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Paths of Automated and Connected Vehicle Deployment: Strategic Roadmap for State and Local Transportation Agencies

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16. Abstract

Automated (AV) and connected vehicle (CV) technologies are now maturing. Exactly how close they are to wide-scale deployment is highly uncertain. While still on their respective paths to full deployment, the technologies have implications for state and local transportation agencies now. What strategies can transportation agencies begin implementing to help them function effectively regardless of what the future brings? This study answers this question by formulating scenarios for AV and CV paths of deployment, using them as a basis for interviews with state and local transportation agencies, and surfacing strategies to prepare for potential issues. Two scenarios were developed. In the *Revolutionary Path*, the private sector pushes the technologies to the market through aggressive R&D investments. Regulatory and policy issues do not hinder progress. Self-driving vehicles are present on the roads in significant numbers by 2025. In the *Evolutionary Path*, the private sector makes step-wise improvements in advance driver assistance systems. Policy, regulatory, and technical issues slow testing and deployment. Significant numbers are not achieved until 2050. Even though evolutionary, the second scenario was perceived as surfacing operational, organizational, and fiscal challenges. The Revolutionary Path was perceived as highly disruptive. Under either, most agencies want to know what the private sector expects of them. Both scenarios caused state and local agencies to consider their preparedness of their workforce. With AV, transportation agencies are faced with a new paradigm of technology deployment – quite different from the intelligent transportation system (ITS) model. CV is perceived closer to the ITS model, in which agencies have more responsibility and control of deployment. Strategies to prepare include review of current legislation, establishment of working groups, outreach to policymakers, planning for workforce development, and addressing economic impacts.

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PATHS OF AUTOMATED AND CONNECTED VEHICLE DEPLOYMENT: STRATEGIC ROADMAP FOR STATE AND LOCAL TRANSPORTATION AGENCIES

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EXECUTIVE SUMMARY

It is 2025, and a critical mass of self-driving vehicles is traveling on U.S. roadways through disruptive innovation in the automotive sector. This future is plausible. Also plausible is a future of slowly evolving automated vehicle (AV) and connected vehicle (CV) deployments so that a critical mass is not traveling until 2050. Trying to predict which of these plausible futures, if either, will actually happen in today's dynamic environment is at best challenging. The answer is probably somewhere in between the two extremes but still highly uncertain. While AV and CV technologies are still on their respective paths to full deployment, they do have implications for state and local transportation agencies now. What strategies can these agencies begin implementing today to help them function effectively no matter what the future brings? This study answers this question by formulating scenarios for AV and CV paths of deployment, using the scenarios as the foundation for interviews with state and local transportation agencies on implications and impacts, and surfacing strategies to prepare for potential issues.

Scenarios of Paths of Deployment

Two scenarios were developed through literature search and expert workshops. In the *Revolutionary* path, automotive manufacturers (original equipment manufacturers [OEMs]), suppliers, and technology firms make disruptive and aggressive R&D investments that accelerate progress in AV and vehicle-to-vehicle (V2V) technologies. Federal and state policies do not hinder development. Vehicle-to-infrastructure (V2I) technology gets stalled in political and financial debates over the business case. The private sector pushes the vehicle-centric applications, and consumer demand is strong. Self-driving vehicles are present on the roads in significant numbers by 2025. In the *Evolutionary* path, OEMs and suppliers achieve step-wise improvements in advanced driver assistance systems (ADAS). But making leaps to limited self-driving automation and then to fully self-driving vehicles proves very challenging. The higher levels of automation pose policy, regulatory, and technical problems at the national and state levels that are slow to resolve. Deployment of CV technologies also bogs down as regulators try to settle on minimum standards. Significant numbers of self-driving vehicles are not present on roads until around 2050. Recognizing that these scenarios represent two opposed extremes, they were presented to a small sample of state and local transportation agency leadership and technical experts to elicit their reactions and to surface the implications.

By small margins, state DOT interviewees thought that the Evolutionary scenario would be most likely, and it was also the most preferred. The main reason was that it would be less disruptive for the agencies. A few thought that AV would follow a Revolutionary path, while CV would follow an Evolutionary path. On the contrary, most local and regional transportation agencies interviewed considered the Revolutionary scenario most likely and most preferred. The rationale was that if the private sector pushes this quickly, they would bring financial resources.

The two scenarios raised different implications for state and local transportation agencies. Even though the Evolutionary scenario was slow to deploy, it was perceived as quite challenging. Interviewees identified operational, organizational, and fiscal challenges. Most want to know what the private sector expects from them. The major implication of the Revolutionary scenario was that they would need to react very quickly to what is *actually* happening rather than being able to take the time to examine what *could* happen. Among specific issues raised were: how it

might change long-term investment strategies and how the transition period, when mixed traffic was on the road, would work. Both scenarios caused interviewees to consider the preparedness of their workforce.

Expectations Regarding AV/CV Deployments

One might view AV/CV implementation among state and local agencies as following an intelligent transportation system (ITS) implementation model, which has been characterized nationally as slow and spotty. However, particularly with AVs, state and local agencies are faced with a new paradigm in technology deployment. With ITS, state and local agencies were in control of when and how the technology would be deployed. With AV technology—whether evolutionary or revolutionary—the perception among state and local agencies is that deployment is driven by the OEMs and the technology firms. Consumer demand may place AVs on public roadways while the regulatory and policy issues are still being worked out. CV technology is perceived as being more like the ITS model of implementation. Interviewees thought the public sector has more responsibility and control in the CV realm. The OEMs are perceived as still having a role in the CV realm, but it will be more prominent in V2V than in V2I. For this reason, there is greater certainty among the interviewees that V2V will happen. On the other hand, there was uncertainty about if and how V2I would deploy mainly because of the costs of implementation.

Strategies to Prepare for Future Deployments

Given where the industry is today with AV/CV technologies, there are strategies that surfaced in the interviews with state and local transportation agencies that would be robust over a wide range of potential alternative AV/CV futures. A successful AV/CV implementation strategy for state departments of transportation, metropolitan planning organizations, and cities might include the following elements:

- Review of current legislation and policies that could potentially impact the implementation of AV/CV technologies.
- Designation of a specific individual within the organization who has responsibility for AV/CV.
- Participation in the national discussion on AV/CV. This may include such groups as the V2I Deployment Coalition (led by ITS America, American Association of State Highway and Transportation Officials [AASHTO], Institute of Transportation Engineers [ITE], and Federal Highway Administration [FHWA]), the AASHTO Connected Vehicle Task Force (made up of state departments of transportation [DOTs] and two Canadian provinces), and CV pooled fund initiatives.
- Establishment of a working relationship with resources in the state or region with useful expertise, such as universities, university transportation centers (UTCs), and national laboratories.
- Establishment of an internal group made up of people in affected groups across the transportation agency organization in order to develop a strategic plan or roadmap for implementation.
- Establishment of an external group of stakeholders to assist in identifying and addressing issues and to serve as a sounding board for strategic plans/roadmaps.

- Outreach to state and local policy makers to familiarize and educate regarding AV/CV.
- Participation in competitions for federal deployment pilots to gain “boots on the ground” experience.
- Development of a plan for workforce development.
- Formulation of a strategy to address the financial challenges of implementation. This strategy may include how AV/CV would help with economic competitiveness and increased operational efficiency.

INTRODUCTION

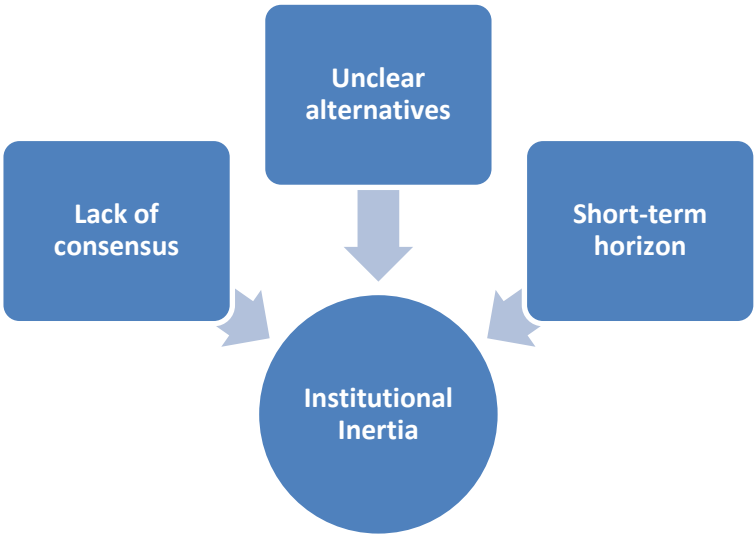
Objectives

Automated and connected vehicle technologies have emerged and are now maturing. Exactly how close they are to wide-scale deployment is highly uncertain. These technologies are expected to have a number of significant societal benefits: traffic safety, improved access to mobility, improved road efficiency, reduced cost of congestion, reduced energy use, and reduced fuel emissions. Societal, political, technical, and economic factors will influence their paths to deployment. A significant characteristic of the AV/CV environments is their speed of change. Transportation professionals and researchers anticipate that AV/CV will introduce big changes in the way Americans travel and the transportation system they use to do so (NHTSA 2013). The nature of these changes and their resulting long-term impacts are unclear; they will most likely vary from state to state. State and local transportation agencies need to understand what this means for them and what they need to begin preparing for now.

The objectives of this research are to (1) formulate scenarios for AV and CV paths of deployment, (2) examine how the plausible scenarios could affect state and local transportation agencies, and (3) provide a strategic roadmap to assist these agencies in preparing for or responding to potential issues.

This research is necessary because state and local agencies tend to be risk averse in reacting to change. Their decisions must address the needs and requirements of multiple constituencies (i.e., the public, state legislators, and federal agencies), and they often face a lack of consensus among these constituent groups. As such, they tend to move forward deliberately and slowly. In addition, funding limitations constrain the ability of the public agencies to experiment or rework investments if change is needed. So they often find themselves with unclear alternatives for moving forward, which leads to short-term planning horizons. Altogether this set of factors and dependencies can lead to institutional inertia, which in turn may influence their effectiveness in addressing evolving conditions, demand, and constraints (see Source: Goodin, 2014

Figure 1). The information resulting from this study can be used to clarify issues, support informed choices, and move state and local transportation agencies further along in proactive decision making.



Source: Goodin, 2014

Figure 1. Risk Aversion in Policy Development.

Background: A Primer on AV/CV

Automated Vehicles

AVs are defined as vehicles in which at least some aspects of a safety-critical control function (e.g., steering, throttling, or braking) occur without direct driver input. Vehicles that provide safety warnings to drivers (forward crash warning, for example) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide that warning involves varying degrees of automation. The adoption of AVs has the potential to greatly reduce or almost completely eliminate automobile crashes by removing human error from the driving equation. AVs use sensors, cameras, light detection and ranging (LIDAR), global positioning systems (GPS), and other on-board technology to operate with reduced, limited, and/or no human interaction (KPMG and CAR, 2014). AVs can be passenger, public transport, and freight vehicles. AVs are not necessarily autonomous. Autonomous vehicles are responsible for driving, solely and independently, of other systems. The Google Car is a prototype autonomous vehicle.

AV technology developments have focused on individual vehicle-centric applications. Vehicle manufacturers have been introducing new automation functions into their vehicles for many years, transferring more and more driving tasks to the vehicle related to both convenience and safety, such as adaptive cruise control, parking assist, and automatic braking. These are collectively referred to as advanced driver assistance systems. Combining these technologies creates more advanced, combined function automated systems.

The National Highway Traffic Safety Administration (NHTSA) has helped to clarify policy and technical discussions around AVs by defining levels of automation (see Source: NHTSA, 2013

Figure 2) (NHTSA 2013). The lowest level is no automation, where the driver is in full control of steering, throttle, and braking. Vehicles with Level 2 automation, such as adaptive cruise control and lane centering, are currently in production and marketplace deployment. At Level 3, the driver is able to temporarily turn attention away from the driving task to engage in other activities but needs to be available to retake control within a few seconds' notice. At Level 4, automated systems replace the driver completely, and the vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for the entire trip. NHTSA policy anticipates that at Level 4 the driver will provide destination or navigation input, but will not be expected to be available for control at any time during the trip, whether the vehicle is occupied or not.

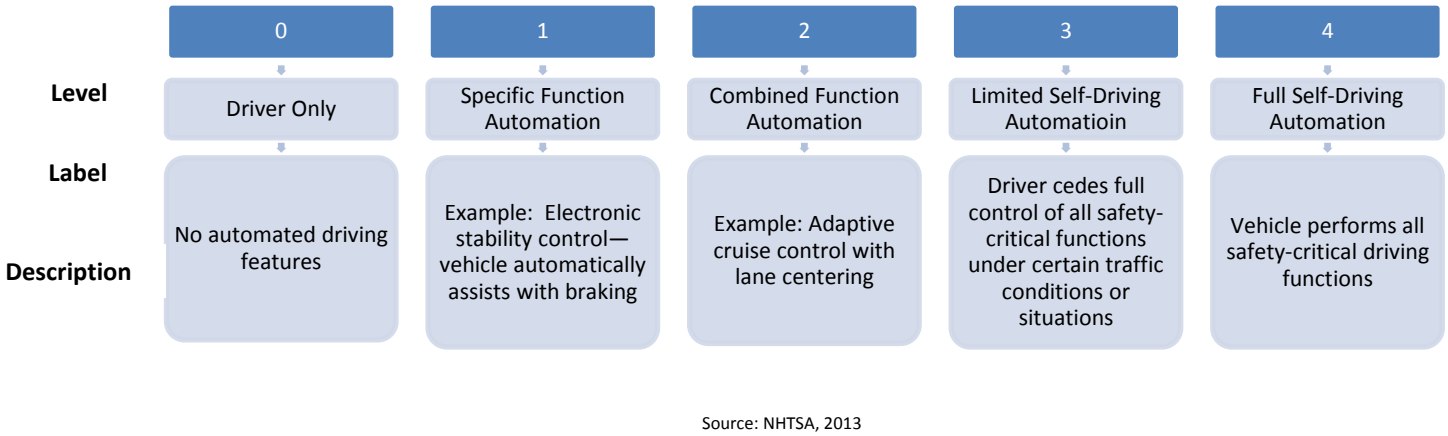


Figure 2. Levels of Vehicle Automation.

How do AVs work at higher levels of automation? An AV basically executes a four-step loop: (1) sense the environment, (2) decipher the location, (3) plan the next move, and (4) execute the plan (Katkoori et al. 2013). Based on this simplified four-step process, the key technology barriers to higher levels of automation are: ability to fuse data streams from multiple sensors, difficulty in handling a dynamic environment or surprise events, limited or unreliable GPS information, sensor susceptibility to noise from other electronic systems in the environment, difficulties in negotiating with human drivers, and inability to handle harsh driving conditions.

Even with these technical challenges, vehicles with varying levels of self-driving capability, ranging from single-lane highway driving to autonomous valet parking, may become available to consumers as soon as 2016 (Mosquet et al. 2015). Several OEMs and Tier 1 suppliers have demonstrated progressive capabilities. In 2013, Mercedes' self-driving car drove 62 miles on German roads. For the 2015 Consumer Electronics Show (CES), an automated Audi A7 traveled 550 miles from San Jose, California, to Las Vegas, Nevada (Shladover and Bishop 2015). Also at the 2015 CES, a fully automated 2015 BMW i3 with the ability to park itself without relying on a GPS signal was showcased (Gareffa 2014). In spring 2015, an autonomous car created by Delphi Automotive completed a 3400-mile trip from San Francisco, California, to New York City, using a modified Audi Q4 sport utility vehicle. The vehicle was equipped with long- and short-range radars, vision-based cameras, LIDAR, a localization system, intelligent software algorithms, and a full ADAS suite (Delphi 2015).

Many feel that the ADAS approach lends itself to evolutionary and iterative progression toward autonomous vehicles (Schwarz et al. 2013). From a business standpoint, automakers' incremental approach allows them to incorporate new features into their vehicles without any disruption to business as usual. It also enables them to offer premium technology and safety-oriented car features that do not depend on breakthroughs in technology, regulation, or liability. In this context, Google's entry into the automated vehicle space is seen as disruptive. Google's approach is to focus solely on producing a fully autonomous vehicle, thus allowing it to become a leapfrog competitor to the traditional automakers. The two approaches are often referred to as bottom up and top down, respectively.

Regardless of approach, AVs are a complex technology that requires testing on public roads. An AV must navigate many real-world situations that cannot be effectively simulated. Public road testing of the vehicles will advance the vehicles to market. Nevertheless, there are a number of technical, economic, legal, and policy challenges that may act as barriers to the implementation and commercialization of AVs (Anderson et al. 2014; Eno 2013; Wagner et al. 2014; Thierer and Hagemann 2014, Shladover and Gettman, 2014). Even though auto manufacturers are achieving higher and higher levels of automation, the production of fully driverless cars that can handle any road situation under any weather condition will require extensive research and testing.

Alongside the future testing by private sector entities, the public sector will need to consider the necessary legal framework or regulation detangling for allowing self-driving autos on the road. Some states have regulated testing to ensure the testing of self-driving autos does not result in harm to system users (Hendrickson et al. 2014; Williams, 2014; Wagner 2015). Other states are considering legislation, while many have reviewed state legislation only to confirm that AV testing was not prohibited. States will also have some role in thinking through the assignment of liabilities when accidents involving driverless cars occur. At the same time, there are standards issues, such as certification, driver's licensing, cybersecurity, and fail-safe operation that will involve some public sector state agencies (IHS Automotive 2014; Shladover and Bishop 2015).

In addition, there are market issues (such as consumer adoption and fleet turnover) that are highly uncertain. Because the technology is still developing, the cost of AVs when mass marketed is highly uncertain, which will in turn impact market penetration. There is the expectation that marginal costs for AV technology on a vehicle will decrease to under $10k (Tannert 2014). However, polling has suggested that only a small portion of US vehicle owners were interested in paying as little as $3000 to have autonomous driving mode in their next vehicle (J.D. Power and Associates 2014). The extent to which the AV technology is only on luxury or high-end vehicles will also impact market penetration. Insurance is another economic factor. What will happen to the insurance market in the context of autonomous vehicles when driving accidents are almost completely eliminated? There are indications that consumers who might own AVs would expect to receive lower insurance premiums (Zmud et al., forthcoming). But when all "drivers" are accident-free, how does the industry define a "good driver" discount?

Policy challenges exist at many levels of government. Privacy issues are a growing national concern, especially as the Internet and technology have made personal information more accessible and easier to collect, access, repurpose, or manipulate. Questions regarding the security, ownership, and use of automotive telematics data must be resolved to ensure policy maker and consumer acceptance of AVs (Stanley and Wagner, forthcoming). Another national

policy issue is the potential labor force implications. AVs could replace workers who earn their incomes as professional drivers or reduce the need for workers who provide medical treatment or vehicle repair relating to accidents. At the state and local levels, there are policy issues relating to road traffic regulation, including road access and rules of the road. Variations in state legislation could hinder the commercialization of AVs across the country. Many states do not have consistent definitions regarding "driver" or "operator" of the car, and so, it might take federal intervention to standardize terms and their application in the context of AVs (DiClemente et al. 2014).

Connected Vehicles

Unlike the case with AVs in which developments are due largely to a private sector push; CV technology has been managed by the US Department of Transportation (USDOT) through entities like the Joint Program Office (JPO) and NHTSA. CVs are defined as vehicles with the onboard communications capability necessary to establish a two-way data linkage between a system onboard and another system not onboard (Baxter 2012). CV systems are comprised of hardware, software, and firmware that allow for the dynamic transfer of data. CVs can be connected to each other (V2V), connected to infrastructure and roadside sensors (V2I), and connected to other road users such as pedestrians and bicyclists (V2X). USDOT efforts have focused on standards development for V2V and V2I message sets and communication hardware, as well as providing significant seed money for initial CV application and hardware development, testing, and analysis. The primary barrier for CV technology has been the absence of private sector willingness to invest in the technologies, in large part because of the lack of a viable business model: the first CVs will be more expensive and have almost no one else (or no other thing) to talk to, resulting in little consumer demand.

CVs are distinguished from connected cars, which may also refer to browser-based Internet functionality with an onboard display or vehicle-based infotainment applications. CV technology is also distinct from crash avoidance technology (i.e., onboard sensors, cameras, and radar applications) that is present on AVs. CVs communicate via dedicated short-range communications (DSRC) that are omnidirectional or potentially through cellular, wireless, or satellite connections. Communicating via these signals allows two equipped vehicles to see each other at times when other vehicles that are only relying on their sensors may not be able to detect the presence of another vehicle (GAO 2013).

USDOT interest in CV technology is due to its potential for vastly improved vehicle safety. Both V2V and V2I communication promise significant safety improvement (Brugeman et al. 2012). In the V2V realm, vehicles would broadcast a basic safety message that includes information such as vehicle speed, heading, and location that could be received by other equipped vehicles so that, cooperatively, crashes are avoided. V2V technology can be auto manufacturer devices that are integrated during vehicle production or aftermarket devices. In the V2I realm, safety is enhanced through communication to/from infrastructure. Broadcasts of signal phase and timing (SPaT) information at signalized intersections can be used for vehicle speed management to reduce the time vehicles spend idling at red lights and to improve traffic flow.

