TRANSPORTATION RESEARCH
CIRCULAR
Number E-C236 September 2018

National Academies–TRB Forum on Preparing for Automated Vehicles and Shared Mobility

TRANSPORTATION RESEARCH CIRCULAR E-C236
ISSN 0097-8515

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Preface

The deployments of automated vehicles, shared mobility services, and other transformational transportation technologies have the potential to dramatically increase safety, reduce congestion, improve access, enhance sustainability, and spur economic development. However, success in meeting these goals is not assured, and there are significant risks that these deployments could cause unintended consequences.

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. This white paper summarizes the deliberations among Forum participants to date, including presenting the case for such research and the topics that should be included.

This paper was developed as a white paper by TRB staff for this Forum. Katherine Kortum and Mark Norman authored the paper, and it was reviewed by Daniel Blais, Transport Canada; King Gee, American Association of State Highway and Transportation Officials; Anne Marie Lewis, Alliance of Automobile Manufacturers; Jim Mahugh, Washington State Department of Transportation; Susan Shaheen, University of California, Berkeley; and Bernard Soriano, California Department of Motor Vehicles. TRB staff anticipate that the paper will be reviewed and updated on an annual basis.

PUBLISHER'S NOTE

The views expressed in this white paper are those of individual white paper authors, the Forum members, and of the Forum participants and do not necessarily represent the views of all participants, the Transportation Research Board, or the National Academies of Science, Engineering, and Medicine. This white paper has not been subjected to the formal TRB peer review process.

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THE CASE FOR TRANSFORMATIONAL CHANGE AND OPTIMISM

Education, economic development, health care, safety and security, demographic changes, transportation: society faces critical issues in all of these areas. Public concern about all of these topics is reflected in polls, surveys, and recent elections. In many ways, the public is skeptical that government institutions and leaders can successfully solve large-scale problems. The transportation community is included in this skepticism, and our problems are not unique.

However, unlike many of the policy areas mentioned above, the transportation community has already laid the foundations for moving in bold new directions. The public and policy makers are both fascinated with the prospects of automated vehicles (AVs), shared mobility services, and other transformational technologies in transportation.

Legislation is being debated at both the federal and state levels. The U.S. Department of Transportation (DOT) has issued guidance on testing and deployment of automated vehicles and other technologies and is continuing to refine that guidance. States are passing laws and regulations on when and where these technologies and services can be tested and operated. Numerous cities competed for U.S. DOT Smart City Grants and are now implementing smart city policies. Every day, media outlets around the world are running stories about "driverless cars."

We have accomplished the important first step of capturing the imagination of the public, practitioners, and policy makers. The next step is determining what to do with it.

THE CASE FOR CAUTION

Success is not assured. The March 18, 2018 pedestrian fatality involving an automated vehicle in Arizona, along with other recent fatal crashes involving vehicles equipped with advanced driver assist systems (ADAS), are stark reminders of the risks involved. These include not only safety, but other areas as well, from increased environmental damage to reduced equity in the transportation system.

The U.S. Department of Energy report *The Transforming Mobility Ecosystem*[1], released in January 2017, offered the following scenarios and projections:

- Successfully deploying a combination of automated vehicles, shared mobility systems, and electric/zero emission vehicles could 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 of travel (VMT), access for new user groups, and continued reliance on fossil fuels could increase energy consumption and related emissions by up to 200% over this same time period.

Clearly, as this one analysis demonstrates, the range of potential outcomes is quite broad. The ultimate challenge is to identify and pursue policies that will push the needle towards positive outcomes. It will not be enough to merely hope for the best; a proactive approach is necessary.

THE CASE FOR TRANSFORMATIONAL RESEARCH

When there are more questions than answers, evidence-based research is critical. The private sector is investing billions of dollars each year in researching and deploying transformational technologies in transportation. To encourage widespread deployment and acceptance, research should address not only the successful launches of these technologies but also the societal impacts. Research undertaken by the public, private, and academic sectors needs to complement and keep pace with the rapid developments in the private sector.

The most effective research model is a collaborative public/private/academic effort to harness the synergy among intelligent transportation systems, connected and automated vehicles, shared mobility services, alternative fueled vehicles, and infrastructure improvements. In addition, each of these developments should be incorporated into broader transformational ideas, including smart cities and the internet-of-things, and into existing transportation systems.

