, “You can plan a system and draw beautiful pictures, but somebody has to make sure those buses run on time.”

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

2001–2011

MISSION: To accelerate the implementation of research results and the deployment of technical solutions to enable a safer, cleaner, and more efficient surface transportation system.

For 10 years, the California Center for Innovative Transportation (CCIT) delivered services addressing technical challenges, systems integration, institutional issues, business models, and change management in the transportation sector. Launched in 2001 as part of California Partners for Advanced Traffic and Highways (PATH), CCIT became an independent center in 2003, and came full circle in 2011 when it re-merged with PATH to become Partners for Advanced Transportation Technology. The new PATH (see page 36) combined two centers that successfully focused on technology with clear public interest goals, both of them with strong California government and industry ties, to make the most robust organization possible.

RESEARCH THRUSTS

- Partnership and commercialization
- Technical and implementation support
- Business cases and marketing
- Technology assessments
- Innovation portfolio management

LEADERSHIP

- Thomas West, Director (at time of re-merge with PATH); Current PATH Co-Director



Thomas West

Below: Transportation professionals and the media gathered at the command center at the CCIT-based 2008 Mobile Century field test, a novel, large-scale proof-of-concept research event that turned students into traffic sensors by equipping them with GPS-enabled phones for a day of monitored driving. The project achieved its three main goals: real-time data assimilation, preserving the privacy of participants, and making the smartphone data usage as economical as possible — advancing the field of location-based services.





SAFE TRANSPORTATION RESEARCH AND EDUCATION CENTER

MISSION: Reduce transportation-related injuries and fatalities through research, education, outreach, and community service.

The Safe Transportation Research and Education Center (SafeTREC) was founded in 2000 as the University of California Traffic Safety Center with a grant from the California Office of Traffic Safety (OTS). It is affiliated with both ITS and the School of Public Health. The center currently supports 12 full-time staff and researchers, an average of 10 to 12 student researchers, and several visiting scholars each year. SafeTREC seeks and conducts externally supported research; provides graduate-level courses through the Department of Civil Engineering and the School of Public Health; coordinates major transportation safety programs for the state through OTS, the California Highway Patrol (CHP), and Caltrans; and hosts community-based training programs.

safetrec.berkeley.edu

Above: SafeTREC co-director Offer Grembek presents at a 2015 road safety and engineering conference in Shanghai. Photo: Courtesy of SafeTREC

RESEARCH THRUSTS

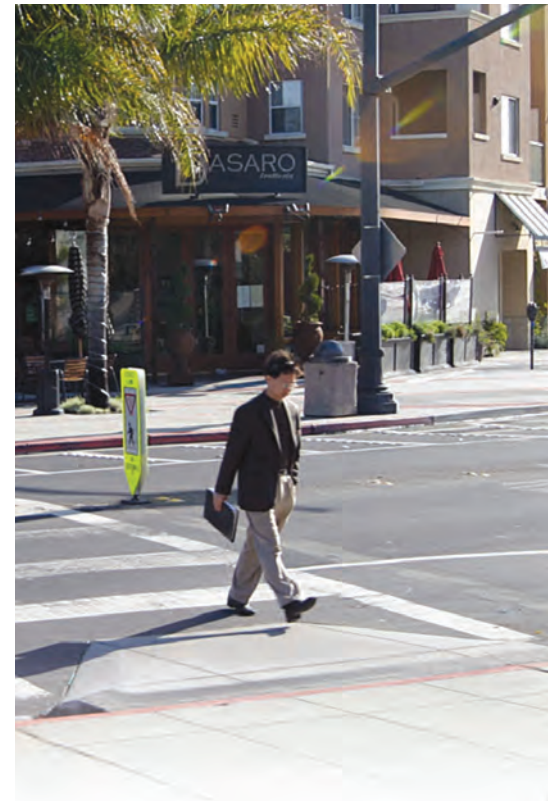
- Technology for road safety
- Large-scale data analysis and modeling
- Policy analysis and community outreach

CAPABILITIES

Transportation Injury Mapping System (see page 49): This web-based set of data and mapping tools covers 10 years of traffic injury data in California, and has new data added as it becomes available. tims.berkeley.edu

The California Active Transportation Safety Information Pages: This website is intended to provide a single, comprehensive, California-centric online destination for authoritative, evidence-based information on practices, methods, and resources to support efforts to improve the safety, efficiency, and attractiveness of pedestrian, bicycle, and other types of non-motor-vehicle travel. catsip.berkeley.edu

Community Pedestrian Safety Training Program (CPST): A joint project of SafeTREC and Cal Walks, this OTS-funded half-day training educates neighborhood residents and safety advocates on how to make their communities safer and more walkable. Since 2009, a total of 36 CPST workshops have been implemented in 34 communities.



Working under a contract with the Centers for Disease Control, SafeTREC produced a major 2015 report on the intersection of transportation policy and health. It made observations and recommendations in three key areas: transportation-related emissions (including GHG), public health benefits of mode shifts such as bicycle commuting, and traffic-related injuries.

Photo: Courtesy of pedbikeimages.org / Dan Burden

LEADERSHIP

- David Ragland, Director; Emeritus Adjunct Professor of Epidemiology
- Jill Cooper, MSW, Co-Director
- Offer Grembek, Ph.D., Co-Director

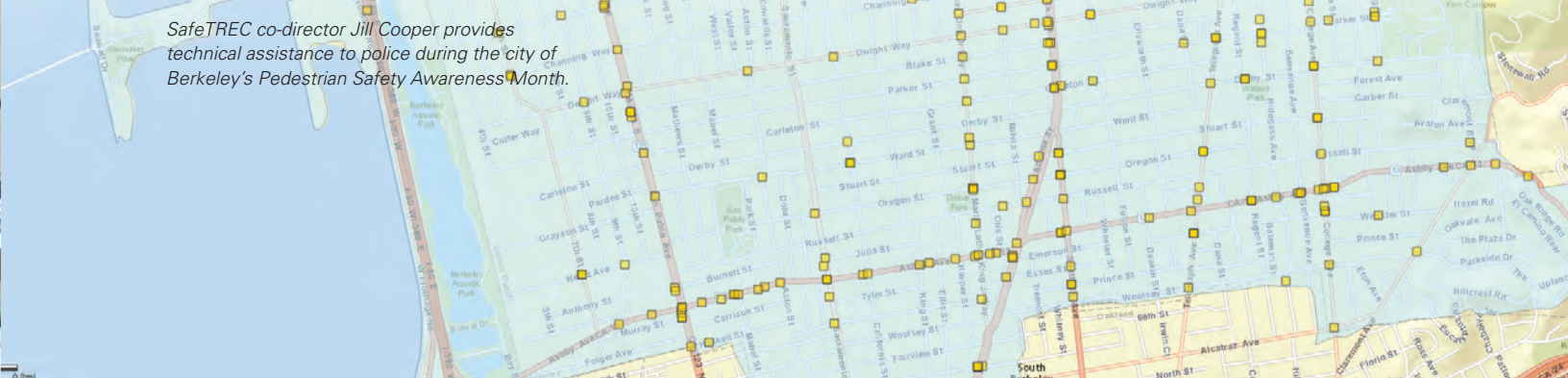
“California’s Strategic Highway Safety Plan for 2015–2019 has adopted a Toward Zero Deaths strategy for reducing traffic fatalities and injuries. The state is also committed to saving energy and improving public health through emphasis on active transportation modes, including walking and bicycling. SafeTREC is working closely with state and local agencies, Native American tribes, and advocacy groups to help implement these goals. Over the five-year span of the plan and beyond, SafeTREC will bring three critical elements to this endeavor: technology for road safety, large-scale data analysis and modeling, and policy analysis and community outreach.”