USDOT has prioritized the safety benefits of CV technology, and NHTSA plans to issue a proposed V2V mandate by the end of 2015 instead of in 2016 as originally planned. It is

expected that NHTSA would not require transportation agencies to deploy V2I because of the investment in new or upgraded infrastructure this would entail. In a survey of expert opinion, most respondents felt that a V2V-only system is possible and valuable, but that a complementary V2I system would be necessary to maximize full public benefits of CV technology (Brugeman et al. 2012). When CV technology is in enough cars, infrastructure, and other road users, a vast network is created. Cars and people are able to give and receive data in real time, allowing road travelers to move more safely and efficiently. A complete CV system will generally include the following components (Wright et al. 2014):

- Roadside communications equipment (for DSRC or other wireless services) together with enclosures, mountings, power, and network backhaul.
- Traffic signal controller interfaces for applications that require SPaT data.
- Mapping services that provide highly detailed roadway geometries, signage, and asset locations for the various connected applications.
- Positioning services for resolving vehicle locations to high accuracy and precision.
- Data servers for collecting and processing data provided by vehicles and for distributing information, advisories, and alerts to users.

Progress in the CV arena has been largely driven by top down (federal to state and local) government research, recommendations, and guidance. Safety applications have been a key goal of CV to date, although operational improvements are an important objective. While technical issues are being addressed through industry and university-based research and development, other important issues in CV deployment are related to funding (e.g., infrastructure investment), security (e.g., cybersecurity related), and legal issues (e.g., liability or regulatory).

CV technology is not required for highly automated vehicles. AVs are guided not by communication with other vehicles or roadside infrastructure, but by internal sensors, cameras, GPS, advanced software, and highly detailed digital maps. Likewise, highly automated vehicles are not necessary to reap the benefits of CV technology. CV and AV are conceptually different technological approaches, though some of the challenges they present to transportation agencies will be similar. Some believe the two technologies need to converge to obtain full mobility, safety, and environment benefits, while others envision completely autonomous vehicles that do not require communication with other entities. Whether the two classes of technologies develop on independent parallel paths or converge in the future is uncertain.

STUDY METHOD

Approach

In the current study, researchers developed two scenarios of potential paths of AV/CV deployment. These scenarios were used as a basis for interviews with state and local transportation agency staff to explore the impact and implications of AV/CV futures. Armed with this information, the research team identified strategies that agencies can implement now to prepare for a future that will include AV/CV technology (see Figure 3).

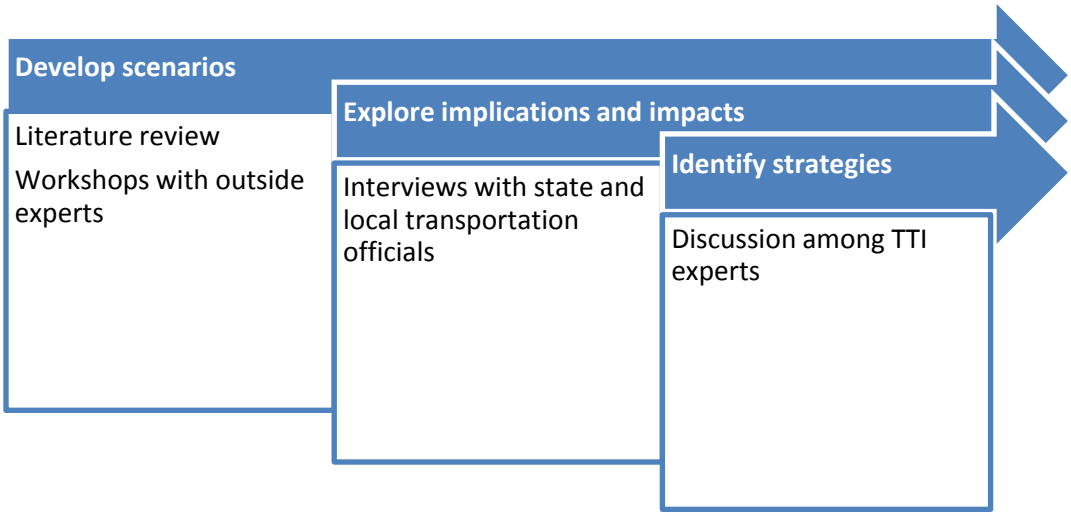


Figure 3. Study Approach.

Exploring AV/CV futures is a complex task that involves a considerable level of uncertainty. Scenarios are a time-tested tool to address this uncertainty (Pillkahn 2008, Courtney et al, 1997). A scenario is a "story with plausible cause and effect links that connects a future condition with the present, while illustrating key decisions, events, and consequences throughout the narrative" (Glenn 2007). There are several contemporary studies and initiatives that have developed future AV and/or CV deployment scenarios (e.g., Wright et al. 2014; Ernst & Young 2014; Hendrickson et al. 2014; Childress et al. 2015; and Levin and Boyles 2015). Most, if not all, have focused only on AV or on CV, considered a limited number of factors over an unspecified timeframe, taken a technology-focused approach in which the scenarios only consider variations in deployment contexts, or failed to distinguish scenarios from projections. In terms of the latter, computer models or simulations can be run to give alternative projections based on different assumptions or inputs to a mathematical model. If the inputs are changed, the output of the model is changed. These outputs are projections, not scenarios. The risk of this is that the full range of uncertainty is not part of the resulting scenarios.

The current study produced two scenarios to depict alternative visions of paths of AV/CV deployment. The research team developed the scenarios with consideration of a full complement of influencing factors (e.g., society, technology, economic, and policy). The different ways in

which these factors play out with and against each other are what lead to the two alternatives. The scenarios also represent extremes (see Figure 4). In this way, the scenarios anchor the edges of the ways in which AV/CV technology may develop in the future so that policy and planning activities at the state and local levels can proceed amid uncertainty. Together the scenarios represent a spectrum of possibilities.

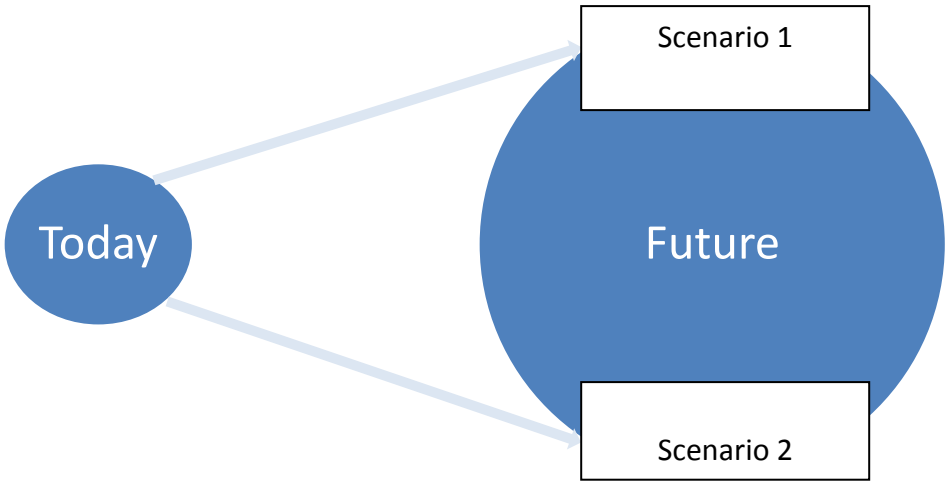


Figure 4. Scenario Approach.

Scenario Development

Scenarios can be developed using several different approaches. Here researchers describe the scenario development process used in this study. Because some of the terminology might be unfamiliar, researchers provide some key definitions in Table 1.

Table 1. Key Definitions.

Term	Definition	Example
Influencing Area	Broad category of major trends of change	This study uses four: • Society • Technology • Economy • Policy
Factor	One of the elements contributing to a particular result or situation	Economy contained four factors: • Consumer buying power • Sectoral disruption • Supportive infrastructure investment • Cost of self-driving technology
Projection	A prediction of a future value of a factor	For cost of self-driving technology, projections were related to additional cost to manufacturer's suggested retail price (MSRP) for a new vehicle

Influencing Areas and Factors

The scenario process began by identifying and examining influencing areas. An influencing area is a broad category of major trends of change. The four in this study were: Society, Technology, Economy, and Policy. A literature search was conducted to identify important trends within each of these influencing areas that might affect AV/CV deployments. Researchers reviewed academic, government, popular media, and industry reports on AVs and CVs, which were identified through Internet searches. The information gathered in the literature review was also used to (1) produce the syntheses on AV and CV technologies that are found in the introduction to this report and (2) identify the factors and projections that would be used to frame the scenarios. Researchers developed a long list of potential factors and narrowed these down to 16 factors based on two criteria: uncertainty and impact. Table 2 presents the list of factors.

Table 2. Factors by Influencing Area.

Influencing Area	Factors	Projection Metric
Society	Market demand for AVs	Degree to which consumers embrace fully automated vehicles
	Consumer acceptance of V2V and V2I	Degree to which consumers accept V2V and V2I applications
	Auto ownership trend	Rate of auto ownership
	Operating environments	Locations of early adoption (type of operating environment)
	Data privacy	Concerns over privacy and data collection
Technology	Interface between driver and vehicle	Ability to seamlessly and safely use vehicle in fully automated or manual modes
	Cybersecurity	Vulnerabilities adequately addressed
	Sensor technology	Speed of accuracy improvements for safety-critical functions (high, moderate, low)
	Vehicles' decision making under uncertainty	Capabilities for artificial intelligence (AI) decisions under unexpected traffic situations
Economy	Consumers' buying power	Ability to afford AVs
	Sectoral disruption	Extinction versus increase in jobs or industries
	Supportive infrastructure investment	Capacity of state to invest in supporting infrastructure for AV and CV
	Cost of self-driving technology	Additional cost to MSRP
Policy	Public policy perspective	Type of regulatory approach—precautionary or market-based
	NHTSA mandate on V2V technology	Year in which NHTSA mandates V2V
	Liability concerns from industry	Changes or shifts in insurance model

Scenario Frameworks

For each of the 16 factors, researchers determined projections based on the information gathered in the literature review. Because the factors were uncertain, researchers produced two or three projections for each factor. The resulting tables were the scenario frameworks. Researchers then held two expert workshops to refine the scenario frameworks. The workshops were held in Washington, D.C., and Austin, TX, and a total of 26 experts participated in the facilitated discussions. The list of participating experts is presented in Appendix A. The experts provided critical feedback on the credibility, consistency, and plausibility of the factors, projections, and the scenario framework as a whole. Researchers also asked the experts to provide their reasoning (or assumptions) for agreement with or changes in the projections. Researchers presented three scenario frameworks to the DC workshop participants. After that workshop, the information was refined and two scenario frameworks were presented to the Austin workshop participants. These two frameworks became the basis for the scenario narratives.

Scenario Narratives

Drawing on the reasoning and assumptions that surfaced during the expert workshops, researchers fleshed out the two scenarios into written narratives: the Evolutionary path and the Revolutionary path. Each scenario presents a distinct vision of how AV/CV might develop and deploy into the future. To further validate the scenarios, researchers sent the scenario narratives to all the expert participants to comment on whether they found the scenario frameworks plausible, understandable, and internally consistent. Researchers used their responses to ensure the relevance and sharpen the content of the scenarios. The resulting scenarios represent extremes, and the actual path of AV/CV deployment is expected to be between these two extreme visions. However, the use of extremes anchors the range of possible futures and also presents two clear alternative futures that work well as a basis for interviews with state and local transportation staff.

Interviews with Transportation Agencies

The Evolutionary Path and Revolutionary Path were developed from a systematic, empirical process, so they represent plausible futures to which transportation officials could react during the interview process. Personal interviews (either by telephone or in person) were conducted with state and local transportation agency staff to examine the implications of the AV/CV paths of deployment. Our original intent was to conduct interviews with a cross section of agencies in terms of levels of involvement with AV/CV activities. However, the persons with whom researchers were able to secure interviews tended to be those persons at leading edge agencies with respect to AV/CV awareness and knowledge. A total of 20 interviews were completed. The list of interviewees is presented in Appendix B. These individuals represent people who are known to have taken an interest in the topic. While emphasis was on state DOT staff, researchers did complete about one-third of the interviews with staff of regional or city transportation agencies.

The interview guide comprised nine qualitative questions, and interviews took an average of 30 to 45 minutes to complete. The interview guide is provided in Appendix C; it covered the following topics:

- General reactions to AV and CV, independently.
- Current policy or planning actions for addressing AV/CV.
- Scenario that is most likely and that is most preferred.
- For the scenario that was most likely:
    - Major implications for the agency.
    - Impacts to the agency's mission, responsibilities, or structure.
    - Possible policy or planning actions to address impacts and implications.
    - Strategies to shape or influence the scenario coming to fruition.

The scenarios are presented in the following section, followed by the results of the interviews with state and local transportation officials. The collated responses for all interviews are provided in Appendix D. The interviews represent a small sample of state and local transportation agencies and so the responses are not meant to be representative of the total universe of such agencies. The information provided in this report represents the thoughts and opinions of the persons interviewed for this study.

SCENARIO NARRATIVES

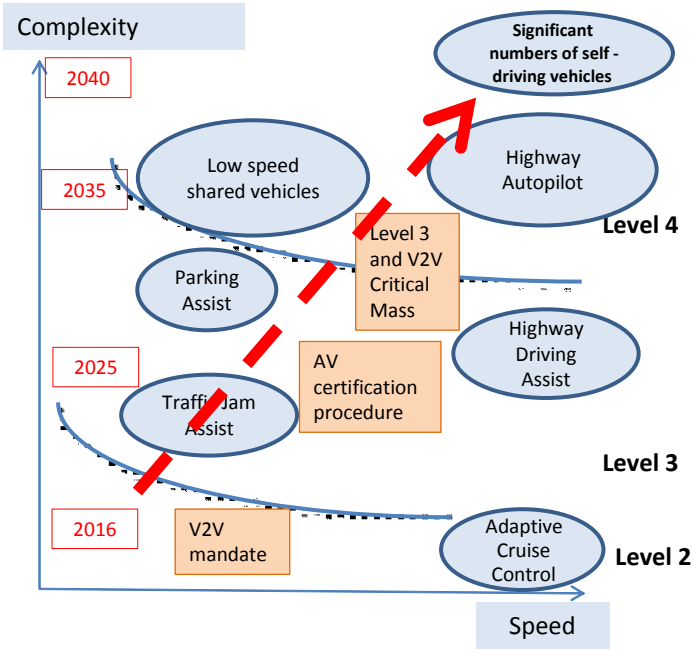
The two scenario narratives provide plausible views of how the future might develop. Because the future is uncertain, researchers do not know whether one scenario or the other, or neither scenario will actually come to be. The actual path of AV/CV deployment will be between the two extremes researchers provide. Together the scenarios represent a spectrum of possibilities. "Narrative" means that the scenarios are formulated in a literary way, as a short story that describes how and when significant numbers of self-driving vehicles might come to be. Unlike many scenario narratives that are written from a vantage point of sometime in the future (i.e., 2030) and look backward, our scenarios were written to portray the path of development into the future from today.

Scenario 1: Revolutionary Path

Automotive manufacturers (OEMs) and suppliers make aggressive and substantial R&D investments that accelerate progress in AV and V2V technologies; federal and state policies do not hinder development to reach significant numbers of fully self-driving vehicles on roads by 2025. The hype of 2015 becomes the reality of 2025.

Disruptive Innovation

In the AV space, disruptive innovation quickly addresses the dual challenges of (1) driving complexity and (2) driving speed (see Figure 5). The private sector pushes development of onboard technology (i.e., radar, stereo/mono cameras, and LIDAR) to be able to mass market vehicles with highly automated driving (Level 3) capabilities by 2017. Through contractual relationships with mapping companies, vehicles have access to necessary digital data on infrastructure elements (i.e., traffic signals and lane configuration) for safe and reliable navigation. These are maintained through car data sharing via V2V capability.



Source: Adapted from European Technology Platform on Smart Systems Integration 2015.

Figure 5. Revolutionary Path of Deployment.

Government Mandates

The federal government mandates V2V for all new light and heavy vehicles in early 2016 and for all vehicles via retrofits by 2018; substantial tax credits are provided to incentivize new vehicle purchases and existing vehicle retrofits in order to maximize societal benefits. The government stipulates that the mandate take effect immediately with knowledge that OEMs and suppliers are technology ready. Knowing that it might take decades to reach a critical mass of vehicles with V2V capabilities through new purchases and retrofits, the industry enhances the V2V communications network through personal navigation devices—specialized aftermarket devices and smartphones. On the other hand, V2I deployments are stalled in political and financial debates over the business case for V2I (i.e., who can afford to absorb the cost of installing and maintaining the system, and where profits will come from). The rapidity of the AV and V2V activities overtake focus on V2I, which flounders for a decade, then becomes unnecessary to reap safety benefits.

Demand for Level 3 Vehicles with V2V

The country's leadership has placed a singular focus on growing the economy. Unconventional oil and shale gas are rapidly exploited and often exported, and lower energy and oil prices boost the economy. Consumption remains a key driver of economic growth. As such, consumer demand is strong for vehicles with Level 3 and V2V capabilities, especially among aging Baby Boomers. Also, pent-up demand among young adults, who have delayed new car ownership, is satisfied by eco-friendly vehicles with high levels of automation.

By 2020, a critical mass of vehicles is operating on the roads with Level 3 and V2V capabilities. Applications include traffic jam assist, highway driving assist, and parking assist. With traffic jam assist, the driver pushes a button to delegate the stress of stop-and-go driving to the vehicle, leaving the driver hands-free free to talk on the phone or chat with passengers. V2V communication alerts the driver when the traffic jam comes to an end, and driving reverts back to the driver. With highway driving assist, the driver cedes driving control to the vehicle in a managed-lane environment. The driver does not have to take over again until exiting the highway. With parking assist, the vehicle automatically looks for a suitable space while passing by and then offers that space to the driver. If the driver accepts, the vehicle automatically parks the vehicle. In the commercial vehicle market, truck platooning is happening. The drivers behind a lead truck cede and retake control of their own vehicles. Outside of the platoon, the trucks are still human controlled.

Early Level 4 Deployments

Federal legislation in 2018, which specifies a threshold safety requirement for fully automated systems and enables manufacturers to self-certify, encourages the private sector to move forward with Level 4 deployments. The first fully automated applications, in early 2020, are small low-speed transit vehicles that operate on loop routes (e.g., government campus, tourist area, college campus, and shopping district). This application is followed closely by automated low-speed taxi or shared vehicles, operated by transportation services disrupters like Car-2-Go and Uber that operate in dedicated city sectors. The economies of scale for such applications enable such systems to proliferate throughout urban areas. Subsidies enable provision of automated transit in rural areas for healthcare or senior services.

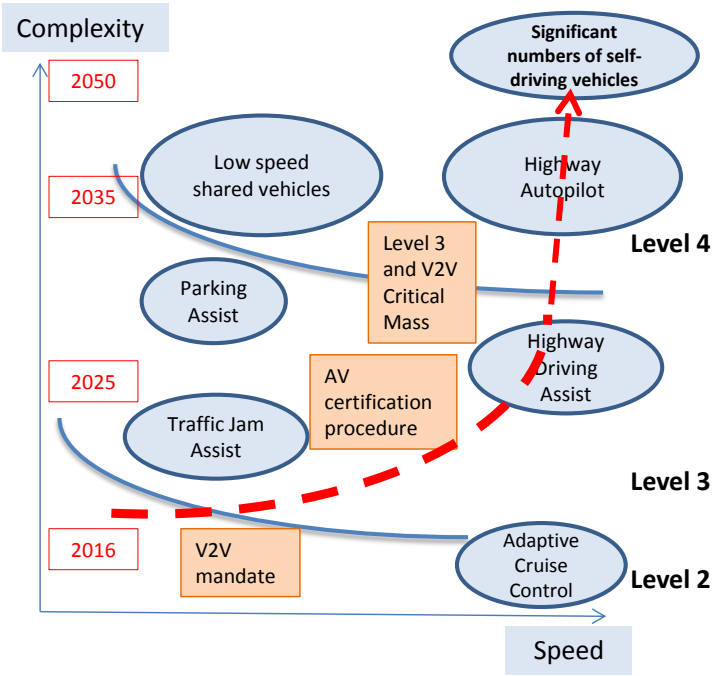
OEMs and disruptive firms like Google and Tesla have marketed individually owned, fully automated vehicles as early as 2018. The passenger vehicles are built to appeal to two different markets: high-end luxury vehicles (i.e., Mercedes, Audi, and Tesla) and small, light eco-vehicles (Honda, Nissan, Google). These are marketed at two different price points. Consumers' willingness to pay is dampened by the lack of space to actually drive the vehicles. In 2020, a few bellwether states pass legislation and make infrastructure modifications to allow on-road operation of fully automated passenger vehicles and commercial trucks on highways. Some insurance companies begin to adapt their rates to the lower risks of Level 4 vehicles.

In early 2021, disruptive start-ups are providing autonomous aftermarket kits that are very popular. Trucking companies embrace the technology because of a strong return on investment, and start-ups apply the technology for urban goods movement in select environments. All of these activities create momentum that motivates state and local agencies to prioritize their infrastructure spending to support automation and translates into increased consumer demand for Level 4 technology. As the demand increases, the costs of the driverless technology lowers, which in turn expands the demand. Self-driving vehicles are present on the roads in significant numbers by 2025.

