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Connected & Autonomous Vehicles and Transportation Infrastructure Readiness

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Final Report

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DISCLAIMER

Executive Summary

The ITS World Congress 2017 (Sunday, October 29th to Thursday, November 2nd) sessions, exhibits, technical tours, and demonstrations offered unique perspectives and updates in the field of ITS, transformational technology, policy and deployment. This setting was the backdrop for a peer exchange that engaged a selected group of state transportation agency chief executive officers (CEOs) on the issue of "Connected & Autonomous Vehicles and Transportation Infrastructure Readiness."[1]

A component of National Cooperative Highway Research Program (NCHRP) project 20-24, which conducts research intended to address the specific concerns of CEOs and other top managers of the state departments of transportation (DOTs)[2], NCHRP 20-24(111) first provided resources to CEOs in advance of the peer exchange. These resources included a contextual, in-depth White Paper, on the state-of-the-art for connected and automated vehicles (CAVs) as they relate to anticipated experiences at the World Congress itself, as well as conference calls presenting background material and setting the stage for the group's forthcoming discussions.

This material was in preparation for the peer exchange workshop, which took place on the last day of the World Congress. NCHRP Leadership Forum Members gathered to discuss their learnings from the week – not just from the World Congress itself, but also from the American Association of State Highway and Transportation Officials (AASHTO) International Day, which took place on October 29th (see: Appendix 1) – and the emerging developments in the field. Among many changes being experienced by public sector transportation agencies, and notably by state DOTs, the development of connected and automated vehicles (CAVs) is highly transformational. Further, the deployment of CAV technology on streets and highways is occurring in the presence of additional technological and industrial changes that add to opportunities and uncertainties in planning, managing and operating the transportation infrastructure.

These challenges were reflected in the topics and discussion points surfaced at the Workshop. Invited guests shared observations made during the World Congress. These observations emphasized attendees' interest in connectivity and cybersecurity, as well as the progression of the industry from discussing deployments to actual deployments, among others. Members then received presentations by the Federal Highway Administration (FHWA) and the U.S. Department of Transportation's

[1] http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4223
[2] http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=560

(USDOT's) Intelligent Transportation Systems Joint Program Office (ITS JPO) on their respective programs in connected and automated vehicles.

These discussions and presentations led to a broader discussion among Members and others present. During these discussions, Members expressed the need to maintain focus on connectivity in the face of increased public and media attention on automation, given their potential for connected vehicle (CV) technologies to make roadways safer and save lives. Namely, Members discussed the various connected technologies, including DSRC and 5G, the timing of and approach to deploying such technologies, and various mechanisms by which to generate momentum for additional deployments, such as leveraging existing infrastructure, building upon the SPAT Challenge, leveraging DSRC use in truck platooning, and prospective roles for smaller states.

Subsequently, Members shared their respective challenges and opportunities as they consider and prepare for connected and automated vehicles (CAVs). The CEO discussion revealed that, even though states are at widely different stages with CAV readiness, all accept the need to actively prepare in a way that is most appropriate for state and local needs. While federal roles and actions are of vital concern to the CEOs, much of the discussion concentrated on the most pressingly-needed CAV applications at the local level, including rural communities. CEOs were very aware of the distinct approaches needed for CV and AV, and emphasized the need to maintain focus on connected vehicle deployment, while beginning the process of de-mystifying the multiple potential roles of highly-automated vehicles.

The process of CV deployment has begun well with AASHTO's SPAT challenge and all states are willing to build on the current base of approximately 65,000 V2X devices deployed throughout the country. While states remain concerned about the needed resources for deployment and maintenance, the longevity of the communication regime (DSRC vs 5G), and the potential need for redundancy, CV is clearly regarded as being compatible with state DOT goals of safety and congestion reduction. Those with CV (V2I) deployment experience described the costs as incremental, and compatible with other ITS investments, even though available funds for all are extremely limited.

The conversation about AV is at an earlier and less well-defined stage. There is a need to socialize the technology across a wider range of organizations within the state, including state legislators. It is important to spell out the "transformational" benefits to the state leaders and constituents alike (at the level of "making our lives better"), and the technology needs to deal with traffic congestion, as well as safety.

CEOs recognize that they need to rely on others for some aspects of AV deployment, but also need to be pro-active in both individual and collective fashion. CEOs are comfortable with the federal government focusing on AV safety and cybersecurity, which are regarded as essential common interests. CEOs also see great value in working

more closely with their peer organizations, and a number of bilateral relationships are in progress.

State DOTs also accept that significant challenges remain within their purview, and these include horizontal caucusing within the state, outreach to communities large and small, outreach to vehicle manufacturers and other non-traditional partners, the development and retention of a well-prepared workforce, and effective constituent and consumer messaging about AV, CV and adjacent technologies such as electrification.

As local and regional deployments occur, it is important to progressively evaluate and document benefits, especially with respect to safety and alleviation of traffic congestion. And effective communication of progress with these goals in critical. For example, in the case of truck platooning, it is essential to supplement current knowledge of economic benefits with evidence concerning the safety impact of platooning.

Important unresolved issues surround CAV data; what are workable models for collecting, sharing, exchanging and/or monetizing data? Can state DOTs develop agreements with OEMs for exchanging and fusing data? How can such agreements provide wide practical value by identifying potholes, etc? What are the appropriate roles for collector and provider, and terms for anonymity and payments? Will monetization of state DOT's data provide support for depleted budgets and CAV infrastructure costs? These data issues also speak to the need for state DOTs to develop more partnerships with private industries and to leverage their great strength: control of the right-of-way.

As state DOTs broaden their interactions with adjacent and local agencies within the state, and with non-traditional industry partners, they need to speak and act more like mobility providers, as well as infrastructure providers. In these interactions, it is necessary to establish needs at the local level, and how state DOTs could best assist local entities to achieve their goals.

Our structured dialog of state DOT CEOs produced some expanded perceptions of avenues to CAV preparedness, and these outcomes could well inform the research and dialog processes undertaken by TRB/NCHRP and AASHTO. The following themes for "state DOTs in the CAV era" address CAV preparedness via state DOT initiatives, capabilities and partnerships, and are amenable to research and convening activities.

Taking More Initiative

- Defining the state DOT as a mobility provider (as well as an infrastructure provider);
- Promoting the transformational nature of CAV to state legislators;
- Undertaking effective messaging for constituents as well as legislators;
- Keeping the focus on CV deployment;

- Establishing a peer-to-peer relationship with OEMs (non-traditional partners);
- Defining the infrastructure/environment elements of AV safety assessment;

Developing Stronger Capabilities and Resources

- Documenting CAV benefits, including traffic efficiency as well as safety;
- Developing awareness of the state of AV technological development along with ITS compatibility;
- Monitoring the national and international state of CAV test beds, deployment and research;
- Developing the requirements of the CAV workforce;
- Developing the "state DOT business model" for CAV data;
- Accelerating 3D digitalization of the infrastructure;

Being a More Effective Partner

- Providing assistance to federal efforts on AV safety and cybersecurity;
- Horizontal caucusing with adjacent state agencies;
- Establishing a new relationship with local communities and entities;
- Helping to define and support smart cities initiatives; and
- Early identification of CAV "red flags" (such as impacts on jobs and parking revenues).

The rich discussion undertaken by state DOT CEOs was indicative of the highly tangible and dynamic nature of CAV development. The implications for state DOTs, and other state and local agencies are profound. Venues such as the ITS World Congress provide excellent opportunities for "deeper dives" such as this NCHRP Leadership Forum. State DOT CEOs expressed their need to show leadership in new initiatives, improved capabilities and expanded partnerships. In turn, TRB/NCHRP and AASHTO and other national stakeholders have new opportunities to assist state DOTs to prepare for CAV.

1. Introduction

From October 29, 2017 to November 2, 2017, Intelligent Transportation Systems (ITS) professionals, leaders, and experts from around the world gathered in Montréal, Quebec (Canada) for the 24th ITS World Congress. One of the preeminent annual events focused on ITS – rotating between Europe, the Asia Pacific region and the Americas – the Congresses provide a key opportunity for public, private and academic stakeholders to examine ITS solutions, debate and build relationships. Businesses have the opportunity to exhibit and demonstrate state of the art ITS solutions.[3] The Congresses also showcase the latest ITS achievements from the city and region hosting the Congress, and can help increase awareness of ITS in the Host region itself.[4]

The ITS Congresses consist of three main areas:[5]

- Congress program sessions – both plenary and parallel – and presentations of the latest developments in ITS;
- Demonstrations – showcases of current ITS technology being developed and deployed throughout the world);
- Exhibition – exhibition booths and dedicated sessions and events.

In Montréal, the program sessions were delineated in seven tracks:

1. Connectivity and Autonomy;
2. Infrastructure Challenges and Opportunities;
3. Smart(er) Cities;
4. Data, Security, and Privacy;
5. Integrated Approach: Planning, Operations, and Safety;
6. Disruption and New Business Models;
7. Innovation, What's Next? The New Ideas.

