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Mini-Workshop on the Importance and Role of Connectivity

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Mini-Workshop on the Importance and Role of Connectivity

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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. The Forum has held five 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 a one such workshop held for this Forum. Jeff Lindley, Katherine Kortum, and Mark Norman authored the paper, and it was reviewed by Chandra Bhat, The University of Texas at Austin.

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 were:

- Jeff Lindley, Institute of Transportation Engineers (cochair)
- Ed Straub, SAE International (cochair)
- Chandra Bhat, The University of Texas at Austin
- Dan Blais, Transport Canada
- Annie Chang, SAE International
- Steven Dellenback, Southwest Research Institute
- Kevin Dopart, U.S. Department of Transportation
- Larry Head, University of Arizona
- Katherine Kortum, TRB staff
- Mark Norman, TRB staff
- Faisal Saleem, Maricopa County Department of Transportation
- Larry Yermack, Cubic

PUBLISHER'S NOTE

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Contents

Introduction

In order to better inform all Forum members and generate discussion on strategic crosscutting issues, members are holding a series of "mini-workshops" in 2019. These mini-workshops focus on answering three main questions: (1) why the subject area is of critical importance, (2) what the current state of play is, and (3) what the future might hold. The mini-workshop on the "Importance and Role of Connectivity" occurred on February 14, 2019 in Washington, DC. This report contains a summary of the workshop, including key takeaways, panelist remarks, summaries of breakout group discussions, and a set of proposed research questions.

WORKSHOP FORMAT AND AGENDA

The workshop consisted of six panelists representing various points of view on the role of vehicle connectivity, followed by four breakout sessions to elicit input on the three main questions noted above. The workshop concluded with brief breakout session summary reports and closing remarks. A key outcome of the workshop was identification of specific research questions in this area that those in the transportation field could pursue.

KEY TAKEAWAYS

Key takeaways from the workshop included the following.

There is considerable popular press about autonomy, but only industry insiders are talking about connectivity. More needs to be done to create consumer awareness of the differences between and the benefits of both connected and automated vehicles. Although automated vehicles and connected vehicles are often grouped together, their situations are different in terms of technological maturity and uncertainty.

It is important to ensure that both the deployment of both connected and automated vehicles, in addition to shared mobility services, focus on a user perspective, not on a vehicle or infrastructure perspective.

Connected automation is critical to enable the transportation system to function most safely and effectively. Two critically important reasons for connectivity include redundancy and the ability to see what sensors cannot. On-board sensors work for immediate vicinity sensing to support collision mitigation and avoidance; cellular communications and dedicated short range communications (DSRC) can support a broader range of applications and over longer distances (such as avoiding collisions due to overtaking maneuvers on high-speed rural two-lane roadways). Also, pricing of streets and managing of curbs will require connectivity.

Connectivity may require a different legislative and regulatory framework than exists today, particularly with respect to public and private sector relationships and to funding and risk assignment and liability.

Consistency and interoperability are critical to the successful deployment of connectivity. Standards development processes may need to be streamlined and accelerated. Vehicle manufacturers are concerned over state DOT inconsistencies in deploying DSRC. On the other hand, state DOTs cannot be dependent on proprietary clouds of data housed within each vehicle manufacturer.

There is significant fear regarding the liability of a failure in connectivity. Failures might include a complete breakdown in the connectivity or the speed being too slow, resulting in injury or death. Even if the technology works perfectly, approximately one-third of all crashes involve driver impairment, and impaired drivers cannot be expected to be able to react to the alerts provided by a vehicle.

The technology debate will rage on, but it is important to focus on the use cases. Each use case is likely to require something different.

The number of devices on the road should not be the sole measure of readiness. Policy, maintenance, and workforce issues matter as well, and pilot projects are the means to determine how these will work. In addition, connectivity is not free. Industry and the public sector need a better understanding of overall costs of the technology, including maintenance costs, before the system is truly ready to accept widespread connectivity.

There will continue to be more questions than answers for the foreseeable future, and ongoing research will be needed.

Opening Panel Session

The opening panel consisted of six panelists representing a variety of points of view on the importance and role of connectivity, both from automated vehicle and shared mobility perspectives. Panelists spoke about why the subject area is of critical importance, the current state of play, and what the future might hold. A primary purpose of the panel presentations was to frame key technical and policy issues in advance of further discussion in breakout groups.

