

TRANSPORTATION RESEARCH
CIRCULAR

Number E-C253

October 2019

**Transformational
Technologies in
Transportation**

*Impacts on Traditional
Research Processes
and Programs*

The National Academies of
SCIENCES • ENGINEERING • MEDICINE



TRANSPORTATION RESEARCH BOARD

**TRANSPORTATION RESEARCH BOARD
2019 EXECUTIVE COMMITTEE OFFICERS**

Chair: Victoria A. Arroyo, Executive Director, Georgetown Climate Center; Assistant Dean, Centers and Institutes; and Professor and Director, Environmental Law Program, Georgetown University Law Center, Washington, D.C.

Vice Chair: Leslie S. Richards, Secretary, Pennsylvania Department of Transportation, Harrisburg

Division Chair for NRC Oversight: Chris Hendrickson, Hamerschlag University Professor Emeritus, Carnegie Mellon University

Executive Director: Neil J. Pedersen, Transportation Research Board

**TRANSPORTATION RESEARCH BOARD
2018–2019 TECHNICAL ACTIVITIES COUNCIL**

Chair: Hyun-A C. Park, President, Spy Pond Partners, LLC, Arlington, Massachusetts

Technical Activities Director: Ann M. Brach, Transportation Research Board

David Ballard, Senior Economist, Gellman Research Associates, Inc., Jenkintown, Pennsylvania, *Aviation Group Chair*

Coco A. Briseno, Deputy Director, Planning and Modal Programs, California Department of Transportation (CALTRANS), *State DOT Representative*

Michael Griffith, Director, Office of Safety Technologies, Federal Highway Administration, *Safety and System Users Group Chair*

George Grimes, CEO Advisor, Patriot Rail Company, Denver, Colorado, *Rail Group Chair*

Brendon Hemily, Principal, Hemily and Associates, *Public Transportation Group Chair*

Nikola Ivanov, Deputy Director, Center for Advanced Transportation Technology Laboratory, University of Maryland, College Park, *Young Members Council Chair*

C. James Kruse, Director, Center for Ports and Waterways, Houston, Texas, *Marine Group Chair*

Mark Reno, Principal Engineer, Quincy Engineering, Inc., Rancho Cordova, California, *Design and Construction Group Chair*

Elizabeth Rushley, Lawhon & Associates, Inc., Columbus, Ohio, *Planning and Environment Group Chair*

Joseph Schofer, Professor and Associate Dean of Engineering, McCormick School of Engineering, Northwestern University, Evanston, Illinois, *Policy and Organization Group Chair*

William Varnedoe, Partner, The Kercher Group, Raleigh, North Carolina, *Operations and Preservation Group Chair*

Fred R. Wagner, Partner, Venable, LLP, *Legal Resources Group Chair*

TRANSPORTATION RESEARCH CIRCULAR E-C253

Transformational Technologies in Transportation

Impacts on Traditional Research Processes and Programs

Report from Workshop 3
Forum on Preparing for Automated Vehicles and Shared Mobility
May 3, 2019

Mark R. Norman
Rapporteur

Transportation Research Board
500 Fifth Street, NW
Washington, D.C. 20001
www.TRB.org

The Transportation Research Board is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal.

The Transportation Research Board is distributing this E-Circular to make the information contained herein available for use by individual practitioners in state and local transportation agencies, researchers in academic institutions, and other members of the transportation research community. The information in this E-Circular was taken directly from the submission of the authors. This document is not a report of the National Academies of Sciences, Engineering, and Medicine.

**Transformational Technologies in Transportation
Planning Committee**

Abbas Mohaddes, *Econolite/CAVita, Co-lead*
Mark Norman, *TRB Resident Scholar, Co-lead*

Steven Bayless, *Intelligent Transportation Society of America*
Myra Blanco, *Virginia Tech Transportation Institute*
Catherine McGhee, *Virginia Department of Transportation*
James R Sayer, *University of Michigan*
Ed Seymour, *Texas A&M Transportation Institute*
Susan Shaheen, *University of California, Berkeley*
Tammy Trimble, *Virginia Tech Transportation Institute*
David Yang, *AAA Foundation for Traffic Safety*

TRB Committees

Hau Hagedorn, *Conduct of Research Committee*
Susan Sillick, *Conduct of Research Committee*
Prachi Vakharia, *Subcommittee on Emerging Ridesharing Solutions*

TRB Staff

Katherine Kortum, *Senior Program Officer*

Preface

In an era of rapidly evolving transformational technologies, can our research projects and processes provide needed answers in a timely manner while still protecting the credibility of our research, and if so, how? That is the basic question that was the focus of this TRB Forum workshop and earlier discussion groups conducted by the TRB Standing Committee on the Conduct of Research.