Additionally, an emphasis of this year's World Congress was smart cities, including the citywide collection and application of electronic data to improve the management of the city's assets and resources. This emphasis was reflected in both the programming, with one of the tracks designated "Smart(er) Cities", but also in the exhibition, where a pavilion was established highlighting smart cities in action. Several cities from around the world were invited to establish experiential exhibits to convey how they are harnessing ITS and other technologies to improve their residents' lives. Participating

[3] http://itsworldcongress.com/congress/about-the-its-world-congress/
[4] Ibid.
[5] Ibid.

cities included Montréal, Christchurch (New Zealand), Copenhagen (Denmark), Singapore, and USDOT Smart City Challenge winner Columbus (Ohio, USA). The emphasis on smart cities was in addition to a strong recent focus on connected and automated vehicles (CAV) in recent congresses.

With its plethora of activity on the latest involving ITS issues, technologies, and deployments, the ITS World Congress 2017 provided a valuable opportunity to couple a peer exchange that engaged a selected group of state transportation agency chief executive officers (CEOs) on the issue of "Connected & Autonomous Vehicles and Transportation Infrastructure Readiness." A component of National Cooperative Highway Research Program (NCHRP) project 20-24, which conducts research intended to address the specific concerns of CEOs and other top managers of the state departments of transportation (DOTs), NCHRP 20-24(111) provided resources to CEOs, including a contextual, in-depth White Paper in advance of the World Congress on the state-of-the-art for connected and automated vehicles (CAVs) as they relate to anticipated experiences at the World Congress itself.

Such resources, and the World Congress itself, established the context for a NCHRP Workshop that took place on the final day of the World Congress in which all state DOT participants discussed their learnings from the week and the emerging developments in the field; for this discussion, selected invitees provided the CEOs with knowledgeable viewpoints and cross-cutting issues. A similar activity took place in 2014, at the ITS World Congress in Detroit, Michigan. This Final Report documents the discussions, topics, and outcomes of that workshop, and is provided as a resource to the state DOT leadership community at large.

2. The NCHRP Leadership Forum and its Workshop

The workshop was held 8.00 AM – noon on Thursday November 2 at the Montreal Convention Center. The 2017 State DOT CEO Leadership Forum was comprised of fifteen members who were all present at the workshop:

- Mr. James A. Barna, Chief Engineer & Assistant Director, Transportation Policy, Ohio Department of Transportation
- Mr. David B Bernhardt, Commissioner, Maine Department of Transportation
- Mr. Shailen Bhatt, Executive Director, Colorado Department of Transportation
- Mr. Carlos Braceras, Director, Utah Department of Transportation
- Ms. Coco Briseño, Deputy Director, Planning and Modal Programs, California Department of Transportation
- Ms. Jennifer Lynn Cohan, Secretary, Delaware Department of Transportation
- Mr. Roger Millar, Secretary, Washington State Department of Transportation
- Ms. Sue Mulvihill, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation

- Mr. Brian W Ness, Director, Idaho Transportation Department
- Mr. William T. "Bill" Panos, Director, Wyoming Department of Transportation
- Mr. Mike Patterson, Executive Director, Oklahoma Department of Transportation
- Mr. Pete Rahn, Secretary, Maryland Department of Transportation
- Ms. Leslie Richards, Secretary, Pennsylvania Department of Transportation
- Mr. John C. Schroer, Commissioner, Tennessee Department of Transportation (2017 Chair, AASHTO)
- Mr. Kirk T. Steudle, Director, Michigan Department of Transportation (Chair, NCHRP Panel 20-24(111))

Additional Workshop attendees/participants from supporting organizations included:

- Mr. Steve Dellenback, Vice President, Southwest Research Institute, and 2017 World Congress Program Chair
- Mr. King W. Gee, Director of Engineering and Technical Services, AASHTO
- Mr. Tom Kern, Senior Consultant, AASHTO
- Mr. Martin Knopp, Associate Administrator for Operations, Federal Highway Administration (FHWA)
- Mr. Andrew Lemer, Senior Program Officer, NCHRP The National Academies of Sciences, Engineering, and Medicine (NAS)
- Mr. Ken Leonard, Director, U.S. Department of Transportation (USDOT) ITS Joint Program Office (JPO)
- Mr. Abbas Mohaddes, Principal, CAVita LLC, and President and COO, Econolite
- Mr. Matt Peak, Manager, Connected and Automated Vehicle Strategies, CAVita LLC
- Mr. Neil Pedersen, Executive Director, Transportation Research Board (TRB)
- Mr. Patrick Son, Managing Director, National Operations Center of Excellence (NOCoE)
- Dr. Peter Sweatman, Principal, CAVita LLC
- Mr. Greg Winfree, Agency Director, Texas Transportation Institute
- Mr. Bud Wright, Executive Director, American Association of State Highway and Transportation Officials (AASHTO)

The workshop agenda is included as Appendix 2. Chairing and moderating duties were shared between Kirk Steudle (NCHRP), Bud Wright (AASHTO), and Peter Sweatman (CAVita).

2. World Congress Orientation

2.1 Program and Attendance

According to early post-congress statements by organizers, the 2017 ITS World Congress was successful in attracting over 5,000 registrants, including 1,391 speakers and moderators, with a combined 258 Executive, Technical, and Special Sessions over five days. The conference sessions included plenaries – including participation by all state DOT CEOs – Executive Sessions, Technical Sessions, refereed Scientific Sessions and Special Interest Sessions.

The most attended session by a large margin was titled "5G Automotive Alliance (5GAA); On the Road Towards LTW-V2X" within the "Infrastructure Challenges and Opportunities" track, demonstrating attendees' deep interest in connectivity and cyber infrastructure. Other popular sessions included "Practical Aspects of Deploying Connected and Automated Vehicles" and "MaaS: Roadmap to the Future of Mobility", both of which were in the "Connectivity and Autonomy" track. Also observed were extensive World Congress conversations about automated vehicle preparedness and cybersecurity, the latter sessions proving particularly popular.

Of course, World Congresses tend to reflect their host city and region, and there was less participation by automotive manufacturers, while automotive suppliers were well-represented. Similarly, the emphasis on smart cities led to more discussion of mobility services and infrastructure. The strong presence of state DOT CEO's in leading roles ensured that questions surrounding the selection, operation and sustainability of ITS technologies – including workforce issues – were well covered. There was an overall strong emphasis on deployment, and research organizations and academic institutions showed a willingness to seek learnings from such deployments.

2.2 The World Congress as an Indicator of the State of ITS

Presentations within sessions, the quantity and type of exhibits, and general discussions with a wide variety of World Congress participants provide perspective on the state of ITS – including the technologies that altogether comprise ITS, the industry itself and the ITS policy environment. Juxtaposition with the substance of other recent industry events such as those of the Transportation Research Board (TRB), AASHTO, and ITS America, provides an indication of how much the overall ITS conversation has changed. Whereas discussions at previous events had revolved around plans to take action and deploy technologies, the 2017 World Congress appeared to mark an increased level of industry maturity, as state DOTs and exhibitors discussed actual activities, deployments, and experiences.

The topic of vehicle-to-infrastructure (V2I) communication, as well as the progress of the National Operational Center of Excellence's (NOCoE's) Vehicle to Infrastructure Deployment Coalition (V2I DC), which was created in 2015 to accelerate the deployment of such technologies,[6] were topics of significant and ongoing discussion. Similarly, the topic of cybersecurity received prominence. The conversation on this issue is not yet mature, for few real answers were posed, but it was nonetheless serious. Agencies and industry members were taking more responsibility for cybersecurity of ITS systems, including connected systems (V2X).

The topic of V2X, includes vehicle-to-vehicle (V2V) as well as vehicle-to-infrastructure (V2I), increasingly includes communication between vehicles, infrastructure and all actors, including pedestrians and other modes such as transit buses and rail. There was greater discussion of the convergence of AVs and CVs – namely how CAVs could leverage infrastructure technologies and receive supporting data from the infrastructure. Similarly, on the exhibit floor, there were more discussions of V2X products and services, with particular attention paid to the visible progress made by Toyota in V2X supporting automated driving. That said, it was noted that AVs received more attention – partially overshadowing the discussion of CVs – with discussions oriented around their path forward and resolution of outstanding issues, such as the need for compatibility as CAVs emerged and shared the road with existing vehicles.

A number of companies on the exhibit floor were embracing new business models around the collection and use of data as it pertains to connectivity. These companies' models sought data from agencies, subsequently applied analytics to the data to turn it into actionable information, then provided this information back to the agencies with the provision that they could use it for their own purposes as well. It was observed that such a model could be a win for the agencies – as the value of their data is upgraded – as well as for the companies themselves. This is an important issue for state agencies, but the right approach to monetizing data may still be elusive.

Several high-quality sessions addressed the topic of how the workforce would be affected by the emergence of CAVs and ITS. Of particular interest were discussions on what sort of talent and personnel were needed now, what projected needs would be five, ten, and more years in the future, and where to find such talent. The discussion pertained to those who are not just scientists and with PhDs, but also for technicians and others who work in the field.

City, state, and regulatory conversations about Shared Mobility (SM) were still relatively immature, partly because comprehensive data on the impacts of SM on safety, traffic

[6] https://transportationops.org/V2I/about

congestion, community-wide mobility, and a broad range of city operations, including parking, are not yet available. Cities were not strongly represented at the World Congress, even though the smart cities concept was highly engaging. It was observed that relatively recent awards by the Advanced Transportation and Congestion Management Technologies (ATCMTD), an FHWA program to support "the development of model deployment sites for large scale installation and operation of advanced transportation technologies…",[7] were highly-competitive and partly aimed at engaging cities. A broad range of learnings as these programs mature will provide rich information for future ITS meetings.