JEFF LINDLEY
Institute of Transportation Engineers

Jeff Lindley opened the workshop by outlining the overall plan for the workshop and introducing the panel session. There is an understandably high level of current interest in technical and policy issues related to the communications medium (e.g., DSRC, 5G cellular) used to connect vehicles and vehicles, vehicles and infrastructure, and vehicles and other system users to enable mobility and safety applications. This level of interest is so high that it had the potential to completely dominate the workshop discussions. Both panelists and breakout session facilitators were asked to keep this in mind and cover the issues in as much of a connectivity medium neutral mode as possible. Lindley then introduced the six panelists, and a summary of each panelist's remarks appears below.

BLAINE LEONARD
Utah Department of Transportation

There is a great deal of popular press about autonomy, but only industry insiders are talking about connectivity. There are two primary reasons that connectivity is so important. First is redundancy: it provides verification of sensor data that is on-board vehicles. An automated vehicle (AV) bases its decision based on what it can see. A connected vehicle (CV) makes decisions based on what it can learn.

Second, connectivity has inherent value that seeing sensors cannot. Connectivity can do five specific tasks better than sensors:

- Signal phase and timing information. Sensors know what the signal state currently is, but connectivity to the infrastructure allows the vehicle to know what the signal is about to do.
- Lane closures. Connectivity can provide much more advance notice than vehicle sensors about lane closures or other diversions.
- Platooning. This is currently focused on use in trucking, but it needs to be in passenger vehicles too. What is an agency's role in platooning? Will vehicles act like a swarm of bees and use self-crowdsourcing to form their own platoon, or should agencies communicate some kind of permission or facilitation to the vehicles?
- Freeway queue detection. Will sensors warn vehicles about queues in time? Sensors might not but connectivity likely will.
- Icy road conditions. As with road closures, connectivity can provide better

information to the vehicle about current or upcoming icy conditions than can sensors, including in areas where the conditions may not be immediately visible ("black ice").

The DSRC/5G argument is not analogous to the VHS/Beta situation several decades ago. Both VHS and Beta existed in the marketplace at the same time and were competing for dominance. With connectivity, DSRC exists and 5G does not. To accelerate the benefits of connectivity, agencies and other practitioners will need to deploy using the technology available now. Some agencies still deploy Highway Advisory Radio, which was cutting edge technology in the 1940s.

Automakers are worried about DSRC because some state DOTs are deploying it and others are not. Some signal systems are connected, and some are still hardwired/manual. An automaker cannot count on agencies around the country to deploy DSRC uniformly. It is more likely they will be able to count on cellular companies to deploy 5G uniformly. However, there are still parts of the country with 3G or "no G." In addition, if users have to pay for the subscription in order for their vehicles to have the benefit, many will not.

In order to be interoperable, agencies cannot depend solely on proprietary clouds of data housed with each automaker. There is no obvious honest broker to bring it all together. State DOTs could perhaps be the common cloud in the future, but if they are not, there is no clear candidate. Interoperability is often meant to be cross-jurisdictional, but it is also cross-automaker.

BRIAN CRONIN
Federal Highway Administration

The FHWA role is often about making information available for research. For connectivity, there are several different use cases.

- Safety. Need low-latency reliable communication.
- Maintenance. Need connectivity back to corporate cloud.
- Traveler info. Info can be delayed by a couple of minutes.
- User info. About a 20-s delay for Audi (for example) for signal timing information into vehicles.
- Work zones. How far upstream can we provide info and have it be useful?
- Signal operations. Real-time at intersections; more delayed for optimization of routes/systems.

FHWA is currently considering the data and potential effects of market failures. The administration has done a great deal of work with DSRC and is trying to better understand 5G options and capabilities, not only for FHWA but also for all stakeholders.

FHWA is focusing on different applications and situations in which deployment of connectivity will provide benefits to transportation systems. Cooperative automation is making it possible for CVs and AVs to work together, and Cooperative Automation Research Mobility Applications is a key FHWA research project. During the summer of 2018, the administration tested platooning with other capabilities on I-95 express lanes in Virginia. Four vehicles in a platoon on the Interstate approached an on-ramp. An entering vehicle wanted to join the platoon, and it did so successfully. For a (faux) work zone, FHWA staff sent a command for the platoon

to change speeds from 65 to 45 and change lanes, and they automatically did while staying in platoon. FHWA staff then sent a command to resume the previous speed. This type of effort only works with connectivity.