Scenario 2: Evolutionary Path

OEMs and suppliers achieve step-wise improvements in advanced driver assistance systems. But making the leaps from Level 2 to Level 3 automation, and then Level 3 to Level 4, proves very

challenging even for technology firms like Google. This slows deployment even for the less complex driving environments such as limited access highways or simpler applications like truck platooning, and it delays reaching significant numbers of fully self-driving vehicles on roads to 2050 (see Figure 6).



Source: Adapted from European Technology Platform on Smart Systems Integration

Figure 6. Evolutionary Path of Deployment.

Policy, Regulatory, Technical Issues

The wide range of policy and regulatory issues that need to be addressed to enable Level 3 automation require reexamination and reconsideration of assumptions on which existing policies and practices are based. This is administratively and politically challenging, and takes time. For example, even incrementally shifting the driving task from humans to vehicles requires changes in insurance. Insurance is state-regulated. Each jurisdiction has its own set of rules and regulations. Questions about whether the auto insurance system should change to be more uniform across states or whether OEMs should be required to accept more responsibility for damages and injuries are debated in Congress and in state legislatures.

The higher levels of vehicle automation (Level 3 and higher) pose technical challenges (e.g., reengaging the operator, cybersecurity, or operation in urban street environments) that take even longer to resolve. Automation above Level 2 allows drivers to disengage from driving monitoring and control tasks for periods of time, and there are robust safety concerns among Congress and state legislatures. Actions at the federal and state levels related to vehicle codes and technical standards for the purpose of ensuring public safety cause slowdowns in technical innovations by OEMs and suppliers starting in about 2018 as they become wary of getting too far

ahead of policy. The precautionary regulatory stance also requires OEMs to certify the safety of their systems. Settling in on a process for deciding whether a specific vehicle automation system is safe enough to operate on public roads across 50 states is cumbersome and takes time.

Infrastructure Requirements

Because AV technology does not progress quickly as in Scenario 1, a greater amount of digital and civil infrastructure support is needed to reach the level of system performance that induces consumer demand. OEMs and suppliers clamor for transportation policies that facilitate the public sector in providing the essential infrastructure to support Level 3 and Level 4 systems. But due to continued Congressional partisanship, state and local transportation agencies remain underfunded for decades. It is difficult for the agencies to finance expansions or enhancements of their facilities and digital capabilities. Deployment of CV technologies also bogs down as regulators try to settle on minimum standards. Meanwhile, as demand for wireless bandwidth from smartphones and cloud-based data storage explodes, lawmakers and federal agencies allow nonautomotive devices to share the airways dedicated to connected cars, prompting concerns about potential interference with wireless signals. Combined, these uncertainties delay the proliferation of V2V and V2I systems, which are now necessary enabling systems for higher levels of automation, until the late 2020s.

Level 3 Market Development Slow

Even though OEMs begin offering Level 3 vehicles in 2025, the vehicle fleet turns over slowly. The average age of vehicles continues to increase to nearly 12 years in 2025 because of an economy that has not fully recovered from the Great Recession. Income inequality in the United States continues to rise slowly. Sluggish growth and limited new business creation do little to tighten labor markets. New jobs continue to come mostly from the lower wage service sector. With no drastic economic shifts, there are, similarly, no real changes in politics or federal spending patterns. The economy is not helping consumers to buy new cars. Vehicle turnover rates and the price of highly automated vehicles are barriers to market development. At the same time, negative media stories about the safety of highly automated vehicles generates apprehension and uncertainty among the consumers and elected officials.

Because legislative prudence is exercised, Level 3 vehicles are only allowed to operate on a fraction of roads that have been pre-approved as having sufficient map data, infrastructure support, and pull-over safe spots to meet minimum national safety certification standards. Only a few states and regions are in a financial position to make the necessary investments. This reduces the usability of high automated vehicles to a fraction of the roadway network. The private sector pushes states and localities to expand the set of approved roads and, in some cases, willingly partners with public agencies to implement the essential infrastructure to do so. New models of public-private partnership develop over the 10 years from 2025 to 2035. Critical mass of Level 3 vehicles operating on the roads begins to be realized by 2035. As CV systems proliferate and more and more Level 3 vehicles are operating on roads, public agencies gather evidence that these technologies are sufficiently beneficial in terms of efficiency of operation and reductions in infrastructure costs. Such evidence motivates agencies to prioritize their infrastructure spending to support automation starting around 2040.

Achieving Level 4 Automation

The most significant difference between Level 4 and previous levels is that at this stage, the AVs are able to confront all the conditions that the vehicle may face. Under the precautionary approach to regulation and policy in the evolutionary scenario, new rounds of testing are required of vehicle manufacturers and suppliers to prove Level 4 system reliability. Despite slow and deliberate development and testing of this technology, component malfunctions/failures and component defects do happen, which are heavily covered in the media. These factors combine to result in slow penetration rate for privately owned passenger and commercial vehicles and only gradual introductions of transit or shared vehicle applications. Self-driving vehicles are present on the roads in significant numbers around 2050.

REACTIONS TO SCENARIOS AND AV/CV IN GENERAL

This section of the report provides interview results relating perceptions of the likelihood and preferability of the scenarios. It also presents current expectations regarding the advent of AV/CV technologies. The information provided in this section and elsewhere in this report represent the thoughts and opinions of the persons interviewed for this study. While this represents a small sample of leading agencies, the findings provide insight into current and future challenges and opportunities pertaining to AV/CV technologies.

Most Likely Scenario

Among all interviewees, the Revolutionary scenario was considered to be more likely than the Evolutionary Scenario. But this outcome was driven largely by the strong opinions of the local agencies. At the risk of quantifying the opinions of a small sample, Figure 7 presents the variation between state and local interviewees.

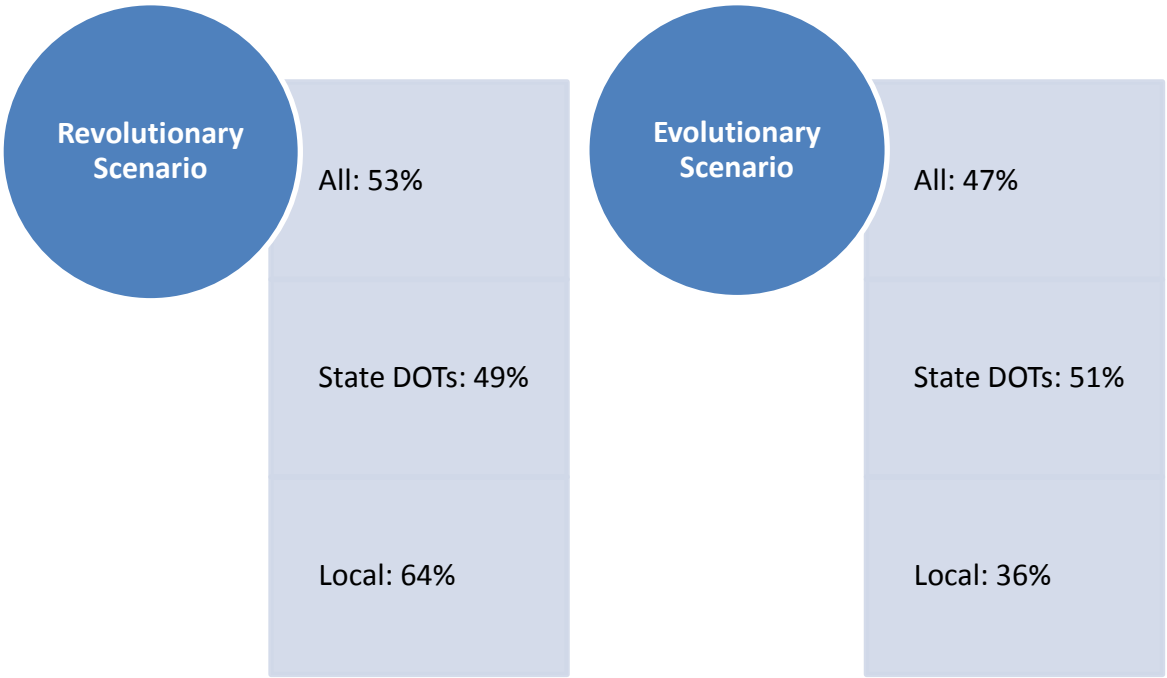


Figure 7. State and Local Interviewees Opinions on Most Likely Scenario.

Among the state DOT staff interviewed, a slight majority thought that the Evolutionary scenario would be most likely. There were varying reasons for this perception. One theme that was raised often was that government would have to be involved, and the associated policy, rules, and regulations would slow down AV/CV deployment. There was a clear sense that regulatory change would occur on an evolutionary path. “The big question here is to what extent the regulatory environment will allow any development to occur.” Another theme was that the iPhone model of quick disruptive technology may not apply to AV/CV. With the latter, there is a lot of more complexity with institutional barriers, safety considerations, and other social issues, like privacy concerns. “When the magnitude of implementation issues becomes clear, there may

be a dampening effect." Some of the implementation issues identified were mapping issues, existence and reliability of connectivity, liability and insurance, and ensuring safety during the transition period when there were mixed fleets (automated/nonautomated) on the roadways. "Unless liability and insurance impediments can be addressed, Level 3 will not happen very soon. Skipping Level 3 is a possibility."

Public agency staff also thought that the fleet will change over slowly, which will slow down developments. For full automation there is an immense amount of cooperation and collaboration across public and private sectors, different levels of government, and various private sector interests (e.g., insurance and OEMs). "OEMs will need to work with states and localities to get necessary data for enabling AV on roads." It should be noted that currently different entities are doing their own thing; planning and preparation is happening in silos.

Some of the state DOT staff interviewed regarded the Revolutionary scenario as more likely. Their rationales focused on a "technology push." They felt that OEMs and technology firms would push AV/CV to the market regardless of whether or not there was an actual market demand for the technology. "The private sector will drive this." Some state DOT interviewees were also of the opinion that in certain industry sectors there would be economic reasons for early and quick adoption. "In the freight industry, for example, this could happen very fast because there is a very immediate payback. Economics drives things very quickly and the economic case for development is better in freight." One person thought the pathway would differ between urban and rural areas: "Rural areas will be more evolutionary; change will happen faster in urban areas." He also noted, "The vehicle sharing market is developing quickly."

There were also a few state DOT interviewees who felt strongly that AV and CV would follow different scenarios. For AV, the most likely scenario was the Revolutionary scenario. The rationale was that AV is private sector driven and technology in the private sector can move much more quickly than in the public sector. "When you look at the types of technologies that AVs are dependent on, the entire industry has moved at an exceptionally rapid pace. They have not waited for government to bless that pace." "As long as there is an appetite for this among the public, they are going to push forward." For CV, the most likely scenario was the Evolutionary scenario because its deployment was within the purview of the public sector. "The public sector has a long way to go before CV can be implemented, and will need time to get there." In addition, currently there is not a strong business model so state DOTs will be slow to invest in implementation. "Until there is a strong business model supporting change, the DOT will not be able to change to support CV."

The local agencies (i.e., tolling agencies, regional governments, and cities) were more consistent than the DOTs in their opinions about the most likely scenario. All but two of our local transportation agency interviewees thought that the Revolutionary scenario was most likely. Nearly all thought that the private sector will drive the development of the market and make it happen. "There is too much money on the side of implementation and allowing it, and no money on the side of banning them." This view assumes that market demand is strong and that consumers will be willing to pay for safety improvements and the "apps" that will be in vehicles. "Having your vehicle become another screen—texting, working, playing—will drive demand for these vehicles." As another individual stated, "I am increasingly confident that there will be consumer demand for AV and CV… the mundane part of driving will be taken over by the

machine." Another said "the market will demand these safer vehicles…hands, feet, free at the same time." A few pointed to the fact that certain transportation sectors would "jump on this very quickly." Such early applications would most likely be fleets (e.g., taxi, trucking, and package delivery companies) rather than individuals buying personal vehicles because there would be an economic incentive for them to do so. "You still need a driver to drop off the package at the mailbox, but all they have to do is carry the package to the door."

Most Preferred Scenario

Among all interviewees and by a fairly wide margin, Revolutionary was the scenario that was most preferred. Again, this outcome was driven largely by the strong preference among local transportation agencies. Figure 8 quantifies interviewees' opinions.

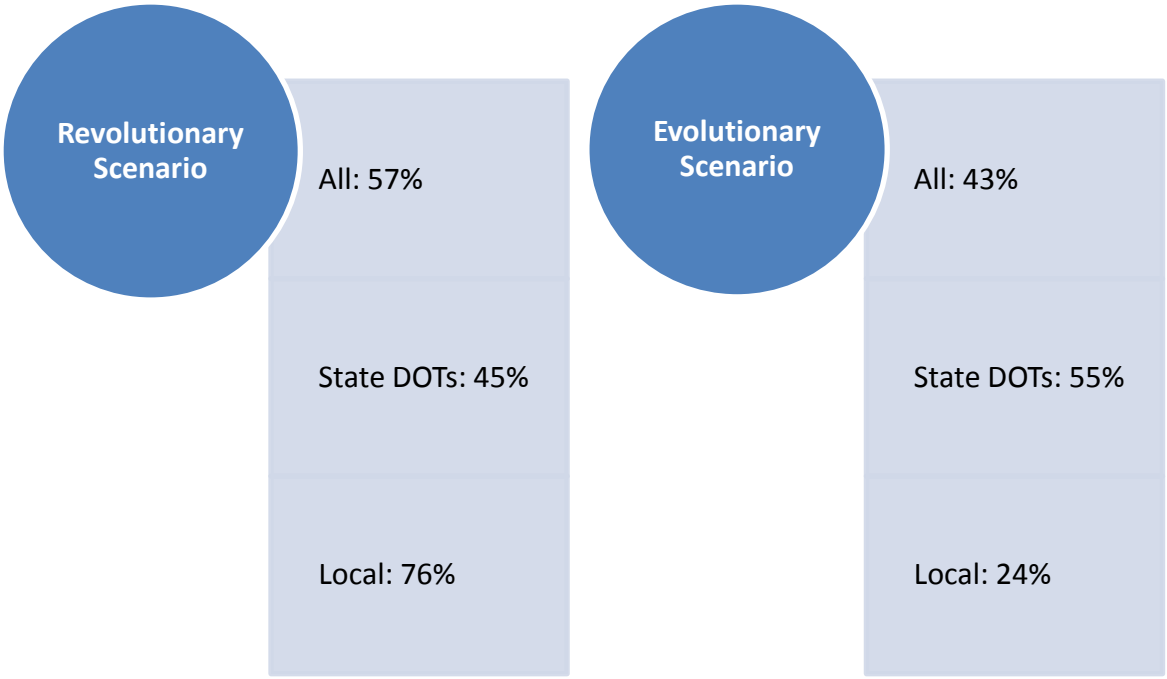


Figure 8. State and Local Interviewees Opinions on Most Preferred Scenario.

The majority of the state DOT interviewees preferred the Evolutionary scenario. By far, the main reason for this was that it would be less disruptive for the agencies. "There are a lot of unknowns." "Evolutionary is much easier for us to adapt to and would be less stressful for the agency." "This is a huge leap in technology—we are moving from horse and buggy to a car all over again." "We don't have the funding. We are in a maintenance and preservation mode. New infrastructure [for CV] is very challenging." There was also the clear sense that the DOT culture might hinder revolutionary change. "Gradual change fits the way DOTs operate better than sudden change; it is difficult to implement new technologies in a DOT structure." "As a large bureaucratic agency, we would not be able to respond quick enough to revolutionary change." "If we go too aggressive, we're not going to be able to keep up."

A few individuals representing the state DOT perspective actually welcomed the Revolutionary scenario because of the benefits to the organization and to society. “We would like to be more proactive.” “It allows improvements to safety mobility and economics in a much faster timeframe, which allows us to lower the cost of transport.” “I don’t think bureaucracy should guide technology development, but the systems need to work beyond the markets that are viable from a pure profit motive.”

The rapidity of experiencing the perceived benefits was also noted among two individuals who felt strongly that AV and CV had to be separated when considering deployment paths. For AV, “This preference [for Revolutionary] is due to improved safety and its benefits.” For CV, preferences leaned toward the Evolutionary scenario due to the perception that CV deployment needed to be driven by the public sector, which moves more slowly than the private sector. “DOT should take a measured and wise approach to implementation.”

The local agency interviewees, on the other hand, overwhelmingly preferred the Revolutionary scenario to the Evolutionary one. “Benefits are evident and manifest and we should realize them as quickly as we can safely do so.” “The opportunity for revolution comes if the Google’s, Tesla’s OEMs come up with compelling products…then consumer adoption will be fairly quick.” “We would rather see us change in the extreme.” There was also the sense that if the private sector pushed this quickly, they would bring necessary financial resources for deployment. “We’d prefer private sector push—we’d have a hard time deploying the capital resources to make this happen.”

Expectations Regarding AV and CV Developments

The scenario preferences are closely linked to interviewees’ expectations about the advent of automated and connected vehicles. Our first interview question gathered individuals’ thoughts on where researchers were with AV and CV technologies. Findings are discussed in the following sections.

Expectations Regarding AV Development

Both state and local staff had the very strong opinion that AV developments were driven by the OEMs and the private sector, and so there was no doubt that AVs would be deployed. “This is going to happen…the private sector doesn’t need the public sector for it to happen.” “Private entities don’t need us.” Because of this, the pace of change was seen as being very fast. “This is progressing a lot faster than the typical policy maker or planner is used to.” And, the sidelining of public agencies by the private sector push was seen as potentially problematic. “We don’t want to be [a] roadblock for prohibiting technology growth, but we want to understand what is happening, and that our systems, policies, and ability work to make sure these are successful.” “There is no clear vision for how AV technology will be implemented.” “Timing is the biggest issue. There are already cars getting ready to come on the market with limited automated capability by 2017.” “Pavement markings, weather issues, and road conditions in general are not ready for Level 4 implementation as yet.”

Both state and local agencies were concerned with what will be expected of them. “We are dealing with a lot of disruptive things so we approach this like all the others—what is being

asked of us?" "What will it mean for the agencies?" "Are we supposed to build special lanes or do they mix and mingle with regular traffic?" "How will AV operate when the road striping has been ground off over the winter… will there be legal implications for the DOT if this happens?"

Expectations were solidly that the AV technology would bring needed benefits. "It is a huge net benefit to the system, three things: safety, mobility, economics." "State is involved in different activities to facilitate technology; purpose is to see benefits—reduced accidents, better traffic management." "AVs are going to provide so many positives (economic and social) that once they start becoming a significant portion of the fleet, they will be transformational."

Expectations Regarding CV Development

State and local agencies were similar in their expectations and concerns about the advent of CV technology. Whereas they characterized themselves as sidelined in AV developments, most talked about being involved in CV through "involvement with national organizations," "pooled-fund study," "AASHTO's V2I coalition," "CV test beds," and "deployment pilots."

However, unlike the confidence that AV would happen, they were less sure about how and when CV would develop. A few of those interviewed envisioned a connection between AV and CV. "Ideally, we would have deployed CV first and then but AV on top of that but we didn't…CV is being developed along a parallel route and they will have to come together at some point or we won't be able to realize the safety benefits." "AV won't need CV, but it will make AVs work better." But generally, the connection was not made. As one individual put it, "The public sector focus is likely to be on CV."

Because there was the perception that the public sector had a larger role in CV developments than AV, there was a concern about not being able to implement as might be required of them. "CV is a quandary: we can't maintain what we have, so how can we upgrade for CV?" "One major concern with CV is the initial cost for implementation, also the ongoing cost from technical support to keep it up and running." "The only CV technology we've looked at is on the emergency-vehicle side; this would [require] a complete central system upgrade that would be very expensive." There were labor force readiness issues as well. "The costs involved and technical support is probably above the level of our support technicians."

Yet, most interviewees believed that the private sector would play a role in CV developments. "Agency overall sees benefits of these technologies, but how quickly or how far it goes depends on private sector." "V2V will certainly happen because it will be industry driven mostly, but not too sure about V2I happening." "Several years ago thought DOTs would have a large role and we all wondered how we're supposed to get ready for that but now I feel that OEMs are taking a large slice of what's going on and that DOTs are diminishing…most of the intelligence will be in cars themselves, not on roadside." "Needs to be joint effort with private sector and states… what to facilitate technology development…states not good at developing apps." One individual even thought that perhaps a private company would make a V2I network in his region in exchange for the franchise opportunity.

CV technology was seen as bringing new opportunities. "Our DOT has objectives for zero fatalities, and CV is going to be what gets us there." "If fleet connectivity exists, then can

vehicles be considered probes?" "States want to use data that come off of the vehicle or from other applications to better manage our roadways." "Big question: who owns the data that will come from CV applications?"

A few individuals voiced concerns about being "too far ahead" in terms of making infrastructure changes to support CV. "I don't think CV is very valuable. We don't want to invest in the Betamax (a technology quickly outdated and irrelevant)." "We don't want to invest but then see technology go the other direction…how do we address this?" "How do you develop a system that adapts in this fast-changing environment where everything is changing?"

SCENARIO IMPLICATIONS

In the interview, researchers gathered information about the major implications for their agencies from the scenario that interviewees found most likely. These findings are discussed below.

