PREPARING FOR AUTOMATED VEHICLES & SHARED MOBILITY
White Paper Prepared for National Academies/TRB Forum

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(DRAFT 1.0)

The deployment of automated vehicles, shared mobility services, and other transformational technologies has 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 negative results.

The National Academies-TRB Forum on Preparing for Automated Vehicles and Shared Mobility was officially launched in early 2018 to facilitate the fact-based research that is 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.

The Case for Transformational Change

Education, economic development, health care, safety & security, transportation.

The public is demanding action to address critical issues in all of these areas.

This is reflected in polls, surveys, and recent elections. A growing portion of the public is losing faith in our institutions, processes, and leaders. Many are frustrated with continued gridlock in Washington, as well as at the state and local levels. They are tired of small-scale steps being taken to address large-scale problems. Many have become cynical about politicians' claims to have solutions. Voters have rebelled against revenue increases, complaining that their current tax dollars are being wasted. Many perceive a society where things are getting worse - while longing for a time when we took bold actions to make things better.

The transportation community is included in this conflict, and our problems are not unique. We operate in the same skeptical environment as the other public policy areas mentioned above. Bold new initiatives are needed to capture the public's imagination and to rekindle faith in our institutions.

The Case for Optimism

There is good news! Unlike the other policy areas, the transportation community has already laid the foundations for moving in bold new directions.

The public and policy makers are fascinated with the prospects of automated vehicles, shared mobility services, and other transformational technologies in transportation.

Legislation is being debated on Capitol Hill in Washington. The U.S. Department of Transportation (DOT) is issuing guidance on testing and deployment of automated vehicles and other technologies. 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 nationwide are running stories about “driverless cars.”

So we have accomplished the first step – we have captured the imagination of the public and policy makers. But like the dog that catches the car, what are we going to do with it?

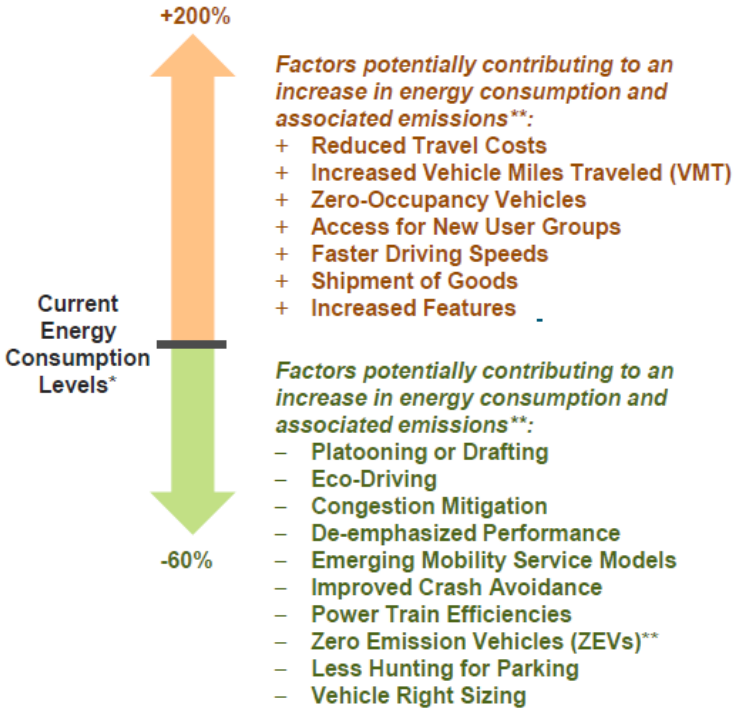
The Case for Caution

Success is not assured. The March 18, 2018 pedestrian fatality involving an automated vehicle in Arizona, along with other recent fatal crashes involving automated vehicles, 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”[i], released in January 2017, offered the following scenarios and projections:

- Successfully deploying automated vehicles, shared mobility systems, and electric/zero emission vehicles in combination 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, 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, then, 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.

However, time is short, as these technologies are advancing rapidly, and there are still more questions than answers.

The Case for Transformational Research

When there are more questions than answers, fact-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 needs to address not only the efficacy of deploying these technologies, but the societal impacts as well. Public sector and academic research 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 research effort to address the synergy among intelligent transportation systems, connected-automated vehicles, shared mobility services, alternate fueled vehicles, and infrastructure improvements. In addition, each of these must be incorporated into

broader transformational ideas, including smart cities and the internet-of-things, and into existing transportation systems.

Such a research effort will need to be fact-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 research 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 fact-based research needed to deploy these technologies in a manner and timeframe that informs policy to best meet long-term goals. These goals include increasing safety, reducing congestion, enhancing accessibility, increasing environmental and energy sustainability, and encouraging economic development and equity.