The National Academies–TRB Forum on Preparing for Automated Vehicles and Shared Mobility was officially launched in early 2018 to facilitate evidence-based research needed to deploy these technologies in a manner and timeframe that informs policy to meet these long-term goals. The Forum has held six meetings since then, promoting discussion among its members and the public, creating white papers, developing research priority lists, and engaging in workshops dedicated to specific questions around automated vehicles and shared mobility. This paper was developed as a summary of one such workshop held for this Forum. Mark Norman authored the paper, and it was reviewed by the following Forum members: Abbas Mohaddes, Ed Seymour, Susan Shaheen, Tammy Trimble, and David Yang.

PUBLISHER’S NOTE

The views expressed in this e-circular do not necessarily represent the views of all Forum participants or members; the Transportation Research Board; or the National Academies of Sciences, Engineering, and Medicine. This e-circular has not been subjected to the formal TRB peer review process.

ACKNOWLEDGMENTS

A small volunteer group of Forum members and TRB staff planned and organized the mini-workshop described in this report. Members of this working group are listed below.

Name	Organization
Steven Bayless	Intelligent Transportation Society of America
Myra Blanco	Virginia Tech Transportation Institute
Hau Hagedorn	TRB Conduct of Research Committee
Katherine Kortum	Transportation Research Board
Catherine McGhee	Virginia Department of Transportation
Abbas Mohaddes (Co-lead)	Econolite/CAVita
Mark Norman (Co-lead)	Transportation Research Board
James R. Sayer	University of Michigan
Ed Seymour	Texas A&M Transportation Institute
Susan Shaheen	University of California, Berkeley
Susan Sillick	TRB Conduct of Research Committee
Tammy Trimble	Virginia Tech Transportation Institute
Prachi Vakharia	TRB Subcommittee on Emerging Ridesharing Solutions
David Yang	AAA Foundation for Traffic Safety

Contents

Summary of Key Takeaways	1
Why Is This Important?	1
Ensuring Quality Science, Getting It First Versus Getting It Right	2
Pursuing New Approaches to Our Traditional Research Processes	3
Fostering Collaboration Among the Public, Private, and Academic Sectors	6
What Can TRB Do?	7
Appendix A Workshop Agenda.....	8
Appendix B Forum Participants.....	9
Notes	11

Summary of Key Takeaways

Key takeaways from participants' discussions and panelist members' presentations at the workshop, and also from the preceding discussion groups conducted through TRB's Standing Committee on the Conduct of Research on this topic, include the following.

- Automated vehicles, shared mobility, and other transformational technologies in transportation provide a unique opportunity to make significant advances in meeting societal goals.
- Success is far from assured—we have more questions than answers. Research is the key.
- Time is short, as these technologies and deployments are advancing, and often changing, rapidly.
- The “need for speed” in the associated research depends on the issue and/or situation.
- Answering a series of questions can help researchers to determine a targeted time frame appropriate for the specific research in question.
- Options do exist to enable our research projects and processes to provide needed answers in a timely manner while still protecting the credibility of our research.
- A number of these options have been employed by others, but more models are needed.
- Collaboration among the public, private, and academic sectors is key to meeting the twin objectives of providing needed answers in a timely manner while still protecting the credibility of our research.
- There are a number of steps that TRB can take, including providing more opportunities for collaboration among the stakeholders through TRB convening activities such as this Forum, conferences, standing committees, and research panels.

Why Is This Important?

Abbas Mohaddes, Econolite/CAVita, posed the following guiding question in his opening remarks: In an era of rapidly evolving transformational technologies, can our research projects and processes provide needed answers in a timely manner while still protecting the credibility of our research, and if so, how? That is the basic question that was the focus of this TRB Forum workshop and earlier discussion groups conducted by the TRB Standing Committee on the Conduct of Research. Mohaddes' comments are as follows.

In recent years, the public has become less confident in the ability of our institutions, processes, and leaders to achieve broad societal goals. Numerous polls show that many are frustrated with continuing gridlock in Washington, D.C., and also at the state and local levels. They are tired of small scale steps being taken to address large scale problems, and have become more cynical regarding politicians' claims that they have the solutions to these problems. At the same time, voters have rebelled against revenue increases, complaining that their current tax dollars are just being wasted. Many believe that things are getting worse, longing for a time when we took bold actions to make things better.

