State DOT CEO Leadership Forum

A Focus on Transportation Futures

Final Report

ITS World Congress

prepared for

NCHRP 20-24(100) Panel

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State DOT CEO Leadership Forum – A Focus on Transportation Futures

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Executive Summary

State Departments of Transportation (DOT) are evolving as Connected Vehicles (CV) and roadside infrastructure to support advanced technologies become more common and enter the market. State DOTs will need to adapt their policies and processes for how the transportation network is planned, designed, and managed. Managers also will need to rethink issues associated with the size of their workforce and the skill sets of DOT employees to meet the needs of the future transportation system. The technologies deployed over these past decades in Intelligent Transportation Systems (ITS) and in the many Transportation Management Centers (TMC) across the nation, together with the operational strategies implemented by the state DOTs in managing their systems, are maturing and there are constant challenges in keeping up with aging and advancing technology. In parallel to these existing systems, industry – auto manufacturers and transportation service providers – also are advancing CV concepts at a quick pace to allow for connected vehicles and supporting systems to be available to the traveling public soon. Today's state DOT Chief Executive Officers (CEOs) are at a point where their leadership will enable lasting change to occur within their agencies, helping CV to become a reality. Issues associated with incorporating the connected vehicle into existing planning processes, preparing for legislators' queries, considering needed policy directions, preparing a workforce equipped with the knowledge and skills to support this future network, and ultimately providing the traveling public with the expected levels of service all must be addressed by today's CEO.

Hosted by the American Association of State Highway and Transportation Officials (AASHTO), a group of CEOs attended the ITS World Congress in Detroit, Michigan to explore the future of transportation. After nearly a week's worth of exploring the latest technology exhibits, technical sessions, and demonstrations, this group came together for a workshop to discuss the issues and challenges posed by emerging CV technologies and the actions they believe are necessary to prepare for a more connected transportation system. While the CEOs recognized that there are many uncertainties associated with CV deployment, the discussion focused on the potential implications of partial or full deployment of connected vehicles within their states. Action steps included activities that might be undertaken AASHTO, FHWA, and a broader CV coalition as well as individual states.

Five central themes emerged in the discussion of issues and challenges:

- Competing priorities related to funding, modes, and other core issues will need to be addressed.
- CV potentially has large implications for infrastructure design, so there is a need for guidance on how and when DOTs should make changes in infrastructure to accommodate CVs.
- Data collection, usage, and governance will dominate CV implementation. DOTs will need to explore opportunities to use private sector data in actively managing traffic and to share data on network characteristics.

- Mobility and safety must be balanced with security and privacy concerns.
- Innovation is occurring rapidly, creating workforce challenges.

Actions the CEOs thought would be meaningful also were addressed at the workshop. Important actions included the following:

- The future of CV has unlimited potential and DOTs will not do it all. ***CEOs should establish the vision and set goals for CV.*** DOTs are in the position to challenge industry to help them get to that future state. The overall CV approach and funding questions require analysis.
- Achieving consensus-driven vehicle-to-infrastructure (V2I) policy statements and getting supportive language in any new transportation bill to move CV forward is essential to ***securing financial support*** for State DOTs.
- DOTs investing in CV must ***engage with the V2I Deployment Coalition*** (V2I DC).
- States will need to ***define a data strategy*** that addresses what data are needed, how it will be obtained, and which entities are responsible for its collection. They also must determine how to provide guidance regarding data sharing and how to address strategies for accommodating the large volume of data within the DOT that is associated with CV, Active Transportation and Demand Management (ATDM), and Vehicle Automation (AV).
- The freight industry is well aligned to show early CV successes. DOTs should ***watch the freight industry for early CV wins*** and success stories.
- Departments of Motor Vehicles (DMV) will become active partners as CV enters the mainstream. DOT leadership should ***engage their Departments of Motor Vehicles*** early in the CV planning process.
- Legislators may inadvertently stifle innovation if they impose overly restrictive laws and regulations on CV. CEOs might minimize this risk by communicating that the ***DOTs are not interested in legislating CV at the present time***, but would like to be engaged when and if legislators begin to discuss CV.
- State DOTs will act as incubators, but at the same time should not go at it alone. There is great value in ***learning from Lead States***.
- The State DOT workforce will change in order to adapt to advancing CV technology and data systems. As these changes occur, each DOT will need to ***adapt its understanding of and approach to DOT staff development***.

This report captures the impressions that this group of CEOs formed while attending the ITS World Congress. It is understood, however, that AASHTO and others must engage all the states in a discussion of the potential implications of connected vehicle technology.

1.0 Introduction

The Intelligent Transport Systems (ITS) World Congress comes to North America once every three years, and to the U.S. even less frequently. The 2014 Congress was located in the American hub of auto manufacturing, Detroit, Michigan, and the timing aligned with several transformational activities in the transportation industry. Communication and sensing systems are enabling the creation of an integrated system as our roadways and vehicles become smarter. These connected vehicles (CV), once only a transportation research concept, are now a reality. Research at the state and federal levels is providing for rapid advancement that defines connected vehicle concepts for state Departments of Transportation (DOT) and other transportation owners and operators.

The Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), and Transportation Research Board (TRB) invited State Transportation Chief Executive Officers (CEO) to attend the Congress, hear from global leaders, explore vendor products and exhibits, experience the latest technologies, and engage in technical discussions. The intent was to engage these leaders and help them understand the issues that today's CEO must consider in order to prepare for the coming CV environment. This initiative also included a workshop at the Congress to hear from CEOs about their experiences, capture their insights, and document the fresh thinking and potential development paths affecting the future of transportation given the exciting advancements being showcased in Detroit.

The objective of this report is to capture the issues, challenges, and proposed actions CEOs must consider in the short term and beyond. This report provides results of the workshop that will help inform the leaders of AASHTO, FHWA, and others as they prepare for a CV environment in the short term and help them set priorities to support DOTs in this effort. This report also will serve as a resource as the industry moves from research to deployment.

2.0 Advancing Technologies within State DOTs

Active traffic management (ATM) systems reduce or mitigate traffic congestion in urban environments by improving the efficiency of existing infrastructure systems. ATM can incorporate a wide range of ITS equipment, including sensors, communications devices, interlinked controllers and signs, and data-processing technologies. This area also is often referred to as Active Transportation and Demand Management (ATDM).

The next wave of vehicle innovation will come in the form of Connected Vehicles – first connected to each other (Vehicle-to-Vehicle; V2V), then to roadway and infrastructure devices (Vehicle-to-Infrastructure; V2I), then to other road users such as pedestrians (V2P), motorcyclists (V2M), and bicyclists (V2B). (Communication with these other road users is often referred to by the term V2X.) Connection is the key enabler of automated vehicle technology and offers the potential for truly integrated system management (vehicles, infrastructure, and operations). Collectively, these technologies represent the future of transportation and have the potential to provide significant improvements in safety, mobility, and energy use in transportation. Ultimately, CV technologies could result in the transformation of our transportation systems through the use of vehicle automation technologies. These technologies could provide for safer transportation while greatly increasing the throughput capacity of existing roads and infrastructure.

CV technologies aim to enable safe, interoperable, networked, and wireless communications among vehicles, the infrastructure, and passengers' personal communications devices, with the goal of improving the safety and mobility of the traveling public, enhancing commerce, and improving the environment. CV technologies focus on V2V and V2I systems. The U.S. DOT's vision[1] for connected vehicle technologies is to transform surface transportation systems to create a future in which the following developments occur:

- Highway crashes and their tragic consequences are significantly reduced.
- Traffic managers have data to accurately assess transportation system performance and actively manage the system in real time for optimal performance.
- Travelers have continual access to accurate travel-time information to help choose among mode, route, and other options, as well as to evaluate the potential environmental impacts of their choices.
- Vehicles can talk to traffic signals to eliminate unnecessary stops and help drivers operate vehicles for optimal fuel efficiency.

AASHTO identified the World Congress in Detroit as an excellent venue to accomplish the following:

- Educate state DOT representatives and other officials about the current state of CV programs, technologies, and Original Equipment Manufacturer (OEM) developments;
- Promote engagement of state transportation officials with connected vehicle stakeholders including U.S. DOT, OEM vendors, academicians, and presenters; and
- Promote discussions about the future of CV developments, with a specific focus on the technology and policy issues most relevant to DOTs and regional transportation agencies.

The ITS World Congress shined a spotlight on the potential of a connected transportation environment and revealed the likelihood that some deployment activities will occur in the short term. Fully connected systems will take many years to materialize based on the needs of the individual states, the traveling public, and ultimately a national system. The following four subsections provide an overview of core CV areas that will be of importance to transportation officials: V2I; V2V; Vehicle Automation (AV); and ATDM.