Evolutionary Scenario

Even though in the Evolutionary scenario, AV/CV was slow to deploy, many interviewees thought it would still be challenging. “Figuring out all the impacts is very difficult.” Agencies had many questions. “Basic road design, do we need to alter things as simple as lane width?” “My agency has a ton of information that we could give to the cars (like approaching crash, icy spot, slow traffic)—is it DOT’s responsibility to pipe it into the cars or do we give it to some third-party aggregator who pipes it into the car?”

There was also the sense that the deployment of these technologies would portend changes for the organization. “Some of the things I use every day would go away, like electric message signs. Vehicle detectors—we have thoughts out there if the cars are collecting these themselves we don’t need that anymore.” “The ITS implications are pretty heavy.”

There were operational challenges. “Folks building the vehicle do not have an incentive to shorten headways—from a liability perspective.” “We could lose capacity on our roadway [because] widespread Level 2 would require vehicles to follow at a safe distance, which human drivers don’t do, which could exacerbate traffic congestion—we could deal with this under an Evolutionary scenario.” Others identified monetary implications. “How do we plan for this?” “How do we reserve resources to support this?” A more Evolutionary path would give agencies more time to “reallocate resources as needed.” “We are ready to invest in technology to see it go, [like] shifting investment in maintenance from traditional ITS to more of the roadside technology that supports vehicle automation, but we need [time] to see and measure benefits in travel time reliability or incident duration.”

There were positive implications mentioned, particularly with regard to data. “The increase in data will help with data-driven planning and operations.” “We would love that data.”

Revolutionary Scenario

A major implication of the Revolutionary scenario was that the public sector will have to react very quickly to what is actually happening rather than taking the time to examine what *could* happen. “We really don’t know what this is going to look like. We don’t want to try and anticipate, we are going to be reactive.”

One important issue is how it might change long-term investment strategies. “Are we putting federal funds for transportation in the right places? Should we be funding BRT [bus rapid transit] and light rail?” “It gets political very quickly.” “Conservatives think we won’t need money for transit or raising taxes to build more roads.” “How should we deal with politics (of the anti-transit versus anti-auto camps)?” In this environment, agencies would be making decisions under high uncertainty. “No one knows exactly how this will play out, what the biggest issues will be, or how to address them.”

There was also the concern that the transition period would be difficult, lacking time to prepare for it. “Mixed fleets—will there be a lot of upfront acceptance or will it be like electric vehicles, with consumers waiting for the charging infrastructure and governments not willing to invest in it?” “We would need to get everything ready for the beta versions and then see it all change.” Maintenance challenges would surface quickly. “Maintaining good consistent striping with our weather patterns is a challenge.” “The biggest issues are markings, signage.” “Continuing to maintain our road with special attention to striping making the roadway visually apparent to machines will be a challenge.”

Other implications related to changes in how the transportation system will be managed. This technology will enable us to “squeeze more capacity out of system, rather than building our way out of congestion.” “We have all these barrier-separated HOV lanes, I could see that becoming an AV-only lane. At some point it gets reversed to where the main lanes are AV only and the HOV then becomes the human-operated vehicle only.” Another person mentioned that the agency would have to have “a much higher standard for maintenance, different design standards, and signal design methods.”

The Revolutionary scenario could force major changes in the organizations, such as culture shift or role identification. “Challenge us to interact with our customer in a new and better way.” “We would need to define what our role would be.” “Change from road builder mode to efficiency mode.” “We also need to think about our role as a “full service transportation provider. Will we still be responsible for deploying this infrastructure or just acting to facilitate the private sector in getting all of this technology out there?” Other individuals mentioned with different phrasing that personnel and staffing would need to change. “We will need people who know how these technologies work and how they can be integrated into operations. We will have new professions integrated into our workforce and we will also need training on how to get our existing operations to interact with new functions.”

STRATEGIES TO PREPARE FOR FUTURE DEPLOYMENTS

To gain an understanding of how state and local agencies are preparing for the advent of AV/CV technologies, the interview included three questions:

- Has your agency developed any near term strategies for proactively addressing any implications of AV and or CV deployments in your jurisdiction(s)?
- Are there any policy or planning actions that your agency could implement to prepare for this scenario?
- Is there anything that your agency could do to shape or influence the scenario coming to fruition?

In the interview discussions with state DOTs and local and regional agencies, common themes began to emerge. While there were some differences in the interview responses between state DOTs and other agencies, there were many commonalities as they begin to address the challenges inherent in implementing AV/CV technologies.

State DOTs

The analysis of interview responses from state DOTs yielded commonalities, referred to herein as Emerging Themes, where responses were shared across a significant number of participant states. Also presented here are Interesting Statements, where a response that was considered noteworthy was received from one or at most two respondents.

Emerging Themes

Several DOTs mentioned that a primary task in their state was to identify and address any legal restrictions in state or local law that might impact AV/CV implementation. “We scrubbed all of our existing laws to see if there is anything restricting.” Some mentioned that the policy and legal framework must be developed. “I think we’re doing a good job of staying on top of policy—we are working with the DMV [Department of Motor Vehicles], looking at policy in state legislation that would need to be changed.” A few were looking to the federal agencies to provide guidance. “What we tell people is we’re in a wait and see mode. We’re going to wait for the Feds to tell us what we need to do.” On the other hand, some are actively choosing a wait and see mode. “We don’t plan to implement any policies pertaining to AV/CV that might limit our ability to be flexible as technology changes. Changes in policy right now would be premature.” “We are keeping an eye on what other states are doing.”

Several state DOTs shared that they find it most effective to prepare for AV/CV implementation by organizing formal initiatives, such as the creation of working groups, steering committees, or task forces that are charged with the development of roadmaps and/or AV/CV strategic plans. These initiatives involve internal and external stakeholders, including the private sector, public sector agencies at all levels, and universities and research laboratories. “We need to continue with ongoing education and awareness building among all agencies. We’ve had discussions with rail and transit and the office of attorney general, secretary of technology.” “Think getting the conversations going now is what is needed.” Some DOTs have partnered with universities to

develop implementation plans. “We’ve partnered with [university] to do an analysis with a timetable for implementation by 2040.”

One individual mentioned undertaking an impacts analysis. “We’ve identified high level areas…likely to be impacted: transportation system planning, cultural and workforce readiness, transportation data, strategic investments, systems and technology, legal and regulatory implementation and collaboration with others. For each, we are identifying a series of expected impacts.” In terms of planning, another individual also mentioned working on “getting AV/CV language in your 25-year state plan…ensures that money is programmed for that activity if it is needed in the future.”

At least one state DOTs is preparing by implementing statewide fiber network to provide the necessary architecture. Some DOTs (not interviewed) have been on this path for years for traditional ITS; the initiative started before the advent of wireless data networks and private investments in fiber. However, there were many other DOTs who stated that they do not plan to implement any changes until they know where the technology is going. For these DOTs, the need for flexibility to react to changes was important. State DOTs seemed to be evenly divided on this. “From a policy perspective we need to be looking at what technologies exist today, and as we continue to build and maintain the roadway system we need to make sure we have flexibility for the system to accommodate these systems... If we are doing new traffic lights we should be looking to put in systems that accommodate future technologies; however, we don’t want to invest in systems that will soon be out-of-date.”

Active involvement in the national dialogue on AV/CV implementation was commonly viewed as a way for state DOTs to stay abreast of emerging issues and challenges in the field. Conferences and symposia provide opportunities for many state DOTs to be a part of the national discussion. Membership and active involvement in such initiatives as the V2I Deployment Coalition (led by ITS America, AASHTO, ITE, and FHWA), AASHTO’s Connected Vehicle Task Force (made up of state DOTs and two Canadian provinces), CV pooled fund initiatives, steering committees for conferences, and the like were also mentioned as avenues for education and discussion. “We need to remain engaged in events like this symposium [*interview conducted at the TRB Automated Vehicle Symposium*] to make sure that we know what is going on and that we have a voice in this development. We need to keep talking to AASHTO and USDOT about our state’s needs in order to make sure our needs are being addressed. It’s not that we are any different from other states, but we have an obligation, since we are on the front line, to tell AASHTO and DOT what we need.” “We want to have a feel of the pulse of what’s happening and be able to influence if we can.”

Many of the interviewees also indicated that their DOT is competing for federal deployment funds. These programs were seen as providing an excellent source of funding for AV/CV implementation projects. Furthermore, being involved in the pilots enabled the states to educate their staff about AV/CV requirements. “[We are trying to] insert ourselves into the mix earlier rather than later.”

Almost all DOT interviewees recognized a need to address their workforce’s ability to manage changing technologies, enormous data sets (their collection and analysis), and associated operations concern. There may be a need to staff up ITS groups in their organizations, and

address the need for enhanced IT/data management and operations groups. Additionally, field technicians will have to be more tech savvy, with a different skill set than is currently common.

Building more partnerships with private sector/OEMs will be needed. Increased interaction between vehicles and infrastructure will necessitate more understanding and coordination between the public and private sector. “Getting involved with OEMs could definitely shape where this goes. We should insert ourselves into the mix earlier rather than waiting.” “We are very interested in partnering with the private sector. We could support a partnership.”

Several agencies stated a need to educate decision makers. For example, one DOT indicated that a funding increase for needed congestion management met with resistance because “Connected vehicles will solve that.” Respondents stated that it is important that elected officials and other decision makers understand what AV/CV can and cannot do. “What we need to be doing is making sure that policy makers know what is going on and educating the public.”

Interesting Statements

One state DOT that is responsible for driver’s licensing in their state is looking into how AV/CV might affect licensing requirements. For example, if a car can park itself, will the ability to parallel park be necessary? If legislative changes are necessary to implement AV/CV, they will need to address driver’s licensing requirements at that time as well. Another individual said his state “could be proactive legislatively if we knew what it was that was going to happen.”

Local Transportation Agencies

Emerging Themes

Many of the interviewees from local agencies are involved with their state DOTs through ongoing formal AV/CV initiatives. They serve on DOT-organized groups such as task forces and working groups, along with representatives from the private sector and other transportation stakeholders, and seek to be a part of the discussion. “What I am doing so far is staying aware and informed as to what is going on and who the major players are.”

State and local transportation agencies noted that involvement with the private sector is important because “so much relies on the private sector and the development of the technology.” “We do have some very important companies and key players in this area—we could be more intentional about working with them.” Many are actively seeking partnerships with the private sector on early deployment opportunities. “We don’t intend to take the lead on that but we will make our system known to the industry as an attractive space for testing of vehicles. We have a lot of sensors, a lot of cameras. We can track vehicles with transponders. We have a lot of useful information and could be a useful partner.” “We should be more intentional about looking at land uses around the region for opportunities where Level 3 and Level 4 could be deployed, like college campuses, retirement communities.”

Several respondents stated that they are planning to include AV/CV in current and future planning efforts but are not sure how to go about it. There is widespread uncertainty regarding what the local role will be in AV/CV implementation, and how responsibility will be shared. “We need to get AV/CV on the planning radar. We need to educate officials and keep up with

technology." "We need research and help in running scenarios (not every MPO needs to run the same scenarios)—we can aggregate to figure out what needs to be done in unique transportation models." "We need to have our Board members on board with AV/CV and well educated about it. Decision makers need to be knowledgeable."

Many expressed concerns about financial resources. For jurisdictions that are struggling to maintain the infrastructure they have, there was concern with how they will come up with the money to implement AV/CV. "Our last plan update had 70 percent of our funding going to maintenance and operations. More will have to go to this to facilitate deployment." Another financial concern is finding the resources to geocode signs on roads under their jurisdiction, although it was also viewed as an opportunity to use AV/CV "as an argument for the sign inventory and geocoding."

Interesting Statements

The implementation of AV/CV could have significant impact on planning for tolling agencies. They are collaborating with research labs and the private sector, monitoring what CV means for a payment platform, putting together procurement for a toll collection system, and working with research labs on new technologies. A question raised was whether toll agencies need to offer dedicated lanes during the transition period. "Our preference would be to have most of the vehicle fleet turn over quickly—without us having to reconfigure the roadway."

AV/CV could facilitate narrower lanes, making more room for amenities like bike lanes, or less pavement. This would impact planning for the roadway network. Implementation of AV/CV could also completely change parking requirements. "For example, if a smart vehicle has already dropped off its passengers, parking facilities would no longer require room for doors to swing open, making room for more slots."

Tying AV/CV implementation to economic competitiveness could be a way to justify the cost of implementation. "We have an economic development arm that includes citizen groups working on economic competitive strategies. How is this region going to position itself for economic development from this technology?" One interviewee stated that he has been told by private sector AV/CV interests that "all that will be needed from operators is good pavement markings and lots of data. We (the agency) can facilitate that by running our roads and modifying them to make them readable, and providing data."

POTENTIAL IMPACTS ON ORGANIZATIONAL STRUCTURE

Even though our interview sample represented organizations that were known to have taken an interest in AV/CV, none of the organizations indicated that there was a specific position in the agency that deals with the topic. Most indicated that there was a point person on technology issues, which includes AV/CV, but no one dedicated to the specific topic. Several of our interviewees mentioned that they were the designated AV/CV person in the organization because they were just interested in the topic. Many said that the focus was at the middle-management level and not "high up in the organization."

Recognizing that future implementation of AV/CV technologies may cause institutional changes within state, local, and regional transportation agencies, the participants were asked to respond to the question "How might the mission, responsibilities, and organizational structure of your agency evolve under this scenario?" Although the question was staged to address the most likely scenario (in their opinion), the resulting changes to organizational structure should be the same regardless of scenario. As before, there were some differences in the responses from state DOTs and other organizations.

Mission

The consensus of interviewees from both state DOTs and local and regional agencies was that the mission of their organizations would not change, and that the benefits of AV/CV would aid them in accomplishing their current stated mission.

Responsibilities

A few agencies are in a "wait and see" mode in terms of changes in organizational responsibilities in response to AV/CV implementation. "We want to get a handle on what the impacts will be before determining how we change. However, this will be a big issue for the agency." "Aren't to that point yet. That could change going forward as we get further along." Most state DOT interviewees noted many potential changes. For instance, there could be a substantive shift in organizational focus from what they described as "the big three"—design, construction, and maintenance—to operations. "A new model could require new management efforts beyond the simple model we have now of building and maintaining roads." An exception is the maintenance of pavement markings and signage, which will become much more critical with AV/CV implementation.

Data management, including collecting data, storing data and analyzing data, would become much more involved. The skill sets for traffic engineers, operations staff, and field technicians would have to change, with associated costs for training. All of these changes will affect a dynamic shift in how resources are allocated. "If there is roadway or roadside infrastructure for CV we might have more responsibilities there with the installation, operation, and maintenance of that equipment. We also might have to do better with our lane markings. Doing all of this is above and beyond what we are resourced for right now." The greater emphasis on operations also creates a different sort of skill set. "What we really need is people with expertise in operations management. We need statisticians and mathematicians. It is a systems operations focus." There is a perception that the private sector will be taking on more of what has

traditionally been a public role, for example in data management and collection. “The private sector will likely take on more roles that were traditionally public in nature.” This is already happening in some states, notably Utah and Florida.

A few individuals noted that safety might become less important in their organizations because of the expected safety benefits of AVs and CVs. “Maybe reduce number of traffic management centers (TMCs)—reduce the number of safety maintenance vehicles roaming the road.” “I could see safety staff responsible for coming up with safety projects diminish a lot.”

Local and regional transportation agencies noted several potential changes to their responsibilities. Toll agencies noted that they could experience an increase in “fleet” customers, such as Uber and commercial fleets, and that this could change their business model. But in general, toll agencies saw themselves as needing to be at the forefront of technology, so in that respect responsibilities would not change with advent of AV/CV technologies. “The mission is to stay in front of the technology. Tolling brings a lot of technology (e.g., cameras, computers, and integrated corridor management) anyway. So we are uniquely positioned to take advantage of the new technologies, unlike traditional highway construction, which is more concrete and steel.”

While tolling agencies were the exception, local and regional transportation agencies will need more technically oriented people, people able to manage data, and more staff in maintenance and operations. The skill sets necessary will be more expensive to obtain, which will impact personnel budgets. One local agency stated that since many safety responsibilities will be addressed by AV/CV, their safety team might be reduced in size. Cybersecurity issues are also a concern and must be addressed. To address security concerns, one agency mentioned that ITS may need to be independent of other systems, which would adversely impact the ability of communities to be fully “connected.”

Supporting infrastructure, including signage and traffic signals, will need to work in concert with AV/CV. Many of the agencies are challenged by maintaining the infrastructure they have, so their potential responsibility to support AV/CV implementation is of concern. Others saw their responsibilities relating to their infrastructure as changing. “Depending on how these develop we may not [be] responsible for operating our [traffic] lights. We are responsible for assigning priority at intersections and doing traffic zones, etc. That responsibility could shift if we don’t keep up. We could fundamentally change.” Cities and MPOs saw an opportunity to have more bike lanes because of an ability to decrease lane widths, and therefore a possible ability to increase their focus on community livability.

Organizational Structure

There were two schools of thought pertaining to changes in organizational structure. There were those who felt that major organizational changes would not occur due to AV/CV implementation versus those who thought a new division would have to be developed that is devoted to this new concept. The latter thought it could not be buried in ITS or operations, while the former thought that tweaks of existing groups might be all that would be necessary. “There may be additional expertise added in this area within operations, IT, safety, and design groups.” “More of an evolutionary change of some functions than a new structure.”

Both groups mentioned that skill sets for existing groups will evolve, as well. One state DOT noted that an interdisciplinary group with representation across the DOT might be required, including people from data management, ITS/operations, maintenance, and safety. A couple of outlier agencies said that they are restructuring right now. “Still in upper management, but we are restructuring to be more nimble to meet these new emerging technologies.” “We are evolving already into an agency that manages the system rather than building it.”

IMPLICATIONS FOR PLANNING FOR AV/CV DEPLOYMENT

People often say "the future is now" to describe bleeding edge technologies that are available today. While AV and CV technologies are still on their respective paths to full deployment, they do have implications for state and local transportation agencies now.

Transportation agencies tend to move forward deliberately and slowly in reaction to change. Looking backward at ITS implementation activities within state and local transportation agencies, researchers see that over the past two decades transportation agencies have used ITS technologies to monitor traffic condition, control traffic flow, and inform travelers. A Government Accountability Office (GAO) report describes deployment of ITS nationwide as "slow" and "spotty" given various sets of planning, funding, knowledge/skills, and coordination challenges (GAO 2012). One might view AV/CV implementation among state and local agencies as following a similar model. Both sets of technologies require agencies to shift focus from planning, construction, and maintenance of roadways to planning the operations of the system.

However, state and local agencies are faced with a new paradigm in technology deployment, particularly with AVs. With ITS, implementation was largely under the purview and control of the state and local transportation agencies. USDOT promoted and supported ITS use through training, technical assistance, information sharing, and some funding. But state and local agencies were in control of when and how the technology would be deployed.

On the contrary, AV technology deployment—whether evolutionary or revolutionary—is driven by the OEMs and the technology firms. AV is being driven by market forces in a way that ITS development was not. Like Uber taxis, consumer demand may place AVs on public roadways while the regulatory and policy issues are still being worked out. The private sector does not necessarily need the public sector's involvement to implement. As one of our interviewees noted, "There are touchpoints where the public sector can participate but it is not necessary." So, while the natural tendency is for agencies to take a "wait and see" approach, that approach does not forestall the need to initiate some planning activities now. AV is going to happen.

The future may be now, but the future is also highly uncertain. As the scenarios presented in this report indicate, even in the AV realm there are multiple plausible futures. Google or another technology firm could disrupt the automobile industry with a self-driving vehicle or the OEMs will continue making and marketing incremental improvements in automation. There is disagreement among the interviewees regarding how close the industry (whether Google or the OEMs) is to self-driving vehicles. Some thought we were "not near as close as Google wants us to think" because of all of the public policy issues (i.e., liability, privacy, and surveillance). Others were of the opinion that this was "progressing a lot faster than the typical policy maker or planner is used to—things happening in [the] next 10 to 15 years." While fleet turnover was seen as a hurdle to market penetration, others could envision a swift change. "The question is, will this be an aftermarket technology or will it require complete vehicle turnover to see penetration?" Regardless of the exact timing, since it will happen eventually, state and local agencies need to figure out what it will mean for them, specifically.

CV technology is perceived as being more like the ITS model of implementation. The public sector has more responsibility and control in the CV realm. The people we spoke with were split as to whether AV needs CV to "really provide value to the system." There were a few agencies that considered CV as the evolutionary precursor to AV and, thus, were ready to implement as much supporting infrastructure (such as fiber) as possible. Others did not want to make infrastructure changes and then be hampered with a "Betamax technology."

The OEMs are perceived as having a larger role in V2V than in V2I. For this reason, there is greater certainty among the interviewees that V2V will happen. "V2V will certainly happen because it will be industry driven." "Most of the intelligence will be in cars themselves, not on the roadside." There are both opportunities and challenges with V2V for state and local transportation agencies. Some are workforce development issues; others are data issues. There was lack of consensus on the importance of DSRC for the vehicle connectivity. The standards process may be too slow and other options (i.e., cellular, Bluetooth, or cloud-based) may overtake. On the other hand, there was uncertainty about if and how V2I would deploy mainly because of the costs of implementation. "CV is a quandary: We can't maintain what we have, so how can we upgrade for CV?" Several of the local agencies envision a business model for V2I in which the private sector provides the equipment that would need to be deployed for V2I. In the AV realm, the private sector was seen as picking up most of the costs. As one DOT mentioned, "We don't want to invest [to changes in infrastructure] and then see technology go the other direction. How do we address without stifling innovation?" An implication that could be drawn across several interviews was that if V2I were in place, it would be value added to AVs and V2V. But if it is not and if implementation is slow and spotty, then other technology solutions may leapfrog it.