The transportation profession is caught in this vortex. Our problems are not unique in this regard. We are operating in the same skeptical environment as other public policy issues—education, economic development, health care, immigration, safety, security, and others. Many think that bold new directions will therefore be needed to capture the public’s imagination and rekindle their hopes.

For the transportation profession, there is good news. Unlike other policy issues, we have the foundations for moving in bold new directions. Policy makers and the public are enamored with the prospects of connected/automated vehicles, shared mobility, and other transformational technologies. Legislation is being considered in Washington. The U.S. Department of Transportation (USDOT) is issuing guidance on testing and deployment, and states are passing laws and regulations on when and where these technologies can be tested and operated. Numerous cities competed for USDOT Smart City grants. Every day, the media runs stories about “driverless cars.” Everyone seems to be talking about these new technologies and services.

So the first step has apparently been accomplished—capturing the imagination of the public and policy makers. However, success is far from assured. Predictions of positive and negative outcomes currently cover a broad spectrum. For example, the U.S. Department of Energy (DOE) 2017 report on “The Transforming Mobility Ecosystem”¹ offers the following range of outcomes.

- A combination of automated vehicles, shared mobility systems, and electric/zero emission vehicles can reduce energy consumption and related emissions by 60% over the next 30 years.
- Conversely, a combination of automated vehicles, zero-occupancy vehicles, increased vehicle miles traveled (VMT), access for new user groups, and continued reliance on fossil fuels could increase energy consumption and related emissions by up to 200%.

The goal for the transportation profession therefore is to proactively identify and pursue policies that will push the needle to outcomes that are positive. However, these technologies and deployments are advancing, and often changing, rapidly. The recent replacement of new dockless bike services with even newer e-scooters in urban areas over a one-year period is a prime example.

There are obviously more questions than answers at this point. Providing answers through evidence-based research is therefore more important than ever.

Ensuring Quality Science *Getting It First Versus Getting It Right*

Susan Shaheen, University of California, Berkeley, stressed the need for ensuring quality science. This was followed by a discussion among workshop participants regarding the trade-offs between quality and speed. The following points were made during the discussion.

We are at a key juncture. The private sector is investing billions of dollars in research to facilitate the deployment of these technologies. Just as these technologies are disrupting transportation, they may also disrupt the research processes traditionally followed by the public sector and academia.

Some have paraphrased the issue as “getting it first versus getting it right.” While these are not always the same, they are also not mutually exclusive. Following traditional research processes, including research transparency and stating assumptions and limitations of the analysis, has helped to ensure quality science over many years. At the same time, research results are often not made available until after the need has passed, the policy decisions have been made, and those responsible for making policy have moved on.

During the discussion, workshop participants emphasized that the “need for speed” depends on the situation. For each research question or situation, individual participants listed the following considerations to help researchers address the question of achieving the right balance.

- What is the ultimate objective of the research?
- What is the urgency?
- What is acceptable risk?
- How much evidence will we need to move forward?
- What are the barriers?
- Can we provide transparency and balance stakeholder influence?
- Can we ensure that the research results are objective, without necessarily being neutral?

Another point made during the discussions was that traditional research processes can too often rely on one set time frame for most research projects. Answering the above questions can help researchers to determine a targeted time frame appropriate for the specific research in question. Once that is determined, the applicable research process can be designed and implemented.

Pursuing New Approaches to Our Traditional Research Processes

The typical life cycle for a research project is shown in Figure 1. The checklist that follows offers options to help research organizations and researchers in producing results that are timely while still protecting quality science. Tammy Trimble from Virginia Tech Transportation Institute presented a list generated from individuals who participated in a series of discussion groups organized by the TRB Standing Committee on the Conduct of Research. The list shown below incorporates additional suggestions from participants at the workshop.