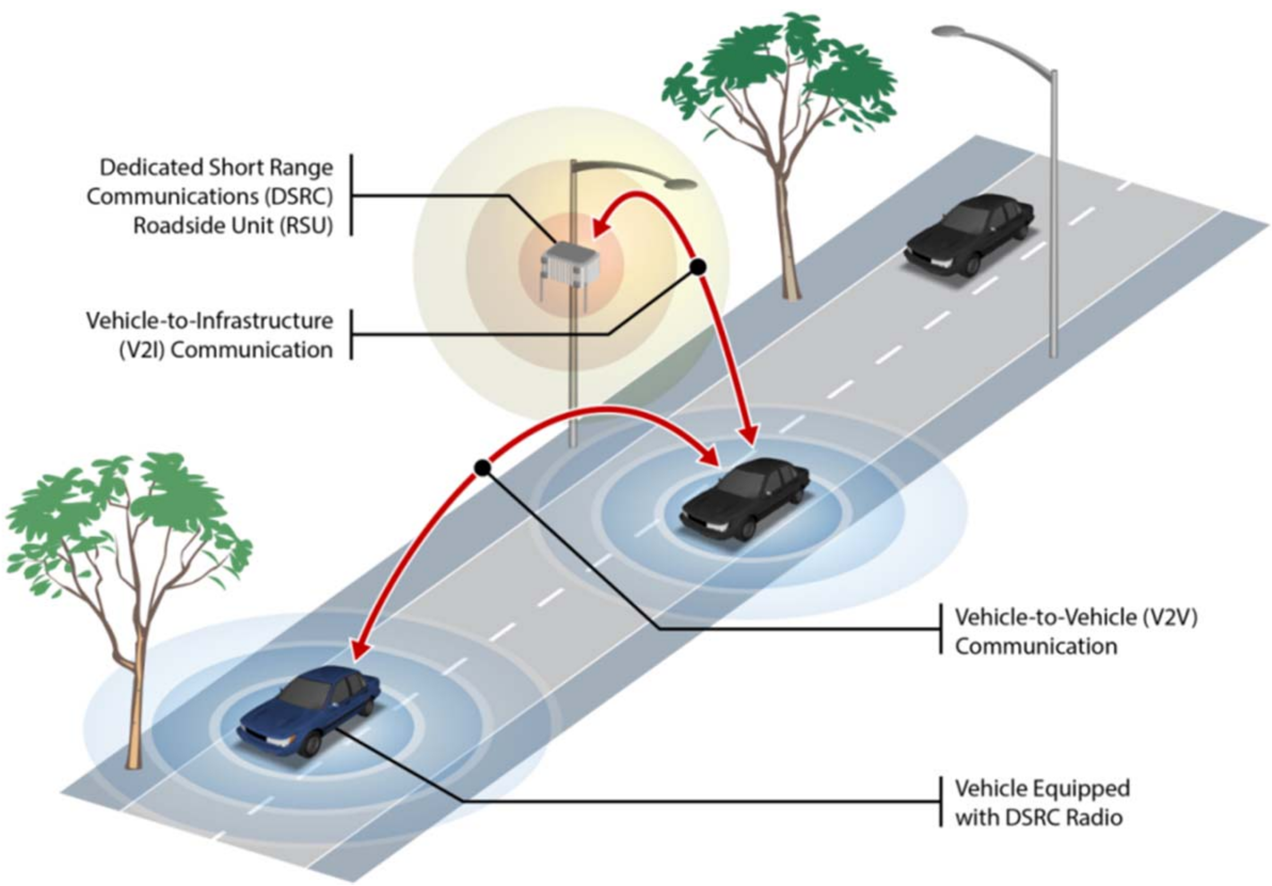
[1] www.its.dot.gov/connected_vehicle/connected_vehicles_FAQs.htm.

2.1 Vehicle to Infrastructure (V2I) Applications

AASHTO has been a partner in the Connected Vehicle initiative since 2004, working collaboratively with U.S. DOT and the automobile industry. Since DOTs design, build, and maintain most of our nation's roadway infrastructure, the AASHTO focus on CVs is primarily directed at the vehicle-to-infrastructure elements of CV technology. DOT planning and deployment of CV infrastructure, particularly if the deployed technologies focus on the Dedicated Short-Range Communications Technologies (DSRC) 5.9 GHz technologies, is expected to be a large undertaking.

The enabling technologies of V2I are the DSRC 5.9 GHz in-vehicle radio and the Roadside DSRC readers (termed "RSUs") installations. The components and high-level functionality of the DSRC 5.9 GHz technology and operational environment are presented in Figure 1. The "back office" supporting these operations will be housed at regional Travel Management Centers (TMC). Note that the DSRC 5.9 GHz in-vehicle radio is also the core enabling technology of V2V applications, as addressed in the next subsection of this document.

Figure 1. Overview of DSRC 5.9 GHz Technology for V2I and V2V



AASHTO has led the way with foundational research into early deployment scenarios in the Footprint Analysis (discussed in later sections). In this research, the "infrastructure footprint" is the infrastructure needed to create a CV environment. It will generally include the following: roadside communications equipment; traffic signal controller interfaces; systems to support security credentialing; mapping and asset systems and resources; positioning services; and data servicing and processing.[2] Building on research by the U.S. DOT, the AASHTO Footprint Analysis has identified early applications that leverage existing ITS deployments. Examples of those early applications, referred to as launch applications by AASHTO, are shown in Table 1.

Table 1. Potential V2I Near-Term Applications for State DOTs and Other Agencies[3]

Safety Applications	Mobility Applications	Agency Operations and Maintenance
• Red Light Violation Warning • Curve Speed Warning • Stop Sign Gap Assist • Spot Weather Impact Warning • Reduced Speed/Work Zone Warning	• Motorist Advisories and Warnings (emergencies, weather, variable speeds, curve speed, oversize vehicle) • Real-Time Route-Specific Weather Information for Motorized and Nonmotorized Vehicles • Advanced Traveler Information System • Freight Operator Real-time Information with Performance Monitoring • Transit Signal Prioritization • Emergency Vehicle Prioritization	• Enhanced Maintenance Decision Support • Information for Maintenance and Fleet Management Systems

2.2 Vehicle to Vehicle (V2V) Applications

V2V applications involve using DSRC 5.9 GHz and global positioning system (GPS), or other wireless technologies that can allow vehicles to "talk" to each other, to enable a variety of safety, mobility, information, and, eventually, vehicle automation applications. V2V research currently is being conducted by the U.S. DOT, and development is underway in the private sector at General Motors, Nissan, BMW, Daimler, Honda, Audi, and Volvo. Working with industry, U.S. DOT may determine mandatory V2V standards for the U.S. market by 2017.

V2V also can be based on a wireless mesh network approach, in which automobiles send messages to each other about what they are doing. This data would include speed, location,

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[2] *National Connected Vehicle Field Infrastructure Footprint Analysis: Final Report Executive Summary.* American Association of State Highway and Transportation Officials, Washington, D.C., December 2013.

[3] Ibid.

and direction of travel, braking, and loss of stability. V2V allows for sensing threats and hazards with a 360 degree awareness of the position of other vehicles and the threat or hazard they present; calculating risk; issuing driver advisories or warnings; or taking preemptive actions to avoid and mitigate crashes.[4]

At the heart of V2V communications is an application known as the Basic Safety Message (BSM). Much of the current U.S. DOT research and testing program related to V2V has been focused on emerging safety applications. The safety vision for V2V is that eventually, each vehicle on the roadway (including automobiles, trucks, buses, motor coaches, and motorcycles) will be able to communicate with other vehicles, and this rich set of data and communications will support a new generation of active safety applications and safety systems. According to the U.S. DOT, V2V communications will enable active safety systems that can assist drivers in preventing 76 percent of the crashes on the roadway, thereby reducing fatalities and injuries that occur each year.[5] Examples of those early applications are shown in Table 2.

In late August 2014, the U.S. DOT and National Highway Traffic Safety Administration (NHTSA) released an advance notice of proposed rulemaking (ANPRM)[6] and a supporting comprehensive research report on V2V communications technology. The report includes analysis of the Department's research findings in several key areas, including technical feasibility, privacy, and security, and preliminary estimates on costs and safety benefits. The ANPRM seeks public input on these findings to support the Department's regulatory work to eventually require V2V devices in new light vehicles.

Table 2. Potential V2V Near-Term Applications

Safety Applications
• Emergency Electronic Brake Lights
• Forward Collision Warning
• Blinds Spot Warning/Lane Change Warning
• Do Not Pass Warning
• Intersection Movement Assist
• Left Turn Assist

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[4] V2V: What are vehicle-to-vehicle communications and how do they work? By Bill Howard. February 6, 2014. http://www.extremetech.com/extreme/176093-v2v-what-are-vehicle-to-vehicle-communications-and-how-does-it-work.

[5] www.its.dot.gov/research/v2v.htm.

[6] www.nhtsa.gov/About+NHTSA/Press+Releases/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications.

2.3 Vehicle Automation

Eventually, the V2V technology described in the previous section also could support aspects of vehicle automation. Perhaps the largest wildcard in discussions about the future of transportation is the advancement of partial-to-full automation of driving functions. While not a new concept, advances in sensing and computing have introduced a set of new players to the traditional automobile industry. Most visible is Google, with the Google Car that is creating excitement via YouTube videos and other marketing efforts.