David Ragland



SafeTREC co-director Jill Cooper provides technical assistance to police during the city of Berkeley's Pedestrian Safety Awareness Month.



WEBSITE MAPS TRAFFIC INJURY COLLISIONS

Motor vehicle collisions are the leading cause of death for Americans aged 3 to 34, according to the National Highway Traffic Safety Administration, and cost California \$25 billion in economic damages each year. Since the 2008 launch of SafeTREC's Transportation Injury Mapping System (TIMS), communities across California have had a powerful new tool that helps identify problem areas. "This tool is meant to provide professionals and the general public with data to identify traffic safety problems and potential solutions," said Sang Hyouk Oum, lead researcher for the TIMS project and SafeTREC's geographic information systems program manager.

Anyone can register for a free account at tims.berkeley.edu and perform customized searches of over two million traffic injuries over a 10-year period. The Office of Traffic Safety-funded system has helped California's state and local agencies analyze patterns of traffic crashes so they can better mitigate dangers. New data is incorporated as it becomes available. TIMS has been the primary data source for California's Strategic Highway Safety Plan, which from 2006 to 2012 has contributed to a 30.4 percent drop in traffic fatalities, a 17.5 percent drop in severe injuries, and a subsequent cost savings of more than \$13 billion.

While state and local records of crash data are publicly available through the CHP, there had previously been no easy way for users to interactively sort through the information and map it by such factors as location, time and date of the collision; weather and road conditions; the influence of alcohol; and whether pedestrians or bicyclists were involved. Information can be sorted by county, city, neighborhood, or along specific routes. "Actually seeing the crashes on a map is a tool in its own right," said John Bigham, the researcher who led the effort. "If a picture is worth a thousand words, a map is worth a thousand rows in a spreadsheet."

Above: A map from TIMS shows collisions that caused injuries in the region near the UC Berkeley campus.

PAVEMENT RESEARCH CENTER

MISSION: Conducts research, education, and technology transfer to further the advancement of pavement technology in support of the U.S. transportation sector.

The Pavement Research Center (PRC) studies pavement materials, systems, management, and recycling. It supports thesis research for master's and doctoral students primarily in the civil engineering graduate program, and employment opportunities for undergraduate engineering students. Technology transfer from research endeavors includes publications and short courses for the transportation engineering community in both the public and private sectors.

UC Berkeley research has been instrumental in expediting improvements in pavement materials, pavement design, pavement rehabilitation, and construction practices for Caltrans and local governments since the 1948 inception of ITS, which included a program of research on asphalts and other materials for pavement structures. In 1989, ITS won the \$9.5 million Strategic Highway Research Program contract to address key asphalt-mix engineering issues, including fatigue cracking and deformation (rutting) from such stresses as repeated trafficking, warm temperatures, and water, and the center was renamed the Asphalt Research Program. In 1994, the center refocused on Caltrans research and was rechristened the Pavement Research Center.

its.berkeley.edu/pavement

RESEARCH THRUSTS

- Materials evaluation
- Design and rehabilitation
- Construction
- Maintenance
- Management
- Recycling

CAPABILITIES

The PRC lab at the Berkeley Global Campus at Richmond Bay houses extensive laboratory and testing facilities.

LEADERSHIP

- Juan Pestana, Director; Professor of Civil Engineering

“The new theme in pavement is ‘integrated.’ We have to look at pavements as an integral component of the facilities and communities they belong to — roads, streets, towns.”

— Pestana



A FORWARD-LOOKING, SUSTAINABLE VISION

Nothing pains Juan Pestana more than the thought of a freshly paved road being ripped up so a locality can install a water pipe or fiber-optic cables. "It happens all the time," he cringes, explaining that the resulting patched surface shortens pavement life and diminishes the performance of the most carefully designed materials. "Could we have foreseen that?" he asks rhetorically. "Can we look at roads differently, and anticipate the use of a road as a right of way for utilities?"

Right: Juan Pestana with one of the PRC's four fatiguing machines, which test how pavement will perform under real conditions by heating, cooling, and bending pavement across four different points to measure the stress.

Background: Test sample from the PRC's shearing machine

Since he took over as director of the PRC in 2014, Pestana, a professor of civil and environmental engineering, has reenvisioned the PRC to focus on complex life-cycle and sustainability issues. "The new theme in pavement is 'integrated,'" says Pestana — integrating new materials such as reused asphalt and recycled plastics, and life-cycle and community concerns such as utilities access and how different stretches of a long highway might wear differently over time. "We have to look at pavements as an integral component of the facilities and communities they belong to — roads, streets, towns."

This approach will impact material performance, construction methods, and pavement choices. Removable concrete slabs might, for example, be part of a utilities access corridor. Recycled materials are an important component of the new approach, but since they haven't been in use very long, researchers need to find new ways to predict pavement behavior. "As we look at both materials and uses over time, we need different evaluation methods, new questions to ask, and new and novel testing to answer them," Pestana says.

Fulfill this integrated research vision, and we will reduce emissions, extend the life of pavement, and reduce the need for repaving, he says. "The PRC does not exist in isolation; we are part of a bigger picture in transportation. We may actually change the paradigm of how roads are designed."

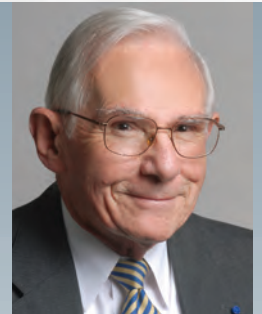


CARL MONISMITH: A LIFE ON THE ROAD

Most people don't think of strawberries when they look at a strip of pavement, but Carl Monismith does. As trucks careen down California freeways, they are jarred by bumps that bruise their cargo. "Make the pavement smoother and you don't damage the strawberries," he says, extrapolating to the costs of packaging and refrigerators that are designed to protect produce on its bumpy ride.