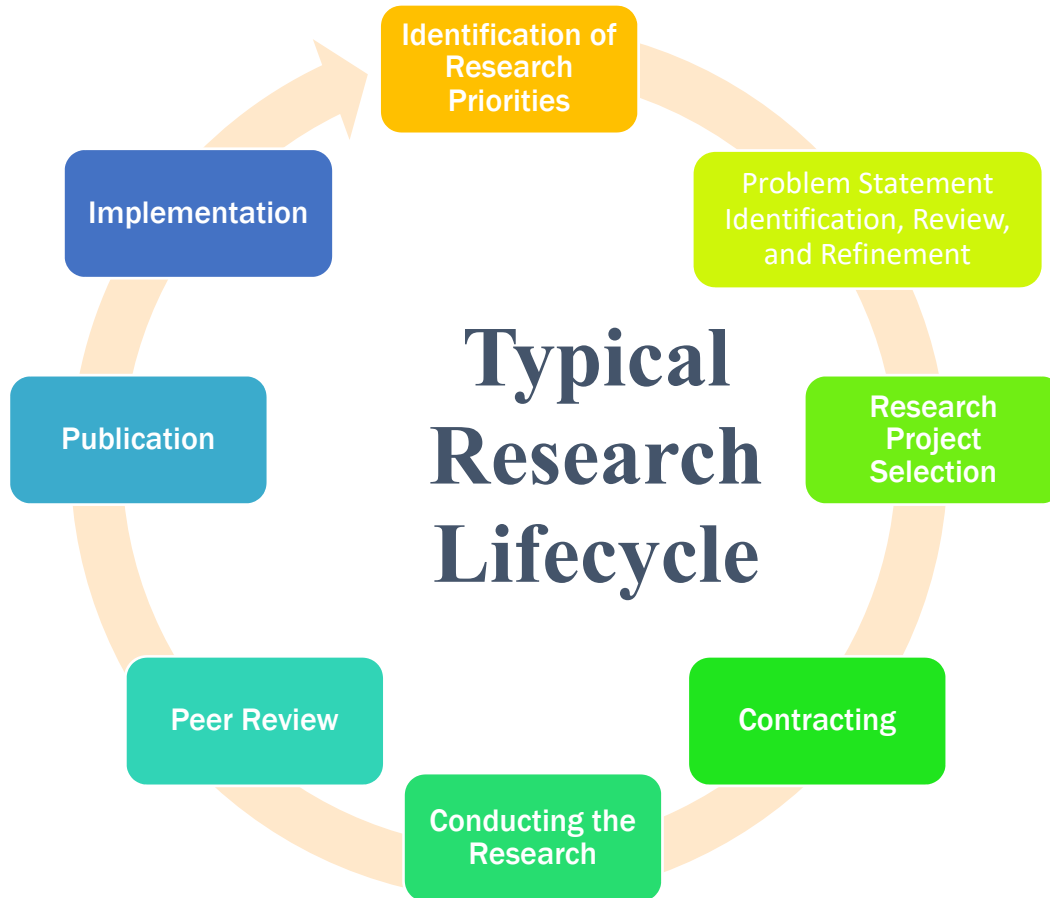


FIGURE 1 Typical research life cycle.

GENERAL RESEARCH PROGRAM MANAGEMENT

- Continuously build and nurture leadership support.
- Look for, and take advantage of, any and all opportunities to reduce administrative burdens.
- Test rapid response models used by others (e.g., National Science Foundation²).

IDENTIFICATION OF RESEARCH PRIORITIES

- Develop and rely on dynamic research roadmaps to establish priorities and to generate individual problem statements.
- Rely on scenario planning to consider emerging needs.
- Employ continuous calls for proposals.
- Seek approaches that will result in a process that is more continuous and more visible, e.g., a research needs dashboard.
- Seek input from stakeholders and the public to understand what is needed in the “real world.”

- Prepare meta-analyses of research done on a policy topic to date, targeted to specific audiences.

PROBLEM STATEMENT IDENTIFICATION, REVIEW, AND REFINEMENT

- Pursue strategic level research—focusing more on broader research program areas rather than just on individual discrete projects.
- Align the need for more applied research (e.g., in smaller states) with desired objectives and outcomes.
- Clearly define the objective of the research at the outset of each project.
- Break research questions into smaller pieces or phases.

RESEARCH PROJECT SELECTION

- Prioritize and select individual discrete projects from broader program areas or roadmaps.
- Balance larger, complex projects with other smaller, shorter time frame projects.

CONTRACTING

- Prepare Requests-for-Proposals (RFPs) that focus more on the outcomes rather than on prescribed, specific research processes.
- Consider relying on Requests-for-Qualifications (RFQs) as opposed to RFPs.
- Prequalify contractors in defined subject areas.
- Employ indefinite delivery/indefinite quantity contracts.
- Award projects with shorter phases.

CONDUCTING THE RESEARCH

- Accomplish tasks in parallel rather than in series, and bring together at the end.
- Enhance the flexibility of the researchers and the staff to achieve the desired outcomes.
- Use interim reporting periods to determine if directional changes are needed.
- Enforce deadlines.
- Avoid scope creep.