While a fully automated driving experience is unlikely to be the norm in the next 10 years, there are several critical issues that DOTs may want to explore. The public expects additional advances and may look to DOTs to help facilitate this transition. It is not too early for DOT CEOs to be assessing how vehicles with automation can potentially operate in their states. Engaging OEMs and reviewing pilot test results also will be beneficial to DOTs that are beginning to assess this technology.

It is important to note that vehicle automation differs from vehicle connectivity. Automated vehicles act independently of V2V or V2I communication through on-board sensing systems. At its core, vehicle automation relies on sensors, robotics, artificial intelligence, machine learning, machine vision, and computer processing to control mechanical processes for vehicle movements. Lane striping, sign reflectivity, and other infrastructure cues are used in combination with navigational technology. There is no standard definition for automated vehicles; some alternative descriptions include autonomous vehicles, smart driving vehicles, driverless cars, or robot cars. The vehicles use sensors to navigate without human input or control. Standardization of the terminology may be on the horizon.

To address the changing nature of the driving experience, the NHTSA proposed a regulatory framework that uses five descriptive levels of automation. This framework ranges from Level 0 to Level 4 with Level 4 requiring no active "driver" role, as shown in Figure 2.[7]

Four states and the District of Columbia have legislation that allows testing of automated vehicles on public roads. Google has the highest volume of testing under actual conditions, with over 750,000 miles driven in test scenarios.[8]

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[7] www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development.

[8] http://ezinearticles.com/?Driver-Less-Cars--Are-They-the-Future?&id=8491179.

Figure 2. Five Levels of Vehicle Automation

LEVEL	DESCRIPTION	EXAMPLES
0 **Driver Warning Systems**	Provides guidance to the driver, but makes no decisions and does not take away control.	▪ Forward collision warning ▪ Lane departure warning ▪ Blind spot monitoring
1 **Automation of Isolated Driver Functions**	Manages individual driver functions, but requires a human driver to continue performing other essential functions.	▪ Adaptive cruise control ▪ Dynamic brake support ▪ Lane Keeping Assist
2 **Automation of Several Driver Functions**	Manages several driver functions simultaneously, but still requires a human driver to handle some essential functions.	▪ Combinations of items from (1) above.
3 **Limited Self-Driving Capability**	Limited autonomous operation in certain environments, with supervision from human driver to handle complex situations.	▪ Handling inclement weather ▪ Interpreting traffic signals ▪ Reacting properly to pedestrians ▪ Handling railroad crossings
4 **Fully Autonomous Operation**	Capable of handling more advanced driving situations and environments, for fully autonomous operation from origin to destination.	▪ Interpreting and avoiding animals/obstacles ▪ Obeying instructions from flaggers and peace officers ▪ Reacting properly to bicyclists

While a transportation system consisting primarily of fully automated-capable vehicles may be decades away, nearer term, partially automated solutions such as vehicle platooning are expected to be in operation in the next decade. For example, V2V can provide for safer, closer headways between trucks and for communications to nearby trucks that will allow "virtual trailering" between trucks. This would allow even closer spacing between trucks, thus increasing capacity and reducing energy consumption. Preliminary research indicates that platooning of vehicles (both automobiles and trucks) could significantly increase highway lane capacity.[9]

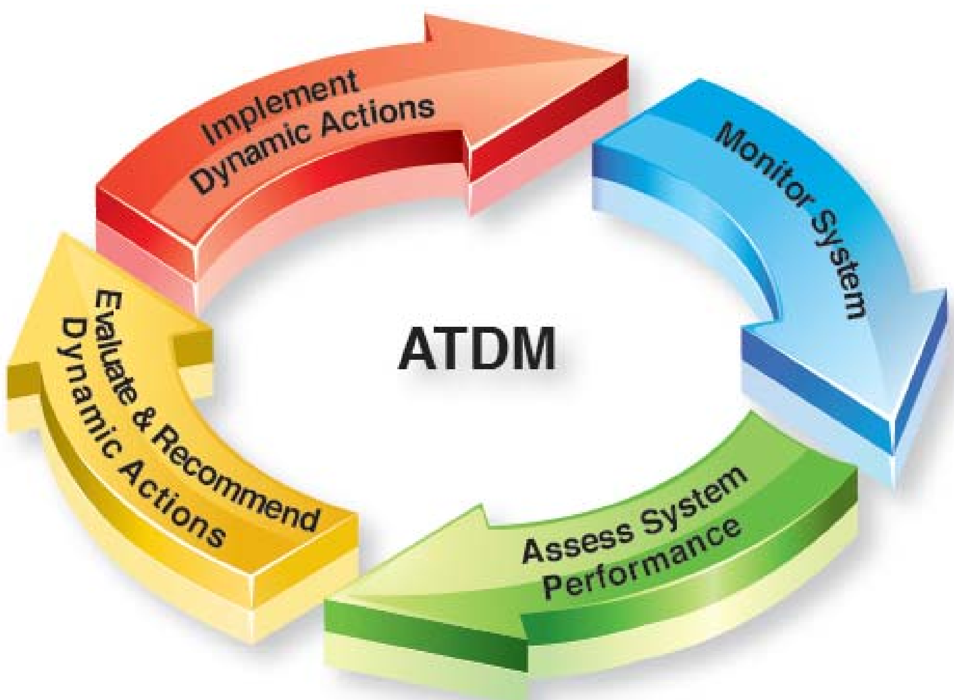
[9] www.gatewaycog.org/download/Strategic%20Transportation%20Plan/Initial%20Concept%20of%20Operations%20for%20the%20I-710%20Zero-Emissions%20Freight%20ITS%20Corridor.pdf.

2.4 Active Transportation and Demand Management Strategies

Active transportation management systems can dynamically manage recurring and nonrecurring congestion based on observed and predicted traffic conditions and are mainstreamed activities for state DOTs and local agencies. According to the FHWA, the approach focuses on trip reliability and maximizes the effectiveness and efficiency of the facility.[10] Investments in transportation management centers, managed lanes, infrastructure elements, and the connected vehicle environment are represented in ATM approaches.

Figure 3 portrays the cycle for ATDM strategies. Active management of transportation and demand can include varied approaches for achieving the goal of improving efficiency. These approaches rely on real-time information and performance thresholds to deliver reliability in the transportation network. The balance between monitoring approaches and interventions is crucial to the overall approach. Overreaction to traffic situations can create as many subsequent challenges as not responding to congestion and system overload. These strategies can range from demand, traffic, and parking management, to more efficient utilization of other transportation modes and assets. Sample strategies include ramp metering, managed lanes with dynamic pricing or reversible lanes, speed harmonization, shoulder lane usage, traveler information, traffic signal control, and transit signal prioritization, among others.

Figure 3. Active Transportation and Demand Management Cycle



[10] http://ops.fhwa.dot.gov/publications/fhwahop13042/sec2.htm.

It should be noted that these systems can operate as standalone and highly advanced transportation systems with or without investments in V2I or V2V communications. Some states have consolidated operations in statewide traffic management centers and others operate multiple regional centers. The ITS World Congress highlighted many advanced strategies that are already available to manage these systems.

Because of the cooperative and open nature of V2V and V2I systems, current ATDM approaches offer a benefit of less vulnerability to security and privacy concerns. As with technology developments in the connected and automated vehicle environment, technology developments in ATDM are also advancing rapidly. Better sensors, improved communications devices, and decades of experience with these systems have improved the efficiency of the nation's infrastructure.

3.0 Current Research Influencing State DOTs

For over a decade, the Federal and state DOTs, together with partners in industry and academia, have led research programs looking at computing advances, data systems, planning horizons, standards, and other facets of CV implementation, all with an underlying objective of identifying technologies to increase safety and enhance mobility on our roadway systems. Using leading edge technologies – advanced wireless communications, on-board computer processing, advanced vehicle-sensors, GPS navigation, smart infrastructure, and others – CVs have the capacity to identify threats, hazards, and information about the roadway and communicate this information to drivers. Early studies led to proofs of concept, which led to pilot tests and have brought actual deployments to bear. What was a research endeavor has turned a corner and become a reality.

The FHWA has a coordinated program devoted to CVs. The research effort is divided into three primary areas: connected vehicle technology, connected vehicle applications, and connected vehicle policy. At the heart of these efforts is a collection of connected vehicle test beds (real-world, operational facilities that offer the supporting vehicles, infrastructure, and equipment to serve the needs of public- and private-sector testing and certification activities).[11]

3.1 Overview of the National Activities

V2I Deployment Coalition

To prepare for the anticipated growing presence of CV, FHWA, together with AASHTO and ITS America, are establishing a Vehicle-to-Infrastructure Deployment Coalition (V2I-DC). This coalition will serve as a focal point for V2I deployment on a national level with participation from public, private, academic, and international sectors of the transportation community. The objectives of the coalition will be to provide leadership on developing CV Deployment

[11] www.its.dot.gov/testbed.htm.

Guidance, establish policies, provide guidance on research initiatives, and promote standards development.