BRIAN KELLER
AT&T

AT&T is a one of the companies working in the CV industry, with 31 automakers purchasing their connectivity from AT&T. These automakers include GM, Ford, Tesla, Audi, and others. AT&T has learned from the automakers' activities, which are primarily telemetry and consumer services like navigation or Spotify. To date, these activities enhance the driver experience but are not yet life-critical.

When there were many small wireless companies, they performed at varying levels of effectiveness. When AT&T brought all the companies together, the parent company had to normalize them. Different chipsets and operating systems made for many different possible deployment combinations, which is part of why DSRC has not taken off as much as it could. Chipsets that end up in products also exist along an evolution spectrum. Those in smart phones are among the most advanced on the market, because people are willing to pay a lot and do so often to have the best technology. Automakers are slower to get new technology into their vehicles, with most taking about 3 years.

Connectivity is not free. Qualcomm is a market leader in research on chipsets, and they expect compensation for their intellectual property. Other steps in the process include manufacturing the silicon, packaging it into a chip, putting the chip into a module, putting the module into a unit, and connecting the unit to a cell network; each of these steps comes with a cost.

The most important consideration is what a customer wants from connectivity. AT&T is aware that cellular is not the only option. The company wants to have DSRC available because its customers, both the state DOTs and vehicle manufacturers, like it. AT&T has made investments in centers where AV testing is occurring and is trying to understand what the state DOTs need.

AT&T is fearful of liability for a failure in connectivity, whether it be a complete failure or whether the connectivity does not work quickly enough, especially if that failure leads to injury or death.

STEVE KUCIEMBA
WSP

The technology debate will continue to rage on, but Forum members and practitioners should focus on use cases, each of which is likely to require something different. An analogy is to work on the edges of the puzzle instead of the middle.

Many infrastructure owners and operators are afraid to take any action because of the uncertainty around the technology and its deployment. The number of devices on the road should not be a measure of readiness. Policy and maintenance and workforce issues matter too, and we have to figure those out through pilot projects. While procurement processes are longer than tech lifecycles, which creates significant challenges for public agencies, we can begin by outlining steps to move forward.

TIM PAPANDREOU
Emerging Transport Advisors

Technology does not understand boundaries, but cities and states have boundaries.

Mobile application programming interfaces are a current barrier to getting something like Mobility as a Service up and running. This is currently the main missing piece in the shared mobility system.

How do state agencies become platform managers to accomplish more than making bad things work better? Many experts feel people are no longer able to operate vehicles, as smartphones are making people into dumb drivers.

How does shared mobility prepare us for automation? The answers are not yet clear.

Pricing of the streets and managing of the curbs will require connectivity. Cities need to understand the price signals for delivery and service providers to use our streets efficiently.

ED BRADLEY
Toyota

On-board sensors are intended for collision mitigation and avoidance, but cellular and DSRC is intended for the longer-distance issues. Some of the Toyota applications of connectivity include intersection assistance and emergency vehicle notification.

In terms of addressing crash risks, DSRC and vehicle-to-infrastructure connectivity may address up to 80% of the non-impaired crashes. About one-third of all crashes have driver impairment as a factor, but Toyota does not expect impaired drivers to be able to react to the alerts.

Breakout Sessions

After the panel session, the workshop moved on to a series of four breakout sessions of approximately 75 minutes each. Each breakout session considered the following questions:

1. What types of connectivity are most important and why?
   - Vehicle-to-vehicle (e.g., for better car following);
   - Vehicle-to-road side infrastructure (e.g., going through traffic signal more efficiently, weather/congestion alerts);
   - Vehicle-to-other road user (e.g., pedestrian, bicycle); and
   - Connectivity between shared mobility providers, vehicles and shared mobility users.
2. What are the most significant challenges in providing each type of connectivity?
   - Latency, reliability;
   - Privacy;
   - Cybersecurity;
   - Institutional (e.g., who pays for maintaining the system);
   - Equity (e.g., a connectivity that requires smart phones, that excludes some people); and
   - Interoperability.
   - Others?
3. If full connectivity is never realized, how would that limit the potential benefits of autonomous vehicles and shared mobility?
4. What questions in this space need more investigation (i.e. research)?

Brief summaries of the discussion and key points from individuals in each breakout session appear below.

BREAKOUT GROUP 1

Much of the analysis to date on CVs has assumed that there is a government mandate to install the technology to enable the necessary communications at some point. What if that does not happen? Does that change the benefits equation? Is there research that needs to be done assuming no CV technology mandate, but also assuming a gradual introduction of AVs? Are multiple ecosystems operating in parallel viable technologically and economically?

