ADVANCING THE FUTURE OF MOBILITY

75 Years

Institute of Transportation Studies, University of California Berkeley

"The Institute of Transportation Studies embodies UC Berkeley's ethos of making the world a better place with its commitment to building a better, more sustainable, and more equitable future. The Institute harnesses expertise from across the campus to advance mobility through technology, safety, policy, and planning."

— Carol Christ, Chancellor, UC Berkeley

"ITS is an essential partner in building a California that features a safe, equitable, sustainable, and multimodal transportation system. ITS develops innovative ideas, technologies, policies, and systems that are bringing California's transportation future to life."

— Toks Omishakin, Secretary of the California State Transportation Agency

▲ *Professor Joan Walker, left, speaks as part of a faculty panel at the ITS@75 celebration. Seated left to right: Professors Elizabeth Deakin, Michael Cassidy, Mark Hansen, Robert Cervero, Adib Kanafani, and Alexandre Bayen. Opposite page: ITS Berkeley Director Daniel A. Rodríguez leads the proceedings at the event.* Photos: Adam Lau

WELCOME

As we celebrate 75 years of transportation research, education, and scholarship, I am privileged to serve as director of the UC Berkeley Institute of Transportation Studies.

ITS Berkeley continues to assemble top scholars, students, and researchers from departments and disciplines across the campus. They represent the very best that our state, our country, and our world have to offer. They collaborate to study how mobility interacts with people, places, the environment, and society at large.

This book offers a reminder of our pivotal contributions to the field and a showcase of our current and emerging research areas, along with the leading researchers behind them. It highlights many of the critical benefits we are delivering to improve accessibility and equity, enhance safety, bring economic vitality to our communities, and improve people's ability to get where they need to go. Going forward, we will continue to build on this legacy, developing insightful analyses, novel policies, and innovative technologies that guide government institutions and meet the future needs and challenges of our changing mobility landscape.

While proudly reflecting on our historic legacy and the many firsts we have achieved, I am excited to lead ITS Berkeley into a bright future where we continue our work as a premier transportation research organization. The future of mobility is already here, and ITS Berkeley is lighting the way into the next generation.

Fiat Lux,
Daniel A. Rodríguez
Director, ITS Berkeley
Chancellor's Professor, Department of City and Regional Planning

Learn more about ITS Berkeley

ITS BERKELEY IN THE AGE OF MOBILITY

▲ *UC Berkeley students get around campus on every form of mobility.* Photo: Amanda Cairo

In an age where technological innovation, urbanization, and globalization are propelling fundamental changes in society and the planet, the UC Berkeley Institute of Transportation Studies embraces the complex interplay of disciplines that encompass our era's expansive transportation environment. Transportation research needs expertise in engineering, design, the physical sciences, and the social sciences to address our most vexing challenges, including climate change and social equity. Collaboration—across policy, planning, operations, and technology—is required to address road safety, air pollution, infrastructure financing, and accessibility for every type of traveler.

We work at the forefront of policies and emerging technologies as they are altering travel in almost real time. We work on the context in which mobility takes place: the diverse people, neighborhoods and places, cities, and regions. Launched in 1947 to tackle the post–WW II era of expansion and innovations in transportation, ITS Berkeley was the first university research center to address the interdisciplinary nature of transportation. This then-novel approach still frames our philosophy to produce leading-edge innovations that impact the movement of people and goods, supporting a future of mobility that improves sustainability, economic health, and quality of life for everyone.

Support for ITS

ITS Berkeley research initiatives and programs are supported by a combination of federal, state, industry, and nonprofit funding sources, as well as gifts and donations. Our annual budget averages between $25 and $30 million and continues to grow. A majority of our research funds come from sponsored projects and public-agency partnerships. Over $20 million annually comes in from federal and state sources. Approximately $3 million comes from the private sector and foundations, including successful industry partnerships and affiliate programs. ITS also has a long history of generating revenue from executive education and professional development programs.

ALUMNI AROUND THE WORLD

Our world-class faculty draws top scholars from around the globe. After students complete their academic work, they are in great demand across the academic, public, and private sectors.

Approximately 32% of our graduates work in academia. Our alumni are teaching and researching at leading public and private universities on every continent except Antarctica.

About 50% of our alumni are also working at leading private sector companies, including Cambridge Analytics, Google, IBM, Meta, and Uber, and are establishing companies and startups in transportation and tech. They also work at not-for-profit and multilateral organizations such as the Inter-American Development Bank and the World Bank.

In the public sector, approximately 18% of our alumni are working on the ground in operations and planning, and leading government agencies, including local, state, national, and international departments of transportation and some of the world's most prominent regional transportation, planning, and transit agencies.

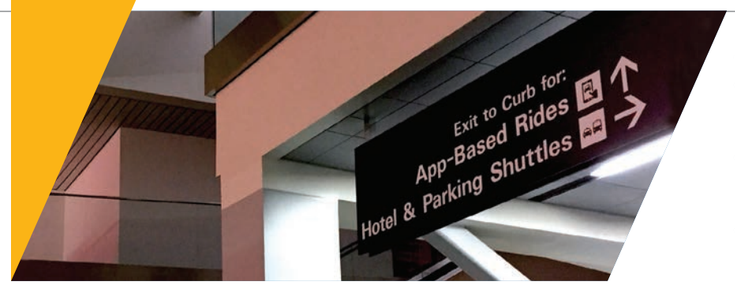
See where ITS Berkeley alumni are working globally:

INNOVATIONS ACROSS THE MOBILITY SPECTRUM

These highlights showcase some of ITS Berkeley's numerous contributions to improving user experience and safety in transportation throughout our 75 years. Our faculty members have literally written the books on transportation engineering and planning used in classrooms around the world.

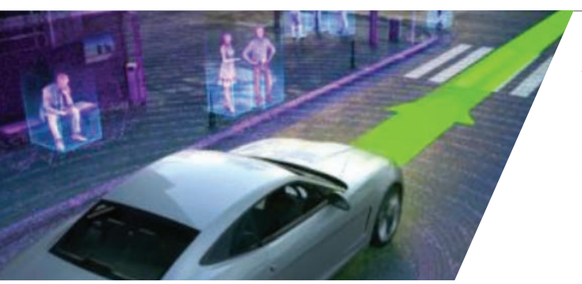
PAVEMENT AND INFRASTRUCTURE

- **1950s–2020s:** Fundamental innovations on asphalt paving mixtures and design improve state and national road systems.
- **2000s–20s:** Exploring hydrogen fuel cell vehicles and supporting infrastructure advances the field of alternative fuels; innovations in battery development, energy grid issues, and charging infrastructure put technology and policy in the forefront of emerging zero-tailpipe-emissions technology.
- **2010s:** Pavement reclamation and recycling research provides a model for statewide use.



SHARED MOBILITY

- **1990s:** Researchers are some of the first to study how early adopters are using smart carsharing systems, helping to define the new mobility sector.
- **2000s–20s:** Sharing economy analyses establish pioneering policy and development, including consumer use, curb usage, environmental impacts, sustainability, and vehicle ownership.
- **2010s–20s:** Research addresses first- and last-mile travel challenges, creates micromobility policy and innovations, and develops equity solutions for an app-driven environment.



AUTOMATION

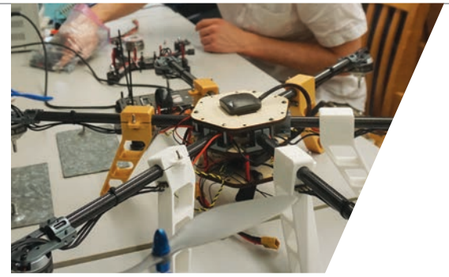
- **1990s:** Researchers lead first-ever demonstration of self-driving vehicles tested on California freeways.
- **2000s–10s:** Automation assistance is developed at ITS and placed on public buses.
- **2010s–20s:** Automation and machine-learning advances lead to connected and automated truck platoon demonstrations, increased university-industry partnerships in automotive computer vision and machine learning, and the first large-scale field test demonstrating how 100 automated vehicles can collaborate to jointly control vehicle flow.

SAFETY

- **1950s:** Innovations increase visibility in foggy conditions and better lighting design for nighttime driving.
- **1990s:** Researchers begin transformational safety-verification work, leading to the emergence of a new academic field: hybrid systems.
- **2000s–10s:** Work on federal policy provides a framework for national safety initiatives for children and mobility, including Safe Routes to School; the new Transportation Injury Mapping System provides easy, free access to California crash data.
- **2000s–20s:** Researchers partner with communities to focus on integrated safety in community planning, bike safety, walkability, and multimodal planning.