The coalition will serve as a focal point in V2I deployment on a national level by supporting Federal, state, and local agencies. It will leverage technical teams comprising the U.S. DOT, transportation system owners/operators, owner/operator associations, trade associations, and other stakeholders. The coalition will also serve infrastructure stakeholders, including states, cities, counties, and local planning bodies, as well as private-sector consultants and practitioners, by providing a forum to assist in deploying V2I systems. The objectives of the V2I coalition include the following: policy guidance and privacy guidance; readiness; research; standards and deployment support; and outreach.

CV Deployment Guidance

The U.S. DOT is in the process of providing guidance (not regulation) via development of a Connected Vehicle Infrastructure Deployment Guidance document based on its own research and AASHTO's analysis of infrastructure needs and deployment approaches. Draft guidance was released in September 2014.[12] A workshop during the ITS World Congress provided an opportunity to explore the draft, which is geared to support successful implementation and operations of connected vehicle technologies. In general, this guidance is targeted to mid-level DOT staff. The document discusses the "what" and "how" of implementing infrastructure and support systems and includes guidelines, best practices, and a toolkit. It also addresses identified high-priority applications, such as V2I safety applications (crash warnings at traffic signals, etc.), and dynamic mobility, road-weather, and environmental applications. The guidance is expected to be finalized in 2015.

The draft guidance also includes discussion of how the connected vehicle environment differs from traditional ITS deployment. These differences include the need for seamless integration and interoperability and the rapid evolution of connected and automated vehicle technologies. In the guidance, Congestion Mitigation and Air Quality (CMAQ) programs are discussed as potential funding sources for connected vehicle deployments. The guidance also provides strategies for including CV in existing ITS equipment deployments (e.g., Dynamic Message Signs, CCTV cameras, vehicle detection stations). These locations likely have existing power sources, cabinet space availability, and established backhaul communications which should lower deployment costs.

A number of additional guidance materials are under development by U.S. DOT to support V2I deployments. These include a benefit-cost analysis tool, a planning guide for state DOTs and metropolitan planning organizations (MPO), a guide to cyber security, communication technology selection assistance, DSRC-related unit licensing, and a V2I message lexicon to establish allowable standard messages and formats.

[12] www.itsa.org/fhwaworkshop.

AASHTO Footprint Analysis

AASHTO has recently completed the Connected Vehicle Field Infrastructure Footprint Analysis, a document that will help prepare DOTs for the eventual deployment of connected vehicles. AASHTO also is working to ensure that the 5.9 GHz band, essential for the development and use of connected vehicle technology, remains free from interference and is used solely for this purpose.[13] The Footprint Analysis provides a national CV field infrastructure framework that includes the following:

- Prioritized applications for state and local agencies, including the data, communications, security, roadside equipment, and information service needs of each agency;
- A set of design concepts and deployment gaps for approximately 10 of the highest priority applications, with sufficient engineering detail to describe an operational system;
- A range of scenarios that illustrates how different government entities – state, county, or municipal – would approach deployment;
- A preliminary national footprint for CV field infrastructure created by expanding the deployment scenarios;
- An initial strategy for coordinated, phased deployment based on the scenarios and national footprint, highlighting interoperability and institutional challenges and opportunities; and
- A set of deployment cost estimates, including the cost of equipment, operations and maintenance, and training and staff development.

This footprint analysis – full report and executive summary and briefing – is available at http://stsmo.transportation.org/Pages/Connected-Vehicles.aspx.

Cooperative Transportation Systems Pooled Fund Study (CTS PFS)

A pooled fund was created to research CV topics selected by the participating states and local agencies. This effort is led by the Virginia DOT, with the University of Virginia Center for Transportation Studies providing technical support. The PFS objective is to facilitate the development, field demonstration, and deployment of connected vehicle infrastructure applications. Pooled fund members include Virginia, California, Florida, Michigan, New York, Wisconsin, Washington, Minnesota, Texas, New Jersey, Pennsylvania, Maricopa County, and the FHWA. Since its inception in 2009, CTS PFS has conducted or led numerous projects on various topics, including Multimodal Intelligent Traffic Signal System, Aftermarket On-Board Equipment for Cooperative Transportation Systems, and the Certification Program for Cooperative Transportation Systems.

[13] www.aashtojournal.org/Pages/020714V2Vtechnology.aspx.

University Transportation Centers

Funded by Federal transportation funds, with matching support from states, universities, and some private corporate funds, the University Transportation Centers program includes more than 100 universities across the country. Several centers have ongoing work in the connected vehicle environment. The Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC), based at Virginia Technological Institute, is a partnership with several other universities to address research that will advance surface transportation through the application of innovative research and the use of connected-vehicle and infrastructure technologies. The center was launched in 2013 and has several research efforts underway, including safety and human factors studies.

Other University Transportation Centers are also engaging in automated and connected vehicle research. Carnegie Mellon's Technologies for Safe and Efficient Transportation (T-SET) center has current projects using advanced technology for collision warning systems, improving bicycle safety with V2V applications, continuous road surface distress indications, trust and security protocols, policy, and data applications. The City College of New York's University Transportation Research Center is exploring policy developments in the connected vehicle environment. As this area continues to move closer to implementation, it is expected that other UTCs will also explore emerging CV issues and topics.

3.2 Selected State Activities

A number of state DOTs, local agencies, and universities have engaged in research, partnerships, and pilot tests of numerous CV approaches and planning activities. These lead states will play an important role in informing the state DOTs' direction as CV advances. While the lead states are critical to advancing CV for all, collecting lessons learned will be equally important. There is no benefit to requiring multiple states to learn the same hard lesson. As a critical mass of CV deployments happen, standards also must be considered. This section highlights just a few of the state-level CV research programs underway across the nation.

California

California DOT (Caltrans) and the San Francisco Bay Area Metropolitan Transportation Commission (MTC) have created a V2I development partnership that established a California Connected Vehicle Test Bed in the Bay Area region. This test program has included participation by OEMs, including BMW, Mercedes, Toyota ITC, VW, and Nissan. The objective of this effort is to assess real-world implementation. Caltrans and the University of California also are leading a consortium that will test V2V truck platooning technologies on California roadways in the 2015 to 2016 timeframe.

Additionally, the Los Angeles County Metropolitan Transportation Authority (LA Metro) and the Gateway Cities Council of Governments (COG) in Southern California have been involved in a freight related CV initiative. For the I-710 freeway, three years of planning and preliminary design activities have been conducted to develop a connected vehicle plan, including developing a concept of operations for truck connected vehicle safety and automation technologies and a footprint analysis of I-710 infrastructure. The effort involved building relationships with the OEMs and other vendors, including a major workshop involving GM, Volvo, Google, the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), and others.

Florida

Florida is home to two connected vehicle test beds, one in Orlando and the other in Tampa, through the Tampa Hillsborough Expressway Authority Selmon Expressway's reversible lanes. These sites enable testing and demonstration of both connected and automated vehicle technology. In addition, the state has launched a comprehensive automated vehicle initiative, including statewide working groups focused on policy, regulation, planning, and freight operations. These working groups are meeting regularly to develop a statewide approach that identifies potential challenges and opportunities and provides recommendations as to how Florida DOT should address AV/CV technology in policies, standards, and infrastructure funding decisions.

Florida hosted a statewide summit of AV/CV stakeholders in November 2013 to develop its initial approach, and a second forum is planned for December 2014.

Michigan

Numerous activities are underway in Michigan through the coordinated efforts of the automotive industry, the Michigan DOT, the University of Michigan Transportation Research Institute (UMTRI), and other groups. The Safety Pilot Deployment (SAFETYPILOT) is being conducted by UMTRI as part of a diverse public-private partnership involving industry, Michigan DOT and other public agencies, and academia. The project includes approximately 2,800 vehicles equipped with V2V devices operating on 73 equipped lane-miles in northeast Ann Arbor. SAFETYPILOT represents just one of a number of CV test beds and research efforts underway in Michigan. Other examples include the City of Detroit Connected Vehicle Test Bed, the I-94 Truck Parking Information and Management System, the Proof of Concept Test Bed in Farmington Hills, and the Michigan International Speedway in Brooklyn.

At the ITS World meeting, the Michigan DOT announced plans to create a V2I communications network along 120 miles of Detroit-area highways.

Arizona

The Maricopa County DOT and its partners, the Arizona DOT, the University of Arizona, and the FHWA, are developing and demonstrating advanced ITS applications that integrate vehicles together with Systematically Managed ARTerial (SMART) roadway systems in Maricopa County. Maricopa County DOT has launched the vehicle integration concept in a field test application on Daisy Mountain Drive in Anthem, Arizona, to demonstrate the capabilities of, evaluate the benefits of, and provide a test bed for future applications. Maricopa County DOT's program test corridor is expanding and includes emergency and transit vehicle priority, enhanced real-time traveler information, and advanced traffic signal technology to reduce travel times.

New York

The New York State DOT began connected vehicle deployment activities in support of the 2008 ITS World Congress in Manhattan. A variety of activities are underway through the joint efforts of public agencies and private sector groups. The Commercial Vehicle Infrastructure Integration (CVII) Program is one component. Projects include deploying on-board instrumentation in snowplow trucks and aftermarket devices in 20 other vehicles, commercial vehicle identification and verification, wireless vehicle safety inspection, communication to maintenance vehicles, grade crossing warning, and heavy-to-light duty vehicle driver safety warnings. These and other pilot projects are being conducted on the New York State DOT INFORM I-495 CVII Test Bed, the New York State Thruway, and CVII corridors in New York City and Long Island.