What is clear in the interviews conducted for this study was the fact that transportation agency staff recognizes that now is a particularly dynamic and rapidly changing environment. Trying to predict the future so that today's decisions will meet future needs is at best challenging. Given where we are today with AV/CV technologies, there are strategies that surfaced in our interviews that would be robust over a wide range of alternative futures. These are strategies that state and local transportation agencies could begin implementing now, to help them function effectively, no matter what surprises the future brings. A successful AV/CV implementation strategy might include the following elements:

- *A review of legislation and policies in place that could potentially impact the implementation of AV/CV technologies.* For example, some states have found that there were laws and/or policies in place that would prohibit driverless technology, and have taken steps to address them.
- *The designation of a specific individual within the organization who has responsibility for AV/CV.* If one person is responsible for implementation and for managing the program overall, it creates one contact point for a program that involves many internal and external organizations. This single contact is important for good coordination between stakeholders.
- *Participation in the national discussion on AV/CV.* This participation may include such groups as the V2I Deployment Coalition (led by ITS America, AASHTO, ITE, and FHWA), the AASHTO Connected Vehicle Task Force (made up of state DOTs and two Canadian provinces), and CV pooled fund initiatives. Active participation can help

agencies stay up to date on developments in the field, aid in networking and building community, and avoid duplicative efforts.

- *The establishment of a working relationship with resources in the state or region with useful expertise, such as universities, UTCs, and national laboratories.* They can be useful for information gathering, planning and strategic efforts, and assistance with early applications in the state/region. This has proven to be a successful model for several interviewees in this study.
- *The establishment of an internal group made up of people in affected groups across the transportation agency organization in order to develop a strategic plan or roadmap for implementation.* These groups may include representation from management, operations, ITS, design, data management/information technology, maintenance, and others within the organization.
- *Establishment of an external group of stakeholders to assist in identifying and addressing issues and to serve as a sounding board for strategic plans/roadmaps.* These stakeholders may include DOT representation, state and regional agencies, the private sector/OEMs, and universities and national labs. It is important for the success of strategic planning that it not be done in silos according to individual stakeholders, with each addressing its own interests only.
- *Outreach to state and local policy makers to familiarize and educate regarding AV/CV*. It is important to get AV/CV on policy makers' radar screens, given competing priorities. Also, there is much misinformation about the advent of these technologies that could lead to misinformed decisions about future investments.
- *Participation in competitions for federal deployment funding to gain "boots on the ground" experience.*
- *The development of a plan for workforce development, as the skill sets will change for professionals within the DOT (including operations, IT, and data management) and field personnel.*
- *The formulation of a strategy to address the financial challenges of implementation. This strategy may include how AV/CV would help with economic competitiveness and increased operational efficiency, as well as the more intuitive safety and environmental benefits.* It would be advantageous to connect with private sector on economic development opportunities, and to be intentional about early deployment opportunities in the city, region, and/or state.

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Ismail Zohdy, Booz Allen Hamilton, Senior Transportation Analyst

AUSTIN, TX

David Agnew, Continental Automotive, Head of R&D Strategy and Intelligence
Doug Feicht, Denali Group, Principal Consultant
Robert Heller, Southwest Research Institute, Program Director
Jason JonMichael, HNTB Corp., National Technology Leader
Scott McBroom, Denali Group, Principal Consultant
Dave Miller, Siemens Mobility, Principal Systems Engineer
J. D. Stanley, Cisco, Public Sector Chief Technology Officer
Darby Swank, Telvent, Vice President Electronic Tolling Solutions
Jim Templeton, Deloitte, Specialist Lead
Ken Vaughn, Trevilon, Founder
Justin Word, Central Texas Regional Mobility Authority, Director of Project Management

APPENDIX B: INTERVIEWEES AT STATE AND LOCAL TRANSPORTATION AGENCIES

Tom Bamonte, North Texas Tollway Authority, Assistant Executive Director, Strategy and Innovation
John Barton, Texas DOT, Deputy Executive Director
Brent Cain, Arizona DOT, Deputy State Engineer
Jim Dale, City of Austin, Managing Engineer
Mark Demidovich, Georgia DOT, Assistant State Traffic Operations Engineer
Jane Hayse, Atlanta Regional Commission, Director, Center for Livable Communities
Mike Heiligenstein, Central Texas Regional Mobility Authority, Executive Director
Charles Howard, Puget Sound Regional Council, Director of Planning
Mark Kopko, Pennsylvania DOT, Senior Civil Engineer
Melissa Lance, Virginia DOT, Operations Systems Manager, Director, Office of Traffic Operations
Greg Larson, Caltrans, Research and Innovation
Bill Legg, Washington State DOT, ITS Operations Engineer
Blaine Leonard, Utah DOT, ITS Program Manager
Andrew Meese, Metropolitan Washington Council of Governments, Systems Management Planning Director
Galen McGill, Oregon DOT, ITS Manager
Matt Smith, Michigan DOT, ITS Manager
Robert Saylor, City of Richardson, Traffic Engineer and Operations Manager
Paul Steinman, Florida DOT, District 7 Secretary
Paul Trombino, Iowa DOT, Director
Sam Zimbabwe, District of Columbia DOT, Associate Director, Policy, Planning and Sustainability

APPENDIX C: INTERVIEW GUIDE

All persons who had agreed to be interviewed were emailed the scenarios and the interview guide about a week prior to the interview. The scenarios document contained an introduction to AV/CV so that each person had the same foundation for the interview questions. The text of that document is provided below. The two scenarios as presented in this report followed immediately after.

Introductory Text to Interview Questions

Automated (AV) and connected vehicle (CV) technologies have emerged and are now maturing. Exactly how close they are to wide-scale deployment is highly uncertain. These technologies will bring acknowledged safety, congestion, and emissions benefits. But societal, political, technical, and economic factors will shape their paths to deployment. A significant characteristic of the AV/CV environments are their speed of change; how the influencing factors will play out over the next several decades is mutable and undetermined.

State and local agencies plan, design, build, operate, and maintain infrastructure, while also delivering transportation services. How and when AV/CV will change these functions needs to be considered as these organizations prepare for the future. As one approach to doing so, the Texas A&M Transportation Institute developed two scenarios of paths of AV and CV deployment (see following pages). The scenarios were developed through reviews of the literature and expert elicitation workshops, and are intended to represent a range of plausible futures.

For purposes of these scenarios, AVs are defined as vehicles where at least some aspects of a safety-critical control function (e.g., steering, throttling, or braking) occur without direct driver input. Nearly every major vehicle manufacturer is conducting R&D related to vehicle automation. The National Highway Traffic Safety Administration (NHTSA) has developed a classification scheme to clarify policy and technical discussions around the concept of AVs (see Figure [C-1]). Vehicles with Level 2 automation, such as adaptive cruise control and lane centering, are currently in demonstration and early marketplace deployment. At Level 3, the driver needs to be available to retake control within a few seconds' notice. Level 4 systems replace the driver completely.

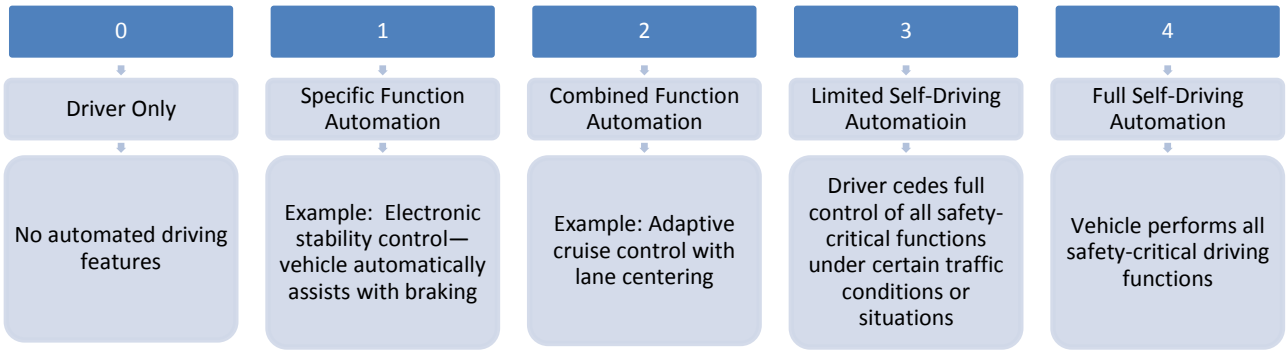

Figure [C-1]. Levels of Vehicle Automation.

CVs are defined as vehicles with the onboard communications capability necessary to establish a two-way data linkage between a system onboard and another system not onboard. CVs can be connected to each other (V2V), connected to infrastructure and roadside sensors (V2I), and connected to other road users such as pedestrians and bicyclists (V2X). When CV technology is in enough cars, infrastructure, and other road users, a vast network is created. Cars and people are able to give and receive data in real-time, allowing road travelers to move more safely and efficiently. It is expected that NHTSA rulemaking would require V2V devices in all new light vehicles but would not require transportation agencies to deploy V2I because of the investment in new or upgraded infrastructure this would entail.

CV technology is not required for highly automated vehicles. AVs are guided not by communication with other vehicles or roadside infrastructure, but by internal sensors, cameras, GPS, advanced software, and highly detailed digital maps. Likewise, highly automated vehicles are not necessary to reap the benefits of CV technology. Whether the two classes of technologies develop on independent parallel paths or converge in the future is uncertain. This is where scenarios come into play. The two scenarios that follow provide plausible views of how the future might develop so that policy and planning activities at the state and local levels can proceed amid such uncertainty. Together the scenarios represent a spectrum of possibilities. Each scenario is plausible but not equally likely to come about.

Interview Questions

1. It seems as though there are a lot of different expectations in the transportation industry about the advent of connected and autonomous vehicles. [Do we need to go over definitions?] What are your [agency's] thoughts on where we are with them?
2. Has your agency developed any near term strategies for proactively addressing any implications of AV and or CV deployments in your jurisdiction(s)?
3. Is there a specific position in your agency that deals with this topic?
4. Now I'd like to focus on the two scenarios. Please tell me your assessment of the **Likelihood** and the **Preferability** of each scenario separately, where 100% refers to

highly likely or preferable and 0% means not at all likely or there is nothing desirable or preferable about a particular scenario.

Scenario	Likelihood	Rationale	Preferred	Rationale
Evolutionary				
Revolutionary				

Next questions about scenario most likely:

5. What are your general thoughts on the scenario?
6. What are the major implications of this scenario for your agency?
7. How might the mission, responsibilities, organizational structure of your agency evolve under this scenario?
    - Mission.
    - Responsibilities.
    - Organizational structure.
8. Are there any policies or planning actions that your agency could implement to prepare for this scenario?
9. Is there anything that your agency could do to shape or influence the scenario coming to fruition?

APPENDIX D: COLLATED RESPONSES BY INTERVIEW QUESTION

INTERVIEW QUESTION 1

1. *It seems as though there are a lot of different expectations in the transportation industry about the advent of connected and autonomous vehicles. What are your [agency's] thoughts on where we are with them?*

Responses from State DOTs

AV:

"Pretty aware of what's going on in testing world but I still cannot figure out how we're going to deal with a mixed traffic stream when we get to allowing them on the roadways. Eventually we may be approaching 100%—the middle section (mixed fleets) is going to be very tricky. Are we supposed to build special lanes or do they mix and mingle with regular traffic? Half the cars are driven by humans then reduce the potential benefits. Improving the capacity of the roadways with vehicles that maximize efficient traffic flow—a real benefit. But don't see that happening during transition period."

"This is going to happen. The private sector doesn't need the public sector for it to happen. There are "touchpoints" where the public sector can participate but it is not necessary. Timing is the biggest issue. There are already cars getting ready to come on the market with limited automated capability by 2017. According to Google we will have them by 2020 but it'll probably be 2035 before we see significant numbers on the road, and they'll probably be pretty much everywhere by 2050."

"Driven by OEM and the private sector. In [state], driver's licensing is under DOT—if there was legislation passed for AV it is possible that license requirements might change. The Deputy Secretary is looking at licensing requirements for AV through AAMVA and other national organizations in which [state DOT] is active. They have a working relationship with [university], and are currently working with them on a research study involving operating a driverless car in [city]. Depending on results, they will look at legislative action necessary for implementation."

"The biggest challenge is that there is no clear vision for how AV technology will be implemented. What will it mean for agencies? How will it be embraced by the public? How will it impact the DOT business model?

There are infrastructure issues too, for example how will AV operate when the road striping has been ground off over the winter? Will the cars still be able to 'read' the markings? Will there be legal implications for DOT when/if this happens?"

"First, we are dealing with a lot of disruptive things (one example, food trucks)—so we approach this like all others—what is being asked of us? Is this a capital improvement request, regulatory function, or what?"

"[State] is involved in a few different activities to facilitate technology—test bed in NOVA working with VA Tech. Equipment along interstates and arterials—Purpose to see benefit back to the state—reduced accidents, better traffic management."

"Is proceeding quickly, but not as much as the buzz would indicate. Pavement markings, weather issues, and road conditions in general are not ready for L4 implementation as yet."

"They are looking at it and engaged on several committees, can't name them… But we believe it is moving in that direction. We want to be fully aware of how this is moving. We don't want to be a roadblock for prohibiting technology growth. We want to understand what is happening, and that our systems, policies, and abilities work to make sure that these are successful. It is incremental in nature, and won't happen all at once, especially with V2V technologies. Autonomous is much further out and wanting to be engaged."

"There is a lack of attention by the federal government in AV research. This is the opposite of what happened in the '90s. The impetus is the industry, which is not a bad thing, but it presents the possibility that AV will evolve without guidance and driven more by market forces. Level 2 is imminent, we have them now but they are at the high end of the vehicle market. Level 3 is a big problem. It has shown up over and over and the big issue is liability and who is responsible if something bad happens. Insurance is a big part of this. If Tesla does what they say they are going to do and send an update to their vehicles that enables automation, and I have insurance through AAA (which uses lots of different factors in determining my rate), all of a sudden I'm not driving anymore and I don't know what AAA is going to do as a result of that. Some insurer might say that you are no longer insured while using the auto driving function, because it is not the insured person doing the driving. Elon Musk said this will happen this summer so it will be interesting to see what will happen. Some of the companies will require people to keep their hands on the wheel, like once every 8 to 10 seconds, and that makes the driver more liable for the driving. That is meant to insulate the auto manufacturer. When we move from Level 2 to Level 3, that is where the manufacturer becomes more liable. If they have some systematic failure in their programs it could bankrupt a company if they have a lot of vehicles out there."

"The private sector, including OEMs and communications providers, is driving development of this. Market ready AV will be ready fairly quickly. It will be somewhere between Level 2 and Level 3 sometime in the next few years. Level 3 in the next few years. The question is, will this be an aftermarket technology or will it require complete vehicle turnover to see penetration? That will impact the timeline. That will proceed at a greater pace because the private sector is not going to wait on the government. The government will eventually move on this but the private sector is not going to wait."

"We believe it is coming and we believe it is coming on an incremental basis. The private entities don't need us. Connected Automation is the real answer. We don't know what to do relative to automated vehicles. We know a number of states have passed legislation but companies are fighting it, so [state] has backed off on legislation. We are talking about it, though. If there was a legislative intent we would be all over it. The one corner of AV we have been involved with for the past 1.5 years, Peloton on truck platooning. They are based out of Stanford in California, who have developed a V2V where trucks can follow closely. They have shown the front and back truck benefit from drafting, and that can help the industry because it saves fuel. They have a thin profit margin; they can save significant amounts on fuel. They have done testing in [state], and we have a lot of trucking firms based there because of the number of crossroads we have in [state]. We think it is good for safety; however, state law prevents close following, and we helped to change the law to allow testing. The legislature wouldn't allow for operations but did allow for testing."

"OEMs are further along than the DOTs are getting their systems up and running. GM Super Cruise in 2017. Audi here in [city] testing out their AV systems. DOT part of that process. Level 3 out there very quickly. I believe the adoption rate from consumers will be fairly quick

and fairly high. Driving is becoming a task people are not interested in doing. More interested in answering their texts, etc. The more we can automate, the better. Look at adoption rates of smartphones and tablets; AVs follow suit. Adoption of AVs a lot more quickly than people realize. [State DOT] taking an aggressive stance on facilitating."

"We are excited about the technology and the changes. It is a huge net benefit to the system, three things: safety, mobility, and economics. Same is true of connected vehicle. We are focused much more on the autonomous side. Don't want to dance around with trying to figure out infrastructure technologies or standards."

CV:

"Several years ago thought DOTs would have large role—we all wondered how we were supposed to get ready for that. What were standards, etc.? BUT now, I feel that OEMs are taking a larger slice of what's going on and that DOTs are diminishing. Most of the intelligence will be in cars themselves not on roadside."

"AV won't need CV, but it will make AVs work better. V2V will certainly happen because it will be industry driven mostly, but not too sure about V2I happening. With the CV there are two aspects: (1) the DSRC, which gets the most attention, and (2) the Internet of Things connection. The IoT and general Internet connectivity will be the bigger component for CV deployment. That's going to enable a lot of these features, not the DSRC.

V2V will likely be on the market around 2017. In the broad sense the Internet connections will happen very fast, 400 million people connected in the next few years, the DSRC will happen more slowly."

"They stay involved with what is going on with CV through involvement with national organizations concerned with CV issues (AASHTO, CV Pooled Fund, etc.). They partnered with [university] on equipping 35 intersections in the [city] region with DSRC. Also, [state DOT] is working on a corridor with 11 instrumented intersections, and hope to have them up and running by the end of the year. They are, like other states, trying to get implementation funding with a state approach, including a working group with MPOs, turnpike authorities, industry, FHWA, [universities], and major cities, with [state DOT] in the lead. They are also active in AASHTO's V2I Coalition."

"They are a part of a CV pooled-fund study (led by Virginia DOT) which, as one of its efforts is studying high-resolution mapping that will be necessary for the implementation of CV technology.

To implement CV, better databases and more detailed mapping will be needed. We will also need satellite communications with security, and we don't know how to do that as yet.

It will require more money, more and higher quality data

From an agency perspective, if fleet connectivity exists, then can vehicles be considered probes? If vehicles are transmitting data, that increases exponentially the data that is available for planning and operations purposes. This could be a great tool for data-driven planning efforts.

Challenges include data necessary for V2V. May be a difference between what could be obtained and what data is needed.

If vehicles become data probes, who will have legal access to data? Should we assume that DOT will have access to data transmit by private vehicles? Will there be privacy concerns?

Two possible models:

- The ‘Bluetooth model’, where data is anonymous, available, and it doesn’t seem to cause concerns.
- Where data is perceived to be ‘Owned’ by the owner of the vehicle or someone which the DOT must get use permission from.

If there isn’t free access to the data collected there will be implementation issues.”

“The automakers (Audi, Mercedes) want people to be in SOVs so more vehicles are sold. Our agency wants you to be a SMART car for 2.”

“With [university], developing automated corridor—keeping infrastructure up to date—digital mapping, road striping. Same corridor as CV test bed in NOVA—I-66—we are hoping to expand that.

Agency overall wants to see benefit of these technologies—but how quickly or how far it goes depends on private sector. Needs to be joint effort with private sector, and states want to facilitate technology development. States not used to doing applications, private sector better at that. But states are not going to let other entities interfere with traffic signals. OEMs and third-party application providers are interested in putting CV applications on interstates. Benefit to states providing data to those providers for those applications. Just like the Googles of the earth—like Waze, they have good data—but state also has internal data that could drive those applications. Bit question—who owns the data that will come from CV applications? Example: HOT lanes or express lanes—travel times for those not a public algorithm would have to come from expressway operator. States want use data that come off of the vehicle or from other applications to better manage our roadways.”

“We are a ways away from being able to fully implement CV’s full congestion and safety benefits. It could be done in as little as 12 months.”

“V2I will impact us and we have to look at the policy side as well, especially with freight. I believe [state] has a requirement about 250 feet following distance and need to look at that in statutes. Just like with other states, we are cash strapped. If there are monumental changes to infrastructure, we are cautiously optimistic. But we don’t want to invest but then see technology go the other direction. How do we address without stifling innovation?”

“Lots of people don’t differentiate the AV and the CV. CV is about giving drivers better information but they can still do what they want, which is a fallacy of CV. We hear talk about CV preventing crashes but at this point it still depends on the driver to respond to the warnings. My old mother is not going to know how to respond to a beep from a CV system. Having said that, it is still better than what we have today and it is a stepping stone to AV but we are not as far long as we should be. I’ve been involved since 2004 in CV and the early ’90s on AV. We don’t really have any deployments but we do have pilots, and those will help the concept forward. Ideally we would have deployed CV first and then put AV on top of that but we didn’t. CV is being developed along a parallel route and they will have to come together at some point or we won’t be able to realize the safety, operational and environmental benefits, especially safety. There are several wild cards, like car sharing and ‘transportation as a service’, which is difficult for older generations to accept. The younger generations will make this happen, particularly transportation as a service. We don’t know if that will reduce the number of vehicles on the road because that is a societal decision and outside the control of this industry.