At times, the focus on cities tended to imply larger cities – those with the budgets and infrastructure who could afford and benefit the most from the deployment of smart city technologies. Thus, rural and small communities were less represented at the event. Nevertheless, the question of local community needs from ITS was a hot topic at our workshop.

[7] https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm

3. CAV State-Of-The-Art: Technologies, Maturity, and Deployments

At the World Congress as well as at the NCHRP Leadership Forum Workshop itself, significant attention was focused on preparation for connectivity, automation, and the intersection of the two. Before discussing these issues from state DOT perspectives, this section reestablishes common definitions and baselines, as well as captures meaningful topical updates learned at the World Congress and beyond.

3.1 Connected Vehicles (CVs)

"CV" generally refers to both connecting vehicles and infrastructure, and to connection among all ground vehicle players: cars, freight trucks, and buses – and potentially motorcycles, bicycles, and pedestrians. CV includes vehicle-to-vehicle communication (V2V), vehicle-to-infrastructure communication (V2I), and "V2X", broadly representing communication between vehicles, infrastructure and other road users (such as pedestrians and cyclists).

V2X involves deployment of sensing and connectivity in infrastructure and potentially interfaces with advanced traffic applications utilizing Intelligent Transportation Systems (ITS). This capability creates machine awareness of the trajectories of equipped vehicles in the immediate vicinity, which applies to vehicles as well as specific features of the infrastructure, such as intersections and curves. Such machine awareness may be used to identify safety risks, but also to condense or smooth traffic flow. These applications of the technology require warnings or notifications for drivers, in order for the driver to make the required vehicle corrections.

The most researched, developed, tested, and understood V2X regime is dedicated short-range communication (DSRC), which are comprised of on-board units (OBUs), road-side units (RSUs), V2X applications that process messages and devise driver warnings, various interfaces, and data backhaul. Considerable R&D effort has been devoted to V2I technology and applications. Work led by the Federal Highway Administration (FHWA) and the Crash Avoidance Metrics Partners (CAMP) has developed an increased range of V2I applications. Work by FHWA has developed the connections between RSUs and traffic controllers, and ITS/controller companies have developed SPAT products. R&D has been carried out to develop "pseudo BSMs" that broadcast BSMs on behalf of unequipped vehicles present in an intersection.

Altogether, the government and automakers have spent over $1 billion over a decade to advance DSRC and V2X technologies.[8]

At the World Congress, the ITS Joint Program Office (JPO) reported that over 72,000 vehicles and 65,000 V2X devices have been equipped with the technology at locations throughout the United States, as indicated in Fig 1. In recent times, a number of state and local agencies have continued to introduce CV (V2I) deployments and to participate in AASHTO's Signal Phase and Timing (SPAT) Challenge.

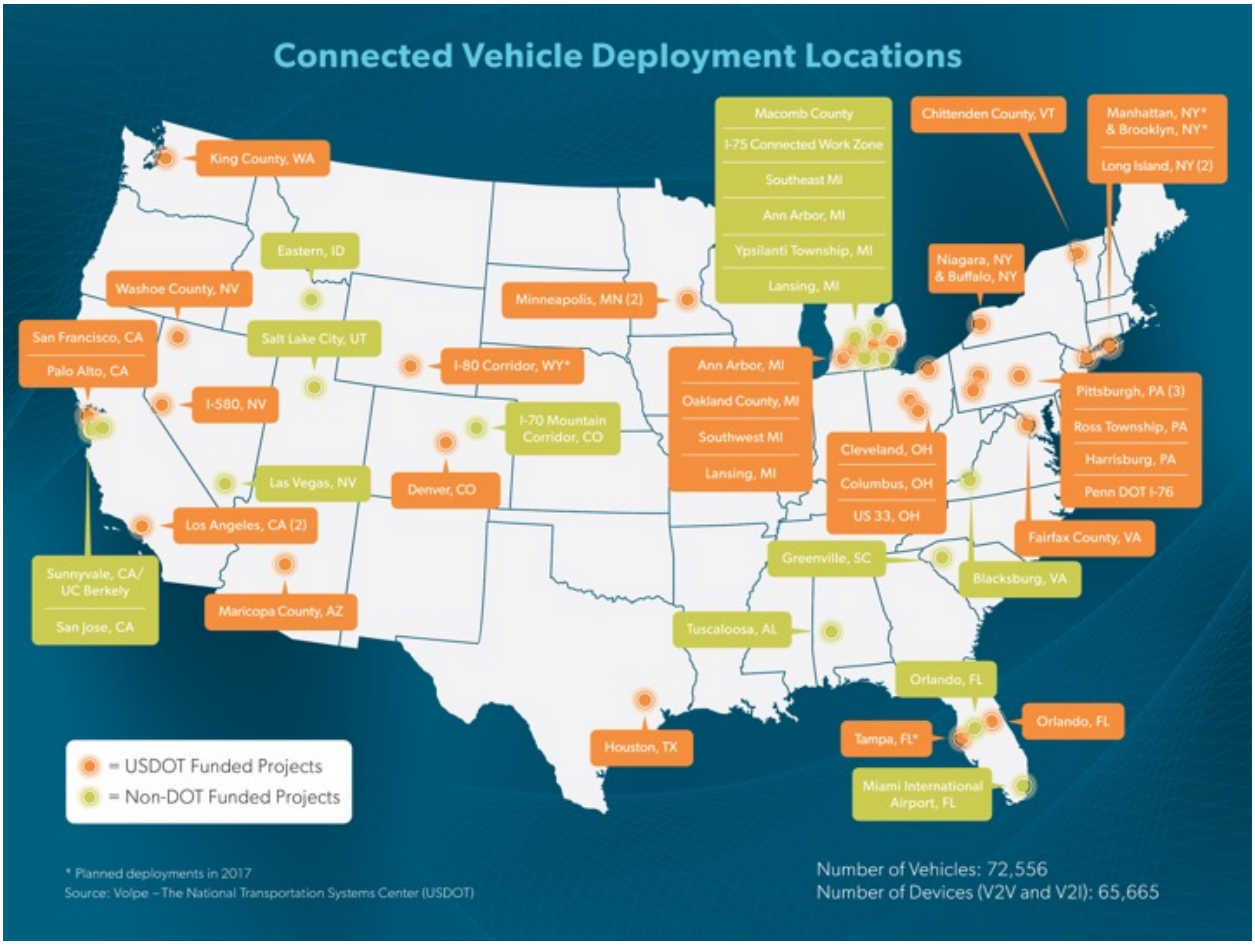

Figure 1. Connected Vehicle Deployment Locations (Source: USDOT)

The time and cost spent advancing DSRC paved the way for a highly-anticipated V2V mandate by the National Highway Traffic Safety Administration (NHTSA). The Notice of

[8] http://abcnews.go.com/Technology/wireStory/ap-newsbreak-govt-pursue-talking-car-mandate-50855129

Proposed Rulemaking (NPRM) requires half of new vehicles to have the capability to transmit their location, speed, direction and other information to other vehicles and infrastructure within two years after a final rule is issued, and all new vehicles to be equipped within four years. The current administration has not been active in advancing the rule amid issues surrounding the desirability of such a mandate on OEMs – although many are in favor – and competing demands on wireless spectrum.

Meanwhile, productive use of DSRC is occurring in the form of heavy truck platooning. A number of congress sessions revealed that all current trials of truck platooning utilize DSRC exclusively to support the short vehicle headways involved. No other solution is available to create high responsiveness of the trailing vehicle's braking system.

Work continues on alternative wireless regimes to DSRC, capable of the message integrity and low latency required for V2X safety applications. Often presented as an alternative to DSRC is so-called 5G wireless networks. 5G networks are to be built upon a foundation of five different technologies that, when combined, are projected to be able to handle 1,000 times more traffic than today's networks, as well as to be ten times faster than 4G LTE. These five technologies are:[9]

- Millimeter Waves, which use higher frequencies capable of hosting more devices and transmitting more data;
- Small Cells, which are portable miniature base stations that help enable millimeter wave broadcasts to overcome obstacles;
- Massive MIMO, which refers to an increased number of antennas per base station;
- Beamforming, which enables the most efficient data-delivery route to a particular user to overcome potential interference from massive MIMO;
- Full Duplex, which modifies the way antennas deliver and receive data in order to achieve high throughput and low latency.

While 5G has the potential to enhance vehicular and other connectivity, and possibly to add to vehicular automation in the future, it has yet to be deployed in scale anywhere in the world and, thus, should be viewed as a speculative technology for CV applications than DSRC.

3.2 Automated Vehicles (AVs)

AVs includes automated and "autonomous" vehicles covering a very broad range of automated function and environment enabling various levels of replacement of human

[9] https://spectrum.ieee.org/video/telecom/wireless/everything-you-need-to-know-about-5g

perception and control. AVs are equipped with Automated Driving Systems (ADSs) which are designed and evaluated for safe operation on public roads and which satisfy safe driving regulations. Highly-automated vehicles (HAVs) include those closest to driverless capabilities and are of particular significance in enabling disruptive change in the mobility of people and freight. Automated vehicle features have to some extent evolved from a class of advanced driver assist systems (ADAS).