OPERATIONS

- **1950s:** Researchers develop techniques to estimate travel times.
- **1960s:** Taking the lead in traffic flow theory and ramp metering, researchers create new technology, advance congestion pricing theory, and develop toll programs adopted by the San Francisco–Oakland Bay Bridge and other California bridges.
- **1970s:** Research leads to the development, placement, and timing of metering lights on the Bay Bridge.
- **1990s:** Researchers create the California Freeway Performance Measurement System, leading to a radical transformation of the traffic sensor industry; the system remains the largest sensor network for highways in the U.S.
- **2010s–20s:** Using Integrated Corridor Management, researchers manage California's transportation corridors as an integrated whole, addressing system-wide needs over particular elements or agencies.



AIR MOBILITY

- **1950s–60s:** Work addresses unprecedented growth in air transport; innovations include new pavement designs to sustain increasing aircraft sizes, lighting technologies to enhance visibility, and technology to assess and manage the noise impact of airport operations.
- **1970s–80s:** Researchers address airline industry growth by creating new ways to measure and enhance airport capacity, resulting in significantly increased use of existing airports, with parallel increases in safety.
- **1990s–2000s:** Researchers develop methods to integrate airspace and airport operations, significantly reducing congestion delays; innovations in collaborative decision methods allow airlines to cooperate on reducing delays.
- **2010s–20s:** Using novel IT and big data technologies, researchers are developing autonomous air mobility technologies; ITS is helping seed UC Berkeley's growing aerospace program.

INFORMATION AND BEHAVIOR

- **1970s:** Revolutionizing the understanding of how people move, foundational work creates travel-demand forecasting and behavior models to inform transportation planning and decision making.
- **1970s–80s:** Making a quantum leap in conditional discrete-choice modeling, researchers increase the variety of more powerful and flexible modeling methods.
- **2000s–20s:** Advances in big data computing enable innovative analyses and modeling, allowing researchers to better understand traveler behavior, including using GPS in cell phones to alter the way traffic data is collected. This work leads to the launching of one of the first apps in North America to collect traffic data from GPS-enabled smartphones.
- **2010s–20s:** Focusing on human behavior and social equity, research provides a framework for using new technology, including a novel study using chauffeur-driven vehicles to simulate households with autonomous vehicles and providing kiosks in lower-income areas to increase access to shared vehicles, rides, and micromobility options such as scooters.

PLANNING

- **1940s–50s:** Research provides groundbreaking and fundamental ideas for planning mass transit in urban areas and informs future policies.
- **1950s:** Before the field of transportation finance was established, researchers investigate and provide key input on transportation financing and proto public-private partnerships.
- **1960s:** Researchers contribute planning, policy, and engineering on Bay Area Rapid Transit development.
- **1990s–2010s:** Researchers provide pioneering vernacular and practices in explaining travel behavior and megaprojects.
- **1980s–2020s:** Research incorporates social equity in the scope of planning including environmental justice, and disability access, laying the groundwork for a stronger push to engage with broader publics for greater inclusivity.

TSRC

TRANSPORTATION SUSTAINABILITY RESEARCH CENTER

AREAS OF EMPHASIS

- Energy and infrastructure
- Advanced vehicles and fuels
- Future of mobility
- Goods movement
- Shared mobility and mobility for special populations

"The growing need for clean, sustainable mobility options reflects an overall urgency in our work. We focus on policies that foster adoption, advanced technologies that are cost effective, and mobility services and technologies that are accessible to everyone."

— Susan Shaheen, TSRC Co-Director

▲ *Recent doctoral graduates Mustapha Harb, left, and Jessica Lazarus return bike-share rentals on their way to campus.* Photo: Amanda Cairo

◀ *At the ITS@75 celebration, Professor Susan Shaheen enjoys doctoral student Mengying Ju's poster while graduate students Franchesca Rodríguez, left, and Alex Pan discuss a project nearby.* Photo: Adam Lau

Mobility Services and Alternative Vehicles

The top research priority at the Transportation Sustainability Research Center (TSRC) is carbon-neutral transportation. TSRC's work looks at transportation systems and public policies that could reduce people's emissions, including decreasing the use of private vehicles while increasing reliance on multimodal transport.

Researchers probe how innovations in the "shared micromobility" sector of bikes, e-bikes, and e-scooters interact with public transit and impact transportation choices. TSRC also explores mobility services such as ride-hailing, including social-equity implications, congestion and airport impacts, and the potential to aid in disaster response. TSRC co-director Susan Shaheen, a civil and environmental engineering professor, studies how shared automated vehicles—from emerging on-demand ride services like Cruise and Waymo to automated shuttles—could help fill mobility gaps in the future.

Adopting Alternative Fuels

The phaseout of internal combustion engines and other climate-mitigation policies have led to urgent, implementation minded questions in TSRC's alternative-fuel research.

TSRC co-director and research affiliate Timothy Lipman, PhD, investigates vehicles and fuels as well as charging stations, the energy grid, and the entire life cycle—how alternative fuels, including hydrogen, are produced and distributed, including the social equity impacts of this large-scale adoption. TSRC also explores how "urban air mobility systems"—so-called flying taxis—could be electrified and automated.

Making Infrastructure Sustainable

Repairing, building, and decommissioning transportation infrastructure all produce pollutants that contribute to climate change and impact the health of local communities. To mitigate these effects, TSRC co-director Arpad Horvath, professor of civil and environmental engineering, is developing decision-support software to demonstrate a project's economic costs and projected changes in pollution emissions and exposures. The tool aids policymakers and communities in making evidence-based, equitable decisions.

Smart Cities

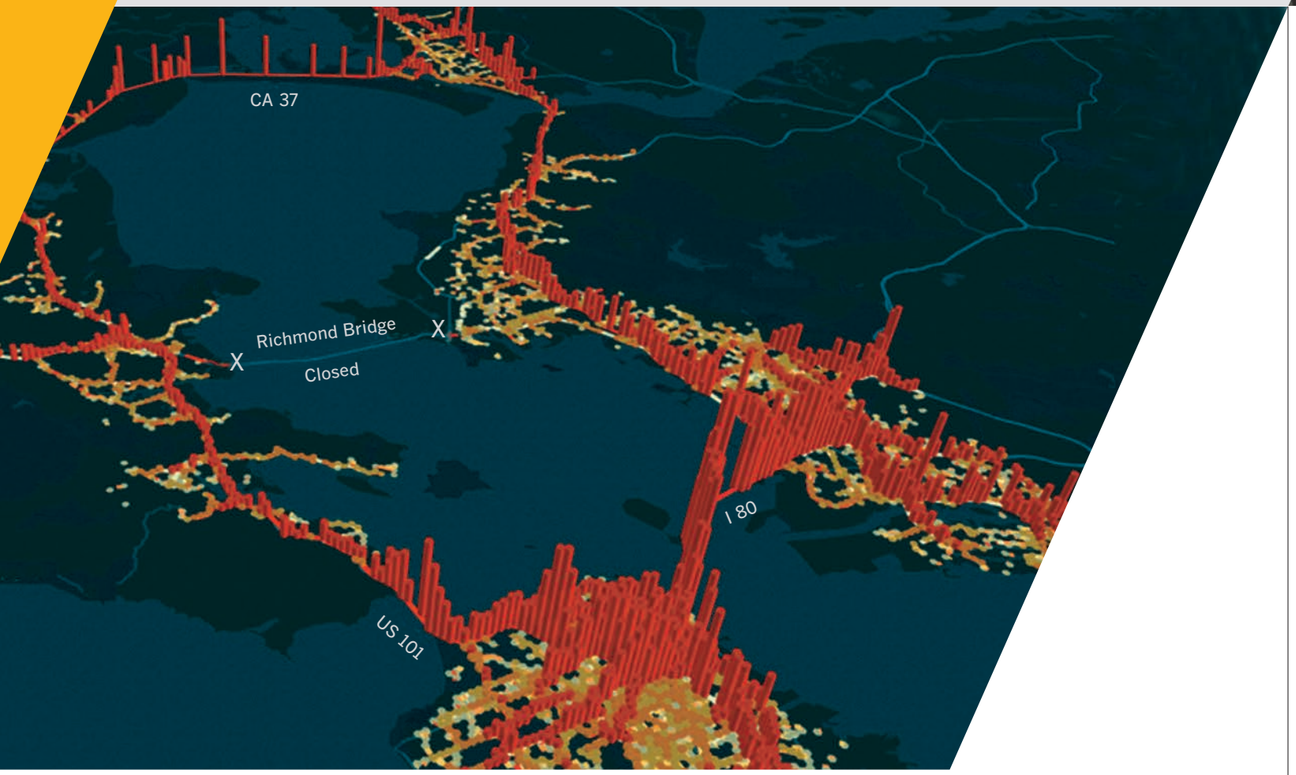
SMART CITIES RESEARCH CENTER

AREAS OF EMPHASIS

- Big data solutions for sustainable mobility planning
- Geospatial data analytics
- Smart and equitable routing control strategies
- Regional-scale discrete event simulation

"The future of transportation management lies not only in understanding the intertwined nature of urban challenges but also in proactively managing them. That takes high-performance computing, quantitative modeling of transportation networks, and deep knowledge in urban mobility."