Such a research effort must be evidence-based to be credible and to minimize the chances of unintended adverse consequences. It should be an effort that can attract talented people into the transportation profession. Finally, it should not only build upon the ability to capture the public's imagination but be able to turn that imagination into a renewed trust.

THE NATIONAL ACADEMIES-TRB FORUM

In 2018, the Transportation Research Board (TRB) of the National Academies of Science, Engineering, and Medicine launched the Forum on Preparing for Automated Vehicles and Shared Mobility Systems. The Forum's objective is to bring together public, private, and academic organizational partners to share perspectives on the critical issues surrounding the deployment of automated vehicles and shared mobility. A key emphasis is on the discussion, identification, and facilitation of evidence-based research needed to deploy these technologies how and when they will best meet long-term goals. These goals include 1) increasing safety, 2)

reducing congestion, 3) enhancing accessibility, 4) increasing environmental and energy sustainability, and 5) encouraging economic development and equity.

As of mid-2018, Forum participants included the U.S. Department of Transportation, Transport Canada, seven state transportation agencies, two local transportation agencies, eight private sector organizations, seven academic institutions, seven TRB committees, four boards of the National Academies, and six partner associations.

These Forum participants have agreed to work together to:

- Share information and perspectives on an ongoing basis
- Identify research needs and priorities
- Facilitate partnerships to carry out the needed research
- Engage the broader stakeholder community

More information on this Forum can be found on the Forum's website (https://trb.org/AVSMForum).

Forum participants have collectively identified more than 100 critical research needs across the following focus areas:

- Safety
- Transportation System Impacts
- Social, Environmental, Energy, and Economic Impacts
- Data and Analysis Considerations
- Cross-Cutting Topics

Each of these research focus areas is covered in more detail below. These research needs have been generated from convening activities leading up to the formation of the Forum, including the TRB Symposium "Partners in Research – Transformational Technologies" held October 31 and November 1, 2016 in Detroit, and the scoping meeting for the Forum held July 10, 2017 in San Francisco. They have been further refined through a January 2018 survey of the organizations participating in the Forum, and an in-depth discussion as part of the February 2018 kick-off meeting of the Forum.

IMPACTS ON SAFETY

After a period of steady decline, annual traffic fatalities have again exceeded 40,000 in the United States[2]. The worldwide total is 1.25 million[3]. Forum participants have stressed that safety impacts must be the highest priority in the transition to and adoption of these technologies.

Much has been written regarding the fact that human error is a factor in the vast majority of crashes. The hope is that by eliminating human error, most of these crashes will be eliminated. Nonetheless, human drivers in the U.S. are involved in about one fatal crash for every 100 million vehicle miles, so it can be argued that human drivers do a lot more right than they do

wrong. For example, human drivers can make critical driving adjustments to help other drivers and avoid crashes, even if those adjustments may be technically illegal.

One research question of particular interest to Forum participants is, "How safe is safe enough?" This question applies both to on-road testing of vehicles in the short term and to longer term deployment. It will be important to have objective data about human driving behavior and decision-making processes as compared to automated driving behavior and decision-making processes to compare the two. Many questions remain about how humans will behave when in partially automated vehicles, how quickly and easily humans will be able to take over the driving tasks when needed, and what means the vehicle will use to alert the driver that a takeover is necessary. In the limited test cases to date, humans have shown varying behaviors and levels of perception. In addition, we do not yet have best practices for standard vehicle behavior in a crash so that it causes the least harm both to occupants and to those outside the vehicle.

Interactions with those outside the vehicle are another area of needed research. Pedestrians, bicyclists, and others on the road are often called vulnerable road users and must be accounted for in the analyses, demonstrations, and deployments. For example, how will automated vehicles communicate their intent with humans, who will not have a face to look at or a driver's eyes to meet when crossing the street or otherwise interacting?

In the short term, Forum participants point out that federal and state agencies are wrestling with their often-competing roles of facilitating innovation and economic development versus guarding public safety. Recent fatalities involving vehicles with varying levels of automation are a stark reminder of the need to balance short-term risks and long-term gains. Research can assist public agencies and the private sector in their search for that "sweet spot" between regulation and innovation, and in their determination of best practices for safe on-road testing.

A November 2017 report by the RAND Corporation[4] concluded that "introducing autonomous vehicles when they are just better than human drivers—as opposed to nearly perfect—could save hundreds of thousands of lives over 30 years." This raises the question of what society will consider acceptable over the short and long term. The status quo? Some reduction in fatalities and injuries? An almost total elimination of crashes? Some Forum participants noted that additional research can help inform policy makers and the private sector in making these decisions and in taking the necessary steps to help ensure the desired outcomes.