The Society of Automotive Engineers (SAE) Standard J3016 (Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems) is widely referenced and has been adopted by the USDOT into the National Highway Traffic Safety Administration (NHTSA) Federal Automated Vehicles Policy (FAVP) for safe testing and deployment of automated vehicles.[10] This standard identifies six driving automation levels[11], comprising:

- Level 0 – No Automation
- Level 1 – Driver Assistance
- Level 2 – Partial Automation
- Level 3 – Conditional Automation
- Level 4 – High Automation
- Level 5 – Full Automation

With many of the basic challenges associated with enabling Level 1 and 2 driving solved, technology developers are focusing attention on developing the ability for AVs to recognize and safely respond to unconventional and unanticipated road conditions, paving the way for Level 4 and 5 automated driving. These efforts have largely been oriented around developing artificial intelligence (AI) software for vehicular control. In 2016 and 2017, developers achieved meaningful advancements within two particular categories of AI best positioned to solve the complex challenges associated with higher levels of automated driving: machine learning, whereby software uses large amounts of data to learn from experiences and improve their performance to achieve a programmed objective without being explicitly programmed to do so, and deep learning, which processes large amounts of data through neural networks that emulate the process humans follow to examine solutions in parallel and in convoluted ways to inform a course of action.

Beyond software, 2016 and 2017 saw the continued advancement of vehicular sensors, with a primary drive to reduce the size and cost of historically bulky and expensive technologies such as Light Detection and Ranging (LiDAR) units. LiDAR is able to

[10] https://www.sae.org/news/3544/
[11] http://standards.sae.org/j3016_201401/

accurately gauge a vehicle's surroundings in many complex situations, as essential to enabling higher levels of autonomy.

In January 2017, the USDOT took steps to facilitate AV testing when it selected and designated 10 Automated Vehicle Proving Ground test sites to "encourage testing and information sharing around automated vehicle technologies."[12] These Proving Grounds complement numerous on-road vehicular tests as well as private AV testing facilities established by leading AV developers and OEMs, including Waymo[13], Uber[14], Peloton[15], and others.

3.3 Relationship Between CV and AV

CV and AV have generally pursued parallel technological and policy paths, and their relationship is evolving, although there continues to be no formal relationship at the national level. The major national stakeholders, including USDOT and state agencies, have been active in both CV and AV and have encouraged a supportive relationship between the technologies. It is commonly believed that CV is an enabler of AV, and that incorporating CV with AV is critical to realizing societal benefits such as reduced congestion, improved mobility, and reduced fuel consumption. However, there are some companies that are pursuing AV without a strong CV component.

There is no doubt that AVs have dominated both the popular press and the trade media, and this coverage has perhaps overshadowed the high value of CV and the significant investment by both the public and private sectors over more than a decade. Nevertheless, CV remains highly-aligned with state DOT goals and is complementary to the rollout of AVs.

[12] https://www.transportation.gov/briefing-room/dot1717
[13] https://www.theatlantic.com/technology/archive/2017/08/inside-waymos-secret-testing-and-simulation-facilities/537648/
[14] http://www.businessinsider.com/ubers-fake-city-pittsburgh-self-driving-cars-2017-10
[15] https://www.trucks.com/2017/08/17/peloton-trucking-startup-trailblazer/

4. 2017 State DOT CEO Leadership Forum – Perspectives, Findings and Priorities

At 8AM on Thursday November 2, 2017, the fifteen members of the 2017 NCHRP State DOT CEO Leadership Forum, along with other select attendees, met to discuss their top findings that emerged from independent review of Peer Exchange Questions (Appendix 3) provided in advance of the Workshop, as well as observations and learnings during the course of the World Congress.

Throughout the discussion, which was moderated by CAVita, Leadership Forum Members spoke openly about working with industry and letting it do the work needed to further develop CAV technologies, but also pushing more for what serves the goals of state DOTs most – namely cutting down on traffic congestion and fatalities. An emphasis was also placed on action and iteration, with one Member putting forth a philosophy of "go out, fail quickly, fail cheaply", then tweak and repeat.

As the Workshop progressed, Members honed in on a number of core goals, challenges, opportunities, and objectives. They emphasized the need to maintain focus on connectivity (in the face of significant media and other attention paid to automation), and discussed challenges and opportunities that ranged from cybersecurity to workforce training and recruitment (among others), and the need to improve and coordinate messaging.

4.1 Maintaining Focus on Connectivity

The timely deployment of connected vehicle technologies remains a primary goal for state DOTs. As several Members pointed out, the timeframe for V2X deployment equates to lives lost and lives saved. For every year V2X infrastructure is delayed, we continue to bear the societal burden of more than 35,000 roadway fatalities.

As previously mentioned, the U.S. government and automakers have spent a collective ten years and approximately $1 billion developing and advancing connected vehicle (DSRC) technologies. Despite this time and investment, many Members observed that the issue is receiving less attention, and momentum may be waning as federal government interest in the V2V mandate stagnates and the media fixates on automated vehicles. While State DOTs have the opportunity to direct attention and control the issue by defining Operational Design Domains, which depict where and how AVs will be deployed and are recommended by NHTSA, clearly more can and should be done.

4.1.1 DSRC and 5G

Another reason for delayed V2X deployment is the apparent competition among platforms – namely DSRC and 5G. The Leadership Forum's discussion on the issue

was not necessarily about picking the winning technology. In fact, some Members are will progress both DSRC and 5G pilots in parallel by, for example, running DSRC demonstrations while taking other actions – such as passing legislation – to support industry's deployment of 5G. This is done with the belief that such technologies may eventually offer complementary functions, as well as redundancy, so that a disruption in one doesn't disable the functionality, as well as to ensure the cost-efficient deployment of infrastructure.

Instead, to a large extent, the issue is one of maturity, with DSRC being the one V2X technology currently capable of realizing the benefits of widespread rollout. While 5G has potential to provide a high-performance form of vehicular connectivity, it is more nascent and, as previously mentioned, is not in significant use anywhere in the world.

That said, uncertainty about the status of the federal mandate, along with the competition among wireless platforms, is causing at least some Members to hold off on wide scale deployment until they can be more certain of the investment. Instead, some members are investing in other areas of ITS, such as queue warnings and workzone responses.

4.1.2 Progressing Independent of Federal Action

With the focus on expediting rollout of V2X, Leadership Forum Members emphasized the importance of coming up with a "Plan B" for advancing DSRC without action from the federal administration. They mentioned several strategies they could pursue alone or in conjunction with one another.

- Leverage Existing Infrastructure

Reflecting on the ITS JPO map and statistics depicting the over 72,000 vehicles and 65,000 V2X devices equipped with the technology throughout the country (see Chapter 3), Members recognized that this existing V2X infrastructure will serve as a baseline that can be built upon. Simply continuing on their existing course of action by incrementally deploying infrastructure can, over time, add to this baseline and serve as a good argument for proceeding with V2X infrastructure. Members added that the knowledge of and experiences with CVs can – and should – also support advancement of AVs.

These deployments aren't the only existing infrastructure that state DOTs could leverage to facilitate the faster rollout of V2X. One Member pointed out that the technology within typical traffic control cabinets at more than 300,000 intersections across the country have underutilized capabilities for managing vehicles at intersections. As the incremental cost of DSRC in traffic cabinets is a small fraction of their overall cost, it makes sense to make better or full use of this latent capability that's already embedded within deployed infrastructure to progressively deploy V2X.

- Build Upon the SPAT Challenge

Members observed that the AASHTO SPAT Challenge's success in mobilizing state and local public-sector infrastructure owners and operators to deploy DSRC infrastructure could serve as a foundation upon which further DSRC infrastructure could be deployed.

The SPAT Challenge put forth a concrete goal: that infrastructure owners and operators would equip at least 20 signalized intersections with SPAT, MAP, and RTCM broadcasts in at least one of their corridors or networks. The broader objective is to establish a SPAT Corridor in each of the 50 states by January 2020. As of September 2017, 18 agencies were identified as participating in the SPAT Challenge, four of which are operational.

By putting forth a goal that is meaningful yet not too large and expensive, the SPAT Challenge paves the way for the type of incremental approach to V2X espoused by a number of participants. Leadership Forum Members recognized the potential to build upon this effort by focusing on continued expansion of the connected infrastructure – for instance, expanding upon the scope or magnitude of the SPAT Challenge – or by complementing it with a similar vehicular challenge – such as challenging state agencies to equip a minimum threshold of vehicles with OBUs, as one Member suggested.

- Truck Platooning as a Meaningful Application

Leading CV applications are those in which DSRC technology is suited to solve an existing challenge, and whereby the market dynamics are such that even marginal deployments can be driven by commercial benefits. Truck platooning is a positive example of a combined CV and AV application assisting the movement of goods.

Trucks have emerged as a leading application for connectivity and automation, given the comparative simplicity of the required technology as well as the operating environment. A significant improvement in fuel economy is achieved via shortened headways and reduced aerodynamic resistance per unit payload.