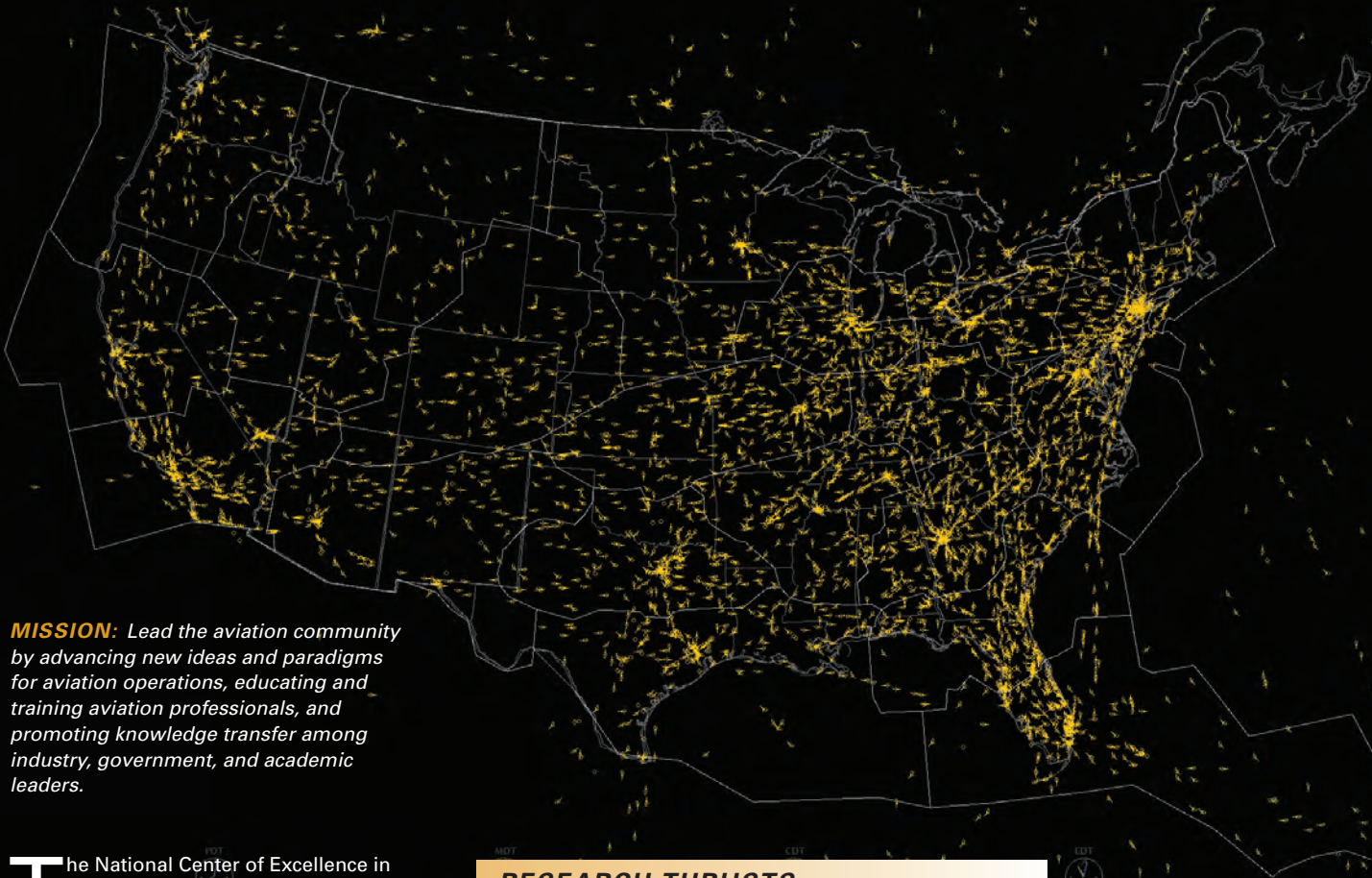
As head of pavement-related research from the late 1950s until his retirement in 2011, Monismith, an emeritus professor of civil engineering, is something of a legend. In a path that in retrospect seems pre-paved, Monismith was selected for engineering training as an army enlisted man, then, as a young UC Berkeley instructor, tapped by Harmer E. Davis to focus on asphalt technology during the post-World War II highway boom. Monismith saw the field evolve as computers and other new technology became available, improving, for example, tests, analyses, and infrastructure materials, which ultimately enabled researchers to predict the behavior of pavements instead of just analyzing the materials that compose them.

Looking ahead, Monismith, who still works two mornings a week, is interested in the promise of platooning trucks on designated, custom-paved truck routes to smooth the ride for cargo while also smoothing traffic and reducing delays and fuel consumption. But when he looks back across 60 years at the PRC, he just sees a lucky life. "I can't imagine a better profession than being a civil engineer, and my colleagues at Berkeley were simply the best."



Carl Monismith

NATIONAL CENTER OF EXCELLENCE IN AVIATION OPERATIONS RESEARCH II



MISSION: Lead the aviation community by advancing new ideas and paradigms for aviation operations, educating and training aviation professionals, and promoting knowledge transfer among industry, government, and academic leaders.

The National Center of Excellence in Aviation Operations Research (NEXTOR) is an association of eight universities contracted by the Federal Aviation Administration (FAA) to provide research support for a wide variety of aviation issues. The alliance was awarded the NEXTOR II contract in 2011 and builds upon the success of the original NEXTOR consortium, which operated under the FAA's Centers of Excellence program from 1996 to 2006.

At UC Berkeley, NEXTOR encompasses both research funded under the NEXTOR II umbrella and other aviation-related work funded by NASA and various organizations.

nextor.org

RESEARCH THRUSTS

- Aviation economics and operational performance
- Air traffic management
- Sustainability and fuel efficiency
- Aviation infrastructure reliability and maintainability

Above: Visualization of air traffic data obtained using NASA FACET
Image: Provided by Dengfeng Sun

LEADERSHIP

- Mark Hansen, Co-Director;
Professor of Civil and Environmental
Engineering
- Jasenka Rakas, Ph.D., Deputy Director

The eight NEXTOR co-directors, one from each of the eight consortium campuses, serve as the governing board.

“Traffic in the manned aviation system is continuing to grow at about 5 percent annually, while the FAA is bracing for one million unmanned aircraft to be under Christmas trees in 2015. Keeping these planes safely separated and contributing to global sustainability goals, while also providing services that are affordable and convenient, is a monumental challenge. UC Berkeley’s aviation researchers will continue to contribute to both problem framing and problem solving through multidisciplinary research in air traffic management, performance analysis, data analytics, and airport planning and design.”

— Hansen



Mark Hansen

Below: NEXTOR deputy director Jasenka Rakas (left) leads her Airport Design class on a field trip to San Francisco International Airport.

Photo: Courtesy of Jasenka Rakas



A DESIGN CLASS HELPS STUDENTS SOAR

The ambitious format of CE 153 Airport Design is to design an airport from beginning to end. Working in interdisciplinary teams, students from computer science, city planning, and the full spectrum of engineering disciplines — transportation, civil, industrial, and mechanical — work together in this capstone class for transportation- and aviation-interested students, mainly seniors majoring in civil engineering.

The class, led by NEXTOR II deputy director Jasenka Rakas, combines analytical and mathematical tools, design, and systems theory. “It takes them through the entire process of formulating an idea, identifying problems, solving them, and finally, presenting the idea,” Rakas says. “They try to understand not only how the current system works, but how to improve it.”

The hands-on class, which includes an airport field trip, is specifically designed to help analysis-focused engineering students use their senses and unlock their creativity. Rakas keeps the content current — including issues like airport capacity, sustainability, extreme weather, and facility design — through strong relationships with industry consultants and the FAA.

Enrollment is perpetually at capacity, but the class has other brag points. Class projects are now an integral part of San Francisco International Airport’s modernization and sustainability program. In the Airport Cooperative Research Program’s annual university airport design competition, class projects have placed in the top two spots four times in just five years, between 2010 and 2015. The most talented students get accepted to top transportation graduate programs, including ITS, and picked up by aviation contractors and consulting firms for internships and jobs.

But for Rakas, who regularly gets thank-you notes from former students whose trajectories the class altered, it’s all about inspiring the next generation of aviation experts. “When you see students not wanting to leave the lab because they’re so passionately interested in the concepts they are working on — then you see the success,” she says.

SMART CITIES RESEARCH CENTER

The Joint Lawrence Berkeley National Laboratory–ITS Berkeley Transportation Initiative

MISSION: *Improve mobility in a sustainable and energy-efficient way by advancing quantitative modeling of urban systems. Foster interdisciplinary training to solve real-world challenges posed by modern cities.*

The Smart Cities Research Center is a collaboration between UC Berkeley and Lawrence Berkeley National Laboratory to improve energy-efficient mobility systems. The availability of data opens new perspectives on activity-based modeling of urban mobility and traffic microsimulations. The new center, currently preparing to launch, will study

mathematical models and data analytics with approaches ranging from behavioral studies to control theory, working with industry and public agencies to collect and model data and use it to develop more efficient transportation networks.