We assume that people are going to be travelling from home to work, which could be far away, but we don’t really know if that model will hold. In the long term, there will be a lot of

jobs that won't require commuting. Unless you are building something or directly managing people in manufacturing you may not have to commute in the future."

"This will be slower to develop, as you've indicated in scenario 1. The issue is figuring out how vehicles will communicate. Control of bandwidth on DSRC and what the IT infrastructure will be complicates all of this. There could be disruptive changes that impact this, such as moving away from DSRC and to wireless for vehicle communications. Moore's Law will impact technology and I think the infrastructure piece will get very complicated. How do you develop a system that adapts in this fast-changing environment where everything is changing? There is also confusion in the public sector about this as they are confusing AV and CV, but they are distinctly different. Practitioners and policy makers are confused; they think they are being asked to enable AV, but the public sector focus is likely to be on the CV."

"We've been engaged to some degree at the AASHTO level for several years. The group specific to that was chaired by our former director and I chair it now. For a while we were in sit-and-watch mode and within the past 3 years we decided to get active. We've decided to get up to speed on this. Our DOT has objectives for zero fatalities, and in the long run CV is going to be what gets us there. We are not going to have the best apps without CV, and that won't happen for a while, so we are focusing on several short-term apps. We are looking at how to deploy CV on a small scale with DSRC, we have developers, we are going to do this regardless but we are looking for funding. We think there is promise here and [state] already has a lot of fiber laid so we are well on our way."

"Further behind on that. V2V standpoint—OEMs still playing cards close to vests. Doesn't make difference if you buy a Dell or HP—to move along we need to get trust among industry. V2I biggest obstacle is dollars. While [state] is blessed with healthy state budget—counterparts across country don't have funds that [state] does for moving V2I forward. Most DOTs making hard decisions between maintenance vs. installing technology. Technology luxury for them at this point."

"I don't think CV is very valuable. We don't want to invest in the Betamax (a technology that will be very quickly outdated and irrelevant."

Responses from Other Agencies

AV:

"I've been following vehicle progress from OEMs. For the most part, they are designing their vehicles to not need to receive support from agencies. That is intelligent of them, because if a vehicle needs support from the infrastructure, that support is going to be so intermittent as you cross agency boundaries or within one due to maintenance, you're not going to be functional if your AV requires that. It basically needs to be self-sufficient. I spoke to Google's VP of automation, and he said one of the big things that they're working on now is construction zones. How they get the information that they're in the zone and how to correctly navigate them. The trouble is just because you see barrels, it is not always obvious what the vehicle should do. He asked a group of a technical meeting in Miami on how to make construction zones more navigable by the vehicles. All agreed that a pure technology solution wouldn't work (transponders in cones, etc.). This couldn't be maintained across the country, especially given low-tech knowledge of construction workers. Maybe we redesign the cones and markings to be more apparent to an AV or a driver as to where they should go. Even the most basic systems in place like the 'lane closed ahead', about one-third of the time are incorrect.

Some method of accurately tracking construction zones is going to be a big thing that falls on agencies as far as cost and complexity related to AV.

Two things that the Google guy mentioned: snow and construction zones. They have rain and fog down pretty well, but when it is deep enough, to figure out exactly where you are on the pavement is very difficult. Humans struggle with this as well. Once the paint is covered, they can't see the road at all.

If there is any ice or snow, the Google car is going to force the driver to take over."

"Private company will make a V2I network in DC in exchange for franchise opportunity."

"Given the pace of change we've seen in a whole bunch of consumer products, real consumer demand for the safety and convenience features of AV and CV. Consumer demand will prompt rapid uptake."

"They are in a strange place with this. What does it mean for MPOs? No one knows the implications. Up to L3, no planning changes are needed and there are no changes in mobility. There is a big split between L3 and L4. L4 is where planning changes will need to occur. They are not prepared for that and don't know how to approach it."

"Progressing a lot faster than typical policy maker or planner is used to—things happening in next 10 to 15 years. L3 already for sale—technology going for lower cost."

"Lots of questions and issues working through them. There are a lot of public policy issues—most difficult thing—Everybody is going to be cautious of liability; big government issues. What level of government? Where we're going—there's going to be an awful lot of state input. There is a lot of work to be done. Not near as close as Google wants us to think. A couple of decades away."

"This is a rapidly developing area. There are many players on the OEM side as well as others like Google. We've met with Google X people on a video conference in July. They are testing here, it is the second city to get a test. They showed us their technology, which basically replaces what a human would have to see and respond to. We asked them what [city] could do to facilitate AV. Their approach doesn't require much from us. They did say that we here in [state] do things different from California with things like signal phasing and such. Our systems could confuse their system. They are looking for examples of different things so they can build the intelligence of their systems. We have unique geometry. They will thus be coming back to us with questions as their vehicle drives around the area. They will come to us to find out what the vehicle needs to do in a certain situation based on our unique configurations, etc.

We have equity issues. We want to be fair to everyone out there. We would want to help other companies but then that gets into the issue of standards. Google is good because we don't have to put any equipment out there.

We think standards are important because it will sustain our investment in the technology over time. It's rapidly changing, but we want the equipment out there as long as possible. Standards sustain that because everyone is on the same page. And if we have standards we are not favoring one company over another."

CV:

"One major concern with CV is the implementation and the concepts that V2I folks tout… is the initial cost for implementation, also the ongoing cost from technical support to keep it up and running. My city is pretty tech. advanced in comparison to some cities, and we know how

much effort is required to keep regular communications going. Adding new communications between all cars and all intersections is a large burden. There are a lot of liability issues if they are not correct. The costs involved and technical support is probably above the level of our support technicians.

This is based on a general perception. The only CV tech we've looked at is on the emergency-vehicle side. Some of the high-end offerings that GTT/Opticom provides for feedback from approaching fire engines and ambulances that they have. We found that they need a central system to support all of this system. The infrastructure is isolate, and needs to communicate to a central system to know what messages to send out. This would be a complete central system upgrade that would be very expensive. The V2I side may not have progressed far enough to have solid prices."

"A private company will make a V2I network in [city] in exchange for franchise opportunity."

"Given the pace of change we've seen in a whole bunch of consumer products, real consumer demand for the safety and convenience features of AV and CV. Consumer demand will prompt rapid uptake."

"This will be required by 2019, and some CV is active now. Again, what does this mean for MPOs? What is the infrastructure plan for implementation? No one seems to have a handle on this at the local level. It is on the horizon and we aren't ready. CV is a quandary: We can't maintain what we have, so how can we upgrade for CV? [Transit provider] has a fully connected vehicle system, and is using it to get real-time travel information to the public. Could be used even better; it is not used to full advantage."

"After the news about jeep hacking and the bill senators put forth—exposed vulnerability will slow things down a bit—you cannot prohibit advancement of technology. You can't put a lid on technology; it's going to advance—need to step back and think about privacy and cybersecurity before it gets too far. Because USDOT more supportive—seems fast—but now not sure with the hacking incident."

"Connected vehicle much faster—evolutionary precursor to AV. In our case, our idea here is to provide for as much infrastructure development as possible—expected arrival. On 183—$500 million construction putting a few million into infrastructure so putting fiber and dark fiber—don't know what technologies will be coming—but that shouldn't stop us from what would work today. Integrated corridor management—could be a part of it. Smartphone applications might be appropriate. Infrastructure that could be turned on. We don't know what cars will look for but want fiber in place just in case. Lack of consensus on whether fiber is needed; we are in process of construction now so putting it in—taking a gamble, but to go back to put it in at some later date would be crazy. Hard wiring something today is kind of silly in some ways but we know where the road is—if we put it in now that portion is done. If technology leapfrogs, then we go to it.

Must figure out infrastructure technologies or standards."

"This should come first and probably will come first. AV requires more technology and a higher tech environment. We already have a lot of features that will facilitate CV, like adaptive cruise control. And for AV to really provide value to the system we will need CV. For example, it could tell what the optimum cruise speed is for a group of vehicles. Audi is interested in getting information on when the signal is going to change. It allows electric vehicles or hybrids to shut down the vehicle to save fuel, or it tells the driver when they need to get ready to reengage in driving. The value of this depends on how we have the lights cycled. The volume on the road and the presence of detection impacts how we would do this.

There is lots of interest from the industry in this and we are getting requests from companies for our data. There are a lot of companies working on these applications."

INTERVIEW QUESTION 2

2. *Has your agency developed any near term strategies for proactively addressing any implications of AV and or CV deployments in your jurisdiction(s)?*

Responses from State DOTs

"Just getting started—procurement for consultant to analyze or assess and come up with roadmap with what we should be looking at. We scrubbed all of our existing laws to see if there [is] anything restricting. Nothing that says vehicle must have a human operating."

"We have launched a connected/automated vehicle (CAV) initiative. It is a guide for a basic strategic plan for addressing the implications of AV and CV development. We have a sort of roadmap that lays out the areas of our operations where there are likely to be impacts. It was written by agency people and was oriented around tying us into the national conversation. We also focus on state-level issues. We are right now trying to define the starting point: how do we get moving? Our work plan over the next year is to identify what we are going to look at first. We are hiring a CAV advisor position and will be forming an agency steering committee to help coordinate across the agency."

"Yes, [state DOT] formed the working group for the implementation initiative, which consists of MPOs, turnpike authorities, industry, FHWA, CM, [university], and major cities, with [state DOT] in the lead.

The new Secretary is interested in investment strategies for the implementation of AV/CV at strategic locations.

They are exploring a statewide fiber network.

IT is investigating Internet protocol to ensure compatibility with AV/CV implementation.

They are testing the technology in the [city] area.

They are also looking at truck platooning, since they are in the major NE corridor. Also, exploring deployment in work zones, weather implementation, and traffic signals."

"We are a part of several AV/CV initiatives:

- AASHTO's Connected Vehicle Task Force (made up of the DOTs and two Canadian provinces).
- CV pooled fund (led by Virginia DOT).
- V2I Deployment Coalition (led by ITS America, AASHTO, ITE, FHWA).
- An in-house AV/CV Exploratory Committee.
- Two CV test deployment projects have been undertaken.
- Participating in the USDOT CV Regional Pilot Deployment Program (have submitted a project proposal for funding consideration).

Strategies include:

- Competing for federal deployment funding.
- They are engaging cities and counties too, and are framing AV/CV as a mobility issue, not an agency issue."

"We don't have formal documentation—our work really around use of CV and AV test corridor—and a research effort at this time. Working with [universities] we want to get the CV technology out there and see what opportunities could unfold. Focus on congestion—and how to improve collisions. How to improve performance measures along those interstates. Really focused on CV—ear to the ground on AV.

Have done legislation review—current legislation is silent; importantly nothing that prohibits. Trying to create environment that encourages testing.

[University] has a test bed that enables controlled tests. Stepping stone for AV testing then on to 'live' roadway.

Sending PPT that presents information on [state DOT]'s AV and CV corridors and infrastructure requirements. These are: I-66 and I-495, arterials Rte. 50, Rte. 29, Gallows Road. [State DOT] owns and operates most roadways in [state] so don't have to do too much coordination with counties or other local agencies for these AV/CV test bed roads.

Coordination with local agencies—Would be a big issue with other states—Not a lot of local agencies involved in any of the activities going on—NCHRP, TRB, or conferences.

[State DOT] submitted a proposal for USDOT CV pilot, if awarded, will enable some expansion of the corridors and fleet vehicles outfitted."

"Yes for CV. They are developing data systems and information systems to take advantage of CV, and have a 5-year strategy for implementation.

No for AV—They can't address AV specifically, as that is not a DOT function, but only as it pertains to CV."

"We are looking at that right now. Director tasked me with laying out the roadmap. He is very engaged in the technology and looking at it. We don't have the near-term, but are looking to develop a roadmap moving forward."

"Not really. We are barely doing anything with CV. We just now have knowledge in our operations department on this. I always get asked what we should do but we don't have anything official. Administration is aware that we need to be ready for this, and there is concern we are not doing anything. We have some research going on but no official strategies or plans."

"We've been focused on simply understanding it. We are developing a strategic group to look at this, and we've formed a partnership with TTI (Accelerate Texas) to understand these issues and help deploy them. We are also looking at emerging technologies and assessing our future role. However, we don't yet have a goal or strategy for carrying this out. [State] has seen this is coming and has laid fiber optics everywhere that will facilitate the connection of infrastructure to vehicles. We are still in the learning stage and trying to figure out [state DOT] role. We are engaged in ITS America, but really we are playing on the margins. We have asked SWRI to develop and prove the ability to have autonomous work zone vehicles that would allow for protection of vehicles that shadow work zone activities. We don't know how long that will take but the idea is if we could use AV functions on high-risk vehicles you could at least take the driver out of the situation. We recently had a crash involving an attenuator. Nobody was hurt, but we could further enhance safety by simply removing our driver from that situation."

"Other than the truck platooning, we don't have anything for AV."

"We have a number of initiatives to stay ahead of the curve just this year.

Developed an executive steering committee—strategic plan for department on how to move forward. Need to have Secretary's sign off before disclosing contents. We hired consultant to

guide us through process. Cross section of folks at meeting to develop—majority DOT folks, ITS, executive team, all the different functional areas of [state DOT] necessary.

Created some working groups to look at policy, engineering, and modal aspects. For example, in engineering, looking at design standards for major infrastructure investments. Making major investments in infrastructure; allowing us to remain flexible. Flexibility to adapt without major reconstruction depending on how technology develops.

Testing facility in [city] area. Original purpose for testing tolling equipment (bringing that back in-house). Then, considered if doing that, then also facility we can rent out to OEMs or first-tier suppliers to test their equipment as well.

Partnerships, such as SwRI, Audi. Desirable place for folks to come. Have torrential rains and heat that folks might be interested in (even if not snow like MI)

Pilot projects – We have V2I in [city] area; Mobileye in a variety of vehicles—data being collected and used to drive concept forward. Truck platooning—starting up. We're looking at any and all concepts for different pilots.

Space program – Now that Space [state] has unused assets; looking at ways to test a variety of technologies like drones and UAV—rocket technology is really autonomous technology. Facilities that are available for P3s.

Ports to test Level 4 technologies. Ports are a closed system. Port of [city] 5000 acres. A lot of places we could be testing Level 4 technology.

Partnerships with universities to see what research they are interested in doing.

2016 – Looking at how to include AV/CV in all long-range transportation plans—getting transportation commission to sign off and get in transportation safety plan. Other big piece, develop public outreach and education program. Elderly population here—opportunity to provide AV and CV technologies—The Villages—largest retirement community in country to develop and get them to buy into concept—reduce crash rates."

"Very focused on AVs, I think it is already here. We will move past it quickly, that is the long-term impact. I don't want to implement Betamax (referring to CV system). Based on our investment strategy, I think it is better to focus on AVs. It is our strategic advantage. I think we can get some here in 3 years or less.

We are developing a state strategy… [university] is running a driving simulator… we are developing a marketing template to try and offer AVs on our system in a few corridors. Scalable enough from a state perspective… have a good blend of urban, rural, and different weather conditions. Focused on the east-end of the state to develop HD maps for corridors on our roads. We're looking at a slow-speed route. Fine-tuning this strategy on the coming months, especially on the mapping. I-380 corridor. Connects [city]… How do we want to implement the system as vehicles evolve? How can we enable AVs to run in our corridor?

We wanted to do HD mapping because a lot of states aren't doing that. We are really not interested in V2I. In order for vehicles to run, we've found they need two things (from our discussions with OEMs): really good paint lines, and HD maps. Mapping down to the cm level on the system… not only collecting data, but transferring data to the vehicle… how do we do that? If base mapping is cm level, it will allow better definition of where the vehicle is. The more Google spends time on the system, they get a better map. We already do mapping, but why not do a more accurate and sophisticated map? We have LIDAR data across the state. Bringing in a firm to help us do the right level of mapping on corridors and surrounding areas. Even from the trial perspective. Looking for high and low speed. They all need the same mapping piece.

We've had linear referencing system since the late '90s, but if you want to route winter operations… you need better info. Because of this need, we are not far away from cm level detail. Next phase for us is going to be 5G. Belief is at the next level, the transfer of information pushes computing to the endpoint because of the speed. The vehicle can consume tons of data about the system and the computer makes the decisions."

"[DOT] only formed 12 years ago, before that we were a public works agency. We are getting more data driven but have limited capacity for what we can do. Public works agencies typically use data for customer service needs. Tech literacy an issue. Actually, the division that deals with urban forestry (trees in city) is the most tech advanced. A breakthrough for us would be just getting a signage inventory—can't tell where or what all the signs are. This would be a huge investment we would need to make first. As a city, we don't have to [be] MUTCD compliant. We have to deal with embassies, contractors putting up their own signs."

Responses from Other Agencies

"Nothing near-term. The timelines in your scenarios are probably fairly accurate in both. For us… looking at 2017 as the earliest date and 2020 as more realistic… that is so far out and no real standards set… we're keeping our eye on it but not making any plans ourselves."

"Implications not really good matchup with MPO responsibilities as specified by fed law. Not really sure that the member agencies would call upon us to do something about it. We're a different MPO since our member agencies are sizeable local governments ([state] and [state] counties and cities). Moving motor vehicles not embraced here. Our policies and strategies are all about facilitating people NOT bringing autos into district."

"CV: [Agency] has engaged the local AT&T innovation lab (The Foundry) on a variety of Internet of Things initiatives. We have Toyota locating 5 miles from our facility. In the short term, we are:

- Reaching out to Toyota and some suppliers for collaboration.
- Monitoring what CV means for a payment platform.
- Putting together procurement for a toll collection system.
- Looking [at] apps that might be appropriate in terms of payment portals in the onboard units.
- Working with AT&T on app-based wrong-way driver warning system.
- Reaching out to AT&T on smart raised pavement markings—low-cost sensor that can be used for a variety of purposes.

AV: On policy side, [agency] has not done anything in terms of either banning or encouraging AVs. We don't intend to take the lead on that but we will make our system known to the industry as an attractive space for testing of vehicles. We have a lot of sensors; a lot of cameras. We can track vehicles with transponders. A lot of useful information and could be a useful partner.

It has not yet affected the way we implement our capital planning. With the leadership of MPO and good fiscal common sense, our capital planning will have to consider whether technology will render need for physical expansion less pressing. Investment in CV and AV may give more bang for the buck than just blowing out our lane capacity."

"They are talking about it and it is on the table, but they will not update their plan until 2018. They know they will address AV/CV in the plan but don't know how. Subsequent plans will address changes at that time."

"No—not in near term. But we have included scenario analysis in preparation for long-range plan. We did several different alternative futures for 2040—very simplistic—L4 would increase all road capacity by 50% (assumption)—VMT goes up; transit use down. Congestion cost went way down. Presentations to keep our board aware—but board is skeptical that will happen in near term. Continue to massage and look at it from all different angles—land use, performance, and community development.

Where it will be deployed first? Interstates or urban? I don't see it is an emphasis area for [state DOT]. Could come up from grassroots level or economic development perspective (AT&T Research Foundry). I know folks who are trying to push testing from a more top-down approach. At this point, nothing is being looked at as a whole. Each company for itself. Need research and help in running scenarios (not every MPO needs to run same scenarios)—can aggregate to figure out what needs to be done in unique transportation models."

"Through our procurement process, we will include whatever technology makes sense. For the eventual coming of that connectivity."

"We don't have a long-term strategy, but at the same time we want to work closely with the companies involved so that we can provide a better, safer transportation system. I have asked Google what they need from us. We have visited SWRI and talked with them about their systems. They have AV and CV systems. There is a lot of promise in the 18-wheeler technologies that notify when a truck is approaching a low clearance. It notifies that the clearance is too low and will stop the vehicle if corrective action is not taken. That would have been a big help up in Salado a while back when that truck hit the bridge and shut down I-35.

[City council] requested a "white-paper" on what we are doing to plan for and facilitate the development of AV and CV. We are still working on it. We are doing things like teaming with [state DOT] to look at commercial vehicles and CV in the [state]. I think TTI was involved. We are the urban partner in that. We are working out the concepts. Also working with Google X. We are doing connected vehicle type work on transit signal priority. We are using GPS data and assessments of whether the bus is behind schedule to extend green lights. It is a V2I application and it doesn't need any equipment in the field. We are also looking to do connected bicyclist work. It involves an app where you activate the app on your phone as you ride and it provides a type of signal preemption. This is very early; it is a prototype we are working with city employees. We need to learn more about what the transit agencies and companies need and want to do."

INTERVIEW QUESTION 3

3. Is there a specific position in your agency that deals with this topic?

Responses from State DOTs

"No—perhaps roadmap will identify that need. All CV talk is buried in ITS world at [state DOT]. Right now, we're rolling them into one bigger topic."

"There will be a point person but [name] is the point person right now on technology issues. The CAV advisor will be responsible for 'pulling the pieces together' and looking at policy and

legal issues. We have a team that worked on the strategic initiative and who have a role on this topic but they are not dedicated to this topic. [Name] is serving as the CAV advisor for now and is helping to get this off the ground until the CAV full time position is hired."

"He is the person with responsibility for AV/CV issues. [Name] is in charge of licensing so will have some responsibility as well."