PEER REVIEW

- Create and maintain a standing pool(s) of peer reviewers.
- Peer review phases of the research as they are completed, rather than waiting until the end of the project to review all at once.

PUBLICATION

- Release phased results of the research as they are completed.

- Release interim results and/or pre-publication findings in advance of final editing.
- Work closely with public affairs and communications experts to package the findings for specific audiences.

IMPLEMENTATION

- Include technology transfer as an integral part of the research project life cycle.
- Take advantage of scheduled field tests and demonstrations when scheduling and designing research projects.
- Use pilot projects to test “laboratory” results.
- Identify and involve a community of stakeholders and partners to deploy the results.

Fostering Collaboration Among the Public, Private, and Academic Sectors

Individual workshop panelists repeatedly stressed during the Forum workshop that collaboration among the public, private, and academic research sectors is key to meeting the twin objectives of providing needed answers in a timely manner while still protecting the credibility of our research. The potential action items that were listed along these lines by panelists include the following.

- Take steps to strengthen our research partnerships among private, public, and academia, and supplement with significant input from the end user—the public:
 - Identify common goals, such as improving safety or alleviating congestion;
 - Involve the public and stakeholders in an advisory role to help define the purpose of the research;
 - Form advisory groups and bring them together frequently;
 - Form non-traditional partnerships for collaborative research (e.g., public sector and industry);
 - Pursue collaboration through tools such as pooled fund studies and shared research roadmaps; and
 - Enlist a community of stakeholders and partners who are ready to deploy the research results.
- Use this opportunity to work with universities to attract the best and brightest into the transportation profession.
- Address the misperception on the level of “duplication” of transportation research. Note that in transportation there are often not enough resources to validate earlier research.
- Reduce competition among researchers that can result in barriers to sharing early results:
 - Encourage academics and public sector researchers to share their results as widely as possible;
 - Form collaborations with private sector stakeholders and partners early on to achieve common goals;
 - Use confidentiality agreements to facilitate the sharing of data; and

- Pursue complementary research among and across sectors to validate and fill gaps from earlier research.
- Communicate accurate research results with the media and general public:
 - Work closely with public affairs and communications experts;
 - Package evidence-based research information targeted to specific audiences; and
 - Ensure communications experts' messages are accurate.
- Foster collaboration between state DOT research offices and other state DOT divisions:
 - Build and/or enhance relationships between the research office and other divisions to facilitate the sharing of ongoing and completed research efforts across the agency;
 - Facilitate pathways for state DOT research offices to work with other DOT divisions to identify and address emerging issues on an ongoing basis;
 - Engage divisions DOT-wide to prepare for the implementation of research results; and
 - Inspire all state DOT research offices with a sense of responsibility for policy research.

What Can TRB Do?

Hau Hagedorn, Portland State University and Chair of the TRB Conduct of Research Committee, presented a number of potential action items, which were supplemented by individual Forum workshop panelists. The resulting list of potential action items for consideration by TRB is shown below.

- Test some of the new approaches to traditional research processes listed above.
- Provide more opportunities for collaboration among the stakeholders through TRB convening activities such as this Forum, conferences, standing committees, and research panels.
- Continue conducting the research and disseminating the results of NCHRP Project 20-102, "Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies."
 - This series of research projects is employing pre-qualified research teams, a research roadmap, and pre-publication dissemination of some research results.
- Consider what options exist for pursuing a strategic research program in these areas.
 - More dedicated funding may be needed to address these issues, especially public policy issues.
- Provide a clearinghouse of information linked to a research roadmap for automated vehicles and shared mobility.
- Solicit input from the TRB Standing Committee on the Conduct of Research on additional steps that can be taken by TRB to address the issues raised above.

Appendix A

Workshop Agenda

Forum Workshop 3

Impacts on Research Processes and Programs

Friday, May 3, 2019

12:15 p.m.–1:45 p.m.