A number of other Forum participants cite similar questions regarding the relative safety impacts of the different stages of vehicle automation. Specifically, what risks are associated with the mid-levels of automation, wherein the vehicle is able to drive itself the vast majority of the time, but the driver is expected to remain attentive enough to take control when necessary?

Law enforcement is another area in which there are unanswered questions. What data is required for law enforcement to perform crash investigations? Does the current data ownership model need to change in order for this to happen? If data is shared, how will authorities be able to access the data for both investigative purposes and for prosecutions? How can vehicle manufacturers and others ensure that the data is adequately anonymized as it is transmitted to enforcement agencies?

Forum participants also recognize the need for research on the safety impacts of shared mobility services, particularly when combined with automated vehicles. What impact will these services have on the population of "drivers" and on vehicle ownership? Will shared mobility drivers be safer than today's mix of drivers? If shared mobility services lead to reduced vehicle ownership, what impact would that have on evacuations due to severe weather or other emergencies?

TRANSPORTATION SYSTEM IMPACTS

Individual Forum participants stress the need for research to take maximum advantage of the combined impacts of the public and private sector infrastructure, private sector automated vehicles, enabling technologies, and shared mobility. There is general agreement that a successful synergy among these presents the best hope for all parties to deploy these new technologies and services to achieve their goals. Forum participants specifically cite differences in working timeframes and available resources as challenges that need to be addressed.

Timeframes to develop and deploy significant advances in software and shared mobility services can often be measured in months, whereas major changes in vehicle designs and deployment are generally measured in years, and transportation infrastructure in decades. Players in the public and private sector seem to agree that successful vehicle-to-infrastructure (V2I) communications and other collaborative efforts significantly increase the potential for positive outcomes. However, they also point out that the private sector needs to offer market-ready products and services in response to market demand–whether or not the public sector is ready to deploy the complementary aspects of the infrastructure.

A number of Forum participants have therefore identified research needs to address "infrastructure enablers." These include potential changes in infrastructure designs and standards, procurement policies, asset management practices, and funding.

AVs and shared mobility may have a significant impact on existing transportation systems, including transit, and the direction and degree of these impacts are yet unknown. There are likely to be some synergies and some competition, and policymakers need research on what policies will be most effective to encourage existing systems to coordinate best with the array of new technologies, mobility concepts, and business models.

Funding, of course, is a particular concern. The majority of transportation funding available to the public sector is dedicated to maintaining the existing infrastructure. Public agencies are seeking answers on how these technologies are affecting traditional revenue streams, the potential for new revenue streams, continued support for legacy systems, transitions to new technologies, and the risks and rewards for investment planning.

Looking to the longer term, some of the Forum participants encourage use cases and scenario planning on critical paths to higher-level automation. Questions to be addressed include how to best accommodate a fleet of mixed vehicles, whether AVs will permit more closely spaced vehicles resulting in changing needs for pavement and geometric design, when and if to allocate dedicated lanes to AVs, how to best ensure first mile-last mile access, and whether zero-

occupancy vehicles should be uniquely regulated or charged. The potential impacts of higher-level automated vehicles and shared mobility on traveler behavior and freight movement have implications not only for the transportation system, but on broader sustainability issues as well. These are covered in more detail in the next section.

SOCIAL, ENVIRONMENTAL, ENERGY, AND ECONOMIC IMPACTS

As mentioned earlier, the synergy (or lack thereof) among automated vehicles, connectivity, shared mobility, and electrification of the vehicle fleet is expected to have profound implications. The potential impacts of these technologies and services on traveler behavior and freight movement will not only affect the future of transportation infrastructure, but will also determine whether social, environmental, energy, and economic goals can be achieved.

The impacts of automated vehicles and shared mobility services on VMT are important factors to consider as both become more prevalent. A growing number of research reports are predicting that these technologies and services are likely to increase, rather than decrease, VMT. Some of the Forum participants therefore suggest research to inform policies that can reverse this trend or can accommodate increased VMT while still achieving broader societal goals.

The research suggested by individual Forum participants will help to inform decisions on policies and regulations. This begins with developing appropriate planning tools to account for the new technologies, mobility concepts, and business models and to identify the right metrics across the range of social impacts. In addition, participants suggest that pilot deployments should be designed to evaluate not only the technical success of technologies but also potential impacts on these social goals.