The research focuses on novel approaches to modeling interdependent energy and transportation systems. The work will leverage analytics capabilities of rich geospatial data and develop novel approaches to studying multiple aspects of urban dynamics in the nexus of cyber,

physical, and social systems. A unifying approach will be developed that uses machine learning along with a variety of optimization algorithms, infrastructure control methods, and policy analysis to produce transportation development scenarios and recommendations to practitioners and decision makers.

Research areas are grounded in the disciplines covered by master's and doctorate programs in civil, systems, and transportation engineering.

smartcities.berkeley.edu





RESEARCH THRUSTS

- Urban data analytics
- Distributed control systems
- Smarter transportation
- Computation social science
- Location-based social networks

LEADERSHIP

- **Anand R. Gopal**, Co-Director; Principal Scientific Engineering Associate in the International Energy Studies Group, Lawrence Berkeley National Laboratory
- **Alexei Pozdnukhov**, Co-Director; Assistant Professor, Civil and Environmental Engineering
- **Alexandre Bayen**, Founding Director; Professor, Civil and Environmental Engineering and Electrical Engineering and Computer Science; ITS Director



Anand R. Gopal
Photo: Courtesy of LBNL



Alexei Pozdnukhov

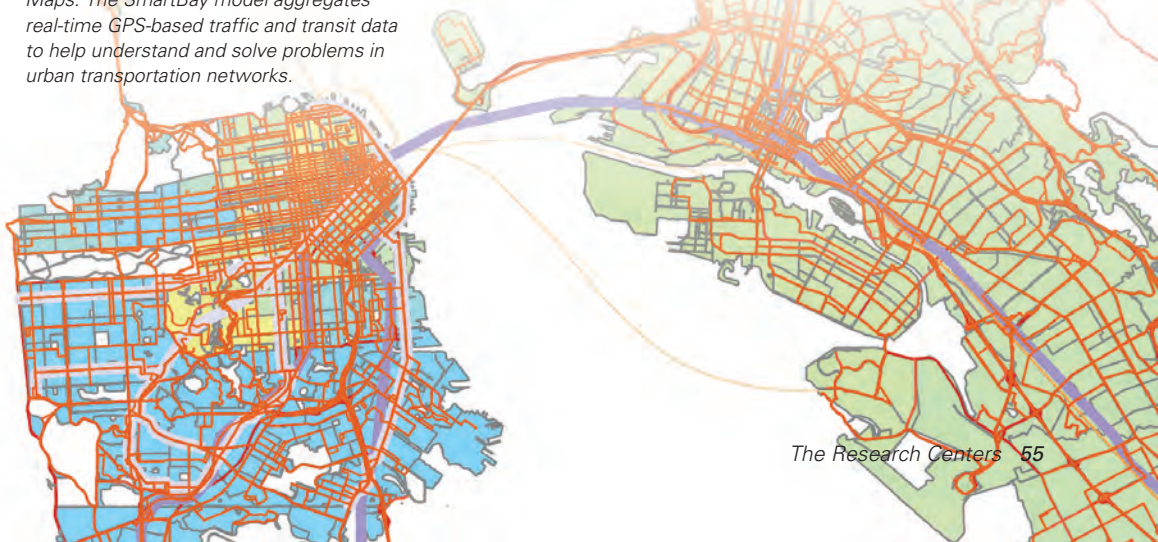
“Cities have grown into complex ‘systems of systems’ saturated by aging infrastructures of increasing maintenance costs, fading control over private data, and a growing pool of interlinked socioeconomic problems. The scaling laws observed in the evolution of today’s cities fundamentally contradicts sustainability. At the same time, technology and connectivity have brought to life unprecedented opportunities to approach these challenges in a data-driven way. The work of our new center lies at this tension point.”