Platooning depends on V2V functionality, and in all current trials this functionality is currently provided via DSRC communication. Leadership Forum Members discussed how a smart approach for generating support for V2X could be by further establishing the safety influence of platooning and by deploying additional CV infrastructure that benefits platooning trucks – infrastructure that can be built upon and used by other CV applications over time.

- Prospective Roles For Smaller States

Leadership Forum Members observed that most of the action around CAVs has been in a minority of states, namely those with prominent technology, OEM, academic, and other CAV-related interests and needs. However, smaller states and cities can learn from the technology leaders and obtain immediate benefit from applications tailored to local needs.

Several Members pointed out that such states have much to offer CAV developers and can similarly benefit from CAV deployment. For instance, small states present scenarios whereby they themselves might serve as leading applications for CAVs. Unique local challenges and niche markets present immediate opportunities.

One example cited by a Leadership Forum Member is winter maintenance of roadway. Small states with large geographies, sparse populations, and harsh winters present roadway scenarios that can be logistically complex or costly for state DOTs to address. In some cases, major route closures occur surprisingly frequently. In such states, CAV applications supporting snow clearance are extremely helpful.

4.2 Core Challenges and Opportunities in Realizing CAVs

State DOTs must resolve meaningful challenges and seize opportunities should they wish to not only see CAVs deployed in their states, but to be deployed in ways that help achieve DOT goals, and provide benefit to residents. Challenges and opportunities included cybersecurity, workforce characteristics and recruitment, coordination and collaboration among various CAV stakeholders, and messaging. And the forum was reminded in the strongest terms that lack of funds is an ever-present threat to the maintenance of the current ITS installed base, before consideration is given to investment in CAV-level technologies.

4.2.1 Cybersecurity

As previously discussed, the topic of cybersecurity received meaningful attention at the 2017 World Congress. Sessions on the topic were popular and highly attended, and agencies and industry members are now taking more responsibility. Still, the issue of cybersecurity is multifaceted, for attacks can target vehicles' behavior on roadways as well as the roadway (ITS) infrastructure itself, both of which affect state DOTs. And attack surfaces are an ever-evolving target, with new threats and tactics emerging regularly, and vehicular approaches to cybersecurity varying from manufacturer to manufacturer.

Given these complexities, Members cited cybersecurity as an area where state DOTs could benefit from federal support, given the commonality of issues across jurisdictions. Such support could facilitate the advancement of standardized approaches to cybersecurity, whether they build off currently voluntary guidance documents such as

NHTSA's "Cybersecurity Best Practices for Modern Vehicles"[16] and Auto-ISAC's "Automotive Cybersecurity Best Practices",[17] or are new initiatives.

4.2.2 Workforce Characteristics and Recruitment

Members identified the need to begin addressing potential job losses that may come from automation, especially in the many states that manufacture vehicles and components, and thus could be affected if the vision for fully automated Shared Mobility – and a reduction in new vehicle sales - is realized.

Similarly, Members identified future challenges associated with their own workforce and recruitment. One Member observed that most of those currently maintaining the ITS system are close to retirement, and that recruiting a new generation of workers is challenging given the attractive offers they may receive from the technology industry. This is particularly true for sparsely-populated states with small workforces. This presents uncertainty and causes concern about the workforce of the future; if the ITS industry is to scale, this challenge will need to be solved.

To solve the challenge, Members discussed the need engage their states' universities, establish training programs that don't just emphasize PhDs but also technicians and other similar "in-the-field" positions, and, for smaller states, to develop the workforce in-state. One Member discussed how an additional strategy could be to engage veterans. Veterans are motivated, action oriented, and in need of a pathway from military service to the workforce. ITS could be that pathway.

4.2.3 Coordination and Collaboration

Members stressed the need to coordinate and collaborate with a variety of agencies, governments, and stakeholders – to "keep talking about CAVs" – as a way to engage and build support for CAV deployments. Several Members emphasized the need for coordination among state agencies. Transportation's evolution is larger than the DOT; in this transformational era. As such, Members discussed:

- Establishing dialog with cities within a state, learning about what they're doing with CAVs, engaging them, and finding out what they know of, and how they view, the technologies.
- Establishing CAV centers, groups, and commissions that might include a variety of agencies – such as the DOT, EPA, utilities, and others – to act as resources to

[16] https://www.nhtsa.gov/staticfiles/nvs/.../812333_CybersecurityForModernVehicles.pdf
[17] https://www.automotiveisac.com/best-practices/

city and local governments, to engage smaller local agencies, and to ensure that municipalities have "skin in the game".
- Holding CAV summits that gather the various stakeholders around the table to bridge divides and deal with problems – such as a potential decrease in revenue from parking fines – now rather than in the future.

Members also discussed the need to coordinate and establish collaborative relationships with industry. This is particularly true on the issue of data. Members observed that there is still a long way to go when it comes to settling on the roles of agencies and private companies in the collection, provision, and processing of the data. Some have observed the existence of "silos" – particularly between public agencies and private companies – that were preventing discussions on how to share data between companies and with agencies. This may be due at least in part to the motivations of companies – i.e. the emphasis on making money rather than making things better. Alternately, it may be that agencies are not well-equipped for sharing data not necessarily because of a lack of desire to do so, but rather a lack of capacity and/or resources to share such information.

Members reflected that solving these issues pertaining to data might require state DOTs to be the ones facilitating the exchange of data between industry members, as well as with government. Additionally, it is essential for the states to work out data collection and sharing agreements with auto manufacturers. Such agreements need to address the roles of collector and provider, anonymity, and payments, and should enable state DOTs to accomplish such practical goals as identifying potholes and vehicular hazards.

Altogether, some Members believe that state DOTs should establish more partnerships with private industries, and should better utilize their great strength – namely their control of the right-of-way. Examples of some efforts cited by Members to be more collaborative included engaging rural medical institutions about how CAVs can help with non-urgent medical emergencies in order to help rural communities, and establishing and operating a task force comprised of a broad array of vested interests – including law enforcement and car manufacturers.

Finally, Members emphasized the need to coordinate and collaborate between states – with one Member suggesting that states "learn from each other, steal from each other, and share with each other" in order to advance CAV deployments and programs, and another Member summarizing an approach as "copy, improve, and execute." – given that many CAV issues transcend state lines and thus warrant a unified approach. This holds true for data, as mentioned above, but other regulatory and infrastructure issues as well. For instance, because AVs use cameras to "see" road markings, states such

as California are replacing four-inch lane markings with wider six-inch lane markings.[18] All states need to be involved in any coalescence around such AV-friendly infrastructure approaches.

V2X is another area in which coordination among states is essential. Members spent time reviewing the ITS JPO graphic depicting "Connected Vehicle Deployment Locations" around the United States, and reflected that the sizeable number of deployments could lend support for those seeking to convince state stakeholders to move forward with V2X.

4.4.4 Messaging

Members reflected that the role of the state DOT is changing, and one Member highlighted particular changes in two key categories. The first category is as the traditional owner and operator of the highway network. Within this category, the need for information and data to inform spending and investment decisions is important. The second category is that of a leader establishing a broader definition of ITS. Leadership requires thinking about and understanding what comprises constituents, and working to build those constituents' support of ITS, by changing the way state DOTs talk about ITS, addressing various modes of transport as well as the communities in which the constituents live.

Significant discussion took place on the DOTs' need to improve messaging. It is essential, Members reflected, that DOTs change the viewpoint of CAVs from "scary" – which leads many in the U.S. (including political leaders) to still be fearful of the technologies – to "this is going to make your life better" – which appears to be the messaging conveyed in countries such as Singapore and others in the Asia-Pacific region.

Furthermore, whereas the U.S. is talking about connected and automated *vehicles*, these regions often refer to connected and automated *mobility*, as another Member pointed out. Framing the issue in terms of mobility can help state leaders and constituents envision a "cooperative connected automated mobility", as one Member termed it, whereby future infrastructure includes not just vehicles, but also other modes such as bikes, and broader issues such as land use, to enhance mobility. A Member suggested that "off-the-shelf messaging" might be a good role for AASHTO.

Messaging that frames the issue in terms of mobility also needs to include discussion of what the DOT – as an infrastructure and mobility provider – can provide communities

[18] http://www.scpr.org/programs/take-two/2017/07/12/57901/california-is-changing-its-roads-for-self-driving/

within the state to enable them to achieve the goals they have established for themselves. This is particularly true for rural communities, where highlighting the use of ITS to solve rural problems – including rural safety – and showing that ITS isn't just for big cities could be particularly important given the quantity and influence of rural legislators in various states. Outreach to small communities, and deployment of appropriate technologies in small communities – while documenting and quantifying outcomes – can be effective strategies. As one Member stated, to build support, it's important for communities and legislators to "touch and feel" all types of high-technology vehicles, automated and electrified alike.

To further educate and build support for ITS among legislators, it would be helpful to highlight how such technologies can improve the economy, alleviate congestion, as well enhance safety, given that these are issues legislators experience directly. Our high focus on safety is, and remains, a national imperative, but the ability of ITS to deal with every-day traffic congestion is a strong selling point. It might also be helpful for tech-oriented mayors to speak out in support for ITS technologies, perhaps through the National League of Cities, local Chambers of Commerce, or other similar platforms, as one Member suggested.