— Jane Macfarlane, Smart Cities Director



▲ *In this Mobiliti report, the height of the red bars indicates traffic delays after a nine-hour closure of the Richmond–San Rafael Bridge as drivers sought alternative routes. With coordinated, dynamic routing, the impact could be reduced by tens of thousands of miles and thousands of hours.* *Image: Courtesy of Smart Cities*

◀ *As the Mobiliti simulation shows, when traffic shut down on the Richmond–San Rafael Bridge, surrounding traffic snarled, including on the San Francisco–Oakland Bay Bridge.* *Photo: Shutterstock*

Smart Transportation and High-Performance Computing

Datasets that come from devices and communication networks provide valuable insights about how cities work, but metropolitan networks are too complex to model in typical computing time. Smart Cities Research Center uses supercomputers to process multiple events at the same time. Agencies can use this big data, coupled with real-world data, to simulate the impact of rolling out new transportation technologies and policies, from modeling the energy efficiency and carbon footprint of entire transportation systems to introducing connected vehicles to the road.

At the center of this work is Mobiliti, a high-performance transportation modeling platform that shows traffic dynamics at a regional scale, developed by Smart Cities researchers in collaboration with the Lawrence Berkeley National Laboratory. Smart Cities has generated Mobiliti reports for most Bay Area cities, with plans to expand to other metropolitan regions.

Scenario Planning for Major Disruptions

The sudden rerouting of traffic due to crashes or evacuations can be chaotic and costly. What if cities could design a rapid response based on well-tested scenarios? The Mobiliti software system simulates the movement of an entire population through a region's road network in minutes, a task that is unachievable by traditional transportation modeling systems at this scale.

Prioritizing People, Not Vehicles

When queues of vehicles get too long at intersections, current traffic management models adaptively change red lights to green. Dimitris Vlachogiannis, a doctoral candidate with Smart Cities, is developing an algorithm that prioritizes the movement of people over vehicles to encourage a shift from single-occupancy vehicles to multiperson travel modes, like carpooling and public transit. Decreasing the number of vehicles on city streets keeps traffic moving, lowers greenhouse gas emissions, and reduces the traffic impacts on communities of concern.

PATH

CALIFORNIA PARTNERS FOR ADVANCED TRANSPORTATION TECHNOLOGY

AREAS OF EMPHASIS

- Connected and automated vehicles
- Digital infrastructure
- Electrification
- Freight and logistics
- AI-enabled technologies

"Our innovations in automation and other advanced technologies are helping to realize a safe, equitable, efficient, and carbon-neutral transportation system."

— Scott Moura, PATH Faculty Director

▲ *PATH researchers test the NEXTCAR vehicle—a Hyundai IONIQ 5 modified with additional cameras, LIDAR, high-accuracy GPS, high-performance computing, and wireless communication technologies—through intersections on University Avenue in Berkeley, CA.* Photo: Courtesy of PATH

◀ *Berkeley DeepDrive, a PATH-affiliated academic-industrial consortium led by computer science professor Trevor Darrell, is using state-of-the-art computer vision and machine learning technologies to investigate how automated vehicles recognize pedestrians, cyclists, and objects in 3D, along with AI mechanisms that teach the vehicle how to respond safely.* Photo: Courtesy of Berkeley DeepDrive

Harnessing Data to Reduce Energy

The NEXTCAR project, based at the California Partners for Advanced Transportation Technology (PATH), is developing connected and automated vehicle technologies that reduce energy consumption by 30% in plug-in hybrid and battery electric vehicles. By communicating with cloud services, the vehicle can tap into remote computations, traffic forecasts, historical data, and automation, and coordinate with other vehicles and infrastructure, enabling data-driven controls that predict and respond to traffic patterns, such as slowdowns and lane changes. The NEXTCAR team, led by mechanical engineering professor Francesco Borrelli and professor of civil and environmental engineering Scott Moura, PATH's faculty director, plans to demonstrate real-world eco-driving through intersection traffic lights and eco-fleet routing for urban delivery vehicles such as Amazon vans.

California Connected Vehicle Testbed

PATH, in collaboration with Caltrans and the Metropolitan Transportation Commission, operates the California Connected Vehicle Testbed, the nation's first connected-vehicle demonstration facility on public roads. Located along El Camino Real in the Silicon Valley communities of Palo Alto and Mountain View, the testbed is growing to 31 intersections outfitted with wireless transmitters that communicate road information, such as traffic signal timing, to connected vehicles. Accessing that data helps connected vehicles perform automated functions in real time, for example, displaying information that allows drivers to adjust their speed in anticipation of a red light. The testbed's operation is led by PATH associate research engineer Kun Zhou, PhD.

Understanding Human Factors

Even if self-driving cars safely sense pedestrians and other non-drivers, how do real people interact with these advanced vehicles? PATH research engineer Peggy Wang, PhD, explores the interaction between highly automated vehicles, or AVs, and pedestrians. Wang's team uses a prototype communication system—an LED panel mounted outside the vehicle—to communicate vehicle actions, such as stopping, to pedestrians to help build trust and confidence when interacting with an AV. Wang is also evaluating drivers' responses to receiving real-time eco-driving information and advice, like when to accelerate or reduce speed, to assess whether these technologies work and how often drivers comply.

SafeTREC

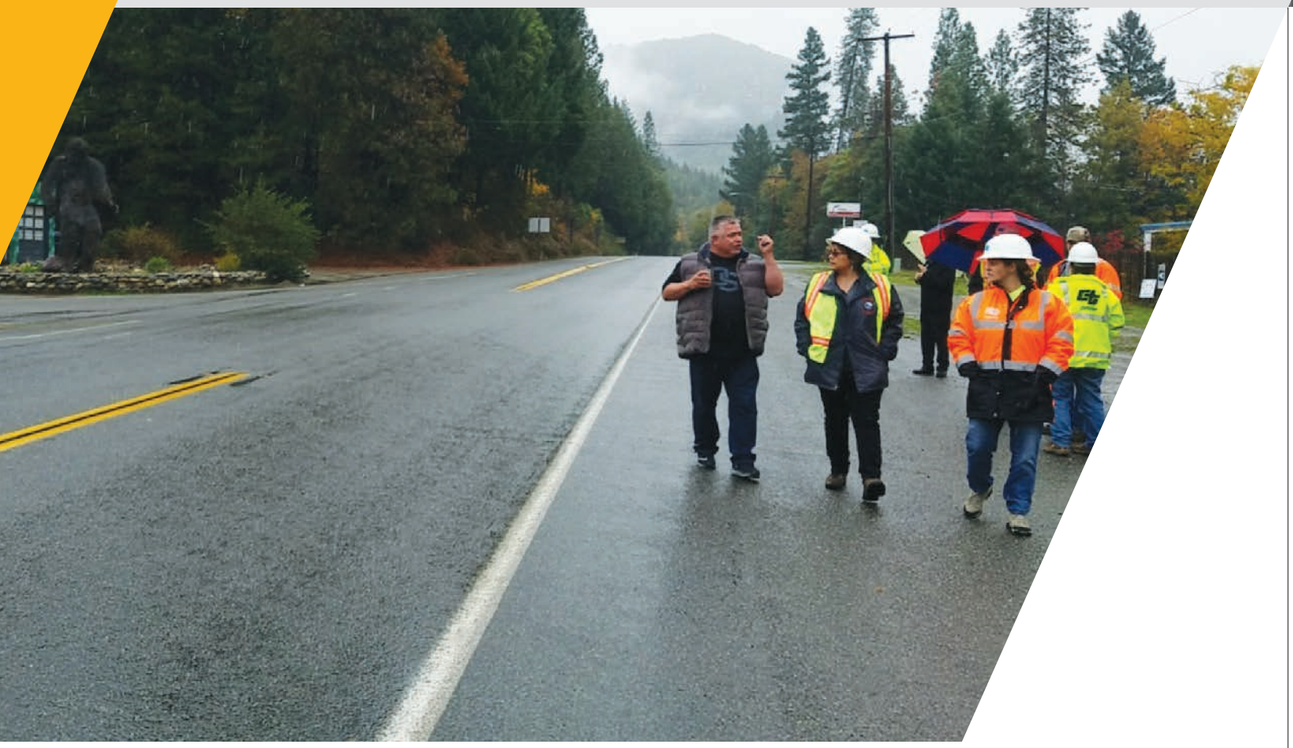
SAFE TRANSPORTATION RESEARCH AND EDUCATION CENTER

AREAS OF EMPHASIS

- Data analysis and data tools
- Active transportation safety research
- Policy analysis and community outreach
- Road safety management research

"SafeTREC envisions a world with zero roadway fatalities or serious injuries and a culture that prioritizes active and safe mobility for all. Pressing transportation safety needs are addressed through research, tool development, public engagement, and data analysis."