As of May 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

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 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-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 are again approaching 40,000 in the United States. The worldwide total is1.25 million. 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 fatal 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.

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.

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 automated vehicles 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.

A November 2017 report by the RAND Corporation[ii] 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 will be acceptable to society over the short and long term. The status quo? Some reduction in fatalities and injuries? An almost total elimination of crashes? 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.

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?

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

Forum participants stress the need for research to take maximum advantage of the combined impacts of the public sector infrastructure, private sector automated vehicles, related 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 pointed 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.

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

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, and the risks and rewards for investment planning.

Looking to the longer term, Forum participants are encouraging 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, 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, 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 or not social, environmental, energy, and economic goals can be achieved.

The impacts on vehicle miles of travel (VMT) will be a major “driver.” A growing number of research reports are predicting that these technologies and services are likely to increase, rather than decrease, VMT. Forum participants therefore recommend research to inform policies that can either reverse this trend or can accommodate increased VMT while still achieving broader societal goals.

The research recommended by Forum participants will help to inform decisions on policies and regulations. This begins with developing appropriate planning tools and identifying the right metrics across the range of social impacts. In addition, participants recommend that pilot deployments should be designed to evaluate not only the technical efficacy 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, low-income individuals, and those in rural areas.

Impacts on the workforce are also identified as a focus area for research. Both jobs lost and jobs created by these technologies and services will have economic impacts across our society. 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?

Data Considerations

Real-time transportation data is now widely available after decades during which there has been a paucity of transportation data. The private sector has been able to make 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. Forum participants have identified the following priority research focus areas:

- Sharing of data related to crashes
- Making data available for research and planning models
- Sharing and managing data for real-time operations and freight supply chains
- Use of transportation data to support smart cities and communities

Public agencies need research results to better identify and share good practices in data curation, sharing, and management. This will need to include 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.

Much has been written regarding cybersecurity as it pertains to vehicles. Forum participants recommend 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 eight priority research topics addressing alternate scenarios for synergy among automated vehicles, 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 planning models will need to revisit the traditional four-step planning process. 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 that will achieve those objectives. This may require new models for scenario planning 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. Forum participants also recommend 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. 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, 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 our 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 and scenario planning than on traditional rear-view mirror research

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.”

Forum participants have therefore urged public/private/academic partnerships be facilitated by TRB and others in order to identify and carry out the barrier breaking research that enables positive transformation.

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 adverse 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
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
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

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TRANSPORTATION SYSTEM IMPACTS

Infrastructure Enablers for AVs & Shared Mobility

Future designs of highways, streets, intersections, etc.

At what point should we dedicate lanes to AVs?

Infrastructure needs for V2I

Impacts on public agencies' procurement policies

Impacts on existing standards and standards-development processes

Critical paths to level 4/5 automation for light and 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 & 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 & 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

AVs impact on asset management practices

Deterioration from vehicles travelling on same track

Implications for work zones

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SOCIAL, ENVIRONMENTAL, ENERGY, & 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
- 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 for mega-regions
- Evaluation of pilot deployments to determine contributions to various societal goals
- How to best serve those with special needs
- Preparing the future workforce
  - Jobs displaced vs. jobs created
  - Attracting the "best & brightest" into the transportation profession

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DATA CONSIDERATIONS

Models for sharing of data

- Public sector use of private sector data
- Sharing of crash data
- Making data available for research and planning models
- Protocols for data sharing and management for real-time operations & 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 & sharing good practices in data curation, sharing, and management
- Investment planning for IT systems, data, and staffing
- Development of data formatting standards

Meeting cybersecurity and privacy challenges

- Cybersecurity and privacy for V2I communications
- Cybersecurity for traffic management systems

Framework for automated/connected vehicle pilot and smart cities data analytics for policy guidance

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CROSS CUTTING TOPICS

Alternative scenarios for synergy among automated vehicles, shared mobility, & alternative fuels

- Models for scenario planning (with critical paths) and use cases
- Auto ownership scenarios and implications
- Rate of deployment of mixed fleet, and implications
- Impacts on land use; 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 ecosystem?

Implications for transportation planning and planning models

- Modeling the impacts of increased penetration of AVs & shared mobility
- 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/regululation
- 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?

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[i]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

[ii] Why Waiting for Perfect Autonomous Vehicles May Cost Lives; RAND Corporation, November 2017: https://www.rand.org/blog/articles/2017/11/why-waiting-for-perfect-autonomous-vehicles-may-cost-lives.html