Impacts on land use and, conversely, how land use affects AVs and shared mobility, are of particular interest to Forum participants. Research areas include impacts on the existing built environment and minimizing future sprawl. Another area of interest is equity, including serving those with special needs, with low incomes, and in rural areas. Most testing is currently occurring in cities and relatively wealthy areas, and perfecting the systems for these environments could exacerbate mobility differentials in rural and less wealthy areas.

Those who work in the transportation industry will also be affected by these changes, and Forum participants identified impacts on the workforce as a focus area for research. Both jobs lost and jobs created by these technologies and services will have economic and personal impacts. Within the transportation profession, what new areas of expertise will be needed, and how can these new technologies and services be leveraged to attract the “best-and-the-brightest” to the transportation profession? How can we design educational and workforce programs to help transition the current transportation labor force into the labor force with the skills and knowledge needed in the future?

DATA AND ANALYSIS CONSIDERATIONS

Real-time transportation data is now widely available to a degree that did not exist before. The private sector has made great gains in leveraging this data, but public agencies have been hard-pressed to keep up. Understanding how this data can best be shared, used, and protected is a high priority for Forum participants.

A considerable amount of research will be needed to develop protocols for how the public and private sectors can work together to share this data while still protecting privacy and proprietary information. Individual Forum participants have identified the following priority research focus areas:

- Sharing of data related to crashes and other incidents
- Making data available for research and planning models
- Collecting, integrating, sharing, and managing data for real-time operations and freight supply chains
- Use of transportation data to support smart cities and communities
- Development of vehicle-to-everything (V2X) communication protocols and procedures
- Analytic techniques to translate data into actionable intelligence in near-real time
- Stability of technology environments for seamless connectivity

Currently a stark asymmetry exists in the data availability and analysis capabilities of industry and all other stakeholders, including regulators and the public. This asymmetry needs to be addressed so that all parties can better understand the effects of the various services. Data is a fundamental need for research, and carefully written policies can extract needed information from industry (such as routes, disengagements, crashes, and other relevant trip data) without interfering with privacy, proprietary information, or vehicle operations.

Public agencies need research results to better identify and share good practices in data compilation, sharing, and management. This includes investment planning for IT systems, equipment, and staffing. Regarding the latter, public agencies need guidance on how to attract and retain those with data expertise.

Many reports and analyses exist regarding cybersecurity as it pertains to vehicles. Forum participants suggest that more attention also be given to cybersecurity and privacy on the infrastructure side, particularly for V2I communications and traffic management systems.

CROSS-CUTTING TOPICS

None of the issues listed in this paper or in other sources will play out in a vacuum, and the interactions among these issues present the most voluminous and complex set of research needs. As a starting point, Forum participants have identified priority research topics addressing alternate scenarios for synergy among automated vehicles, connectivity, shared mobility, and alternate fuels.

Forum participants stress the need for transformative new approaches to planning, research, testing, and education to parallel the transformative transportation technologies. These new approaches will need to use systems approaches to determine how this will work from beginning to end with all players in the ecosystem.

Transportation planners and modelers may need to revisit the traditional four-step planning process and consider activity-based models that are more rooted in how people use time, especially because innovative mobility services may impact time use by changing the value of time spent traveling. With so many uncertainties in the future, planners may need to rely more on objective-based planning – starting with the long-term community objectives and working backwards to plan, model, and implement policies to achieve those objectives. This may require new scenario planning models that include critical paths and use cases. The rapidity of developments and the explosion of available data may necessitate more emphasis on short-term and/or real-time planning. Some of the Forum participants also suggest that more attention be given to planning for rural areas.

Many research studies to date have concluded that, while the public is fascinated by these new technologies and services, there remains considerable skepticism around safety, security, and privacy. These studies often include among their recommendations the need to better educate and train all users. Certain Forum participants also point out that some aspects of user knowledge and behaviors are not likely to be changed, and research is needed to identify and adapt to these.

Determining the best approaches for keeping policy makers up-to-date and informed is another critical research need. Forum participants point out that this is needed to develop and implement policy frameworks for governmental regulation and intervention and to help prepare for evolving roles of the public and private sectors.

TRANSFORMING TRANSPORTATION RESEARCH

Just as these technologies are disrupting transportation, several Forum participants point out that traditional approaches to research are also facing disruption. In some cases, more quick-response research will be needed, as opposed to conventional research processes that can take years.