— Katherine A. Yelick, Vice Chancellor for Research, UC Berkeley



▲ *SafeTREC conducts Tribal Transportation Safety Assessments using input from Tribal communities about their transportation choices, challenges, and opportunities. The evaluations help Tribal staff and leadership plan safety improvements for all travel modes on Tribal roads and pathways and on roads accessing Tribal lands.* Photo: Courtesy of SafeTREC

◀ *Researcher Julia Griswold, PhD, left, co-leads SafeTREC's virtual reality bicycle simulator lab. Civil and environmental engineering doctoral student Han Wang co-developed the technology, which shows how factors such as traffic speed and parked cars can influence a cyclist's roadway experience—without exposing study participants to hazards. Findings will help Caltrans and local agencies evaluate bicycle networks and target improvements.* Photo: Amanda Cairo

Bicycle and Pedestrian Safety

Walking and bicycling are active, carbon-neutral transportation modes that improve human health while helping to reduce climate change. To improve pedestrian and bicycle safety, the Safe Transportation Research and Education Center (SafeTREC) works closely with communities and local, regional, and statewide partners to develop publicly available tools and resources that help guide policy and planning decisions. Their work includes adding pedestrian and bicycle infrastructure elements to the State Highway database, helping form pedestrian and bicycle advisory committees for local governments, and providing a systemic approach to pedestrian and bicycle safety.

Community Engagement and Public Partnerships

Communities play an important role in "moving the needle" with local decision makers by advocating for active transportation projects in their local jurisdictions and identifying the most critical projects. SafeTREC prioritizes engaging communities and giving them the tools and support they need to communicate with decision makers and affect statewide policy. For example, SafeTREC helps communities collect local data required for infrastructure improvement grants, contributes to the California Strategic Highway Safety Plan Steering Committee's work, and provides expert testimony to the California Assembly and Senate on bills related to traffic safety. The center's work for the California State Transportation Agency's Zero Traffic Fatalities Task Force board includes studying critical issues such as safer road designs.

Data Tools

SafeTREC develops and maintains tools that support informed data-driven decision making, safety planning, and programming for communities, governments, and Tribes. Their Transportation Injury Mapping System, or TIMS, can query and map local crash data. Street Story, an online community engagement platform, is a user-friendly interface that collects community-level input on roadway concerns and ideas for improvement.

Air Mobility

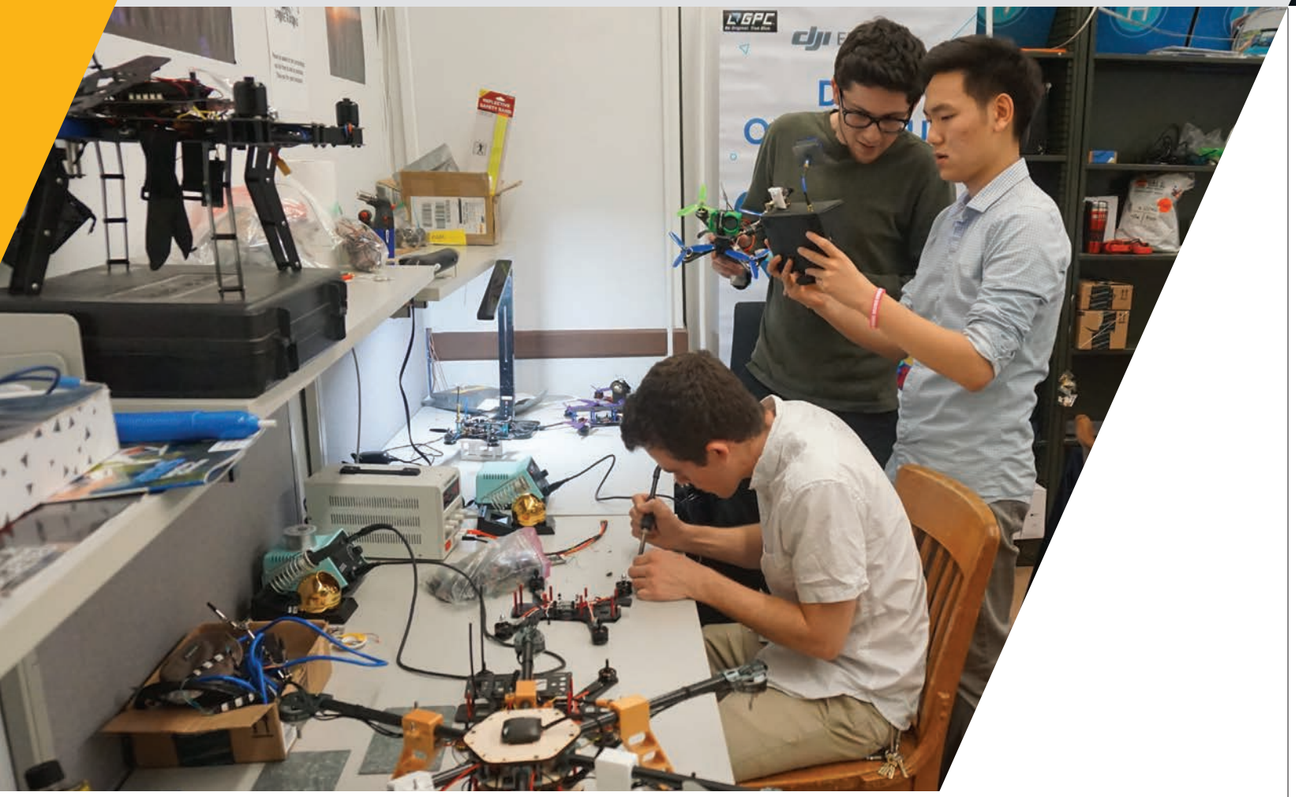
AIR MOBILITY RESEARCH

AREAS OF EMPHASIS

- Sustainability and fuel efficiency
- Aviation economics and operational performance
- Air traffic management
- Aviation infrastructure
- Aerospace engineering

"We're addressing changes in airspace management, adapting to urban and regional air corridors and to changes in the technology, including automation. We're looking at strategies for decarbonizing that promote sustainable aviation fuels, with a particular focus on California policy."

— Mark Hansen, NEXTOR Director



▲ *From left, UAVs@Berkeley club members Trey Fortmuller, David Hooper, and Ryan Park build drones in ITS Berkeley's McLaughlin Hall.*
Photo: Amanda Cairo

◀ *From left, students Ambroise Levrard, Hugo Roucau, and Jad Osseiran, with Professor Jasenka Rakas, showcase their work on designing vertiports—hubs for air taxis—at the Master of Engineering Showcase. Wayne Delker, former executive director of the College of Engineering's Fung Institute for Engineering Leadership, looks on.*
Photo: Golnaz Shahmirzadi

Sustainability

ITS is home to NEXTOR, a Federal Aviation Administration "Center of Excellence," as well as broader investigations and collaborations on the current and future growth of air mobility. Sustainability is a major focus in all this work, including streamlined airport design, fuel economy—burning less conventional fuel but also promoting sustainable aviation fuels, such as hydrogen and biofuels—and air traffic management strategies that, for example, give priority to flights that use sustainable fuel.

Delivery Drones

Home deliveries create more truck traffic, leading to excessive carbon emissions, double parking, and other impacts. ITS research involving unmanned aerial vehicles, or drones, explores whether delivery drones can be deployed at a scale large enough to mitigate some of these negative impacts. How much drone traffic can a city's airspace accommodate? How do drones avoid conflict with other drones, with infrastructure, and with people? Systems engineering professor Raja Sengupta, a longtime leader in developing drone software, and transportation engineering professor Mark Hansen are developing systems and strategies for drone air traffic management that address these questions and test the system's scalability.