Texas

The Texas DOT, the Texas A&M Transportation Institute (TTI), and other public- and private-sector groups are actively involved in CV and AV research, test beds, and deployment efforts. TTI, Battelle Memorial Institute, and traffic control equipment manufacturers Econolite and Siemens recently undertook a project for the FHWA focused on developing interfaces between the traffic signal controller and RSE to enable signal phase and timing (SpaT) and related messages for connected vehicle applications. A prototype SpaT system was developed, installed, and tested at FHWA's Turner-Fairbanks Highway Research Center facilities in McLean, Virginia. The system continues to be used in other CV research at Turner-Fairbanks. Texas DOT and TTI have created the Accelerate Texas Center to serve as a catalyst for the development, testing, and implementation of CV and AV technologies. The center also will help commercialize CV and AV technologies. The owners of the Circuit of the Americas Formula One Race Track in Austin are exploring ways the track can support the initiative, and outreach is underway to other private and public sector groups. In addition, the TTI Transportation Policy Center is supporting the Texas legislature by examining a range of policy issues associated with V2V, V2I, and AV.

Virginia

The Virginia Tech Transportation Institute (VTTI) is the leader of the public-private Virginia Connected Vehicle Test Bed project. The test bed includes connected intersections and other facilities located along the I-66 corridor. It also includes a closed-course Smart Road in Blacksburg. The test bed is part of the Connected Vehicle Infrastructure-University Transportation Center (CVI-UTC); members include the University of Virginia, Morgan State University, and the Virginia Center for Transportation Innovation. The Virginia DOT is an important partner, along with other public and private groups.

4.0 Pre-World Congress Thought Points

The need for a pathway to CV deployment is urgent, but to create it, the issues, timelines, and resources of DOTs must be defined. Today's CEOs are the leaders who will usher in CV programs within each state, and through collaborative activities such as the V2I Deployment Coalition, spread their knowledge and experience throughout the nation. A key question for CEOs is how the states should move forward in preparing for, if not promoting, the shift to CV environment.

There appears to be a consensus that the industry is at a turning point and the next question to ask is "Now what?" How do the research data, pilot results, and tests documented and developed over the past decade flow into real-world implementation? And what is the role of DOT CEOs? Will the approach be similar in all states? What are the timelines? How will DOTs integrate V2I into legacy, or existing, ITS?

The workshop at the ITS World Congress intended to capture the unique perspective of state DOT CEOs following nearly a week's worth of conference events, demonstrations, and expositions. This section outlines the goals of the workshop and provides the context for states to capitalize on the transformational impact of CV on tomorrow's transportation safety and mobility.

Primarily, the state DOTs were engaged to identify the issues today's CEO must consider and how the CV environment will change the DOT, both in the short and long term. To address these questions, several themes were originally posed for discussion.

4.1 Policy and Regulation

As with any new, innovative transportation strategy, the institutional and public policy issues associated with CV may pose the greatest challenge to accelerated implementation. For an implementation as comprehensive as the envisioned deployment of connected vehicles, the challenges could be significant. This new paradigm for infrastructure operations will test existing institutional and policy frameworks in five general categories: financial, governance, human resources, outreach, and legislative.

Financial

Funding transportation infrastructure, operations, and maintenance continues to be an ongoing challenge for most DOTs. With Federal funding uncertain, DOTs have been increasingly motivated to address potential shortfalls at the state level. Funding and financing methods that extend beyond traditional approaches are often being considered and used.

The current assumption is that there will be no congressionally designated funding to support the deployment of CV field infrastructure and associated operations and maintenance costs. These costs, however, have broad eligibility under Federal-aid funding programs in the same manner as ITS field infrastructure. The same locally driven process for funding allocation used for ITS may be adopted for CVs. Promoting the safety benefits of CV should provide a strategic advantage in securing funding sources. Federally funded deployment incentives to seed pilot projects and demonstrations represent one possible approach for advancing CV deployment. The development of alternative funding strategies through private or commercial arrangements is also possible but will depend on local priorities and policies and may require legislative action.

Prior to the workshop, the participants were asked to think about what legislation, if any, would be needed to help advance funding for CV infrastructure and operation.

Governance

In many states, DOTs are confronting the erosion of statewide network control and governance as transportation funding initiatives substitute for or supplement state fuel taxes through locally levied taxes, thereby shifting decisions about major transportation projects to local, metropolitan, and regional agencies and governments. This evolution may have implications for the delivery and ongoing support of connected vehicle infrastructure. Locally funded projects have the potential to create fragmented responsibility, but they also may be a source of innovation in planning, investment, and delivery.

A unique element associated with CV deployment is the need for agencies to actively participate in the governance and implementation of security measures due to the cooperative nature of connected vehicle communications. The establishment and operation of the Security Certificate Management System (SCMS) will necessitate creating a governing body for security services in which some representatives of state and local transportation agencies would logically be included.

The SCMS is being finalized by the automotive OEMs, with assistance from academia and the security industry. This system is based on the principle of maximizing individual privacy while maintaining the highest levels of security. While the full details of this system have not been released, it is understood that it will incorporate multiple layers of security credentialing and a separation of organizations and databases that will prevent any one organization, or individuals inside or outside of those organizations, to ascertain both the vehicle identification and location at the same time.[14]

Human Resources

Program and service execution are among the most important issues to users of the transportation system. Most DOTs are confronting the challenge of delivering effective and reliable day-to-day services with declining resources, which often translates to steady

[14] http://docs.house.gov/meetings/SY/SY15/20140618/102385/HHRG-113-SY15-Wstate-MaddoxJ-20140618.pdf.

decreases in staffing levels. At the same time, many DOTs are facing the challenges and opportunities of hiring new staff to replace long-term employees who are retiring.

Additionally, an increased emphasis on CV operations will require expanded education and training to ensure that staff have the necessary expertise to operate and manage the system. New technological applications will require the development of different workforce skills. Staff development and training will be required for deployment, operations, and maintenance of connected vehicle systems, and the requisite skill sets will differ from those associated with typical ITS deployments. The development of human resources could proceed parallel to planning and system development to assure professional capacity is consistent and mature as implementation proceeds. Changes in workforce skills may also be needed to accommodate new partnering arrangements with the private sector, such as legal, financing, and contractual or innovative procurement expertise.

Outreach

Policy making and public support for connected vehicle deployment will depend on the ability of transportation agencies to communicate the value and benefits of the new technology. The speed of deployment will be influenced by the degree of success in generating awareness, acceptance, and enthusiasm, bolstered by public trust and confidence in the implementing agencies. Public outreach is a shared responsibility among the many partners involved in advancing CV systems. State and local officials have key roles to play in crafting the appropriate messages and effectively communicating with policymakers and the public.

Legislative

There is a range of state-level legal and legislative issues that may have unique relevance to connected vehicle deployment. Examples of these issues include data privacy, ownership, and use; liability and limitations to risk; insurance; intellectual property; procurement; law enforcement; and vehicle titling and registration.

Liability concerns, though not a barrier to CV deployment, may slow deployment of fully cooperative systems and reduce their potential benefits. The effectiveness of CV relies on the shared use of data among vehicles, infrastructure, and devices, yet there is risk for any one manufacturer when the safety of its product's passengers is partially dependent on another manufacturer's product. There may be reluctance to introduce the full functionality of these technologies in the United States due to its litigious climate. Research into shared-liability regimes, including limiting (but not eliminating) the liability of automakers and other device makers, as well as the operators of connected infrastructure, including the security system and traffic operations, would be beneficial to addressing these potential problems.[15]

[15] http://docs.house.gov/meetings/SY/SY15/20140618/102385/HHRG-113-SY15-Wstate-MaddoxJ-20140618.pdf.

Privacy is a central policy aspect of CV. The CV environment has been designed from the beginning to be very protective of privacy of individual drivers or vehicle owners or operators. The BSM that is broadcast from vehicles is anonymous and contains no information that identifies the vehicle or driver. As standardized by the Society of Automotive Engineers (SAE), it only contains information about a generic vehicle's instantaneous location, heading, acceleration, speed, and vehicle status such as brake application and steering wheel angle. By design, the V2V system does not track or record vehicle movements, and security credentials are updated on a very short-term basis. Because of this design, it is practically impossible to track the location or meaningful path history of a vehicle or person through the V2V system (in contrast to the relative ease of doing so with cell phones).

Of course, no electronic data system is completely impervious to cyber-attacks and hacking attempts, and vehicles and vehicle systems are potential targets of such attacks. While no attacks are known to have been mounted in the real-world environment, there have been a small number of demonstrations of hacking into embedded (built into the individual vehicle) systems by academic and research organizations. And V2V/V2I systems, along with infotainment and communications systems, may offer an additional "attack surface" into the vehicle due to their nature (enabling data exchange). Conducting continued research on cybersecurity for vehicles, including these V2V/V2I messaging and security systems, to understand any vulnerabilities and potential countermeasures would be beneficial.