Options include:

- Re-evaluating research processes to generate answers in real time
- More leveraging of field operational tests that proved so successful for intelligent transportation systems (ITS)
- Developing dynamic/living research roadmaps
- Relying more on use cases, scenario planning, and case studies than on traditional retrospective research
- More interdisciplinary collaboration with researchers in such fields as wireless communications, computing methods, law, ethics, and social science

In addition, the interface between research and policy needs to address the following questions:

- What is an acceptable level of risk?
- How much evidence do we need to move forward?
- What new approaches can we apply to peer review and other conventional research processes?
- How can we balance influence among stakeholders?
- How should we address attacks on science and research?
- How can we ensure that research is objective without necessarily being neutral?

To accomplish this, the public sector, private sector, and academia will need to strengthen their research partnerships, in part by expanding traditional definitions of what types of organizations are part of the "transportation community." A number of Forum participants have therefore urged that TRB and others facilitate public/private/academic partnerships to identify and carry out the barrier-breaking research that enables positive transformation.

TOP TEN RESEARCH NEEDS

At its July 2018 meeting, the Forum determined its ten highest priority research questions. A full catalogue of research needs is listed at the end of this paper, but the Forum chose the following prioritized list:

1. Models for data sharing
2. Safety scenarios during the transition to highly automated vehicles
3. State and local policies to ensure safety prior to deployment
4. Infrastructure needs for AVs and shared mobility
5. Social impacts of AV deployment and shared mobility
6. Inclusion and equity needs for AVs and shared mobility
7. Impacts of higher-level automated vehicles and shared mobility on traveler behavior and freight movement
8. Impacts of shared mobility on transit and vice versa
9. Implications for transportation planning and planning models
10. Impacts of AVs and shared mobility on land use and vice versa

STRATEGIC QUESTIONS AND NEXT STEPS

Also at its meeting in July 2018, the Forum posed four overarching strategic questions for researchers and practitioners to address:

- What can we do to build awareness of the potential transformational impacts on society across a broader spectrum of people?
- What options exist to generate and fund a significant strategic research effort or program to inform policy decisions?
- How can we best leverage existing research programs to help address these issues?
- What new approaches to our conventional research processes should we consider?

These overarching questions will be a focus of the Forum's activities in the future and they inform the list of research needs that follows. The Forum will continue to refine the list of priority research questions and prepare research problem statements. Future work products may include white papers, working groups, and structures for information sharing.

CATALOGUE OF RESEARCH NEEDS

The full listing of critical research needs, as identified to date by Forum participants, is shown below. Forum participants will update this listing on a regular basis. Future versions of this catalogue will note research that has been completed and/or is underway.

SAFETY
Potential positive and negative impacts on safety due to AVs
Determining how safe is safe enough
What is the tipping point for safety?
Developing new certification tools and processes
State and local policies to ensure safety prior to deployment
Clarifying federal and state responsibilities
Roles of simulation, modeling, and off-road testing vs. on-road testing
Risk management strategies during on-road testing
Standards for vehicle responses in emergency situations
Potential safety scenarios during the transition to highly automated vehicles
Educating drivers on AV capabilities
Re-engaging drivers' attention when human intervention needed
Implications of long-term mixed vehicle fleet
Examining the role of human behavior in maintaining safe operations
Interacting/communicating intent with manually operated vehicles and vulnerable road users
Liability in a world of AVs
Impacts on insurance and tort law
Impacts on law enforcement and first responders
Minimum set of safety data needed for AV operations and crashes
Impacts of shared mobility on safety
Impacts on evacuations
Safe operations of commercial vehicles

TRANSPORTATION SYSTEM IMPACTS
Infrastructure enablers for AVs and shared mobility
Future designs of highways, streets, intersections, etc.
At what point should we dedicate lanes to AVs?
Infrastructure needs for V2I
Establishing a stable technology environment to enable public agencies to support connectivity
Impacts on public agencies' procurement policies, including Buy America requirements
Impacts on existing standards and standards-development processes
Critical paths to level 4/5 automation for light/heavy-duty vehicles (use cases)
Timeline scenarios
Synergy within the transportation ecosystem
Convergence between connected vehicles and automated vehicles
AV deployment in a shared mobility environment
Urban/suburban/intercity/rural environments
Heavy-duty vehicles/light-duty vehicles/transit/bikes/pedestrians
Impacts of truck platooning on other users
Accommodating low-speed automated delivery vehicles (e.g., robots)
Potential impacts of higher-level automated vehicles and shared mobility on traveler behavior and freight movement
Impacts of shared mobility on VMT and system capacity
Behavior of other road users around highly automated vehicles
Should zero-occupancy vehicles be regulated?
Impacts of shared mobility on transit
Helping transit agencies solve first mile/last mile issues
Models for integration of AVs and shared mobility with transit/micro-transit
Impacts on infrastructure funding
Impacts on traditional revenue streams
Pricing levers to support policies and societal goals
Continued funding support for legacy systems
Risks and rewards for investment planning
Impact of AVs on asset management practices
Overall impacts on pavements and structures
Deterioration from vehicles traveling on same track
Implications for work zones