- Welcome and Introduction (Abbas Mohaddes, Econolite/CAVita)
- Transformational Technologies: Can Our Research Processes Keep Up? (Tammy Trimble, Virginia Tech Transportation Institute)
- The Value of Quality Science (Susan Shaheen, University of California, Berkeley)
- Research Best Practices: Resources Available from TRB and Conduct of Research Committee (Hau Hagedorn, Portland State University and Chair of the TRB Conduct of Research Committee)
- Presenter Q&A
- Panel Discussion
 - Panelists: Abbas Mohaddes (Moderator), Cathy McGhee (Virginia DOT), David Yang (AAA Foundation for Traffic Safety), Sue Sillick (Montana DOT, and TRB Conduct of Research Committee), Chandra Bhat (The University of Texas at Austin), Jim Sayer (University of Michigan)
- Closing and Next Steps (Abbas Mohaddes)

Appendix B Forum Participants

TRB Forum on Preparing for Automated Vehicles and Shared Mobility May 3, 2019

FORUM MEMBERS

Paul Ajegba Director Michigan DOT	Miriam Chaum Head of Public Policy Self-Driving Cars Uber
David Anderson Program Manager Energy Efficient Mobility Systems U.S. Department of Energy	Steven Dellenback Vice President Intelligent Systems Division Southwest Research Institute
James Barna Assistant Director Transportation Policy Ohio DOT	Kevin Dopart Program Manager Vehicle Safety and Automation U.S. DOT: Office of the Assistant Secretary for Research and Technology
Steve Bayless Vice President Regulatory Affairs and Public Policy Intelligent Transportation Society of America	King Gee Director of Engineering and Technical Services American Association of State Highway and Transportation Officials
Chandra Bhat Director for Center of Transportation Research The University of Texas at Austin	Reema Griffith Executive Director Washington State Transportation Commission
Daniel Blais Senior Analyst Innovation Centre Transport Canada	Art Guzzetti Vice President for Policy American Public Transportation Association
Coco Briseno Deputy Director Planning and Modal Programs Caltrans	Robert Hazlett Senior Engineering Manager Maricopa Association of Governments
Thomas Byron Assistant Director of Strategic Development Florida DOT	Larry Head Acting Dean College of Engineering University of Arizona
Annie Chang Project Manager, Technical Programs Global Ground Vehicle Standards SAE International	Patricia Hendren Executive Director I-95 Corridor Coalition
Jean Crowther Senior Planning Associate Alta Planning & Design	Roger Huff President HGLC, LLC

George Ivanov Manager Policy Development and Regulatory Affairs Waymo	Carol Schweiger President Schweiger Consulting
Gregory Krueger Program Director for Emerging Technologies in Transportation HNTB	Ed Seymour Executive Associate Agency Director Texas A&M Transportation Institute
Jane Lappin Director of Government Affairs and Public Policy Toyota Research Institute	Susan Shaheen Adjunct Professor and Co-Director, TSRC University of California, Berkeley
Jeffrey Lindley Associate Executive Director Institute of Transportation Engineers	Steven Shladover Program Manager Mobility at California PATH Institute of Transportation Studies University of California, Berkeley
Jim Mahugh Assistant Design Engineer Washington State DOT	Scott Shogan Vice President WSP USA
Catherine McGhee Director Virginia Transportation Research Council	Bryant Walker Smith Assistant Professor School of Law University of South Carolina
Abbas Mohaddes President Econolite/CAVita	Patrick Smith New Mobility Policy Analyst New York City DOT
Jessica Nigro General Manager and Head of Technology and Innovation Policy Daimler North American Corporation	Bernard Soriano Deputy Director California Department of Motor Vehicles
Timothy Papandreou Founder Emerging Transport Advisors	Daniel Sperling Professor Department of Civil and Environmental Engineering University of California, Davis
Faisal Saleem ITS Branch Manager and SMART Drive Program Manager Maricopa DOT	Prachi Vakharia Affiliate Steer
Jim Sayer Director University of Michigan Transportation Research Institute	Greg Winfree Director Texas A&M Transportation Institute
Scott Schmidt Manager of Vehicle Safety Regulations Alliance of Automobile Manufacturers	David Yang Executive Director AAA Foundation for Traffic Safety
	Lawrence Yermack Strategic Advisor Cubic Transportation Systems Inc.

Notes

1. The Transforming Mobility Ecosystem: Enabling an Energy-Efficient Future; U.S. Department of Energy, January 2017.
<https://energy.gov/sites/prod/files/2017/01/f34/The%20Transforming%20Mobility%20Ecosystem%20Report.pdf>.
2. National Science Foundation Grants for Rapid Response Research (RAPID).
https://www.nsf.gov/pubs/policydocs/pappguide/nsf09_1/gpg_2.jsp#IID1.

The National Academies of **SCIENCES • ENGINEERING • MEDICINE**

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, non-governmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at www.national-academies.org.

The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to increase the benefits that transportation contributes to society by providing leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied committees, task forces, and panels annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

Learn more about the Transportation Research Board at www.TRB.org.



TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.

www.national-academies.org