Aerospace Engineering

In response to a growing demand for researchers and developers in the fields of aviation, defense, and space exploration, UC Berkeley launched the aerospace engineering major in fall 2022, with several ITS professors in its teaching ranks. Student interest in the subject is already high, with at least 300 actively involved in aerospace-related clubs on the Berkeley campus. In addition, UC Berkeley recently signed a land-lease agreement with NASA on a 36-acre plot at Moffett Federal Airfield in Mountain View, CA, potentially a major asset in supporting the aerospace program.

PRC

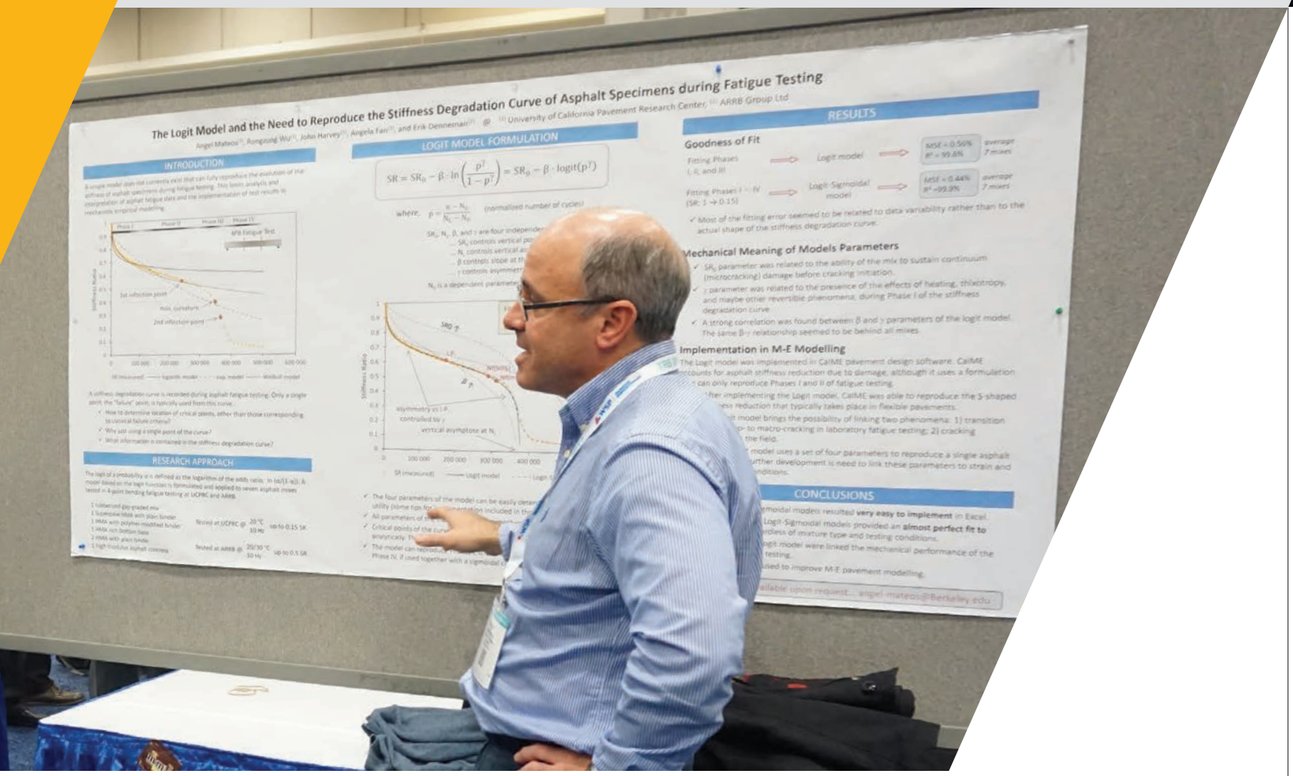
UNIVERSITY OF CALIFORNIA PAVEMENT RESEARCH CENTER AT BERKELEY

AREAS OF EMPHASIS

- Pavement design and modeling
- Full-scale testing of pavements
- Alternative and improved pavement materials
- Life-cycle analysis of pavements

"Everything we do now has either a direct or ultimate focus on the sustainability of our roadway network."

— Angel Mateos, Principal Investigator



▲ *Principal Investigator Angel Mateos presents research at a Transportation Research Board meeting in Washington, D.C.* Photo: Amanda Cairo

◀ *Every year, Caltrans recycles five million used tires into asphalt, diverting them from landfills and waste piles destined for burning. But you can't just throw tires in the asphalt mix. PRC's technical solutions have resulted in asphalt that is more resistant to cracking, helping to make Caltrans a world leader in tire recycling.* Photo: Shutterstock

Sustainability Across the Life Cycle

Greenhouse gas emissions don't just come from vehicles—the roads themselves have a carbon footprint. The UC Pavement Research Center (PRC) develops tools and technologies that help Caltrans minimize the climate and environmental impacts of highway design and maintenance operations, both across highway networks and for specific projects. One key tool that PRC developed for Caltrans is eLCAP, software that quantifies the carbon emissions from building and maintaining pavements and supports decision making that lowers those impacts.

Researchers also continue to develop highly resilient materials that extend the life of pavements across a road's life cycle, including new technology that uses combustion ashes and volcanic deposits—abundant in California—to make Portland cement, decreasing the cement industry's environmental impacts. Another new technology is embedded instrumentation—built-in sensors that reveal what is going on inside the pavement before the failure is visible at the surface. This information can lengthen a road's lifespan by improving maintenance methods.

Recycling the Roads

Asphalt mixes for pavement use mined and petroleum-based products—materials with high environmental impacts. In a joint effort with Caltrans and CalRecycle, PRC is working to increase the amount of recycled material used in highway reconstruction, from roughly 15% of the mix to 40%. The process—milling used pavement and then adding a plant-based "rejuvenator"—makes asphalt that is more sustainable and less costly than using nonrecycled materials. "In one shot, we have a product that is cheaper and has a lower environmental impact," says Angel Mateos, PhD, PRC's principal investigator at UC Berkeley. PRC's guide to pavement recycling supplements the California Highway Design Manual.

TechTransfer

TECHTRANSFER PROFESSIONAL DEVELOPMENT AND TRAINING

AREAS OF EMPHASIS

- Pavement design, construction, and maintenance
- Planning policy and funding
- Traffic engineering, signals, and safety
- Work-zone safety and traffic control
- Active and multimodal transportation
- Airport systems planning and design
- Professional education in innovation and technology

"Filling a unique space, TechTransfer covers so much more than technical classes. As California's preeminent transportation training program, we get the latest research results and best practices into the hands of professionals who immediately apply them to meet today's challenges."

— Laura Melendy, TechTransfer Director and ITS Berkeley Assistant Director

▲ *Ching-Yao Chan, PhD, co-director of Berkeley DeepDrive, briefs international executives on the future of connected and automated vehicles and how these technologies will impact their industries.* Photo: Jim Block

◀ *TechTransfer's online classes on pavement design, construction, inspection, and maintenance help local agencies save time and money while meeting their training needs.*
Photo: Courtesy of PRC

Educating Aviation Professionals

TechTransfer's popular Airport Systems Planning and Design short course stretches beyond airport planning and design to explore the challenges and uncertainties involved in planning airports. Taught by leading practitioners and experienced instructors, the five-day course is offered in conjunction with NEXTOR, the ITS Berkeley–based Federal Aviation Administration Center of Excellence. The course is continually evolving to reflect new and changing technology and design, the current mobility environment, and emerging issues facing airport planners, operators, and consultants around the world.

Partnering to Maintain California Roadways

Local governments maintain over 80% of California's pavement lane-miles, roadway that carries nearly half of the state's vehicle miles traveled. TechTransfer created a partnership with the City and County Pavement Improvement Center to develop and provide training on the most advanced, cost-effective, and sustainable pavement practices to better repair and maintain California's roads. Courses support engineers, managers, technicians, and construction inspectors with trainings on designing, managing, and constructing pavements.

Professional and Executive Education

TechTransfer's Learn2Launch, the Silicon Valley Innovation and Entrepreneurship Program, is an immersive, hands-on approach to the study of innovation and entrepreneurship. The semester-long, graduate-level intensive course combines lectures, workshops, field trips, and discussions with renowned Berkeley faculty from engineering, business, law, communications, and other disciplines, and guest lecturers by some of the most dynamic innovators in Silicon Valley.

TechTransfer also hosts custom executive education programs designed to meet the needs of working professionals. One such program is a week-long module combining transportation and the Silicon Valley ecosystem, a stop on the École Polytechnique's international Executive Master Program.