"He is the person who does that as part of his job. There is also an effort underway to form an AV/CV Exploratory Committee, which is made up of representatives from Operations, Planning, Programming, Risk Management, Legislative Affairs, and a few external people from MPOs, etc."

"We would do it through ITS group—but we're small, only 1700 traffic signals with copper wire system. These would need major updating to set stage for AVs. We would have a concern about making major investments in ITS that wouldn't get used."

"If we were to win the pilot proposal—we would make that investment. Now straddles between operations and research part of [state DOT]."

"He is the designated AV/CV person at [state DOT]."

"I will be the oversight, but there will be others involved."

"I am the focal point for the research on this, and the Traffic Operations Division has a position that is supposed to deal with CV from a technology perspective, but it is a middle management–type position. It is not high up in the organization."

"We had someone devoted to [AV/CV initiative] but moved him somewhere else. We have a strategic planning office that oversees Area 41, the Technology Task Force and [AV/CV initiative]. The idea is to expand that office but we are not there yet."

"He is the guy on this. Management is engaged and asks about it but there is nobody else."

"Actually yes, [name] is the gentleman that's running the AV program. I did 20 years with [state DOT]; this has been one of my passions.

[State] looking at more the pieces and parts with OEMs. [State] focused on how to implement this stuff, like what do design standards look like? What should I be looking at when building new bridge structure if I know AV only use 10-foot lane and tighter shoulders as well—could I put more lanes across? How does that change configurations for ramps (wider)? Put two-lane exits off these structures? Little things we can do today in concrete asphalt, steel, how do we implement that? Change design standards to make those structures/ ystems more effective for AV/CV? How do we work with bus industry so they start adapting more quickly? Trucking industry—to implement sooner before later? How does that affect our traffic flows?"

"We are beginning this process. [Name] has been our go-to person."

Responses from Other Agencies

"Traffic Engineering and Operations Manager (me) everything to do with traffic signals and signs falls in mine. Since I'm really interested in them, I'm the one that is taking over."

"It's not anybody's job if you don't have an AV/CV person. Sort of falls through the cracks. The MPO is a service organization to its member agencies. Our organizational structure and positions are to serve our government agencies. None of them are mentioning AV or CV yet."

"[Agency] created a strategy and innovation office. It's small, myself and a colleague. Its purpose is to keep an eye on the CV space. We're starting to reach out to startup community to see if we can jumpstart innovation in AV/CV—accelerator program, hackathon, etc."

"No, they have approached it from the general planning perspective."

"We desperately need a position. Does the ITS position morph into the technology position? Now has: Transportation technologist—he has his hands in everything—app developer. MPOs will have to understand technology at a whole different level than we have now. Technology savior for congestion problems."

"No there's not one—it's embedded with operations and engineering. When you're small like we are it's a lot to ask—there [are] opportunities to collaborate with groups out there working on this—This is much further away than people think."

"No. It has fallen on the Arterial Management Division to look at this. We are the technology division for the department. The council white paper came to us."

INTERVIEW QUESTION 4

4. *Now I'd like to focus on the two scenarios. Please tell me your assessment of the* ***Likelihood*** *and the* ***Preferability*** *of each scenario separately, where 100% refers to highly likely or preferable and 0% means not at all likely or there is nothing desirable or preferable about a particular scenario.*

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push				
Evolutionary Path: Business as Usual				

Responses from State DOTs

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	10%	We're dealing with DVD players, or television. There were no institutional barriers and lives on the line—with CV there's a whole lot more complexity and safety factors and	70%	I don't like red tape. Personal early adopter. But realities are probably that things don't move so fast. If so, agency would be challenged. Trying to play catch-up rather than guiding it. Tail would be wagging the dog. Social

		social issues. I don't think the technology can rapidly get there by 2025. There are too many things going on.		media on fire before we even picked up on the uses of it and how we could work it into our business. Stay behind the curve. The OEMs are running with this faster than government.
Evolutionary Path: Business as Usual	90%	Track record of this whole program—we've been talking about it forever. Not made a whole lot of progress. A lot of talk, not much action. Government being involved does not make it easy with lots of policy, rules, and regulations.	30%	

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	50%	These are two ends of the spectrum and what actually happens will occur somewhere in between. The fleet changes over slowly, so that will be evolutionary, but the technology happens quickly, so that will be revolutionary. In the freight industry, for example, this could happen very fast because there is a very immediate payback. Economics drives things very quickly and the economic case for development is better in freight. Platooning, for example, should be coming online soon. There are significant savings to be had in terms of fuel.		
Evolutionary Path: Business as Usual	50%	The big question here is to what extent the regulatory environment will allow any development to occur. Regulatory change is likely to occur on the evolutionary path.		Evolutionary is much easier for us to adapt to and would be less stressful to the agency. However, there will still be things to struggle with, like how to adapt as an agency. We aren't ready to answer those questions yet.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	45%	Once there is a market with public acceptance of the technology, AV/CV will implement quickly. The example used was tablets. Once people saw the value of tablets and they seemed commonly used, a tipping point was reached. He expects same with AV/CV technology.	25%	Fast deployment will be hard for the DOTs to keep up with—it is difficult to implement new technologies in a DOT structure. On the other hand, fast deployment and the grassroots support it would generate would help with any political issues that may arise (e.g., why are we spending money on self-driving cars when there are potholes and bridges to repair?).
Evolutionary Path: Business as Usual	55%	When the magnitude of implementation issues become clear, there may be a dampening effect. Some of these potential issues include loss of connectivity, mapping issues, safety and reliability of connectivity, and, most importantly, safety considerations. Communications will need to be safe, reliable, effective, and it can be hard to release control. Major change takes time from a DOT perspective.	75%	This should be driven from the private sector, but state DOTs will have to implement through the challenges that will be encountered. GRADUAL CHANGE FITS THE WAY DOTs OPERATE better than sudden change.

NOTE – He felt strongly that AV and CV had to be separated when considering paths, due to the rationale described below.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	AV is 80% CV is 25%	For AV – Highly likely, because the consumer is buying it and the OEMs are pushing it. For CV – Unlikely because DOT will have difficulty doing what they have to do for this scenario.	AV is 75–80% CV is 25%	For AV – This preference is due to improved safety and its benefits. For CV – This is a lower preference because it may not be achievable under the standard DOT model of operation.
Evolutionary Path: Business as Usual	AV is 20% CV is 75%	For AV – A concern is that one extraordinary event could prevent AV from being fully implemented, for example a failure that caused a catastrophic and highly publicized accident. For CV – Until there is a strong business model supporting change, the DOT will not be able to change to support CV.	AV is 25% CV is 75%	For AV – Need to look at bigger benefits. For CV – He would prefer this approach for CV so that DOT could take a measured and wise approach to implementation.

"*Revolutionary* (Likely 70%, Prefer 80%) – Google just a technology not a market—how to build the market? Price has to come down. Also to get fleet penetration would have to scale very quickly (this means fleets) rather than individuals buying personal vehicles. We'd prefer private sector push—we'd have a hard time deploying the capital resources to make this happen.

Evolutionary (Likely 30%, Prefer 20%) – Fraught with really big challenges. You need someone who can get out ahead; build market confidence. This will be happening and an unknown is the public's tolerance of risk. This approach is contractual and standards driven. Need to study and test. A regulatory approach that can be cumbersome. And, if the public demands regulation for safety, then change will be glacial. We would rather see us change to the extreme.

Scenario Most Likely: Revolutionary"

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	20%	I think it's aggressive. From the standpoint of the OEMs, on the V2V mandate, and the amount of data they can provide—they are only willing to give basic safety message—CV building blocks for AV. They will need to work with States and localities to get necessary data for enabling AV on roads.	30%	Would like to see something in the middle—infrastructure would need to be kept up—roadway pavement—need to be maintained at higher level for AV side (reflectivity). If we go too aggressive not going to be able to keep up.
Evolutionary Path: Business as Usual	80%	Basic safety messages don't provide the data we need, if OEMs were on board with providing additional data, and then we could move forward more quickly. All dictated by OEMs or aftermarket providers. Limited information slows things down. Privacy concerns will also slow us down. Technologies might be caught up in liability concerns. For full automation there has to be change in perception—insurance companies on board. Insurance cost for AVs would prohibit consumers demand. Need to have all localities on board—for non-interstate applications. Traffic	70%	If we go too slowly, we may move on to next technology that hasn't been introduced yet. Supportive to get it out quicker in our urban area—more investment in rural areas to get infrastructure to where it needs to be.

		signals information necessary for interest; need to get all localities on board for that—and infrastructure upgrades. Traffic signals not connected to communications systems now.		

NOTE: This interviewee felt that AV and CV must be discussed separately.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	85% for AV 15% for CV	AV is more likely to follow this path because technology in the private sector can move much more quickly than the public sector.	70% for AV 15% for CV	Will require more collaboration between public and private sector, and collaboration in a different way than business as usual or the 70% would be higher.
Evolutionary Path: Business as Usual	15% for AV 85% for CV	The public sector has a long way to go before CV can be implemented, and will need time to get there.	30% for AV 85% for CV	Needs to be driven by the public sector, which moves more slowly.

He stated that AV is most likely to implement in a revolutionary scenario and CV is most likely to be evolutionary.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	55%	Private sector will drive this and we are not able to move at the same speed. V2V tech is handled by the private sector… On the back-end with agency side, we want to be up there… but question the time schedule. There are a lot of concerns about cybersecurity and technology. **Note: numbers in this response do not add to 100% by desire of respondent*	40%	There is a lot of unknowns. Just from my exposure, it is moving very rapidly. And we don't know where it is going. CV is happening and a lot of safety benefits. Autonomous is much further out. The issue about how they deal with rain, pavement markings, signing, etc. It could be handled, but these need to be addressed. To have agencies come back and modify change and enhance… that is idealistic. We don't have the funding. We are in a maintenance and preservation mode. New infrastructure is very challenging.
Evolutionary Path: Business as Usual	80%	People will like this, but there is also a concern with government getting people's information. That could be a huge issue. Just seeing what happened in OR w/using VMT to supplement the state highway fund… the privacy issues were significant. Sharing data… as long as the public is comfortable with the tech, it will just take time for the public to accept it.	80%	The way government moves… the public perception about information privacy and sharing issues. This is a huge leap in technology… we are moving from horse and buggy to a car all over again. Trying to make it fit the current system now. Is that the right thing? Tech is moving so fast, but the infrastructure doesn't change that fast. We need adaptability and the policy will help, but that will just take time.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	40%			
Evolutionary Path: Business as Usual	60%	I don't believe that these technologies will arrive overnight.	100%	As a large, bureaucratic agency we would not be able to respond quick enough to revolutionary change.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	65%	The revolutionary path is twice as likely to happen. When you look at the types of technologies that these are dependent on, the entire industry has moved at an exceptionally rapid pace. They have not waited for government to bless that pace. The wireless industry and companies like Uber are illustrative of this. Uber was willing to pay penalties to do their thing and I don't see the private sector waiting on this either; as long as there is an appetite for this among the public they are going to push forward. They won't wait for the bureaucracy to allow this. There are no real	60%	I don't think bureaucracy should guide technology development, but the systems need to work beyond the markets that are viable from a pure profit motive. For example, there are cell services that work well in big cities but they don't work well in smaller rural areas because the companies have not invested there. The idea for these technologies is that they should be seamless. Look at satellite radio. It works everywhere. The same benefits would need to be seen with AV and CV. CV and AV might be beneficial in urban areas but it would be just as valuable in rural areas. It doesn't matter where you are getting the data. It could be from any number

		drawbacks to this and there are not any apparent negative aspects to moving this forward on their part. Government agencies are slow and risk averse. We have to plan for all sorts of scenarios and risks and our procurement process slows things down, which squashes innovation. On the connected vehicle issue: I think that the scenarios are accurate in that area.		of companies or sources, like Waze. However, it should work everywhere, and government may have to play a role there.
Evolutionary Path: Business as Usual	35%		40%	

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	90%	We are going to have to adapt to them; we don't know how to respond.	80%	I'm OK with the revolutionary path. We would like to be more proactive.
Evolutionary Path: Business as Usual				

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	80% CV			
Evolutionary Path: Business as	60% AV	OEMs aren't going to wait for government to figure this out.		

Usual		Consumer demand out there (older and younger).		

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	85%	I believe the tech advancement is going to happen faster than we anticipate.	100%	Speed of application: it allows improvements to safety mobility and economics in a much faster timeframe, which allows us to lower the cost of transport.
Evolutionary Path: Business as Usual	25%	Policy getting in the way will push us to the evolutionary path. They drag their feet. People will see business opportunities and jump on it in the revolutionary side.	0%	Too slow.

Responses from Other Agencies

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	Highly likely	Some specific differences, but think this is 85% likely. I think we are going to see the taxi and trucking companies jumping on this very quickly. Package delivery as well (like FedEx, UPS, USPS). OEMs are very aware of liability, and everyone is recording 360 deg. of data and holding it in the car for long periods of time b/c their AV will always be the ones doing the correct thing and following the law. If they're in an accident, it will always be the other	100%	It has the smallest impact on municipalities insofar as things we need to implement.

		vehicle's fault and they want to prove it. With the increase in data and reliability… the delivery and truck companies will want that liability decrease. You still need a driver to drop off the package at the mailbox, but all they have to do is carry the package to the door. I think the cost will deter V2I from implementation, but as soon as high-level AVs are available, there will be a transformation at the low end because car sharing will be much easier. OEMs will set price points higher with the idea that multiple families share it. If they market it correctly, it is a savings. 99% of the time our car is unused. Car sharing is really going to take off at the low end.		
Evolutionary Path: Business as Usual	17% likely	The combination of the concern for liability and policy on the behalf of automakers… I don't think it is that big of an issue as this scenario posits. OEMs seem very confident that they can perform better than a human in most conditions. The other side of this scenario… that the Congress drags things out… unless something changes, there is too much money on the side of implementation and allowing it, and no money on the side of banning them. I don't see cost being that big of an impediment. On Level 4 automation… Google is very close to having a commercially available system. OEMs are close behind as well.	Very low. 10%	Couple of things in this that it would be nice to see, but overall, I am a big fan of AVs and I want to see them improve rapidly. Even V2V are dependent on other things outside the car being there. The car that might crash into you has to have V2V; if not, it isn't helpful. Every use case for V2V and V2I require everyone to have it, and everyone has to pay attention b/c you can't rely on it all the time.

"Evolutionary (Likely 80%, Prefer 80%) First applications will be freight movement—truck platooning—because these drivers have higher licensing and training standards now. The slower you go the more time you have to evolve the infrastructure.
Revolutionary (Likely 20%, Prefer 20%) Technology is there but infrastructure will not be there. Fleet turnover is a big problem—would need financial incentive for consumers. Pedestrian safety is a concern. Challenged by the fact that laws, funding built under certain assumptions. If they change quickly, agency can't keep up. Look at Uber, how it's already challenging to manage mobility in DC without driverless vehicles. On the positive side, people are ready today for less expensive paratransit or mobility solutions."

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	70%	Haunted by the ghost of Segway. Worried that all of this stuff will be nothing more than a Segway. But increasingly confident that there will be consumer demand for AV and CV. Having your vehicle become another screen—texting, working, playing—will drive demand for these vehicles. The mundane part of driving will be taken by the machine. Depending on how we go politically could be public policy push for facilitating AV/CV for to enable lighter, fuel-efficient vehicles that are better for environment.	100%	We move in fits and starts and there is such potential here; such an opportunity for economic leadership; benefits are evident and manifest and we should realize them as quickly as safe to do so. Chances of success coming from having compelling products rather than running like paratransit program. The opportunity for revolution comes if the Googles, Teslas, OEMs come up with compelling products that wow and amaze us. If they succeed, then consumer adoption will be fairly quick. Aftermarket—ways of giving existing vehicles AV and CV—really important.
Evolutionary Path: Business as Usual	30%		0%	

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	60%	Private sector will drive this, and will force the market. L2 improvements will spur the market from the customer perspective. People like security, safety, especially in congested urban areas. Safety and security improvements and private sector "apps" will drive the market.	80%	Safety benefits.
Evolutionary Path: Business as Usual	40%	Public sector will lag a bit but will be forced into it. (Side note: He felt the economy language in the description was too strong.)	20%	He did not like the negativity in the second scenario description.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	60%	More rev than ev—to a point then plateau. MetroQuest survey on technology—awareness of AV, would use? The market will demand these safer vehicles. Hands, feet free at same time.	40%	
Evolutionary Path: Business as Usual	40%		60%	More time to prepare and accept the change. GA general assembly—double $$ for maintenance and operations. Critical piece to operate safely—striping, signals, no potholes. We are going to

				be putting even more into maintenance and operations. But such a disruptive force, nobody is going to be totally ready for it. Zoning requirements for parking, impact on transit (synergistic on each other).

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	65%	Not take to 2050—looking at something in the late 2030s.	50%	I'm not driven towards the rapid adoption—as some people who just like technology. I'm not sure people know where they're going with this new technology.
Evolutionary Path: Business as Usual	35%	Fleet turnover is huge. It's going to take a while. People are keeping theirs longer.	50%	I don't have a strong bias—if it could be proven to be safer—demonstrated to be safer.

Scenario	Likely (0–100%)	Rationale	Prefer (0–100%)	Rationale
Revolutionary Path: Disruptive Private Sector Push	85%	We are hearing about the rapid change, and the companies aren't waiting for us. SWRI and Google are moving ahead as are Tesla, Audi, and BMW. We are already on this path.	85%	We are already in a reactive mode. We don't want to dictate. We need to be thoughtful and deliberate in how we work with companies. I could see a business model where the private sector provides the equipment that would need to be deployed for V2I and the services we are looking to implement.
Evolutionary	15%	However, there are	15%	I do think we are going to

Path: Business as Usual		security and other policy issues. Government will be involved somehow and step in. We just don't know what all is going to happen on the regulatory front. Right now we are just in catch-up mode. Emergency vehicles are among the first "connected" vehicles in terms of V2I and signal preemption. We have around 70 "opticon" sensors on signals that detect the strobe lights on the vehicle but it requires line-of-sight, which can be difficult in an urban area. We can now tell where the vehicle is without the sensors and we want to consume that data by the system. The big benefits is that we can reduce response times because we will be able to clear vehicles from the path of the emergency vehicle. We are able to do a lot of this wirelessly but we have to have a good communications network		need to be involved in deploying equipment in the field to facilitate the deployment. Private companies are telling us to do things incrementally; don't do a big pilots. We will start with a few signals and see how it works. At the city level, we are concerned about all modes, transit bike and pedestrian, and emergency vehicles. We are concerned with how our system moves all of these things. We like working with signals because everything moves through those signals. I could see a time though when signals go away at some point. If we know where everything is and where it is going we can move everything through intersections very quickly. But we need to maintain a multimodal focus. Freeways are much more controlled environments and there is more of an opportunity for autonomous applications to be deployed there. There is not as much going on as in the city; not as many road markings, There are better opportunities on the freeway system to test AV.

INTERVIEW QUESTION 5

Ask Questions of Scenario <u>Most Likely</u> (circle):
Revolutionary Scenario Evolutionary Scenario

5. What are your general thoughts on this scenario?

Responses from State DOTs

"*Evolutionary* – Most of my concerns are related to the way CV and AV mix with the regular cars on the roadways. Where the rubber hits the road."

"*Note: would not choose a scenario*—Really, neither is likely to happen. (*The interviewees would not commit to saying whether one or the other was most likely, even after repeated prodding by the interviewer to do so.*)
V2I development will occur along the evolutionary tract. V2V could occur on the revolutionary tract due to the private sector being more involved and responsible for development. The AV side will mostly be revolutionary. It's important to keep in mind that the pathway will depend on the segment of the transportation industry you are looking at. There will be other factors at play in where this happens. Likely to be a big difference between rural and urban areas. Rural areas will be more evolutionary, change will happen faster in urban areas. The vehicle-sharing market is developing quickly, and ACCV development there will follow the revolutionary tract."

"*Evolutionary* – He thinks that implementation will be somewhere around 2040."

"He feels AV is likely to be revolutionary and CV will be evolutionary. His general thoughts are that there are significant differences in level of detail in the scenarios that made it distracting to try to compare them."

"*Revolutionary* – Not as confident that there will be a critical mass by 2025—definitely cars on the road but critical mass?"

"*Evolutionary* – This is a more realistic timeline. I think [of] this as making a little more sense."

"He stated that AV is most likely to implement in a revolutionary scenario and CV is most likely to be evolutionary."

"*Evolutionary* – Generally, this is a good thing and we embrace it. But since it is moving so quickly, figuring out the impacts is very difficult. We are all challenged."

"*Evolutionary* – The big issue is liability and insurance, particularly in [state], which leads the nation in litigation. These issues will force development to take longer than we think. Level 2 will happen in the next decade and will be widespread by 2025, and unless those liability and insurance impediments can be addressed, Level 3 will not happen very soon. Skipping Level 3 is a possibility, because the auto manufacturers would rather just leave the driver out of the equation. Level 3 relies on the driver to act as a backup to the system, and the industry would rather just cut the driver out altogether in the event of a systems failure."

"*Revolutionary* – We don't really know what this is going to look like. We are going to have to respond. We don't want to try and anticipate; we are going to be reactive."