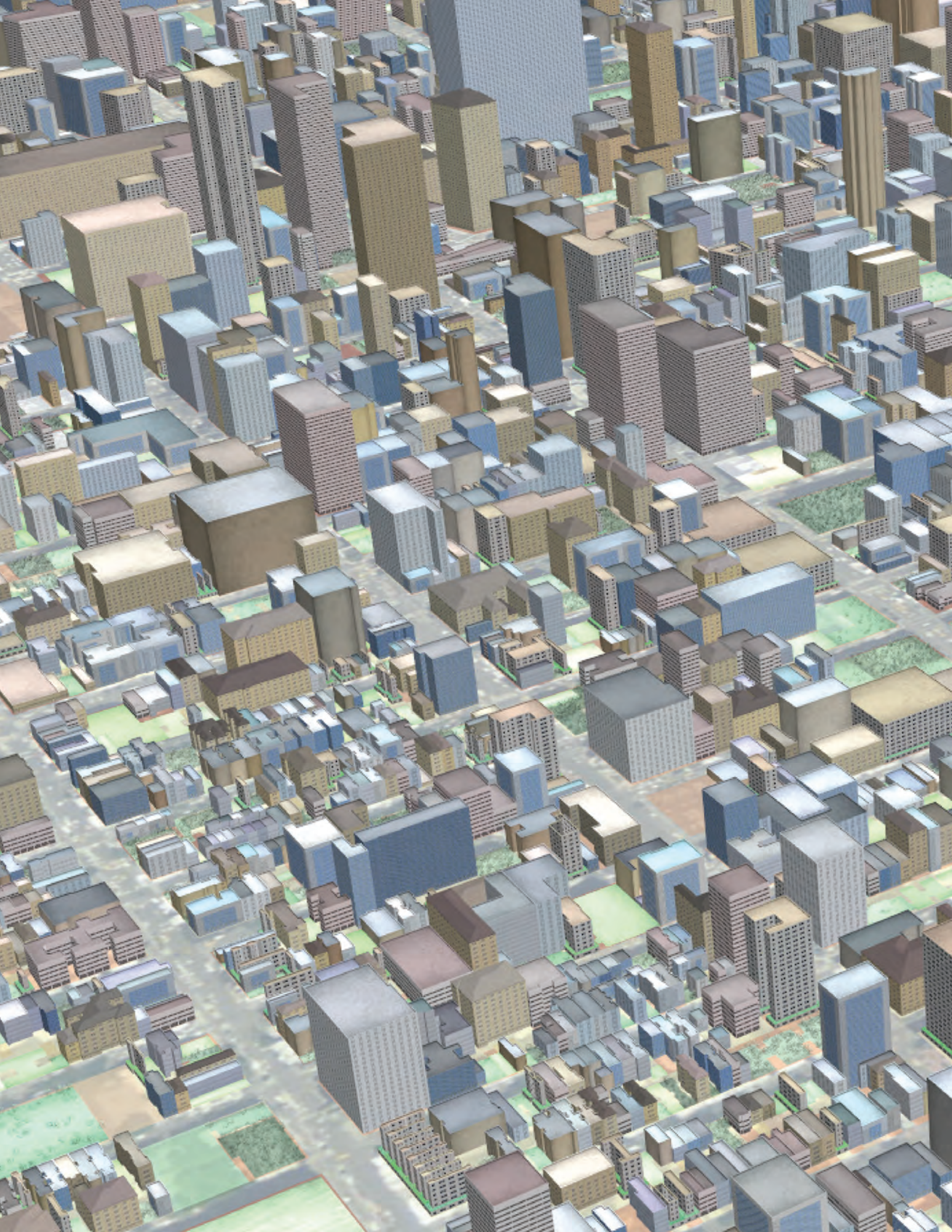
— Pozdnukhov

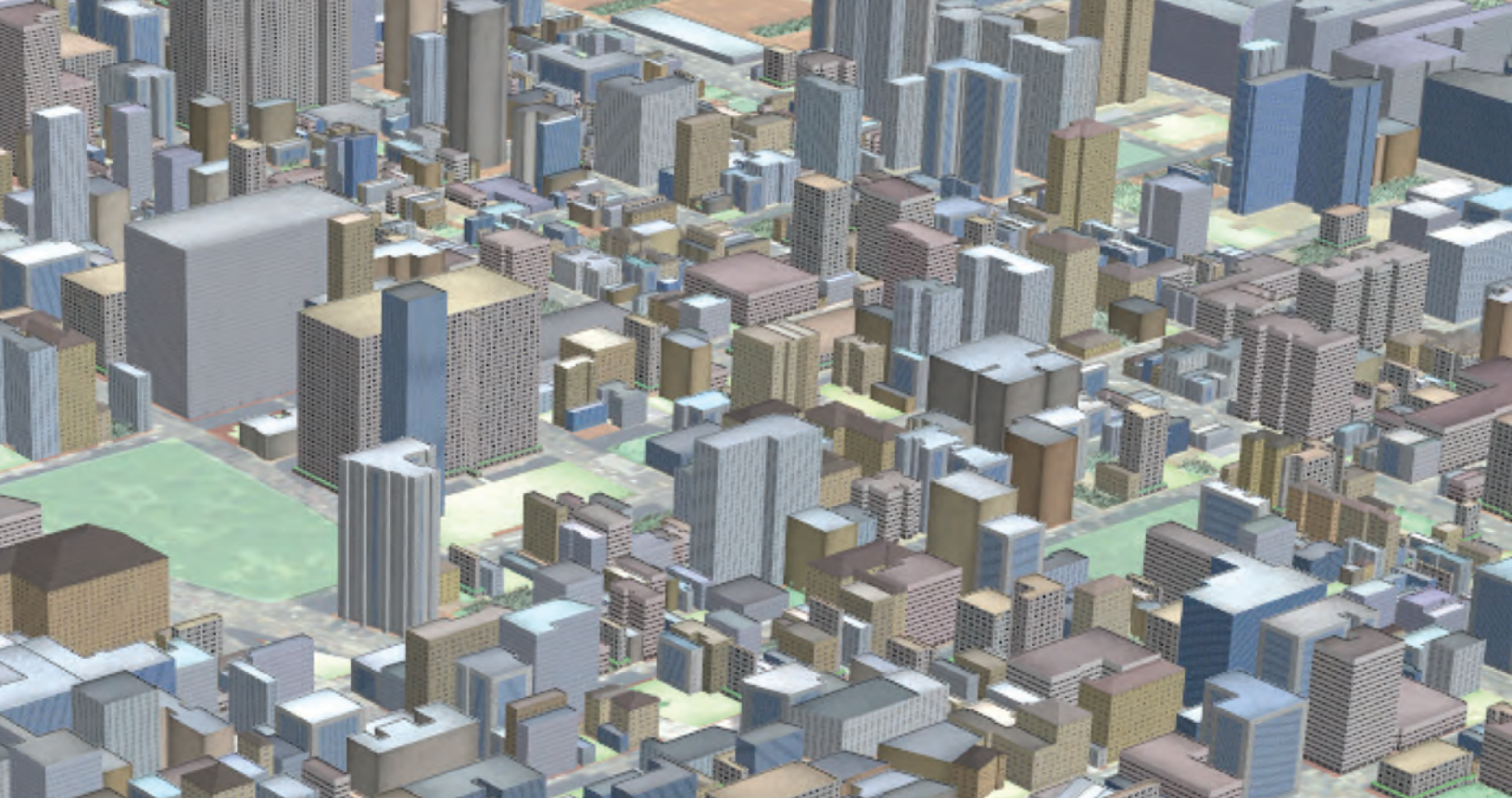
Left: Smart Cities is the first collaboration between ITS and the Lawrence Berkeley National Laboratory, shown here in an aerial view that includes the UC Berkeley campus and San Francisco Bay.

Photo: Roy Kaltschmidt, courtesy of Lawrence Berkeley National Laboratory

Maps: The SmartBay model aggregates real-time GPS-based traffic and transit data to help understand and solve problems in urban transportation networks.







PARIS

The Future



STRATEGIC GROWTH AREAS

21ST-CENTURY TRANSPORTATION CHALLENGES

Along with many nations in the world, the United States is dependent on transportation to maintain its economic activity and development. Over time, U.S. infrastructure has grown in order to support this activity. But in this new era of technological change, global warming, and urban growth, our society collectively faces several new challenges. Issues recognized as major by the Transportation Research Board include:

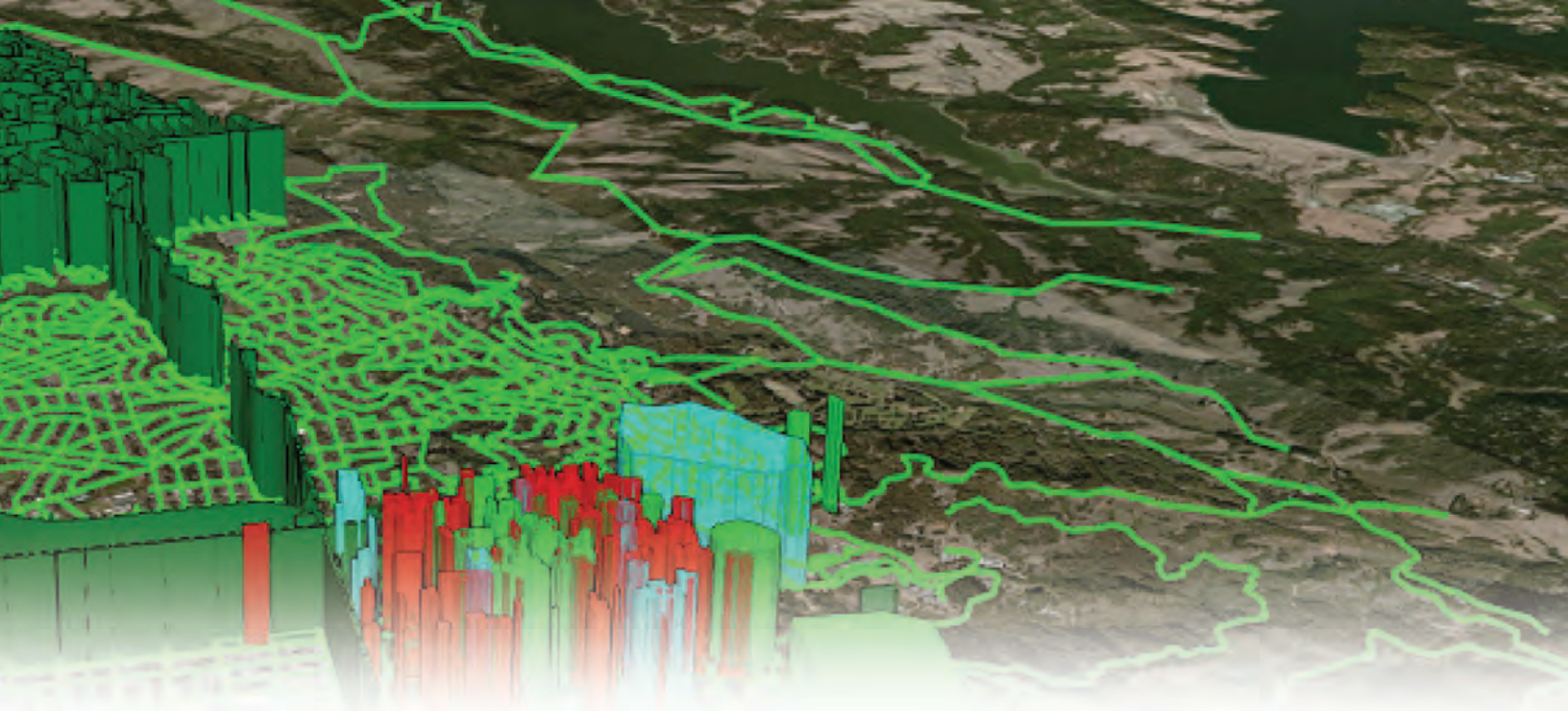
- **RELIABILITY AND RESILIENCE.** Our transportation system must improve its ability to respond to fluctuations of demand, disturbances, and economy-driven ridership growth.
- **SAFETY.** Technology and policy have significantly improved safety over the past decade, but the numbers of transportation-related deaths and injuries every year are still high.
- **ENERGY.** While new technologies and paradigms appear promising, transportation's energy footprint remains very large, and the sector's reliance on fossil fuels is unsustainable in the long term.