5. Advancing CAV Preparation by State DOTs

This research project undertaken for NCHRP Panel 20-24(111) focused mainly on the discussion and observations of the state DOT CEOs who participated in the project's leadership forum during calendar 2017, leading up to and including the ITS World Congress in Montreal. The experiences of the CEOs at the World Congress varied, and the conference program's coverage of CAV and ITS technology, policy and research was necessarily incomplete. We therefore sought to supplement the CEO discussion with informed opinion from ITS leaders, national stakeholders, USDOT representatives and others.

By placing the outcomes of the CEO discussion in the context of the on-going dynamic of CAV development and deployment, we have attempted to extract implications for the research and dialog programs of TRB/NCHRP and AASHTO. These organizations are both critical to the CAV preparedness of state DOTs, and of a broader range of organizations. An over-riding theme of the research was a much-increased need for collaboration, sharing, emulation and adaptation of CAV initiatives.

5.1 Emerging Priorities Discussed by CEOs

The CEO discussion revealed that, even though states are at widely different stages with CAV readiness, all accept the need to actively prepare in a way that is most appropriate for state and local needs. While federal roles and actions are of vital concern to the CEOs, much of the discussion concentrated on the most pressingly-needed CAV applications at the local level, including rural communities. CEOs were very aware of the distinct approaches needed for CV and AV, and emphasized the need to maintain focus on connected vehicle deployment, while beginning the process of de-mystifying the multiple potential roles of highly-automated vehicles.

The process of CV deployment has begun well with AASHTO's SPAT challenge and all states are willing to build on the current base of approximately 65,000 V2X devices deployed throughout the country. There is a strong drive among states to "copy, improve and execute", and we are already seeing useful applications such as truck platooning and snow clearance. While states remain concerned about the needed resources for deployment and maintenance, the longevity of the communication regime (DSRC vs 5G), and the potential need for redundancy, CV is clearly regarded as being compatible with state DOT goals of safety and congestion reduction. Importantly, CV is complementary to emerging ITS deployments for advanced traffic management and corridor management. Those with CV (V2I) deployment experience described the costs as incremental, and compatible with other ITS investments, even though available funds for all are extremely limited.

The conversation about AV is at an earlier and less well-defined stage, and is becoming more intense. There is a need to socialize the technology across a wider range of organizations within the state, including state legislators. It is important to spell out the "transformational" benefits to the state leaders and constituents alike (at the level of "making our lives better"), and the technology needs to deal with the crippling issue of traffic congestion, as well as safety.

CEOs recognize that they need to rely on others for some aspects of AV deployment, but also need to be pro-active in both individual and collective fashion. CEOs are comfortable with the federal government focusing on AV safety and cybersecurity, which are regarded as essential common interests. CEOs also see great value in working more closely with their peer organizations, and a number of bilateral relationships are in progress.

State DOTs also accept that significant challenges remain within their purview, and these include horizontal caucusing within the state, outreach to communities large and small, outreach to vehicle manufacturers and other non-traditional partners, the development and retention of a well-prepared workforce, and effective constituent and consumer messaging about AV, CV and adjacent technologies such as electrification. Public CAV statements from many more tech-oriented mayors would provide great assistance in a broad effort for education and outreach. States with significant vehicle manufacturing activities need to adopt a very broad approach to the advent of AV, as manufacturing jobs may be impacted by a reduction in vehicle production brought about by more efficient utilization of vehicles.

As local and regional deployments occur, it is important to progressively evaluate and document benefits, especially with respect to safety and alleviation of traffic congestion. And effective communication of progress with these goals in critical. For example, in the case of truck platooning, it is essential to supplement current knowledge of economic benefits with evidence concerning the safety impact of platooning. It is also necessary to socialize and discuss potential negative impacts of AV – such as reduced parking revenues - at an early stage.

Important unresolved issues surround CAV data; what are workable models for collecting, sharing, exchanging and/or monetizing data? Can state DOTs develop agreements with OEMs for exchanging and fusing data? How can such agreements provide wide practical value by identifying potholes, etc? What are the appropriate roles for collector and provider, and terms for anonymity and payments? Will monetization of state DOT's data provide support for depleted budgets and CAV infrastructure costs? Questions also surround the ability of state DOTs to take a more assertive position on cyber-infrastructure with AV manufacturers who are dependent on detailed maps and metadata, and need to identify Operational Design Domains.

These data issues also speak to the need for state DOTs to develop more partnerships with private industries and to leverage their great strength: control of the right-of-way. AVs require redundancy in data sources, and state DOTs should be prepared to participate in the development of 3D imagery of the infrastructure. Such cyber assets can help inform the construction of roadways and other infrastructure, as well as supporting the operation of AVs.

As state DOTs broaden their interactions with adjacent and local agencies within the state, and with non-traditional industry partners, they need to speak and act more like mobility providers, as well as infrastructure providers. In these interactions, it is necessary to establish needs at the local level, and how state DOTs could best assist local entities to achieve their goals.

5.2 On-Going Influence of Technology, Policy and Research

Although the location of the 2017 World Congress proved not to be conducive to broad participation by OEMs, there was plenty of evidence of accelerated efforts to develop automated driving systems at the higher levels of automation (SAE Levels 4 & 5). Software and hardware sub-systems are under intense development, including the use of artificial intelligence and deep learning, as well as more affordable versions of technologies such as Lidar. AV has also been prominent on the infrastructure side, with the designation of National Automated Vehicle Proving Grounds, and the announcement of Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) awards by USDOT.

The release of NHTSA's policy document Automated Driving Systems 2.0: A Vision for Safety has provided a comprehensive quality-assurance framework for AV safety, but recommends that manufacturers nominate Operational Design Domains without reference to potential roles of those who "own" the infrastructure. There is a need to introduce infrastructure elements in Version 3.0 of the policy, currently under development. The role of CV in assisting AVs to meet important goals such as traffic progression and energy efficiency was amply demonstrated by one major OEM (Toyota), showing the value of traffic control preview information communicated to the automated vehicle.

As the reality of lucrative AV markets comes inexorably closer, the industrial ecosystem continues to expand, merge and recombine. Major and leading players come from the automotive industry, but representatives of non-traditional sectors have also established their primary roles in the front line of AV. ITS industries are beginning to develop AV-related product features to assist the technological compatibility of AVs, intersections, roadways and operating environments. The USDOT Smart City Challenge has created CAV awareness and demand in many cities, as well as new computational capabilities, in some cases enabled by ultra-high-speed processors developed for automated driving

systems. And national-recognized AV proving grounds potentially provide a broader AV-friendly footprint, including opportunities for not only deploying technology but also accelerating the development of AV traffic policy.

While AV developments have tended to overshadow CV in the public as well as industrial arenas, recent progress with CV (V2I) deployment – including the SPAT challenge - has been promising. Federal delays in proceeding with V2V rulemaking, along with ambiguity concerning DSRC and 5G, are of concern to state DOT CEOs. Nevertheless, there is a sense that connectivity will prove indispensable to AVs, that optional wireless regimes will be available and that redundancy will exist. It is clear that USDOT continues its high-level commitment to life-saving mobility technologies, and that these technologies center on CAV.

The number of CAV model deployments, test beds and research consortia across the country continues to expand and an increasing number of industrial partners are becoming involved in diverse geographic locations, in varied combinations, and with distinct CAV use cases. Discussions are underway across the country and overseas to develop greater interaction between projects, although there is currently limited overt collaboration between these activities. There is currently no national roadmap for CAV research, although TRB are addressing this with a new roundtable entitled Preparing for Automated Vehicles and Shared Mobility Services. And ITS World Congresses play an important role in cross-fertilizing CAV programs in North America, Europe and Asia-Pacific. It is noticeable that CAV activity, with distinctive local characteristics, is expanding in Canada, Scandinavia, the United Kingdom, Singapore, Australia and New Zealand.

5.3 Implications for DOT Preparations and the Programs of National Stakeholders

TRB/NCHRP and AASHTO play a critical role in underpinning state DOTs' preparations for the large-scale rollout of CAV. Many important CAV research statements arise through the committees of TRB, the panels of NCHRP, and the committees and task forces of AASHTO, along with further collaborations with ITS America and ITE. NCHRP 20-24(111), the AASHTO V2I Deployment Coalition and the AASHTO CAV Executive Leadership Team play a central role, and there are many others. The NCOE provides an important national umbrella for advancing technology in the infrastructure.

Our structured dialog of state DOT CEOs produced some expanded perceptions of avenues to CAV preparedness, and these outcomes could well inform the research and dialog processes undertaken by TRB/NCHRP and AASHTO. The following themes for "state DOTs in the CAV era" address CAV preparedness via state DOT initiatives, capabilities and partnerships, and are amenable to research and convening activities. The following listing is provided in the interests of stimulating research planning and

could potentially enhance on-going processes of research formulation and overall assistance to state DOTs.