ITS Library

INSTITUTE OF TRANSPORTATION STUDIES LIBRARY

"The ITS Library is a thriving community space that brings students from multiple disciplines together in scholarship, research, and comradery. But data services are the heart of the library—we help patrons curate, and publicly share datasets, and we connect people with the data that they are looking for."

— Kendra K. Levine, ITS Library Director

▲ *Students and researchers from the Bayen lab use the library as a space to collaborate. Clockwise from top left: Gilbert Bahati, Alexandre Keimer, Jessica Lazarus, Shuxia Tang, Bingyu Zhao, Zhe Fu, and Tanya Veravalli.*
Photo: Amanda Cairo

◀ *The library is home to the Institute's official sport: ping pong. Clockwise from top left, Professors Carlos Daganzo and Michael Cassidy engage students Xuan Jiang and Zhiyi Tang in a competitive match at this ITS Berkeley tournament held on the first floor of McLaughlin Hall.*
Photo: Amanda Cairo

A Resource for Berkeley and Beyond

The ITS Library has a long tradition at UC Berkeley. Opening its doors to students in 1948, it is the nation's first comprehensive transportation library and serves as one of the leading transportation libraries in the United States. The library supports research at ITS Berkeley and all University of California ITS campuses, as well as external research needs, including requests from public agencies and the news media.

For example, ITS Library director Kendra K. Levine helped a *Washington Post* reporter locate documents showing the impacts of highway planning on community displacement. "The ITS Library was instrumental in documenting discriminatory and racist practices, information that enabled us to reflect on past mistakes and actively consider ways to avoid them in the future," says ITS director Daniel A. Rodríguez.

Digital Assets and Information Services

With stacks of books on just one side of its fourth floor McLaughlin Hall space, the library has shifted its mission to providing information services, connecting users to a vast array of electronic resources and digitized collections.

Library staffers also curate resources to help researchers better engage with projects concerning environmental justice and social equity and help ITS students, faculty, and researchers make their work freely available by providing guidance on open-access publishing and copyright, and by publishing datasets. Leveraging tools like the Transportation Research International Documentation database, the eScholarship repository, and Open Access journals, the library aims to put more information into a greater number of hands.

A Place for Students

As the center of student life at ITS Berkeley, the library is a study space, a collaborative work environment, a research hub, and a venue for meetings, hackathons, and social events. Since the 1960s, starting with Professor Gordon Newell, ping pong has been the official sport of ITS Berkeley and continues to thrive, including in the library.

COLLABORATION AND PARTNERSHIP

Transportation reaches across fields of study and societal, geographic, and governmental boundaries. By collaborating with academic colleagues, governments, and communities, ITS Berkeley looks at problems through multiple lenses to solve the big mobility-related questions of our era.

◀ *The UC Berkeley community arrives on campus on many forms of active transportation, including bikes, scooters, and walking. ITS health-related research examines the benefits of bike safety, active transportation, and equitable access to microtransit options like e-scooters and e-bikes.* *Photo: Ann Brody Guy*

Enhancing Health and Well-being

As director of ITS, city and regional planning professor Daniel A. Rodríguez is advancing an initiative to probe the intersection of transportation and health. "The walkability of cities, the availability and efficiency of transit, and the equitable access of active, on-demand microtransit like bikes and scooters, all help reduce vehicle miles traveled and contribute to the health of individuals, communities, and the environment," Rodríguez says. Rodríguez, a Chancellor's Professor, is cultivating research relationships in complementary disciplines—such as environmental health, agricultural and resource economics, and epidemiology—to join forces with ITS to better understand how transportation affects health and formulate policy options to improve well-being.

Rodríguez's own research engages health topics such as bike safety, how transportation policies such as road pricing and accessibility affect mortality, and the impacts of COVID-19 on travel behavior, telework, and equitable job access. Working with researchers in health, economics, engineering, geography, and public policy, Rodríguez studies how the physical attributes of the urban environment—for example, bus routes, green spaces, and supermarkets—are related to individual behaviors, individual and community health, and to air quality.

Health and safety are also central to SafeTREC's mission. Researchers collaborate with communities to establish priorities and produce data and reports that guide policy. For example, for a research synthesis led by SafeTREC co-director David Ragland, a professor emeritus of epidemiology, researchers consulted with local and state transportation agencies and community groups to document risk patterns for pedestrian injury for Black, Hispanic, and Native American populations. Ragland also addresses the interaction of ethnicity and income and evaluates solutions to reduce pedestrian injury among these populations.

Advancing Disaster Response

In recent years, devastating California wildfires have forced more than half a million people to evacuate their homes. Civil and environmental engineering professor Kenichi Soga is leading an interdisciplinary, multicampus UC team to improve Bay Area disaster response. Researchers are combining expertise in complex systems modeling, risk management, and human-computer interaction to simulate wildfire evacuation methods in two Bay Area communities, and they are educating community members on how to escape wildfires safely.

"We need to think about the interactions of decision making, communications between organizations and the public, and traffic patterns during a wildfire so that we can improve evacuations in the future," says Soga, who is also the director of the ITS-affiliated Berkeley Center for Smart Infrastructure and a Chancellor's Professor.

Recent disasters have also exposed a lack of resources to transport and shelter all evacuees, especially underserved populations like the elderly and disabled. In a first-of-its-kind policy brief, former student Stephen D. Wong, now an assistant professor of transportation engineering at the University of Alberta, and co-advisor, Professor Susan Shaheen, worked directly with individuals in several fire-affected communities, including communities of concern.

Their report suggests that emergency management agencies and local relief organizations partner with companies in the sharing economy—such as Airbnb, Lyft, and Uber—and private citizens to transport underserved people and ensure social equity in evacuations.

▲ *Professor Kenichi Soga is leading a multicampus, interdisciplinary team tackling wildfire evacuation and risk mitigation. The project includes taking evacuation simulations, like this board game developed at UC Davis, into the digital realm.* *Photo: Courtesy of Thomas Maiorana*

"Increasing the reach and capacity of public transit networks, including rail, is essential to reducing greenhouse gas emissions from transportation."

— Ethan Elkind, Berkeley Law, from the 2021 report, "Analyzing Rail Transit Project Costs and Delays"

Professor Karen Trapenberg Frick, left, mentors for Self-eSTEM, a program that provides interactive, culturally responsive STEM literacy, leadership, and technical training for BIPOC girls and young women. Also pictured: Self-eSTEM co-founders Shalonda Tillman and Adamaka Ajaelo, fourth and fifth from left, plus graduate student mentors and participant Alexis House, center front. Photo: Courtesy of Self-eSTEM

Law and Policy

ITS affiliate and Berkeley Law research director Ethan Elkind specializes in the intersections among law, transportation, and climate change. Elkind, who leads the Climate Program at Berkeley Law's Center for Law, Energy and the Environment, studies transportation issues, such as how to improve electric vehicle (EV) charger deployment in lower-income communities, and develops policy solutions to accelerate EV adoption in the U.S. and globally.

Analyzing Megaprojects

Karen Trapenberg Frick, a city and regional planning professor, works on the politics and challenges of infrastructure development and implementation, including massive-scale megaprojects. Notably, Frick analyzed how conservative politics have affected sustainable planning efforts, and her research on the new eastern span of the San Francisco–Oakland Bay Bridge addressed key questions, including how a 1995 estimate of $250 million soared to $6.5 billion by 2014, and why such a complex design was chosen in the first place.

Understanding Travel Behavior

Professor Joan Walker, chair of the Department of Civil and Environmental Engineering, examines how multiple factors impact travel behavior—influences often outside transportation. For example, Walker worked with engineering, planning, and agriculture and resource economics colleagues to study the impacts of the COVID-19 pandemic on travel behavior, such as how commuting and telework impact equitable job access. Walker is also analyzing how new mobility options, including autonomous vehicles and public microtransit options like e-bikes and scooters, affect travel behavior.

Professor Dan Chatman, chair of the Department of City and Regional Planning, looks at travel behavior in relation to the built environment, often reaching into communities to survey transit users and administrators directly. Chatman's research includes studies addressing which U.S. transit systems succeed and why, and the implications of immigration trends for sustainable development and economic growth.