The Federal government will establish requirements for addressing privacy and security issues. The question for state DOTs is whether there is a need for additional privacy and security policies and requirements at the state level, or whether Federal requirements will be sufficient.

4.2 Planning, Design, and Management and Operations

Information technology will connect the users of the transportation system to each other and to its owners and operators. Huge amounts of data flowing throughout the transportation system will enable owners and operators to improve their operations and provide enhanced mobility to the traveling public. This data-rich environment will result in a more efficient and effective system: fewer crashes, better managed congestion, timely identification and response to maintenance and operation needs, and reduced travel costs.

New vehicle technologies are expected to facilitate a dramatic reduction in crashes and improved mobility, which in turn may precipitate changes in infrastructure design, travel patterns, and car ownership. Automated driving systems already are reducing crashes, and advanced autonomous systems may provide additional mobility and safety benefits.

Planning

One of the biggest hurdles to the widespread adoption of CV/AV technologies involves adapting current and planned infrastructure requirements to accommodate connected, semi-autonomous, or fully automated systems. Infrastructure improvements required to take full advantage of connectivity are costly and must be adapted to support emerging technology.

Existing processes for planning, traffic modeling, and capacity considerations should be reexamined in light of the long-term impacts of automation and connectivity. Closer following distances, reduced lane widths, and shorter merge areas are all potential outcomes. Dedicated lanes to prevent mixes of connected/automated and non-automated vehicles could be used to make this transition.

Defining and identifying the infrastructure necessary to ensure smooth transitions to new technology and developing appropriate strategies to implement them into state, MPO, and other long-range planning processes will be required.

Without a crystal ball, the analyst's best tools are projections that are highly sensitive to variables impacted by potential new technology deployments. Widespread adoption of new vehicle technology that reduces driving demands, improves safety, and increases mobility could also provide incentives for increasing acceptable commute times and distances for personal travel. If the commute becomes productive time, it is possible that more extreme commuting could occur, with offices located far from the residential locations employees choose. At the same time, these technologies could encourage dramatically different vehicle ownership patterns. While some efficiency gains could be made, an increase in Vehicle Miles Traveled (VMT) is a very real possibility for both connected and automated vehicle technology. Both CV and AV may affect travel behavior, and many of the tools planners use therefore must adapt to these changes.

Design/Operations

Adapting current and planned infrastructure requirements for connected, semi-autonomous, or fully automated systems may require states to generate more information about existing infrastructure, planned improvements, and work progress. Information on lane widths, bridge clearances, abutment locations, intersection designs, and all associated information will be of great value to the industry. CEOs can expect to face questions regarding preparedness for designing a system that supports new vehicle technologies.

New investments in infrastructure to facilitate V2I communication will be required to implement connected vehicle programs. The spectrum and technology questions remain unanswered, as noted earlier, with AASHTO working to ensure that the 5.9 GHz band remains free from interference and is used solely for CV purposes. DSRC, advanced cellular, Wi-Fi, and Wi-Max all have potential connected vehicle applications. If safety is the primary concern, it is unlikely that the public will allow private infrastructure investments to provide traffic control or lane keeping.

Urban areas, with greater lane volumes, more traffic control devices, and limited rights-of-way, will likely require creative and more costly retrofits to accommodate connected vehicles. If V2I were deployed in rural areas, with limited access to electricity or broadband, substantial infrastructure upgrades to accommodate the technology would be required.

Automation may rely on consistent signage, pavement markings, or even roadway materials. Separated infrastructure may be required in urban and rural areas alike. Parking, lighting, and safety barrier requirements may be relaxed if vehicle utilization increases. Flexibility in designs – at least as CV transitions in – is an approach that may benefit states considerably.

5.0 Workshop Review and Findings

On September 10, 2014, state DOT CEOs and other leaders gathered in a National Cooperative Highway Research Program (NCHRP)-sponsored workshop at the ITS World Congress in Detroit, Michigan. The workshop was designed to focus on issues related to the preparation of state DOTs for the world of connected vehicles and ATDM. Through a facilitated conversation with state DOT CEOs guided by those questions posted throughout this report, the state DOT CEOs addressed a wide range of issues, challenges, and opportunities. The following questions were posed to the CEOs in advance to use as a guide for workshop preparation. The questions were intended to frame some of the discussion at the workshop and reflect the current state of the practice as states begin to plan, design, and operate the transportation network of the future.

Overall High-Level Discussion Points

- What are the issues today's CEO must consider?
- How will the CV environment change the DOT in the short term? Longer term?
- Are V2I deployments a strategy to augment current capacity or another layer of infrastructure?

Policy and Regulation Area

- What legislation, if any, would be needed to help advance funding for CV infrastructure and operation in your state?
- How do you see CV being implemented in your state? Are there issues at different levels of government that will need to be addressed?
- What do you see as the biggest human resource challenge to CV deployment within your agency?
- What are the first steps needed in aligning your current workforce to become a CV-ready agency?
- What do you see as the first items your legislators will ask you about with regard to CV within your agency?
- What privacy, security, and other legislative issues do you see as critical in your state?

Planning, Design, and Operations Area

- What are some of the first areas within your DOT that will need to adapt to a CV space?
- What did you see at the World Congress that influenced your views on CV for your DOT?
- How does the CV future influence your infrastructure investment decisions today? What about in five years from now? What needs to happen within a certain timeframe to accommodate the forthcoming drastic changes in the way transportation infrastructure is funded in your state?
- What specific infrastructure investments need to be made to facilitate new technologies? Do these vehicles need dedicated infrastructure? Is there a substantial difference between urban and rural investments with respect to these technologies?
- Did you see technologies or exhibits at World Congress that changed the way you see the infrastructure future in your state? How? What ITS elements are in place now that you expect to use to support a CV environment? Are you currently investing in technologies that may go away?
- What resources do DOTs need "now"? What resources will DOTs need in the short to medium term? What are the research needs of DOTs and how can FHWA/TRB help fill them?
- Our current roadway network is generally equipped with communications, power, sensors, and detection. How will CV build on this existing system and what steps need to occur now to position your DOT to quickly harness the CV environment?
- How do you see your workforce changing? What about staffing, training, or hiring in-house personnel as experts or outsourcing for that expertise?
- How can AASHTO best communicate CV guidance from U.S. DOT and information provided by the CV industry (OEMs, technology providers, etc.) to create CV resources that will help state DOTs that have just begun to grapple with the planning challenges of Connected Vehicles?

5.1 Workshop Discussion

This section highlights some of the important items discussed during the workshop. AASHTO Executive Director Bud Wright opened the conversation with his observation for the connected vehicle industry – simply that we do not know all of the answers. AASHTO's objective was to get as many state DOT CEOs to attend the World Congress as possible and to expose them to CV technologies and opportunities for implementation. He hoped that workshop participants were able to consider short- and long-term goals regarding CV in the context of their departments. AASHTO will support DOTs by monitoring the implementation challenges that DOTs face as CV technology deployments approach and by facilitating peer exchanges about deployments. The outcomes from this workshop discussion will be used to inform AASHTO's connected vehicles strategic direction.

Robert Arnold, Director of the FHWA Office of Transportation Management, provided an additional welcome and background. Specific to the CV discussions, the FHWA will release V2I Deployment Guidance in 2015 and released a draft version of the document during the World Congress. Mr. Arnold hoped that each state representative would review this draft document and participate in the discussions with FHWA on the deployment guidance materials. He indicated that Moving Ahead for Progress in the 21st Century Act (MAP-21) includes funding provisions for performance management strategies, but it does not explicitly include an ITS category. ITS strategies are typically well-suited for performance management, however, and they are strong candidates for such funds.

The CEOs participating in the workshop concurred with Mr. Wright's statement and offered their own views on the issues and challenges facing state DOTs. Lance Neumann of Cambridge Systematics then led a facilitated discussion with the CEOs to discuss the transportation network of the future and what it means to today's state DOT.

During the World Congress the Belle Isle technology showcase exhibited how autonomous vehicles are close to becoming a reality – at least in proof of concept; however, not all technology, legal, and liability issues are resolved and there are still technological issues to be addressed. The costs of CV components may put the technology out of reach for the general population at present, but these costs are declining and are expected to soon be such that they are accessible to the mainstream consumer. It is difficult at present to predict whether CVs will lead or follow fully autonomous vehicles. There also is the possibility that autonomous vehicles will not become a mainstream reality at all, and this potential outcome must not be excluded from the conversation at this workshop.

At the Congress the auto manufacturers clearly stated that they are committed to V2V technologies. Mary Barra, CEO of General Motors, announced Cadillac's plans to begin introducing semi-autonomous cars and systems within two years (called Super Cruise). The role of DOTs will be largely focused on V2I applications, such as installing RSUs on sharp curves to provide warnings to approaching, properly equipped vehicles. The benefits of V2I are expected to be more significant than those of V2V initially, as V2V benefits require a certain degree of market penetration before they are realized. There will be a role for DOTs with V2V and that role is yet to be defined.