What more needs to be done to create more consumer awareness of the differences between and benefits of both connected and AVs. What needs to be done to create public trust in these vehicles as they transfer some level of driver "control" to the vehicle or to the "system"? How do we explain the value proposition?

How do we ensure that both the deployment of autonomous vehicles and shared mobility services focus on a user perspective, not just on a vehicle or infrastructure perspective?

There will be some level of unintended consequences along the autonomous vehicle deployment path, similar to the equity issues that have arisen in the deployment of shared mobility services. How can we be better prepared to deal with these unintended consequences when they inevitably happen?

BREAKOUT GROUP 2

Infrastructure-to-vehicle vehicle communication is important. It will also be important to avoid putting the burden of connectivity on vulnerable road users (e.g., pedestrians and bicyclists).

Current understanding of the overall cost, including maintenance cost, of the technology is limited.

Equity about types of technology in different vehicles is a concern. Will potentially life-saving technology initially or permanently only be available in higher-end vehicles?

What are the incremental benefits of deploying connected AVs beyond deploying just (unconnected) AVs?

Economic analysis and use cases will be important. These will need to include business models for sustainment and consider a services model versus a built network

Interoperability will be important for connectivity to be successful. How do we develop standards and turn data into information and disseminate it widely? What institutional issues are created when crossing jurisdictional boundaries and across companies?

What legislative frameworks are necessary to support the deployment of connectivity for both shared mobility and autonomous vehicles?

BREAKOUT GROUP 3

Use cases will be key to understanding and addressing connectivity issues. Ensuring that use cases robustly reflect the various dimensions of AV and shared mobility deployment and the benefits of connectivity (and issues created if connectivity does not exist) will be critical.

Connected technologies must be interoperable. Standards development processes need to be streamlined and accelerated. System considerations need to be given equal weight with equipment and data sharing interoperability concerns.

Connectivity may require a different legislative and regulatory framework than we have today, particularly with respect to public–private-sector relationships, funding and risk assignment/liability.

BREAKOUT GROUP 4

Connectivity types are different in AV and shared mobility contexts.

It is important to consider different levels of communication - very near, mid-distance, and long distance. This is akin to communicating information for the three layers of the dynamic driving task, which are

- A strategic layer with a long time horizon for trip planning, route redirection, etc.;
- A tactical layer, measured in seconds for maneuvering on the roadway; and
- An operational layer, measured in milliseconds for the vehicle control level (i.e. horizontal and longitudinal control).

Why are we communicating with others? Safety is a big reason, but it is important to remember other reasons as well. We need to connect people, not just vehicles, and consider

which stakeholders are missing from the discussion.

Where will connectivity change behavior the most? First in the infrastructure, then the vehicles, or vice versa?

Scalability and time-to-market are both important to remember. How long until we realize the benefit?

“Immunity to change” is a problem, as are different market forces. Are market acceptance and profitability key considerations?

What are the definitions of “connectivity” and “fully connected”?

What risks are created without full connectivity? What additional or new risks exist if we reach full connectivity? A disconnected computer is useful, but it is far more useful when connected to the internet.

Active safety assessment is important. In a data-rich environment, measuring data will change. We can measure hot spots of conflict instead of just crashes.

What are the potential models for the honest data broker?

Interoperability and accessibility may prove to be challenges. Many authorities are responsible for the decisions in these areas, and many different market forces (including supply chain and users) influence penetration.

Key Research Questions

The panel and breakout sessions included a rich discussion of issues. This discussion did not directly lead to the identification of specific research questions in most cases, but the following research questions are raised for consideration by those in the AVs and shared mobility industries.

- What use cases need to be analyzed to create a full understanding of the potential benefits and other implications of connectivity?
- How do predicted benefits of deployment of autonomous and shared vehicles change if connectivity is limited or does not exist? Phrased another way: What are the incremental benefits of deploying connected AVs beyond deploying just (unconnected) AVs?
- How do connectivity needs and benefits change between very near, mid-distance, and long distance applications?
- How can the needs of vulnerable users (e.g. pedestrians and bicyclists) be accommodated without requiring them to bear the full responsibility of always being "connected"?
- How will the ability to assess safety issues be different / improved in a fully connected environment?
- What viable options exist for managing and providing access to the data that will be generated in a fully connected environment without compromising privacy or creating cybersecurity risks?
- What is the consequence of sharing information such as a wrong-way driver with human drivers or human AV safety operators? How do humans react when they receive messages that are time critical and potentially life-threatening?

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