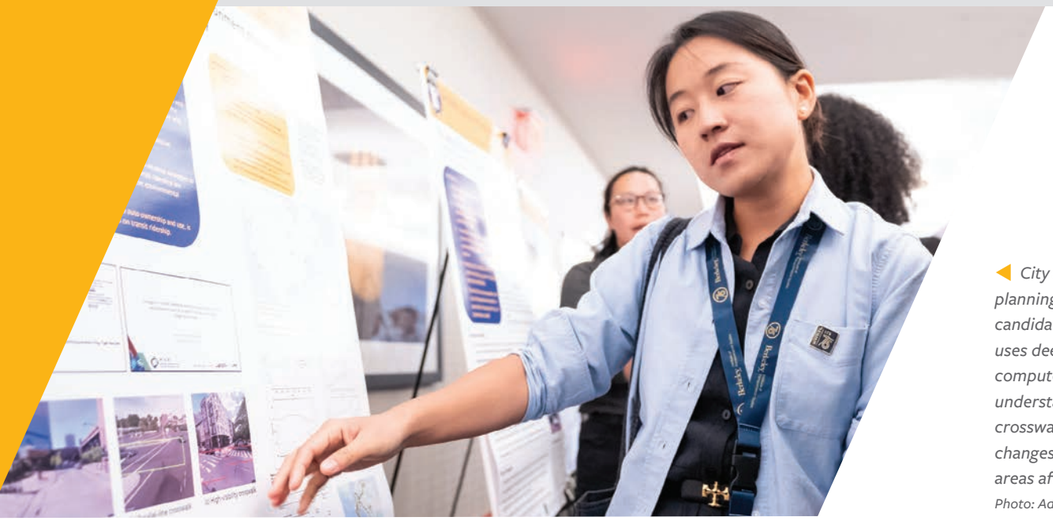
Using Data to Improve Mobility

Ride-hailing and delivery services are transforming curbs—once-innocuous infrastructure elements dedicated mainly to parking—into dynamic spaces used for a variety of competing activities. By collecting dashboard-camera data from UC Berkeley's shuttle bus system, electrical engineering and computer science professor Murat Arcak and PATH researcher Alexander Kurzhanskiy, PhD, aim to assist cities with this rapidly changing environment by analyzing how urban curb space is used.

ITS Assistant Director Laura Melendy shows off ITS research during an official visit from California State Senator Josh Newman. As the Institute's administrative lead, Melendy oversees ITS's numerous partnerships, collaborations, and governmental relationships. Left to right: ITS Library Director Kendra K. Levine, Melendy, Sen. Newman, and the senator's senior advisor, Michele Newman. Photo: Amanda Cairo

GRADUATE STUDENT RESEARCH

ITS Berkeley students come from diverse disciplines and from universities across the United States and around the world. They are the heart and soul of the Institute: fierce in their research pursuits, passionate about their fields of study, and open to new ideas.



◀ *City and regional planning doctoral candidate Meiqing Li uses deep-learning-based computer vision to understand how crosswalk and sidewalk changes in transit station areas affect transit users.* *Photo: Adam Lau*

Addressing Equity in Traffic Enforcement and Safety

Several SafeTREC students earned fellowships that probe questions of equity in traffic enforcement. City and regional planning student Ethan Ebinger studied the implementation of the Berkeley City Council's vote to become the first city in the United States to separate traffic enforcement from the police department. City and regional planning student Alejo Alvarado analyzed police-stop data to identify how Oakland's road-safety enforcement practice results in disparate outcomes across racial groups, including how communities of color, particularly Black people, are over-policed in the city. Jonathan Kupfer, a civil and environmental engineering student, analyzed bicycle collision data to understand racial disparity in bike safety.

Other recent SafeTREC-based student projects are investigating ongoing traffic safety changes resulting from the COVID-19 pandemic, simulated scenarios for autonomous vehicles, and the impacts of traffic-light failures on the risk of crashes at intersections.

Leveraging Data

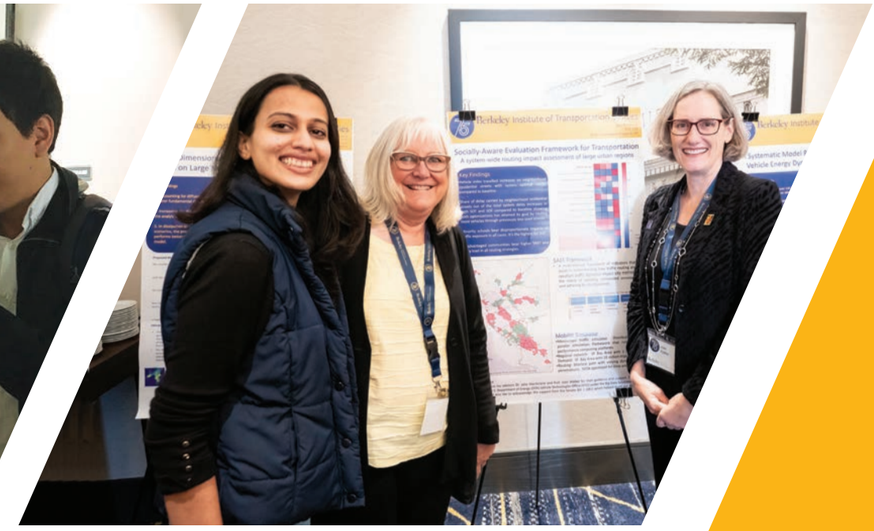
Doctoral candidate Juan Caicedo, working with civil and environmental engineering professors Joan Walker and Marta C. González, uses data science to understand how socioeconomic factors influenced travel demand during the COVID-19 pandemic. Using smartcard data to forecast transit use, Caicedo has also developed tools to fill a gap in the field, including an open-source benchmarking system and a meta-analysis of existing approaches. Caicedo's innovations have made existing methods more robust to systemic shocks, such as strikes and pandemics.

Investigating Climate, Mobility, and Equity

Doctoral candidates at the Transportation Sustainability Research Center (TSRC) are probing numerous intersections of mobility and social equity. Doctoral candidate Aqshems Nichols is examining transportation access to community college and how this impacts outcomes, such as access to good jobs. Recent graduate Jessica Lazarus investigated how pricing and fare strategies impact the mobility of underserved travelers. Other students working with TSRC are exploring the equity impacts of California's Clean Mile Standard, a set of policies requiring ride-hailing companies like Lyft and Uber to reduce greenhouse gas emissions. Drivers for these companies, many from underserved populations, own or lease their vehicles and could bear financial consequences from the law. Numerous TSRC doctoral-student investigations are also helping to inform the California Air Resources Board, the California Public Utilities Commission, Caltrans, and other policy-making bodies.

Studying the Digital Infrastructure

Travelers increasingly interact directly with a digital infrastructure, from ticketing systems to signage that displays real-time arrivals for transit. City and regional planning doctoral candidate Dagin Faulkner is exploring this infrastructure with the aim of providing planners and governments with a more complete picture of the financial costs and cybersecurity considerations of developing and delivering these services.



▲ *Civil and environmental engineering (CEE) doctoral candidate Juan Caicedo, right, has used data science to understand how socioeconomic factors influenced travel demand during the COVID-19 pandemic. Left: City and regional planning student Melanie Gu.* *Photo: Courtesy of Transoc*

▲ *CEE doctoral candidate Anu Kuncheria, left, presents at the ITS@75 student poster session. Kuncheria's tool can help policymakers consider the potential unintended consequences that routing apps like Google and Waze can have on neighborhoods, safety, mobility, equity, and the environment. Kuncheria worked with Jane Macfarlane, center, the Smart Cities research director, and Joan Walker, right, CEE professor and chair.* *Photo: Adam Lau*

THE FUTURE OF MOBILITY

Infrastructure, technology, planning, behavior change—many of the most critical transportation issues gaze forward. Changes that advance a future of carbon-neutral, equitable mobility start with research conducted today.

◀ *Professor Mark Hansen, left, leads a panel at the ITS-hosted symposium, "The Future of Aviation: Advancing Aerial Mobility through Technology, Sustainability, and On-Demand Flight." From center, Dave Merrill and Will Heyburn, both from air mobility companies.* *Image: Event video*

Advanced Air Mobility

On-demand air taxis, transit-like air buses, delivery drones—transformative aviation technologies and services, collectively known as advanced air mobility—are taking flight. ITS Berkeley is a leader in shaping this emerging sector.

Hosting two future-looking conferences, we convened leaders and thinkers from the public, private, nonprofit, and academic arenas to exchange ideas about advanced air mobility policy, research, and sustainability.

Our faculty investigates cutting-edge policy, technology, and infrastructure questions. Professor Mark Hansen has examined how existing regional airports might be leveraged to serve the new sector, and Professor Jasenka Rakas's students study how to design and implement vertiports, new infrastructure optimized specifically for urban air mobility vehicles. Professor Alexandre Bayen has developed digital tools that help designate air corridors. Professor Raja Sengupta has evaluated how potential air corridors might affect traffic flow and safety and bring economic and environmental benefits.