SOCIAL, ENVIRONMENTAL, ENERGY, AND ECONOMIC IMPACTS
Net positive and negative social impacts of AV deployment and shared mobility
Managing unintended consequences (e.g., security, privacy, labor impacts, insurance)
What are the right metrics and measurements that should be used to improve social outcomes?
Diverse planning tools to address key social and environmental transportation issues
Addressing social inclusion and equity in shared mobility
Helping to ensure equity of access to AVs and shared mobility
How to best serve those with special needs
Impacts on land use, and how land use impacts AVs and shared mobility
Facilitating active/livable communities
Impacts on the built environment
What's in it for rural areas?
Integrating shared mobility into megaregion planning
Evaluation of pilot deployments to determine contributions to various societal goals
Preparing the future workforce
Jobs displaced vs. jobs created
Support for those whose jobs are displaced
Attracting the "best and brightest" into the transportation profession

DATA AND ANALYSIS CONSIDERATIONS
Models for sharing of data
Public sector use of private sector data
Sharing of crash and other incident data
Making data available for research and planning models
Development of vehicle-to-infrastructure (V2X) communication protocols and procedures
Access to data by law enforcement agencies
Protocols for data sharing and management for real-time operations and freight supply chains
Use of transportation data to support Smart Cities
Getting the most out of "Big Data"
Limitations and capabilities of future technologies and the cellular network
Identifying and sharing good practices in data curation, sharing, and management
Investment planning for IT systems, data, and staffing
Development of data formatting and archival standards
Analytic techniques to translate data into actionable intelligence in near-real time
Meeting cybersecurity and privacy challenges
Cybersecurity and privacy for V2I communications
Ensuring that data is adequately anonymized
Interdisciplinary collaboration with researchers in wireless communications, computing methods, ethics, and social science
Cybersecurity for traffic management systems
Framework for automated/connected vehicle pilot and smart cities data analytics for policy guidance

CROSS-CUTTING TOPICS
Alternative scenarios for synergy among automated vehicles, shared mobility, and alternative fuels
Models for scenario planning (with timelines and critical paths) and use cases
Developing means of estimating likely times for start of deployment and rates of market growth for the different new services
Auto ownership scenarios and implications
Rate of deployment of mixed fleet, and implications
Impacts on land use and density
Common set of deployment tools for freight operations
How strong are the various links among AVs, CVs, EVs, and shared mobility?
Models for Mobility-On-Demand (MOD)/Mobility-As-A-Service (MaaS)
Impacts on airport landside operations, seaports, and intermodal facilities
Systems approach – how will this all work from beginning to end with all players in the ecosystem?
Implications for transportation planning and planning models
Modeling the impacts of increased penetration of AVs and shared mobility
New planning tools - revisiting the traditional 4-step planning process
Moving to objective-based planning
Evolution to near-term or real-time planning
Planning for rural areas
What constitutes success/failure of pilots and deployments?
Education
Training for all users
Clarifying the value of new systems/technologies
Consumers attitudes/perceptions regarding safety, security, and privacy
Informing policy makers
Precursory policy analysis for these technologies and services
Policy framework for government intervention/regulation
Impacts on the traditional roles of the public and private sectors
Risks of "doing nothing"
Cooperative national research plan for automated vehicles and shared mobility systems
Develop widely shared and continuously updated research roadmap
Conduct gap analysis
Develop topology for setting priorities and for conducting research
Facilitate public/private/academic research partnerships
Streamlining of traditional research processes
What is the barrier-breaking research that enables transformation?

Notes

1. The Transforming Mobility Ecosystem: Enabling an Energy-Efficient Future. (2017) U.S. Department of Energy. https://energy.gov/sites/prod/files/2017/01/f34/The%20Transforming%20Mobility%20Ecosystem%20Report.pdf
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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. C. D. Mote, Jr., 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.

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