Taking More Initiative

- Defining the state DOT as a mobility provider (as well as an infrastructure provider);
- Promoting the transformational nature of CAV to state legislators;
- Undertaking effective messaging for constituents as well as legislators;
- Keeping the focus on CV deployment;
- Establishing a peer-to-peer relationship with OEMs (non-traditional partners);
- Defining the infrastructure/environment elements of AV safety assessment;

Developing Stronger Capabilities and Resources

- Documenting CAV benefits, including traffic efficiency as well as safety;
- Developing awareness of the state of AV technological development along with ITS compatibility;
- Monitoring the national and international state of CAV test beds, deployment and research;
- Developing the requirements of the CAV workforce;
- Developing the "state DOT business model" for CAV data;
- Accelerating 3D digitalization of the infrastructure;

Being a More Effective Partner

- Providing assistance to federal efforts on AV safety and cybersecurity;
- Horizontal caucusing with adjacent state agencies;
- Establishing a new relationship with local communities and entities;
- Helping to define and support smart cities initiatives; and
- Early identification of CAV "red flags" (such as impacts on jobs and parking revenues).

6. Concluding Remarks

The rich discussion undertaken by state DOT CEOs was indicative of the highly tangible and dynamic nature of CAV development and the rapid pursuit of CAV products, services and markets. Simultaneously, we are witnessing a technological tipping point, a make-over of the automotive industry, a rollout in our infrastructure, and a coming-of-age for government agencies at all levels. The implications for state DOTs, and other state and local agencies are profound. Venues such as the ITS World Congress provide excellent opportunities for “deeper dives” such as this NCHRP Leadership Forum and are emblematic of a new era of collaboration, sharing, emulation and adaptation. State DOT CEOs expressed their need to show leadership in new initiatives, improved capabilities and expanded partnerships. In turn, TRB/NCHRP and AASHTO and other national stakeholders have new opportunities to assist state DOTs to prepare for CAV. The increased volume of localized activities may require the use of innovative methods for awareness and dissemination.

Appendix 1: AASHTO International Day – Overview, Highlights, and Links to Presentations

AASHTO International Day at the ITS World Congress in Montreal
October 29, 2017

Overview, Highlights, and Links to Presentations

Overview

Now in its 14th year as an integral part of the ITS World Congress, AASHTO International Day (presented by the American Association of State Highway and Transportation Officials and National Operations Center for Excellence (NOCOE) in partnership with the Transportation Association of Canada (TAC)) brought together transportation officials from around the world to take on topics of consequence addressing the transportation challenges and opportunities facing public agencies. The 14th Annual AASHTO International Day (AID) had as its purpose:

- To seek the perspective of policy experts and practitioners representing each of the three ITS regions (ITS America, ITS Europe (ERTICO), and ITS Asia Pacific) on the state of art of integration of technology and infrastructure operations.

The *2015 ITS World Congress* AASHTO International Day was dedicated to an information exchange on infrastructure readiness for connected and automated vehicle (CV/AV) initiatives. At the *2016 ITS World Congress* AASHTO International Day experts discussed the importance of integrating and adapting current ongoing ITS deployments and operations with the CV, AV, and other emerging technologies.

The *2017 World Congress* event focused on peer-exchange sessions on the range of current CAV deployments, pilots, and initiatives now taking place around the United States, Canada, and internationally with specific attention to:

1. Policies and Programs to support CV and AV Deployment with specific emphasis on government relations, institutional frameworks, and infrastructure owner and operator roles.

2. CV and AV Technical programs and field deployment initiatives; including CV and AV pilots, testing and reporting results; planning-level scenarios; research and development to integrate current and upcoming technologies to mainstream ITS,

CV, and AV systems; standards; cyber security; privacy; and security certificate management systems.

Highlights and Links to Presentations

Ten contributors from around the world presented on the two panels. Here is a listing of presenters and highlights from their remarks. Links to their full presentations are available on this webpage.

Panel 1: Policies and Programs to support CV and AV Deployment with specific emphasis on Government relations, Institutional Frameworks, and Infrastructure owner and operator roles.

Moderator: Carlos Braceras, Executive Director, Utah DOT

- Dr. Johanna Tzanidaki, Director of Innovation & Deployment, ERTICO

ERTICO's engagement with the European Union and its member states (shaped most recently by the signing of the Amsterdam Declaration in April 2016) has helped to generate a comprehensive approach to strengthen and accelerate deployment of cooperative, connected, and automated mobility.

- Wee-Shann Lam, Group Director for Technology & Industry Development, Land Transport Authority, Singapore

The Land Transport Authority (LTA) is fully proceeding fully on four tracks to accomplish AV deployment in Singapore (fixed route and scheduled services such as buses; point to point mobility on demand such as driverless pods or taxis and ride hailing services like Uber; freight and utility; and key enablers such as public acceptance and standards and regulations around AV (related to highway codes, functional and usage safety, cyber security, and vehicular data management) that would facilitate the deployment of this new technology.

- Craig Hutton, Director General, Strategic Policy, Transport Canada

Integration of CAV technologies into the Canadian transportation sector will require a high degree of collaboration and investment across all orders of government, industry and other stakeholders and has led a National Policy Framework and efforts to prioritize actions over the short, medium and long-term to regulate vehicle safety, align regulations and standards, encourage innovation, educate the public, protect data privacy and security, build and upgrade infrastructure, and prepare for the eventual transition to roadways with both automated and non-automated vehicles.

- Ken Leonard, Director, ITS Joint Program Office (JPO), U.S. DOT

The Department recently released a new, non-regulatory approach to promoting the safe testing and development of automated vehicles—*Automated Driving Systems: A Vision for Safety*. It paves the way for the safe deployment of advanced driver assistance technologies by providing voluntary guidance that encourages best practices and prioritizes safety and technical assistance to States and best practices for policymakers.

- Leslie Richards, Secretary, Pennsylvania DOT and AASHTO

Because a state DOT cannot and should develop automated vehicle policies in a vacuum, PennDOT has started a Statewide Connected and Automated Vehicle Strategic Plan that will: build upon existing research, identify the steps to prepare for AV technologies, define a comprehensive set of focused, reasonable and deployable applications, consider various levels of investment, and provide critical missing data and information pertaining to the early deployment of connected and automated vehicles.

Panel 2: CV and AV Technical programs and field deployment initiatives including CV and AV pilots; testing and reporting results; planning-level scenarios; research and development to integrate current and upcoming technologies to mainstream ITS, CV, and AV systems; standards; cyber security; privacy; and security certificate management systems.

Moderator: Shailen Bhatt, Executive Director, Colorado DOT

Presenters:

- Francois Fischer, Senior Manager, ERTICO

ERTICO's Technical program and field deployment pilot to support CV/AV takes on connected driving via the Intercor initiative (seeking to validate a number of communications, security and C-ITS services) and CV/AV with CONDORDA (focusing on a number of emerging technologies) and AUTOPILOT (applying three use cases and engaging in the important role of the Internet of Things (IOT)). ERTICO importantly plays a strong role to support assessment and testing on a range of CV/AV initiatives funded by the EU.

- Masato Minakata, Project Manager, Vehicle Safety Planning, Toyota Motor Corporation

Japan's longstanding SIP-adus initiative (the Cross-Ministerial Strategic Innovation Promotion Program for Automated Driving systems for Universal Services) continues to make significant progress to realize automated driving via its intensive cooperative R&D

program across 11 areas. Large-scale FOT for the final step to the goal began in October 2017 (see http://www.nedo.go.jp/english/sip_ai2017.html#overview for details).

- Francois Thibodeau, City of Montreal Innovation and Mobility Team

The City of Montreal has been conducting a number of pilot projects to further CV/AV that will be on display at the World Congress. They include a DSRC demonstration (RSU + Controller + cars (around Palais des congrès)) and the Notre-Dame Corridor de Mobilité Intégrée with Port Authority with the objective of using 40 RSU as part of the initial goal of SPaT Challenge and the intent to develop a strategy to integrate with existing infrastructure and enable new services that will ensure safe travel for people, optimize the mobility of people and goods, and promote a sustainable approach.

- Martin Knopp, Associate Administrator for Operations, U.S. Federal Highways Administration, U.S. DOT

While automated vehicles potentially offer new benefits in travel comfort, convenience, and affordable accessibility, there are also questions on how automated vehicles might negatively affect mobility, congestion, traffic flow, contribute to urban sprawl, diminish public transit use, increase fuel use, or lower tax revenues previously generated by driver licensing, fees, or fines. So, it is critical for the US DOT and the stakeholder community to prepare the roadway infrastructure for automation, explore the benefits of automation and other innovations, position FHWA to serve as a resource for transportation agencies, and assess current programs and policies to ensure they meet future needs and support innovation. The 2035 CV/AC scenario development process, the CV pilots, the NCHRP project 03-127 on Cybersecurity of Traffic Management Systems, the National SCMS (Security Credential Management System), research into Cooperative Adaptive Cruise Control (CACC), and ongoing work on truck platooning are emblematic of the Department's efforts to pave the way for CV/AV.

- Bill Panos, Director, Wyoming DOT and AASHTO

The (US DOT funded) Wyoming DOT Connected Vehicle Pilot designed to test and deploy advanced dedicated short-range communication (DSRC) technology to improve safety and mobility (supported by 75 roadside units and 400 instrumented fleet vehicles), will use vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-vehicle (I2V) connectivity to improve monitoring and reporting of road conditions to vehicles on I-80 (402 miles along Wyoming's southern border and the essential east-west connector for freight and passenger travel). The corridor averages more than 32 million tons of freight deliveries each year. The data collected by fleets and roadside units gives drivers in Wyoming improved travel information through services like the Wyoming 511 app and the commercial vehicle operator portal (CVOP).