Researchers are also exploring how to create a highly inclusive system that operates more like transit, with larger vehicles, more trips, and lower costs than the first-generation air taxi concept.

Sengupta's extensive work on unmanned aerial vehicles includes developing a laser system that helps drones detect other objects. Professor Susan Shaheen and researcher Adam Cohen have studied policy-related questions, including market demand, equitable access, and legal and regulatory issues. "Our research is laying the groundwork for making advanced air mobility a reality in California," Sengupta says.

Autonomous Vehicles and Mobile Traffic Control

Can self-driving vehicles help remove stop-and-go traffic waves, reduce bottlenecks, and increase fuel efficiency? Alexandre Bayen, the Liao-Cho Professor of Electrical Engineering and Computer Science, led the CIRCLES project—a $20 million, multicampus effort that included the U.S. Department of Energy, the National Science Foundation, the U.S. and Tennessee transportation departments, and three major automakers—to investigate whether a small percentage of autonomous vehicles inserted onto the road can help control traffic flow.

In November 2022, the consortium conducted the largest self-driving flow-control experiment ever performed, with 100 vehicles controlling traffic for a few hours each day on I-24 in Nashville, TN. The experiment demonstrated that technology can successfully move from the lab to roadways at scale, and preliminary results suggested that deploying automated vehicles can effectively change overall traffic behavior.

Bayen, the ITS director from 2014 to 2021, is leading the ongoing effort. The work builds on Bayen's FLOW open-source framework and on prior collaborative research. By integrating human-driven and autonomous traffic, Bayen says, "We aim to improve the future of transportation and advance the convergence of artificial intelligence, simulation, traffic engineering, and vehicle technology."

Making Transit More Accessible

With ride-hailing services like Lyft and Uber now a ubiquitous part of urban transportation, civil and environmental engineering professor Michael Cassidy is exploring policies to encourage these companies to be better transit participants. Cassidy is tackling issues like expanding access by installing public communication devices and providing subsidized first- and last-mile services for designated transit stations. The research also examines solutions to congestion-producing practices, like disincentivizing double-parking through fees.

▲ *Professor Alexandre Bayen acknowledges the CIRCLES team, visible on screen, for successfully completing the 100 self-driving vehicle field operational test in Nashville, TN, during the media event held at the end of the test.* *Photo: Vanderbilt University*

"Machine learning is being integrated into many aspects of transportation. The beauty of the techniques we're using is that they can take human mobility data, learn from it, and then apply it to improve system efficiency."

— Professor Alexandre Bayen

A novel study on California high-speed rail is one of numerous research questions supported by the Statewide Transportation Research Program, which allows ITS to make grants directly to researchers. *Image: California High-Speed Rail Authority*

State-Funded Research, Curated by ITS

California's high-speed rail system has been widely criticized, in large part for the initial operating segment that runs through the Central Valley—excluding the large Los Angeles and San Francisco population centers. But what if the much-maligned "train to nowhere" route had unplanned positive benefits? Smaller cities on the route, including Gilroy, Fresno, and Merced, are home to many of the state's most vulnerable and underserved communities, comprising immigrants, farm workers, and other low-wage earners. Professor Mark Hansen is leading a study to measure the benefits the trains might bring to these communities, such as improved access to community colleges and job centers, like the Amazon warehouse in Fresno.

The project is just one of numerous forward-looking investigations that ITS supports through the Statewide Transportation Research Program (STRP), an annual injection of transportation-research dollars from the state. While ITS carries out critical transportation research sponsored by state agencies, "STRP funds allow us to make grants directly to researchers, broadening the types of questions we can ask," says ITS director Daniel A. Rodríguez, "and the novel directions our researchers can go to support California." Other recently funded investigations include an EV charging infrastructure assessment, how shared automated vehicles can increase options for visually impaired travelers, and the equity impacts of smart transportation strategies.

ITS Berkeley also carries out important research, led by the UC-wide Institute of Transportation Studies and Professor Susan Shaheen, under the California Resilient and Innovative Mobility Initiative. RIMI serves as a living laboratory that brings together university experts, policymakers, public agencies, industry stakeholders, and communities to address the state's rapidly evolving mobility developments, prepare the state for future crises, and keep California at the global forefront of transportation innovation.

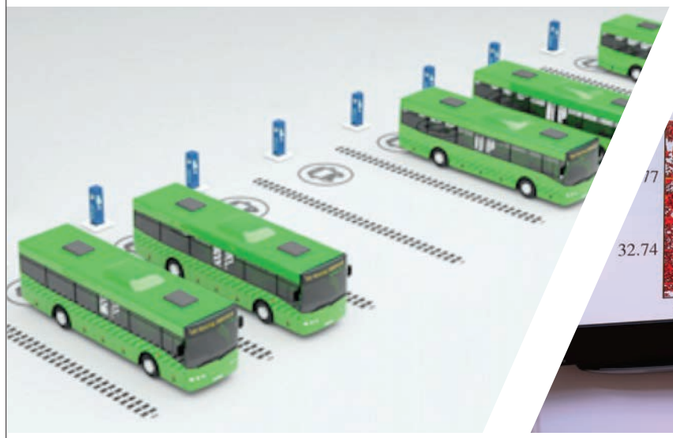
Electrifying Transportation

Scott Moura, civil and environmental engineering professor and PATH faculty director, develops innovative tools to ease the adoption of electric vehicles, or EVs. Moura's research has been commercialized into the cloud-based EVOPT solution, which guides fleet operators by estimating the total cost of ownership, emissions, and energy. EVOPT is being used to electrify bus fleets in several U.S. states and Italy.

Moura is also piloting a smart EV charging infrastructure on UC Berkeley's campus that uses machine learning to optimize price and power delivery for individual users—information that can reduce facility operating costs, user service costs, and greenhouse gas emissions. In addition, Moura is developing EEZ Mobility, a tool to support the fair distribution of EV charging infrastructure, which typically has lower implementation rates in communities of concern. Building on data from CalEnviroScreen, which identifies underserved communities for cities and policymakers, Moura's tool predicts the accessibility, economic benefits, and health impacts of deploying public charging infrastructure.

Leveraging Mobile Phone Data

City and regional planning and civil and environmental engineering professor Marta C. González develops computer models that analyze data from mobile devices, and then uses AI and network science to understand how urban infrastructures interact with mobility and energy. One recent study used billions of mobile phone records to understand the appearance of traffic jams. Another project, co-authored by Professor Scott Moura, analyzed EV charging data from Bay Area phones and yielded insights that can ease drain on the energy grid as more EVs come online.



Professor Scott Moura's research has been commercialized into the cloud-based EVOPT solution, which uses physics-based models and machine learning to help fleet operators estimate the costs of electrification. *Image: EVOPT*

Professor Marta C. González, left, and her graduate student Ayse Tugba Ozturk use digital traces from cell phone data and credit card purchases to understand commuter behavior and support city planning. *Photo: Paul Kirchner*

WORKING TOGETHER FOR A CLEAN-TRANSPORTATION FUTURE

California leads the way. Our culture of innovation and collaboration has made our state the global epicenter for sustainability and clean mobility. From the capital to the field, we are building streamlined transportation infrastructure, expanding public transit and bike and pedestrian corridors, and investing in clean transit projects and zero-emission vehicles to advance our state's climate and public health goals, all while creating good-paying jobs. As we continue our work to make this clean-transportation future a reality, UC Berkeley's Institute of Transportation Studies is a key research partner.

Gavin Newsom
Governor of California

THE ENGINE OF INNOVATION

What is a smart city? The precise definition is constantly changing as technology and community needs change. 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.

Barbara Lee
Congresswoman for the 12th District of California

▲ *Doctoral candidate Fangyu Wu shows members of a European documentary film crew technology from the CIRCLES project, which introduced 100 self-driving vehicles into traffic to help smooth traffic flow.* Photo: Amanda Cairo

UC Berkeley Institute of Transportation Studies
Director: Daniel A. Rodríguez
Assistant Director: Laura Melendy
Communications Director: Amanda Cairo
ITS Library Director: Kendra K. Levine

Learn more about ITS Berkeley

Berkeley Institute of Transportation Studies

Advancing the Future of Mobility is a print and online publication celebrating the 75th anniversary of the Institute of Transportation Studies at the University of California, Berkeley.

its.berkeley.edu

Cover: Doctoral candidate Xin Peng, left, developed a system that uses colored LEDs and radio frequencies to recognize ownership of unmanned aerial vehicles, or drones. Professor Raja Sengupta, right, works on drone airspace and technology issues, including developing a laser system that enables drones to detect nearby objects. Photo: Paul Kirchner