- **INFRASTRUCTURE.** The transportation infrastructure is aging. This is not only true of physical infrastructure like bridges and roads, but also of monitoring and control infrastructure, which is essential for efficient and safe operations.
- **MOBILITY SERVICES.** Mobility services offered by the public sector lag far behind the private sector. This includes services such as smartphone-based ride services and newer on-demand transit vehicles that could disrupt the mobility network in the near future.
- **RESEARCH AND DEVELOPMENT.** There has been a significant decline in R&D funding used to invent new solutions to these problems, from both the public and private sectors.

These challenges are visible at almost any scale — at the national, state, county, and city levels; in intercontinental travel; and across modes.

Map: A rendering of airspace over the streets in Berkeley, California. ITS researchers say managing airspace will be part of the coming unmanned autonomous vehicle revolution.

Previous page: An urban development simulation created by UrbanCanvas, software developed by city and regional professor Paul Waddell's company Synthicity, now an Autodesk company.



ITS MEETS THE CHALLENGE

Today, we have entered a new era of transportation largely driven by technology and data. Most of the solutions to society's greatest transportation challenges will rely on subtle combinations of science, engineering, and economics work, allied with policy and implementation. Most of these will happen in public-private partnerships, often involving government, academia, and the private sector. Together, these scenarios precisely define the ecosystem of UC Berkeley's Institute of Transportation Studies.

The Institute's strengths are grounded in the intellectually rich community at Berkeley, which spans multiple disciplines in the fields of engineering and science, policy and planning, economics, public health, and business. Moreover, research, education, technology transfer, and information management — the four core missions of ITS defined in our 1947 charter — continue today as meaningful and impactful missions. Just as our research focus areas will evolve over the next decade as society, technology, and data tools evolve, our four core missions will continue to adapt to this changing landscape.

To address these contemporary transportation challenges, ITS has identified four strategically important growth areas that leverage the academic and research expertise that consistently rank UC Berkeley the top public university in the world:

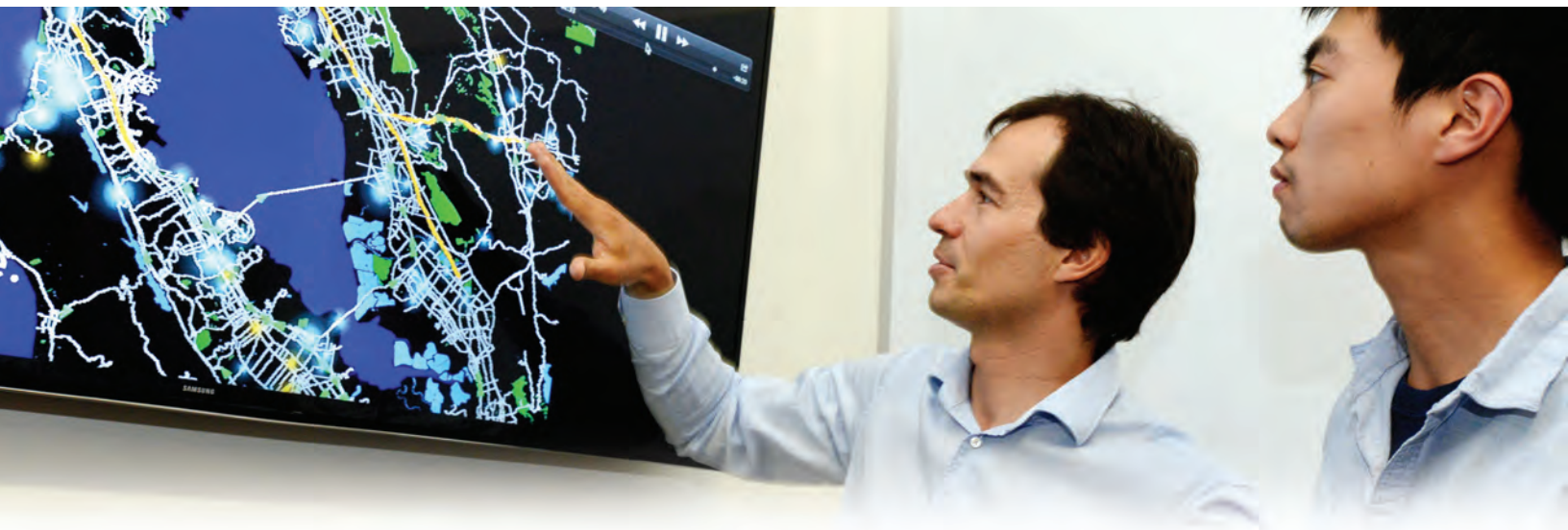
- **Large-Scale Data Analytics**
- **Automation and Connectivity**
- **Sustainable Mobility**
- **Energy**

These strategic growth areas enable applications that address society's biggest challenges. Working with our robust research centers, our affiliate faculty structure, and our strong campus relationships, the Institute is positioned to do the essential work of advancing 21st-century transportation solutions.



The past decade saw the explosion of data, with the convergence of sensing, computing, and communication on single platforms, and the transportation landscape is just beginning to see the profound changes to come from the use of this data by new technologies in the fields of automation, energy, planning, and operations. A new era is beginning in which the transportation sector has the opportunity to enable decision making based on large-scale data analytics. The Institute's track record of contributions in the field of data and analytics includes freeway monitoring, crowdsourced traffic data, and simulations for urban planning. Today, data is the dominant culture at ITS. But in order to usher this field into its next generation, developments are needed beyond transportation, particularly in machine learning, vision, cloud computing, control, and optimization — all areas with strong expertise at UC Berkeley.

ITS has already built on numerous campus initiatives and institutes at the forefront of data analytics to bring the benefits of these advances to transportation. Partners include the Simons Institute, a new theoretical computer science institute exploring unsolved problems at the limits of computation, and the Algorithms Machine People (AMP) Lab, which works at the intersection of machine learning, cloud computing, and crowdsourcing. ITS is also collaborating with Systems and the SmartCities academic programs, both hosted by the Department of Civil and Environmental Engineering. New faculty in these programs integrate machine learning — especially deep learning — communication, control, behavioral modeling, and other disciplines, shifting the demographics at ITS. Through the Large-Scale Data Analytics growth area, ITS will use these extraordinary assets to advance data-driven transportation solutions.



Q&A *Alexei Pozdnukhov: Smart Cities*

Assistant Professor, Civil and Environmental Engineering; Co-Director, Smart Cities Research Center

Transportation interests: I work on developing new scalable methods of data analysis that will be used for planning and operation of transportation in future cities. To increase efficiency and reduce the environmental footprint of transportation, new tools and methods are required to leverage the insights hidden in data streams.