DOTs are not accustomed to the rapid pace of developments in technology, and their processes may not be well suited to accommodate it. Innovation and change are happening fast and will likely outpace government's ability to set standards and regulations. Typical regulation processes take over five years, which represents multiple generations for technology hardware. For the connected vehicle industry, it is a tremendous amount of time and the pace of change is accelerating. This may represent the larger hurdle facing DOTs regarding a CV future.

Changes in technology require new workforce skills and organizational structures in agencies. Many state DOTs may not be prepared to meet the demand for new skills that will be required to implement these technologies. There needs to be a focus on workforce development and training to align needed skills with operational requirements.

Data is the currency of the future's automated and connected vehicle environments. Data-sharing arrangements with third-party providers, open data, and data collection equipment and investment are key elements of implementation.

Chief executives would support the development of a national initiative on CV. If each of the state DOTs has disparate regulations and structures, innovation and implementation will be impeded. At the same time, overregulation at any level may stifle innovation.

511 is an illustrative example of an ITS system whose deployment was constrained by the longer implementation timelines common to DOTs. As a result, it was already becoming obsolete even before it was fully deployed.

Cybersecurity issues remain a concern. The opportunity to "hack" systems will remain a critical risk for states to address.

The informed discussion and detailed conversation among executives at the workshop raised important themes of issues and challenges and was followed by a discussion on actions and next steps to take. These workshop findings are presented below.

Issues and Challenges

There were five major themes that emerged from the discussion among the CEOs. Each theme area touches upon the others and has multiple levels. For instance, data systems have challenges associated with housing and managing the vast and varied transportation data, as well as managing a work force that will support the large quantity and varied quality of data. Below is a summary of the key challenges discussed at the workshop.

Data

Data was presented as the currency of future transportation opportunities. The DOTs collect, analyze, and archive great volumes of data. Within each data set there are issues of accuracy, granularity, ownership, governance, and quality. Between states, there are issues of standardization. Within a DOT there are issues of changing skill sets of the DOT employee required to harness the power of the data being collected. When the private sector enters the data discussion, the DOT is the convener. The DOT data should be "machine ready" if meaningful partnerships are to be advanced. Data-sharing arrangements with third-party providers, open data, and data collection equipment and investment are key elements of implementation.

Competing Priorities

Today's DOT is constantly challenged with funding constraints, and it appears this concern will not subside until comprehensive, long-range transportation laws are enacted to address the issue. With the funding challenges related to maintaining the existing transportation system the competing priority of a DOT focusing on technology systems, expansion or enhancements is a severe limiting factor. When technology and highly automated vehicles are brought into the discussion of what today's DOT is managing, competing priorities often dictate or limit a direction. The CEOs attending the workshop encouraged AASHTO to speak in a single voice in relaying the message to address long-term transportation funding in Congress.

Infrastructure Design Implications

> *Strategies such as adaptive signal control, adaptive ramp metering, dynamic shoulder use, variable speed limits, congestion pricing, incident management, and dynamic lane management are all promising Transportation Systems Management and Operations (TSM&O) strategies that rely heavily on rich traffic data.*

The CEOs discussed the infrastructure requirements of a future transportation system. The infrastructure needs specific to the connected vehicle are outlined in the AASHTO Footprint Analysis. It was generally understood that planning for these systems must start today to be ready for the arrival of highly automated connected vehicles. A model used in Utah was highlighted as a success: Utah DOT builds in communications infrastructure (either empty conduit or fiber optics) with each roadway project. Having done this over the past 15 years, Utah DOT now has a substantial and meaningful communications network. It was noted, however, that until the specific "needs" of the future system become known, it is difficult to do much. There are still many unknowns and the system must be viewed as a whole rather than as individual deployments (currently seen as pilot deployments). We don't know what we don't know and until that basic definition of needs occurs it is difficult for the DOT to plan. Once a planning horizon is defined, aspects of design will then need to be addressed.

Mobility and Safety

With respect to mobility and safety, the CEOs agreed that a system needed to be secure. Issues related to cybersecurity, credentialing authorized data and message providers, and hacking need to be addressed. While the safety benefits appear to present a solid case for making investments, the reliance on systems may open other issues of liability. At the same time, the CEOs expressed an appetite for retiring some customer mobility service options such as 511 systems that may have outlived their usefulness.

Workforce and Innovation

Innovation and change is happening fast and will likely outpace government's ability to set standards and regulations. The typical regulatory process takes over five years - multiple generations for technology hardware. For the connected vehicle industry the pace of change is accelerating. The workforces for future DOTs will be smaller, likely with further reduced resources at their disposal. The skill sets necessary to provide for this future mobility are not clearly understood at this point, providing a significant challenge to organizational change. Changes in technology require new workforce skills and organizational structures in agencies. Current state DOTs are not prepared to procure employees with the new skills that are required to implement these technologies and will be required to make a focused effort to align needed skills with operational requirements. DOTs often lack the basic staff capabilities to engage the new private sector data providers in effective and efficient manners.

Actions/Next Steps

To facilitate the discussion, Lance Neumann of Cambridge Systematics next focused the workshop participants on a discussion of potential next steps. The question: as CEOs of state DOTs, what action items have emerged while exploring the World Congress and having this discussion, and how can we advance ATDM and CV within the context of the future DOT.

Several participants noted the value of AASHTO's leadership in the CV program and how the DOTs rely on AASHTO for being that "one strong voice representing all of the DOTs." AASHTO has built a strong and advantageous relationship with the auto manufacturers. A clear desire emerged for AASHTO to lead and explain the importance of ATDM and CV for inclusion in the next Federal transportation funding bill. It also was noted that AASHTO's leadership is necessary in order to have a clear national initiative on the connected vehicle. It was recognized that now is the time for CEOs to establish a path for the CV within DOTs while recognizing that some states will be lead implementers, others will be mid-level participants, and some states will choose to watch and wait for their time to enter the programs. Regardless, all agreed that greater visibility and understanding of the path to CV benefits all states.

The CEOs also noted that with the numerous unknowns the DOTs are at a disadvantage. Each state should work to identify and articulate priorities, objectives, and goals to be addressed by CV and the autonomous vehicle. Having goals clearly defined will guide future investment decisions and foster the establishment of funding priorities within the DOT.

Several CEOs were concerned about the need for CV standards to ensure consistency across states. Several states are involved with pilot projects and, although early, standards should be considered. CEOs noted a need for information on potential costs, recognizing and addressing security issues, and making the business case for various CV applications.

The below actions captured the next steps identified by the workshop participants.

Developing a Vision for the Connected Transportation System of the Future

It is the CEO's role to establish the vision and set goals for the world of CV, not design the "how." The future of CV has unlimited potential and DOTs will not do it all. DOTs must allow the private sector to "achieve the how." DOTs are in the position to challenge industry to help them get to that future state.

High-definition maps for autonomous driving applications require highly precise roadway data—something that DOTs also require for their maintenance monitoring programs. By establishing partnerships for shared data collection, both of these entities could reduce costs.

The CEOs recognized that there is a lot of uncertainty surrounding the deployment and evolution of CV technologies and that the private sector would drive much of this agenda with or without action from the public sector. As a result, the CEOs thought it was important for AASHTO and the states to articulate a vision for the connected transportation system and use this vision as a platform for discussion and collaboration with a range of private sector partners. Elements of such a vision that ought to be considered include active traffic management, real time decision-making (signals, lane management, shoulder lane management, congestion pricing, incident management, etc.), a concerted push toward zero fatalities, more mobility options, and one integrated multi modal system. In the workshop there was support for AASHTO (or others) to commission an effort to develop such a vision.

Securing CV Financing

Securing financial support for CV within the state DOT environment will be require achieving consensus among stakeholders regarding V2I policy statements. These statements should include language supporting CV in upcoming transportation funding reauthorization. Approaching legislators as a unified body of DOTs, officials, and other stakeholders will show coordinated, collaborative support for the deployment of V2I technology. A funding vision that describes the "smart transportation system of the future" might be a more successful approach than "rebuilding the infrastructure of yesterday".

V2I Deployment Coalition (V2I DC) Involvement

FHWA, AASHTO, ITE, and ITS America have identified many relevant partners and stakeholders to include in the V2I DC. The coalition will create a CV/AV task force within its operations subcommittee to work closely with the coalition exploring issues specific to AV. The list of stakeholders/members will be inclusive, encompassing auto manufacturers, device OEMs, TRB, Crash Avoidance Metrics Partnership (CAMP), and other private- and public-sector associations. AASHTO has a reputation for consistently delivering on projects and initiatives; it could leverage this credibility to encourage private-sector participation in this coalition.

Recognizing that not all state DOTs were able to attend the ITS World Congress, AASHTO or the V2I DC should develop a strategy to educate and engage all states in exploring the implications of CV.

Also, the CEOs must work with AASHTO to ensure that all committees within AASHTO are informed and engaged in the CV discussion. The emergence of CV will influence all areas of

DOT operations – from planning to design and operations. Failing to engage other AASHTO committees will hamper implementation.