Appendix 2: Workshop Agenda
v.05
October 6, 2017

National Cooperative Highway Research Program

State DOT CEO Leadership Forum 2017

Workshop Agenda

November 2, 2017
8:00AM – 12:00PM
Palais des Congrès de Montréal; Room #524A

Connected and Automated Technologies and Transportation Infrastructure Readiness

Prepared for:
NCHRP 20-24(111)

Prepared by:
CAVita, LLC

Disclaimer:

The information contained in this agenda and workshop was prepared as part of National Cooperative Highway Research Program NCHRP Project 20-24(111).

SPECIAL NOTE: This material **IS NOT** an official publication of the National Cooperative Highway Research Program, the Transportation Research Board, or the National Academies of Sciences, Engineering, and Medicine.

Time	Topic	Lead
8:00	**1. Opening and Introductions**	Peter Sweatman
8:10	**2. Panel Discussion** High level overview of World Congress from the perspectives of ITS research and deployment, CAV and infrastructure readiness **Moderator: Kirk Steudle, NCHRP 20-24(111) chair** **Panelists:** **Steve Dellenback (Vice President, Southwest Research Institute; Chair, 2017 ITS WC Program Committee)** **Abbas Mohaddes (President and COO, Econolite)** **Greg Winfree (Agency Director, Texas Transportation Institute) (Invited)** **Bud Wright (Executive Director, AASHTO)**	Kirk Steudle, NCHRP 20-24(111) chair
8:45	3. **Highlights of USDOT's ITS/CAV/infrastructure research program** 3.1. FHWA programs in connected and automated vehicles 3.2. ITS JPO programs in connected and automated vehicles	Martin Knopp, Associate Administrator for Operations, FHWA Ken Leonard, Director, USDOT ITS JPO
9:15	4. **Member Roundtable Discussion** Each member presents their top three findings and observations based on the Peer Exchange Questions	Group Discussion

10:00	BREAK	
10:15	5. **Moderated Breakout Discussions** 5.1. Group #1: State of ITS deployment 5.2. Group #2: Automated Vehicles 5.3. Group #3: Smart Cities	
11:15	6. **Final Peer Exchange Findings** Observations for broader circulation to senior leadership in state and local agencies	Group Discussion
11:50	**7. Summary and Next Steps**	Peter Sweatman
Noon	CLOSURE	

Appendix 3: Peer Exchange Questions

National Cooperative Highway Research Program

State DOT CEO Leadership Forum

Workshop at World Congress 2017

Peer Exchange Questions

Prepared for:
NCHRP 20-24(111)

Prepared by:
CAVita, LLC

The White Paper entitled Connected and Automated Technologies and Transportation Infrastructure Readiness discussed (I) leading-edge themes in CAV and related technologies and (II) questions raised in key areas of state Department of Transportation (DOT) responsibilities. The main discussion points are summarized in the following. It is anticipated that Leadership Forum Members will select from these points for the purposes of Forum activities at the World Congress.

I. Leading-Edge Themes in CAV and Related Technologies

1. Safety of AV Transition

The issue of avoiding increased safety risks during the AV transition period – when AVs mix with conventional vehicles, and AV driver/operator roles are still evolving – has emerged as a major challenge, especially given that it is a challenge likely to persist over decades, as at least some number of conventional vehicles will remain on roadways. Safety questions exist for infrastructure and traffic operation, and law enforcement.

To minimize such risks, AV early adopters may concentrate on closed communities, precincts and campuses. Important learnings are anticipated. Local agencies will need to deal with the most challenging conditions: dense, complex urban environments.

2. Connected Infrastructure Supporting AV

National stakeholders have generated recent momentum in deploying V2I, which could play a major role in supporting and accelerating the deployment of AV. The nature and value of CV assistance to AV is an important topic. Further, it appears that the deployment of AV systems could follow a segmented “quality assurance” approach that would benefit from a corresponding focus on AV operating environments.

3. Emerging Business Models Based on Big Data

State and local agencies may be facing opportunities with the biggest of big data. There are significant issues with data collection, analytics and access. The security certificate management system (SCMS) would change each vehicle’s identification every five minutes, which might limit data’s usefulness. And the security and ownership of – as well as rights to – CV and AV systems and data is paramount. Leadership in this field could become vital to state DOTs’ long-term future.

4. Adoption of AV in the Trucking Industry

The trucking industry may represent an early adopter of AV. This industry requires specific consideration of AV deployment, not the least because truck-specific AV

applications address well-defined vocational requirements. State DOT responsibilities for freight corridors with increasing truck traffic make this an important topic.

5. State DOTs Supporting Cities

Given the importance of city CAV programs in technology deployment, the increased challenges for AVs operating in cities, and cities' relative lack of access to R&D support, state DOTs have an opportunity to provide technical and policy assistance.

6. Adoption of AV in the Shared Mobility Industry

Cities continue to play an important role in the development of the shared mobility (SM) industry, and SM could play an important role as an early adopter of AV.

II. Peer Exchange Questions

1. General

What's beginning to change?

1.1 What are the current opportunities for applying ITS solutions to traffic safety and traffic management?

1.2 How are mobility services, including intermodal trips, influencing the use of cars and roads?

1.3 How do smart city concepts influence current and emerging ideas on planning and operations?

How do we deal with major change?

1.4 How and when does CAV begin to influence ITS solutions and the operations of state and local agencies?

1.5 Who are the early adopters of CAV?

1.6 How should agencies best extract lessons from CAV deployments and consortia?

1.7 What key lessons emerge from CAV deployments to date?

1.8 What are the implications of CAV for data systems and data-driven management?

1.9 What are the responsibilities of state and local agencies for ensuring the cybersecurity of CAV?

2. Infrastructure and Operations

2.1 What infrastructure preparations and provisions may be required for AVs?

2.2 What additional maintenance will be needed for AVs?

2.3 What forms of support could CV provide for AV?

2.4 How should CV be interfaced with ITS architectures and deployments?

2.5 What will be the next step after SPAT?

2.6 What lessons are learned from trials and demonstrations? What are the next steps to full deployment?

3. Safety

Remaining safety questions for CV deployment include:

3.1 What is the influence of the density of CV deployment in the traffic stream?

3.2 How can deployment density be increased, or effectively increased?

3.3 How can the benefits of CV be extended to vulnerable road users, including pedestrians and cyclists?

Important issues for AV deployment include:

3.4 How will automated and conventional, human-controlled vehicles interact

3.5 Will human occupants be able to resume control of AVs from time to time?

3.6 How will AVs make ethical considerations and tradeoffs, such as differentiating between human participants in the event of an unavoidable accident?

3.7 What processes will ensure safe stop capabilities and locations in the event of automated system interruptions?

3.8 What is the role and potential licensing of AV passengers, as operators?

4. Freight and Transit Movement

4.1 What type of routes are most appropriate for truck platooning?

4.2 How do platoons of trucks from different manufacturers interact?

4.3 How do platooning and other advanced vehicles meet state requirements for minimum headways?

4.4 How do we set requirements for truck automation demonstrations?

4.5 What's the best way to assess AV safety as it applies to heavy trucks in depot-to-depot testing and demonstration environments?

4.6 How does CAV contribute to transit operations?

4.7 What is the role for freight and transit signal priority?

5. Policy, Standards, and Harmonization

5.1 What strategies and business models are most appropriate and can be embraced for CV rollout, including the provision of roadside equipment?

5.2 What are the benefits and costs of CV deployment?

5.3 What assistance in needed in the provision of a security certificate management system (SCMS)?

5.4 What is the role of state DOTs in the identification of AV operating environments, and extension of those operating environments?

5.5 How will CV be deployed in support of AV, and what are the benefits and costs of doing so?

5.6 What CV and AV information should be required by local agencies?

5.7 Can and should partnerships be established with smart city programs?

6. Environmental Impacts

6.1 Will CAV cause the number of vehicles, and VMT, to increase?

6.2 Will CAV cause transit ridership to reduce?

6.3 Will CAV cause energy usage, emissions, and the carbon footprint to increase?

6.4 How will highly-automated vehicles (HAVs) affect cities in terms of parking and street traffic?

6.5 What metrics should be used to evaluate the environmental impacts of HAVs?

7. Law Enforcement and First Responders

7.1 How do AVs of differing manufacture deal with “discretionary” driving issues such as short-term speed limit exceedance or lane encroachment?

7.2 Will human drivers adopt aggressive or intrusive driving strategies when interacting with AVs?

7.3 Will conservatively-programmed AVs cause unintended consequences in traffic?

7.4 How will enforcement officers and first responders recognize an AV?

7.5 How will enforcement officers communicate with an AV, and “pull it over”?

7.6 How will enforcement officers ensure that a stationary AV is in a safe mode?

7.7 How will first responders deactivate AV systems after an accident?

7.8 What guidelines may be needed for escorting, or “packaging”, heavy AV trials?

7.9 How will municipal revenue models be affected as increasing numbers of AVs programmed not to park illegally or incur traffic citations reach roadways, potentially depriving agencies of revenue streams?