Background: I started my career as a machine-learning researcher working on pattern recognition, primarily in computer vision. However, modern cities are increasingly dense and data-rich, penetrated with IT systems and smart infrastructure that generate media streams. You start seeing patterns in urban dynamics that are rich and detailed. It inspired me to switch my focus on what we call urban data analytics.

Above: Alexei Pozdnukhov (left) works on his SmartBay Project with a student. The project, which aims to be a decision-support tool, applies data mining and machine-learning techniques to cell phone data and social network signals to analyze and model Bay Area activities and travel habits.

Pressing research questions: One of the challenges for me is to understand how these heterogeneous data sources can be leveraged to close the control loops over city infrastructure. It is not sufficient to be able to just observe changes. We should be able to manage everyday operations as well as the longer-term evolution of the complex urban systems that we have engineered. It will soon become challenging to operate urban infrastructures as they become increasingly dependent on data flows and the algorithms that process the data. The resilience of this data-centric design will need to be addressed, especially as it brings in human behavior, with all its inherent uncertainties as more and more data come directly from handheld and mobile devices. Finally, infrastructure systems that were previously decoupled are becoming more interconnected and interdependent, introducing an extra layer of complexity. For example, the electric grid is becoming coupled with transport via a growing fleet of electric vehicles.

Automation is an inevitable transportation trend that has been accelerating in recent years, most visible in advances in automated and connected vehicles. But ground transportation is only one application of this technological field. The opportunities arising from automation include safety, cybersecurity, fuel efficiency, vehicle-to-infrastructure interaction, vehicle-to-vehicle interaction, and automated operations. Because almost all mobility services and applications will rely on partial or full automation in the near future, the field is crucial both strategically and pragmatically. Before autonomy becomes a reality at a ubiquitous scale, multiple advances are needed in robotics, machine learning, vision, control, and optimization. ITS has partnerships with several campus initiatives in these fields. For example, CITRIS encompasses more than 40 roboticists working on applications spanning transportation, human-machine interaction, unmanned autonomous vehicles (UAVs) medical robots, and exoskeletons. And together with new PATH leadership, the Institute has started to invest in the field of deep learning (see page 29).

Finally, UAVs are rapidly appearing in our skies at a rate of more than 200,000 units a month, likely leading to a full redesign of airspace in the coming decade, a paradigm shift that will rely on a complex interplay between technology, policy, and engineering, and will change mobility, logistics, and services as we know them. The field of logistics and remote services is in the infancy of a revolution, leading to a not-distant future in which drones will inspect bridges, provide first aid in disasters, and deliver packages. The Institute is at the heart of this transformation, with strength both in UAVs and air traffic control, in particular through NEXTOR (see page 52) and in partnership with the CITRIS People and Robots Initiative.

Q&A *Raja Sengupta: Unmanned Autonomous Vehicles*

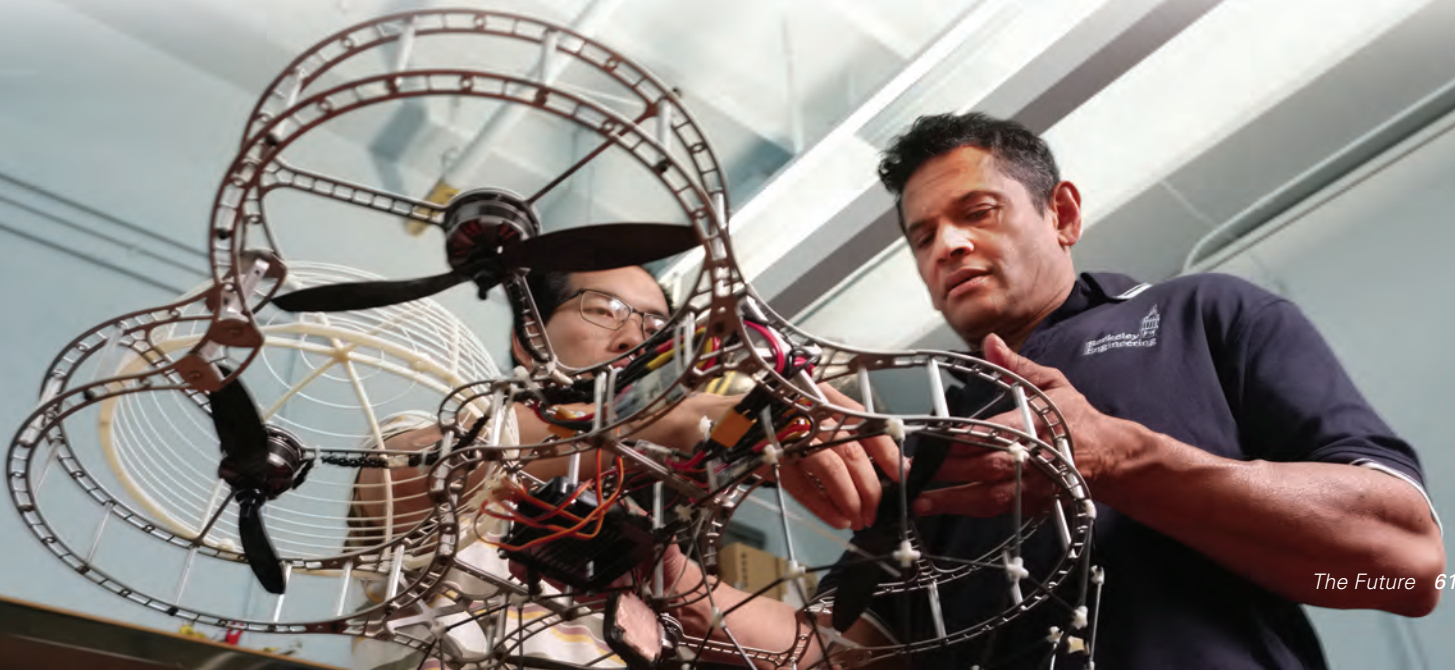
Professor, Civil and Environmental Engineering

Transportation interests: The national registry holds 220,000 aircraft — a measure of the size of our National Airspace System (NAS). The drone industry sells that many unmanned aircraft every month, upwards of two million a year. If an aircraft has a 10-year life, the NAS will go from 220,000 aircraft today to 20 million aircraft in a decade. When an industry grows by two orders of magnitude, old management systems fail. There are many exciting new research opportunities in unmanned aviation. This is what I now study.

Background: I am one of the creators of Berkeley's first drone program in 1998. From 1998 to 2014, I worked on unmanned aircraft. Back then there was no unmanned aviation outside the military. But today, for the first time in the history of aviation, the aircraft has become a consumer product. We are witnessing the birth of unmanned aviation, which is what I study: Where and how can unmanned aircraft fly?

Pressing research questions: The biggest questions will flow from government pressure on aviation. Aviation has a predominant federal regulator and operator: the Federal Aviation Administration (FAA). By contrast, the roadway system has no federal operator at all, and a regulatory authority shared across our three-tier system of government. I find it hard to believe federal predominance will work as unmanned aviation grows to consumer scale. We will need more state and local governance. At the same time, the FAA is unlikely to smoothly relinquish its regulatory and operational authority for fear of leaving a vacuum in which reckless unmanned flying will harm people and property. In the future, the UAV industry is projected to reach \$80 billion in value. The industry has aircraft but lacks airspace. Without space to fly, we cannot realize this value. So, unmanned airspace management is the next revolution.