Define a Data Strategy

Workshop discussions also focused on issues surrounding data and data systems the DOTs currently have, currently have but may outsource in the future, and currently have at accuracy levels that need adjusting. CEOs understood that each state needs to develop a data strategy that addresses what data is needed, how it will be obtained, and which entities (public or private) are responsible for its collection. The DOTs need to determine how to provide guidance regarding data sharing and ownership, including having a framework for requesting data (including procedures, formatting, and structure). That framework would address strategies for accommodating the large volumes of data that will be generated with the advent of CV, ATDM, and AV. Forming data partnerships with mapping and other mobility services firms may be a critical first step. Both Utah and Florida have entered into agreements with mapping firms to begin sharing data and information.

Watch Freight for the Early Wins

Most CEOs in the workshop agreed that freight systems were important to DOT operations and may offer early wins and cost benefits for CV. Because fleets already have some of the necessary equipment and the freight community encompasses a population of more than two million drivers it is a readily available and suitable community for testing and confirming the viability of CV technologies and systems.

As with other CV and ITS applications, there will be regulatory and technological challenges to overcome before any freight pilot projects can be executed, but the benefits are attractive.

Engage DMVs

DMVs will become active partners as CV enters the mainstream. Some states are already using their DMVs to establish regulations for CVs. As CV visions and goals are established, the DMV should be a valuable stakeholder within each state. Issues concerning licensing, regulation, and registration will be handled by DMVs; without their cooperation and consultation, the large potential benefits of CV will be squandered.

Resist Legislating CV/AV

Legislators may inadvertently stifle innovation if they enact overly restrictive laws and regulations to govern CV/AV (a situation which is not unprecedented). Given the current uncertainty regarding CVs and AVs, it may be prudent to defer any significant legislative action until efforts such as activities with the V2I DC and other stakeholders have made additional progress on addressing the issues. As one participant stated, a simple and effective message is needed when legislators broach the subject. CEOs might indicate that the DOTs are not interested in legislating at the present time and that details are still taking shape, and if, on the legislator side, a process starts, that they should engage the DOTs before much detail is decided on.

Learn from Lead States

States should act as incubators, but at the same time not go it alone. States should pool resources to optimize pilot testing efforts and explore approaches to system security and credibility. The better approach is not to think of individual technology projects, but to bring technology along with each and every DOT project.

U.S. DOT will be sponsoring new CV pilot projects over the next several years. Lead states will be heavily involved in these pilots and will generate lessons helpful to all states.

Develop an Understanding of DOT Staff Development

It was clearly stated by several participants that the DOT of the future will look very different from the DOT of today. The DOT's role will change as more and more technology is deployed. This increase in technology and the introduction of accompanying data systems will require a shift in the workforce. A workforce today of civil and construction engineers will be supplemented with computer scientists, data engineers, and programmers. Today's planners need to be versed in the technology that may impact their projections and modeling efforts. The transition will occur slowly, but the planning for this future workforce must start today.

6.0 Summary

The underlying concepts and technologies supporting the Connected Vehicle program have been referred to as transformational. Up to this point, independent, disparate efforts have addressed an isolated technology or a specific corridor configuration. Proof of concept and research results are stacking up. That transformational realization is now at the doorstep of each and every state DOT in the nation, whether it is a rural state challenged with ways to better manage weather events or a highly urbanized area that must address safety and mobility issues.

To date, a few states have engaged in pilot tests, proofs of concept, and research documentation. Federal activities have further advanced the development timeline by funding standards activities, deployment tests, and other planning and policy activities. U.S. DOT has announced an aggressive pilot program that will deploy an initial wave of projects. Through 2020, there will be multiple awards for implementing the CV via pilot tests.

While all of these efforts in the public sector are important and valuable, the private sector representatives at the World Congress made it clear that they are accelerating their efforts to deploy various CV technologies and that these efforts are likely to accelerate. To keep pace, AASHTO, FHWA, and the CV coalition may need to accelerate their efforts as well, including by continuing collaboration with the full range of stakeholders engaged in CV efforts.

This final report is intended to inform and motivate the CV/AV conversation going forward, including identifying potential next steps for DOTs. The workshop discussions documented in this report should assist AASHTO and FHWA in developing specific actions and schedules to advance various CV initiatives. In addition, there is interest in developing a strategy to address CV funding and to follow up on workshop results.

Appendix A. Glossary of Terms

	Definition
Active Transportation Demand Management (ATDM)	An approach to dynamically improve operational efficiency through use of one or more of several options. Also referred to as Active Traffic Management (ATM).
Aftermarket Safety Device (ASD)	A connected device in a vehicle that operates while the vehicle is mobile but which is not connected to the data bus of the vehicle.
Backhaul	The closed network communication links between a Traffic Management Center (or other back offices), links between TMCs, and field installations (such as traffic signal controllers, traffic cameras, and other sensors). This could also include the link between the Security Credential Management System and roadside distribution device.
Basic Safety Message (BSM)	The core data set transmitted by the connected vehicle (vehicle size, position, speed, heading acceleration, brake system status) and transmitted approximately 10x per second. A secondary set is available depending upon events (e.g., ABS activated) and contains a variable set of data elements drawn from many optional data elements (availability by vehicle model varies). This would be transmitted less frequently. The BSM is tailored for low latency, localized broadcast required by V2V safety applications but can be used with many other types of applications.
Crash Avoidance Metrics Partnership (CAMP)	A consortium of Toyota, Nissan, Honda, Mercedes, Hyundai-Kia, Volkswagen/Audi, GM (Principal Member), and Ford (Principal Member). CAMP was formed to accelerate the implementation of crash avoidance countermeasures in passenger cars to improve traffic safety.
Connected Device	Any device used to transmit to or receive messages from another device. A connected device can be subcategorized as an OBE, ASD, VAD, or RSE. In many cases, the connected device will be a DSRC device, but other types of communications can and are expected to be supported.
Connected Vehicle (CV)	A vehicle containing an on board unit or aftermarket safety device. Note that vehicles may alternatively include a Vehicle Awareness Device (VAD), which transmits the BSM but does not receive broadcasts from other devices and cannot directly support vehicle-based applications

	Definition
Connected Vehicle Reference Implementation Architecture (CVRIA)	A set of system architecture views that describes the functions, physical and logical interfaces, enterprise/institutional relationships, and communications protocol dependencies within the connected vehicle environment. The CVRIA defines functionality and information exchanges needed to provide connected vehicle applications.
Dedicated Short-Range Communications (DSRC)	DSRC is a technology for the transmission of information between multiple vehicles (V2V) and between vehicles and the transportation infrastructure (V2I) using wireless technologies.
Global Positioning System (GPS)	Using satellites to calculate the longitude and latitude. GPS can also determine altitude.
Intelligent Transportation Systems (ITS)	Systems that apply data processing and data communications to surface transportation to increase safety and efficiency. ITS systems will often integrate components and users from many domains, both public and private.
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged.
Original Equipment Manufacturer (OEM)	An original equipment manufacturer refers to the entity that originally manufactures an item that may be branded and sold by others. In the Connected Vehicle environment, it is commonly used to refer to automobile manufacturers.
Roadside Equipment (RSE)	Term used to describe the complement of equipment to be located at the roadside. The RSE will prepare and transmit messages to vehicles and receive messages from vehicles for the purpose of supporting V2I applications. This is intended to include the DSRC radio, traffic signal controller where appropriate, and interface to the backhaul communications network necessary to support the applications, and to support such functions as data security, encryption, buffering, and message processing.
Roadside unit (RSU)	A connected device that is only allowed to operate from a fixed position (which may in fact be a permanent installation) or from temporary equipment brought on-site for a period of time associated with an incident, road construction, or other event. Some RSEs may have connectivity to other nodes or the Internet.
Security Certificate Management System (SCMS)	A proposed governing body for security services in which some representatives of state and local transportation agencies would logically be included. The SCMS is being finalized by the automotive OEMs, with assistance from academia and the security industry. This system is based on the principle of maximizing individual privacy while maintaining highest levels of security.
Transportation Management Center (TMC)	A regional or statewide location where traffic freeway operations management systems are based. Data about the freeway system

	Definition
	are collected and processed, fused with other operational and control data, synthesized to produce "information," and distributed to stakeholders such as the media, other agencies, and the traveling public from the TMC. It is also where agencies can coordinate their responses to traffic situations and incidents.
V2V	Short for vehicle-to-vehicle communications: a system designed to transmit basic safety information between vehicles to facilitate warnings to drivers concerning impending crashes.
V2I	Short for vehicle-to-infrastructure communications: a system designed to transmit information between vehicles and the road infrastructure to enable a variety of safety, mobility, and environmental applications.
V2X	Communication from vehicles to all other devices/modes not covered by V2I or V2V. This could include pedestrians, motorcycles, construction equipment, railcars, etc.
Wireless Mesh Network	A wireless mesh network is a large wireless network that is built by stitching many smaller, individual wireless networks together. As two or more suitable individual wireless networks come within range of each other, they may connect to each other and form the beginnings of a mesh network. This mesh network will then grow and shrink as other individual wireless networks come within range or go out of range of the rest of the mesh network.

Note: Most definitions from 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products Handout, September 2014.

Appendix B. Participants

State DOT CEO Leadership Forum A Focus on Transportation Futures

Participant List

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