Raja Sengupta (right) and his student work on the landing apparatus for an unmanned autonomous vehicle student project designed to deliver coffee. The assignment addressed the challenge of protecting consumers from propellers as they remove goods from delivery drones.



The sustainability issues now of global concern cover numerous aspects of transportation, including greenhouse gas (GHG) emissions, energy footprints, congestion, and mobility. This encompasses the reliability and cost of travel and quality of life, especially in urban areas. These issues are particularly critical for California, and therefore, central to the Institute's mission to serve the state. California's leadership in sustainability has accelerated with Governor Brown's ambitious goals. His bold Executive Order B-30-15 aims to reduce GHG emissions to 40 percent below 1990 levels by 2030. The watershed Global Warming Solutions Act of 2006, AB 32, established a goal of reducing state emissions to 1990 levels by 2020. These efforts are supported by the 2012 Executive Order B-16-12, which calls for 1.5 million zero-emission vehicles in California by 2025. Another major California effort, SB 375, calls for integrating land use, public transit, road transportation, and housing strategies to reduce local pollution, GHG emissions, and transportation infrastructure costs.

Current and future ITS research supports these efforts — for example, in the development of critical new state infrastructure, including electric vehicle-charging stations, hydrogen-fuel stations, vehicle-grid integration, and high-speed rail. New technology and data analytics central to ITS research are leading to more efficient energy footprints at the individual scale, and they are redefining demand and supply on an economic scale. To understand and support the new field of mobility in the sharing economy, ITS leverages research that spans impact analysis, user-choice modeling, behavioral economics, policy, life-cycle assessment, and urban planning.

As the Institute works to build a sustainable transportation future in California and beyond, our impact will be measured not only by the scholarly articles and technological contributions of our researchers, but also by their impact on policy, following a long UC Berkeley legacy of faculty influence on policymaking at the state and federal levels.



Q&A Robert Harley: Air Quality and Sustainable Transportation

Carl W. Johnson Chair in Engineering; Professor and Chair, Department of Civil and Environmental Engineering



Transportation interests: I study transportation-related air pollution problems. Most of my group's research in this area has been about on-road sources such as gasoline-powered automobiles and diesel-powered heavy-duty trucks. The main questions we address are understanding how air pollution contributions from on-road sources change over time, and how effective are new catalytic converters

and exhaust-particle filtering systems for controlling diesel emissions. We also study air pollution related to off-road engines, including railroad locomotives and marine vessels.

Background: In cities around the world, motor vehicles are a major contributor to air-pollution problems, especially in California, where the electric power sector is relatively clean. Automotive sources are in close proximity to people, so the potential for exposure and adverse health effects is high.

Pressing research questions: There has been significant success in controlling emissions from light-duty passenger vehicles over the last several decades. In contrast, major new efforts to control diesel-truck emissions are still unfolding. Another key future challenge is to think about how current use on petroleum-derived fuels can be reduced through more efficient vehicle and engine designs, and through use of all-electric and hybrid powertrains.

Above: The Port of Oakland generates truck traffic that impacts air quality in West Oakland. State regulations that banned the oldest, dirtiest diesel trucks reduced emissions of unhealthy pollutants from these trucks by half in a matter of months, as Robert Harley, left, and his research team found in a 2012 study.

GROWTH AREA ENERGY

To successfully address the increasing importance of energy in the transportation sector, it is necessary to expand the capabilities of ITS beyond a transportation-centric perspective. Toward this end, the “Transportation Initiative,” a new alliance between ITS and the Lawrence Berkeley National Laboratory (LBNL), was forged in 2015 to leverage the considerable complementary expertise of the two research organizations: The Institute has 60 years working at the core of transportation, LBNL has 80 years of history in energy, with major contributions in fuels, batteries, and the grid — three fields that are migrating to the core of transportation challenges.

UC Berkeley boasts a depth and breadth of energy-related research, including the Energy and Resources Group, Berkeley Energy and Climate Institute, Berkeley Energy Resources Collaborative, Energy Institute at Haas, and Sustainable Infrastructures Initiative within CITRIS. Several departments are in the process of developing new curricula in the field of energy. For example, the Department of Civil and Environmental Engineering has launched the Energy, Civil Infrastructure, and Climate program, designed to educate a new class of professionals who apply engineering, environmental, economic, and management perspectives to address complex problems such as environmentally informed design of transportation systems, embodied energy of construction materials, electricity from renewable sources, and biofuels, and address overarching societal problems such as adaptation of infrastructure to a changing climate.

The Energy growth area is designed to leverage these extraordinary campus resources and to unite and expand ITS research on alternative fuels, batteries, and grid-related issues to pioneer a next-generation infrastructure of interfaced electrified vehicles (EVs) and grid, and the markets to support it. This work will have impacts on many connected applications, including traffic operations, public policy, funding, and, of course, energy markets.

Q&A *Scott Moura: Electrified Vehicles*

Assistant Professor, Civil and Environmental Engineering

Transportation interests: Electrified vehicles are the main transportation-related application that motivates me. I’m specifically interested in how we can enhance driving range, power, charge times, and cost in EVs. The answer to these questions inevitably leads one to examining EV batteries. How do we squeeze out more performance, safety, lifetime, and value from batteries?

Background: I grew up in Los Angeles, a city that’s notorious for consuming years of your life sitting in traffic. As a child sitting in traffic, I took notice of vehicles uniquely suitable for the urban environment. This got me interested in green transportation. As a grad student, I attended the University of Michigan, located in the epicenter of the American automotive industry. There I was exposed to transportation technologies of the future, including EVs, batteries, and integrating EVs with the electric grid.

Pressing research questions: Energy storage, in my mind, is unquestionably the biggest and most pressing research challenge in the coming decade. Energy storage is the linchpin enabling technology for so many critical objectives, including clean transportation, integrating renewable energy into the grid, and enhancing resilience across both transportation and energy infrastructures. Consider EVs and their batteries. They create zero tailpipe emissions, can be charged at home or work from rooftop solar, and are insensitive to political strife overseas. Furthermore, they can be repurposed in a post-transportation afterlife for stationary energy-storage applications, such as backup power for hospitals and schools. To enable this vision, however, requires battery technologies that are cost-effective, efficient, and safe — topics my research lab is laser-focused on.

Scott Moura, right, works with a student on an electric scooter Moura uses to test battery storage. Behind them, an environmental chamber simulates the effects of different weather conditions on batteries.



LAST WORD



What is a smart city? The precise definition is constantly changing as technology and community needs change. As U.S. Secretary of Transportation Anthony Foxx says: "The reality of transportation is that it's future-oriented.... If we're planning for what we have, we're behind the curve."

But some things remain constant. Our mobility sector must be economically and environmentally sustainable, interconnected, and resilient. Achieving these ends takes constant research and planning.

No institution is better equipped to tackle these challenges than the state's flagship public research university. Innovation is the engine of the economy, and UC Berkeley is California's engine of innovation. The "next big thing" in transportation will reflect ideas born and developed here.

Congresswoman Barbara Lee

```
from trajectories pandas dataframe
```

```
ser_id, True)
```

```
dex.levels[0][-1], True)
```

```
led_by_extract_all_trajectories=False):  
from trajectories pandas dataframe
```

```
to geoJson'.format(user_id)
```

```
es: out += begin
```

```
, "LineString")
```

Inside front and inside back covers: Detail of source code used by the Connected Corridors project, which applies data analytics to mobility. The ITS-based California Partners for Advanced Transportation Technology hosts the project.

PHOTO LEGEND

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ITS Berkeley
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Front and back covers: A visualization of GPS probe measurements used by the Mobile Millennium system to compute real-time travel time estimates in San Francisco, California