"Revolutionary thoughts: We're looking at Volvo to use one of their AVs. They're doing their system in [city], and I rode in it. It is phenomenal. Its ability to read signs is incredible. I think it will accelerate. Part of the reason I think it is disruptive is because it is combining many companies and sectors: tech, OEMs, eventually maybe even airplane companies. Many different types of firms coming in and around new technologies on the roadway system.

Google doesn't think of themselves as an OEM, but they're still building cars. They're in this to solve the software engineering equation. Looking to solve the equation. Not worrying about the business case. Most companies want to make money with this. Different players will move in and out, which will be disruptive. If public policy and regulatory issues come into play, all it does is impede the development. If it is forced down such a path, it will end up on the revolutionary side.

Long-term, you have to stay away from legislation to begin this application. Legislators think they're enabling innovation, but they're actually constraining it."

Responses from Other Agencies

"*Revolutionary* – Just to reiterate, AVs in general are going to provide so many positives (economic and social) that once they start becoming a significant portion of the fleet, they will be transformational. Society is going to adapt to them in ways that we can't even imagine right now. It will free up so much personal time, lower costs so dramatically, and make things possible that are impossible today. Dropping your 8 year old off at school and picking them up, that is revolutionary. Frees up parents to work different jobs and hours than what they are constrained to right now. Elderly people can keep driving longer than they could before. As all of these factors start to be realized, they will rapidly drive adoption."

"*Evolutionary* – Need to shape in a way to reinforce existing goals—to reduce externality to neighborhoods (congestion, pollution, etc.)."

"*Revolutionary* – Loved the swoopy chart—very effective. Relatively short and to the point."

"*Revolutionary* – The public sector will be reactive to the tech sector. The public sector will have to react to what actually happens rather than find out what could happen. It gets political quickly (from the anti-transit, anti-auto groups)."

"*Revolutionary* – Policy question—are we putting federal funds for transportation in right places? Should we be funding BRT and light rail? Conservatives think we won't need money for transit or raising taxes to build more roads."

"*Evolutionary* – Safety benefits, ease of operations. Driver to have some time back on longer trips. Driving is very time intensive; robs people from productive time. I wouldn't be surprised if toll roads the early adopters because there is less congestion more certainty—for all electronic. It is more realistic to think toll or managed lanes facilities; it would work better. For us, throughput would be a big benefit—for revenue generation standpoint. Negative impact on demand? The only thing that will mitigate toll roads is financing. We're going through a bit of lull—prices are reasonable, perfect storm of being able to build as much as we can because of the market place. More difficult to finance roads in 10 years than now."

"If revolutionary gets too far out front and doesn't address things like cybersecurity, you could see government step in and have the evolutionary scenario take over. This may happen if the public has concerns that aren't being addressed."

INTERVIEW QUESTION 6

Ask Questions of Scenario <u>Most Likely</u> (circle):
Revolutionary Scenario Evolutionary Scenario

6. What are the major implications of this scenario for your agency?

Responses from State DOTs

"*Evolutionary* – Basic road design, do we need to alter things as simple as lane width? Since cars are controlling themselves maybe we can have skinny lanes. Separating necessary with a barrier of some kind? Do we need to deploy sensors or transponders on the road? My agency has a ton of information that we could give to the cars (like approaching crash, icy spot, slow traffic) that's coming in from a variety of sources. Is it DOT's responsibility to pipe it into the cars or do we give it to some third-party aggregator who pipes it into the car? Some of the things I use every day would go away, like electric message signs. Vehicle detectors—we have thousands out there; if the cars are collecting these themselves we don't need that any more. And, the car data is probably better than what we have. The ITS implications are pretty heavy."

"*Note:* Would not choose a scenario – We have identified seven high-level areas of our agency and its operations that are likely to be impacted: Transportation System Planning, Cultural and Workforce Readiness, Transportation Data, Strategic Investments, Systems and Technology, Legal and Regulatory Implementation, and Collaboration with Others identified. For each of these areas we are identifying a series of expected impacts. It's all fairly high level. We are working on prioritizing where to focus right now."

"*Evolutionary* – The major implications are primarily monetary. Also, how do they plan for this? How do they reserve resources to support this?"

"He feels AV is likely to be revolutionary and CV will be evolutionary.
For AV in the Revolutionary scenario: Based on current knowledge, there will have to be a much higher standard for maintenance, different design standards and signal design methods.
For CV in the Evolutionary scenario: They can operate this way effectively, and this will also help with getting needed data. The increase in data will help with data-driven planning and operations. This would give them an opportunity to build necessary relationships with other agencies, reallocate resources as needed, and revolutionize how the DOT is operated."

"*Revolutionary – Safety*: Transition period is a difficult time. *Mixed fleets*: Will there be a lot of upfront acceptance or will it be like electric vehicles (consumers waiting for the charging infrastructure and governments not willing to invest in it)—Agency is willing to make changes in infrastructure to assist but don't want to be too cutting edge—get everything ready for the beta versions and then to see it all change. Interested in how a market for AVs will form and what share of the total market it is."

"*Evolutionary* – Either scenario there needs to be investment—shifting investment in maintenance from traditional ITS (e.g., variable message signs) to more of the roadside technology that supports vehicle automation. More time to make those shifts. It's going to take some time to get all 50 states on board. Ready to make some investments in that technology to make it go. Need to see and measure benefits in travel time reliability or incident duration—will see push from agencies when you can put numbers on the benefits."

"*For AV (Revolutionary)* – No one knows exactly how this will play out, what the biggest issues will be (markings, signage, etc.) or how to address them.

For CS (Evolutionary) – Data and other information required will be a challenge, and they are in the process of addressing the implications of that."

"*Revolutionary* – How DMVs operate, that would likely change. There could be implications with privacy issues and cybersecurity. Personnel and staffing would need to change; we would need to define what our role would be.

TISMO concept: transportation systems and management in operations. Basically, how can we squeeze more from less because we don't have the funding? How can we get more throughput and looking at everything from a systems standpoint? Emerging tech like AV/CV are included. This is driving the agency's… restructuring from the growth from the 2000s to moving into the preservation and maintenance side."

"*Evolutionary* – We could lose capacity on our roadway. Widespread Level 2 would require vehicles to follow at a safe distance, which human drivers don't do, which could exacerbate traffic congestion. We could perhaps deal with this under an evolutionary scenario.

However, if Level 2 includes a connection between vehicles you could close this gap, which would reduce impact on capacity. Another consideration is making more efficient use of ROW. We could squeeze the width of the lanes and put more capacity in existing ROW, but this would require a significant penetration of CV capable vehicles. I'm also generally talking about freeways here. Not thoughts on arterials and so forth."

"*Revolutionary* – It will have an impact on our work force. We will need people who know how these technologies work and how they can be integrated into our operations. We will have new professions integrated into our workforce and we will also need training on how to get our existing operations to interact with the new functions. It's like where we have had to work in an increasingly mobile world and have to adapt to using smartphones and tablets instead of just desktop computers. I think there will be significant impacts to freight and mobility, so having operators that understand all of this and can evolve the efficiency of these operations, which will help serve our state better. We also need to think about our role as a "full service transportation provider." Will we still be responsible for deploying all of this infrastructure or will we just be acting to facilitate the private sector in getting all of the technology out there? If we have "transportation as a service" in the long term then maybe the private sector will get more involved with basic operations. The government doesn't want to run airports or railways so maybe roadways will be the same. It could significantly impact the way we look in the future."

"*Revolutionary* – The first two things that come to mind are (1) AV depend on reliable striping and signing, and that would be a challenge. Maintaining good, consistent striping with our weather patterns is a challenge. There is a whole other issue with snow on striping. We plow down to the pavement so we get visibility fairly quickly, but that is only state roads. (2) In a broader sense there will be issues with privacy and so forth, and all of this data is going to give us some challenges. The minute we start wanting that data the moment the public is going to get skeptical,

AV would be well served with SPaT. The Google car can look at signals but can't tell when it will change. SPaT can do that. We can give real time data on traffic conditions, weather, and so forth. We would like very detailed data on where cars came from and where they are going. A lot of agencies are using things like Bluetooth and we would love to have that type of data. We don't care who it is or why they are traveling; anonymity is fine. But we would love that data. We are looking at very innovative solutions to traffic congestion but what we have now is not good enough."

"*Revolutionary* – I think it will accelerate the role of the DOT. What is the role of the DOT? My answer is that the future of the DOT is the fusion of information. Regulatory, land use, telecommunications, etc. All of these are fusing around transportation.

My belief for the future is that we will be facilitators of infrastructure. Not being a gatekeeper but a convener. We have data points… every process we have, if you draw them back, they start with a data point. If the data is bad, the outcome is bad. The more we do that, the better we are set on the revolutionary path to take economic advantage of that.

What do people want from DOTs? Information about road conditions, etc. People want info, and DOTs can be that provider. Info will become more valuable than the infrastructure, and it will make the infrastructure better."

Responses from Other Agencies

"*Revolutionary* – "Doesn't really follow your rubric:

As the vehicle capabilities advance past that of humans, we're going to have to make some decisions on how we reap the efficiency out of the system without it being 100 percent automated. With AVs, we can have much closer following distances at higher speeds, which means we don't need to build as much roadway, but we will still have to deal with the person who has an outdated car that can't follow closely. Same thing with traffic signals. You don't need the same perception reaction times that we include in every formula right now. That is extra capacity you gain from this alone. Right now we are building factors to compensate for the range of human responses… If we didn't have to do that and had values that are minimums for what the reality is for AVs, we would be able to reduce crashes and increase efficiency. When we get up to state highways, there is talk about specific facilities that are AV-only vehicles. We have all these barrier-separated HOV lanes, I could see that becoming an AV-only lane. At some point it gets reversed to where the main lanes are AV only and the HOV then becomes the human-operated vehicle only."

"*Evolutionary* – We are a service organization to our member agencies and they have not asked. They would look to universities first before coming to us. There are MPOs more excited about this than our Board. They have a lot of other things on their plates."

"*Revolutionary* – Consumer expectations of how they interact with a [organization] will increase. We are going to have to satisfy their demand about good, timely data about traffic conditions, pay for travel quickly, easily. In a one-tap method. Challenge us to interact with our customer in a new and better way. People think about us when they are on the tollway. In scenario, we will have people call us when they are driving.

Roadway side – Continuing to maintain our road with special attention to striping, making the roadway visually apparent to machines. Will be a challenge. But less than a challenge than we think—excited by the potential of the smart raised pavement markings.

Capital expenditure side – Let's squeeze more capacity out of our system. Convince OEMs to shorten headway—rather than building our way out of congestion.

Challenge – Folks who are building vehicles do not have incentive to shorten headways—from liability perspective. We have a huge incentive for them to do so. More capacity and offer people better experience. How to get people building technologies to do this? Public policy and economic challenge. Ford wants people to be able to drive hands-free but keep headways the same—but as highway department—we want to cut headways in half and double capacity– to get more capacity and traffic flow and save hundreds of thousands to

billions of dollars. It would be a profound shift for us, from highway builder to highway maintainer. But manufacturers face the Liability challenge."

Culture shift – Road builder mode to efficiency mode. Like electric generation industry—do you get more capacity through conservation or building new plant?"

"*Revolutionary* – They are being reactive to what is happening. How will it change agency investments? How should they deal with the politics (of the anti-transit vs. anti-auto camps)?"

"*Revolutionary* – Policy question—are we putting federal funds for transportation in right places? Should we be funding BRT and light rail? Conservatives think we won't need money for transit or raising taxes to build more roads."

"*Revolutionary* – If we are in catch-up mode then we might not be able to keep up with their (private sector) needs. That would be my concern: that they get too far ahead. Our procurement processes might slow things down. We also have to plan for this, which could slow things down. We are hearing a lot of this from city council. They are attuned to business needs and want to know that we are being responsive and reactive. We need to stay aware of what is going on. So far they haven't needed us to do much, we just give them information, but one day that could change. Whatever they need from us could hold up broader development.

We need to make sure we are adequately resourced in terms of people who know what these developments mean for our agency. What we could do to make it better is simply get more resources, expertise, and funding."

INTERVIEW QUESTION 7

Ask Questions of Scenario <u>Most Likely</u> (circle):
Revolutionary Scenario Evolutionary Scenario

7. *How might the mission, responsibilities, organizational structure of your agency evolve under this scenario?*

Responses from State DOTs

Mission

"*Evolutionary* – I don't think that really changes. The tools and technologies used to give there would not change."

"*Note*: Would not choose a scenario – Doesn't really change. These are just different ways to deliver the mission. How we go about that mission might change, but it doesn't really change what we do."

"*Evolutionary* – The DOT's mission will change regardless of which scenario comes to pass, but the focus of the DOT will change from the "big three" now (design, construction, and maintenance) to operation."

"He feels AV is likely to be revolutionary and CV will be evolutionary. The DOT will evolve from an agency that does transportation only to one partner in a network of agencies that are responsible for mobility (such as DHS, etc.)."

"*Revolutionary* – No change."

"*Evolutionary* – States will have different data sources and need to figure out how to use that data—when a lot of CVs on road—then figure out how to use that data for operations with

full automation, then much fewer crashes; traditional operations and maintenance programs to support AVs."

"He feels AV is likely to be revolutionary and CV will be evolutionary—none."

"*Revolutionary* – It definitely would evolve. Our director is looking at this as a part of the TISMO strategy. How does the DOT be flexible and nimble to these new advances?"

"Evolutionary – We just got a new mission statement and I think this would all fall in line with it. Our current mission statement calls for a sustainable, integrated multimodal transportation system that meets the needs of the people of [state]. I see CV and AV fitting into that."

"*Revolutionary* – I don't think the mission will change much. We are supposed to provide a safe and reliable transportation system, and maybe in the future we are just doing this more in partnership with others. I think we will still need to think through and plan out those safe and reliable solutions."

"*Revolutionary* – It facilitates what our existing mission is. We are about optimizing traffic flow, safety, and enhancing the economy, which is accomplished by moving goods and people, and this helps."

"He feels AV is likely to be revolutionary and CV will be evolutionary—not really change. Still going to need the hard infrastructure, concrete, etc. Still believe there is a mission for DOTs, but need to be more adaptable and flexible. We embrace that. How can you do that strategically?"

"*Revolutionary* – We're already changing. Our strategic plan's first goal is being a performance managed organization. Very focused on performance outcomes. Second piece is on data quality. If we don't have good data about the system… and open this data to allow private partners to consume the data and make it better. I can't predict the scenario of what it looks like in 2040, but it will look different than today. If we make good decisions today about where we are going, it will make our 2040 org successful. If we focus on data quality, communication, we will be successful."

Responsibilities

"*Evolutionary* – Definitely change; I could see ITS blown into obsolescence. I could see safety staff coming up with safety projects diminish a lot. We have planners, financial people, construction, and utilities—still the need for them. I don't see that changing much. Changes to: traffic engineers, folks involved with traffic signal timing."

"*Note*: Would not choose a scenario – We aren't far enough along to determine this. We have determined there will be impacts but don't think we are to the point of identifying how to adapt to those changes. We want to get a handle on what the impacts will be before determining how we change. However, this will be a big issue for the agency. The private sector will likely take on more roles that were traditionally public in nature. We may also be looking at changes in how we invest."

"*Evolutionary* – No new ones, just tweaking the responsibilities of individuals within the organization"

"He feels AV is likely to be revolutionary and CV will be evolutionary. The responsibilities of existing groups in DOT will evolve, but this will not change the basic structure of the organization."

"*Revolutionary* – Perhaps in parking management. Now we deal a lot with parking. Perhaps opportunities to enhance responsibilities like in the use of shared vehicles—or being able to

put in more bike lanes or park more vehicles because of more efficient use of the existing infrastructure."

"*Evolutionary* – Maybe reduce number of TMCs—reduce the number of safety maintenance vehicles roaming the road. Having more time will enable agencies to adapt. Then, the time of culture shift that too aggressive a schedule would entail."

"He feels AV is likely to be revolutionary and CV will be evolutionary—data management resources will have to be enhanced, and pavement markings will become more important as well."

"*Revolutionary* – Responsibilities: we have to change from a growth state to a preservation standpoint. Not just moving people and goods."

"*Evolutionary* – If there is roadway or roadside infrastructure for CV we might have more responsibilities there with the installation, operation, and maintenance of that equipment. We also might have to do better with our lane markings. Doing all of this is above and beyond what we are resourced for right now."

"*Revolutionary* – In the foreseeable (near and midterm) these things won't be available everywhere, maybe just in major urban areas. If you are out in the middle of nowhere it likely won't work. The role of [state DOT] could realign around delivering these services and maintaining and operating the "non-connected" parts of the system. You could see two 'product lines.' We have had a 'unified focus with decentralized groups', but a new model could require new management efforts beyond the simple model we have now of building and maintaining roads."

"*Revolutionary* – We are already shifting towards more efficient operations. This would tie into that. The department is already catching on, but what we really need is people with expertise in operations management. We need statisticians and mathematicians. It is a systems operations focus. We already contract to the private sector a lot. We are among the smallest DOTs in the nation in terms of manpower because we use a lot of consultants. That won't shift, but our skill sets will."

"*Evolutionary* – Biggest thing, engineers need to be more versatile. Myself, I didn't take any classes in wireless technologies, through various short courses now trying to get up to speed. Talking to our universities as they are developing their curricula—not only hard core engineering—got to get into how these systems work together. Training of our staff."

"*Revolutionary* – What is our role today? A lot of DOTs… we are set to beat them. We are constructors and designers of infrastructure today, but that isn't our future. We talk a lot about mobility and how you assess it. Safety mobility and economics… The difference from today is not about the vehicle, it is the person/product inside the vehicle. We need to focus on the commodities moving on our system. Improving that mechanism… This difference will cause changes in our organization."

Organizational Structure

"*Evolutionary* – I think so—some new division or section would have to be developed that is devoted to this new concept—could not be buried in ITS or operations. Whole new division required. While safety could be reduced."

"*Note*: Would not choose a scenario – Aren't to that point yet. That could change going forward as we get further along."

"*Evolutionary* – Since the mission will be more focused on operations, there will be more emphasis there. There may be additional expertise added in this area within operations, IT, safety, and design groups."

"He feels AV is likely to be revolutionary and CV will be evolutionary. IT will have to be strengthened to be able to manage data better. Will need to rethink how IT does things."

"*Revolutionary* – Not as large a safety team."

"*Evolutionary* – Adapt organization to deal with new technology—more of an evolutionary change of some functions than a new structure. A lot of stuff is in the research side and will need to move to the operations side."

"He feels AV is likely to be revolutionary and CV will be evolutionary—no major organizational changes, although the responsibilities of some groups may need to be tweaked."

"*Revolutionary* – Organizational structure: Yes. We are restructuring right now. Still in upper management, but we are restructuring to be more nimble to meet these new emerging technologies. Maybe have a division specifically focused on operations."

"*Evolutionary* – We are evolving already into an agency that manages the system rather than building it. We used to be a 'capital delivery machine', but we are becoming an agency that has to be better at squeezing efficiency out of the existing roadways. If there is electronic infrastructure that is needed then we don't have the skill sets in [state DOT] to accomplish that. We may not need to develop it in-house but we would need access to that expertise. I don't think anyone in the [state] government would want to expand [state DOT], so we would likely access that expertise through the private sector. That's a policy decision. We need 'electronic technician' skills, which is 'more than an electrician but less than an engineer'. We are having a challenge with finding those skill sets already."

"*Revolutionary* – It's a little too soon to tell what this would look like; I don't have the vision of that future reality."

"*Revolutionary* – Our fiscal thinking is already shifting. Our leadership is already thinking about using significant funds on ITS. If the same operational objectives can be met without construction, it portends the shift towards operations."

"*Evolutionary* – We have to be adaptable. Can't outgrow growth in [state]. Focusing on TSM&O concepts. So we are outsourcing more of the routine tasks. We used to have more of the maintenance. But Commission doesn't give us more people. How are we structured to get the most bang for buck with FTEs we do have? Filling of potholes, etc. with asset maintenance contracts. Rotating those freed-up FTEs into more TSM&O functions where we consider where core functions are going."

"*Revolutionary* – Both scenarios would affect this, but revolutionary is faster. It will be about opening up to providing data. We become a customer. This is the biggest shift. People that use the transportation system are our customers. The difference is now, under moving to AV/CV… we become the customer and reverse the role. Now we consume the data off the vehicles. We become the customer. This is very different, but it lowers the cost and makes us better about being able to see what is happening on the system. It will lower our costs."

Responses from Other Agencies

Mission

"*Revolutionary* – Our mission will stay the same to provide safe travel with minimal delay. That will stay."

"*Revolutionary* – One possibility is if we move to AV Uber-like fleets rather than individually owned vehicles then challenge because our customer will change. Fleets rather than customers. Auto dealers, OEMs, AT&Ts who have vehicle fleets. All same mission—safe, affordable transportation—means will change to broaden the more options we have."

"*Revolutionary* – No change. Substance might change but not mission."

"*Revolutionary* – No, we're such a comprehensive agency anyway—interdisciplinary (aging, workforce, planning) mission will stay the same."

"*Evolutionary* **–** In some respects it already has—our commitment to include the most technology available to us in our projects. Whether dark fiber, or whatever. The mission is to stay in front of the technology. Tolling brings a lot of technology (cameras, computers, integrated corridor management) anyway. Uniquely positioned to take advantage—unlike traditional highway construction, which is more concrete and steel."

"*Revolutionary* **–** No, our mission is to operate the transportation system in the most efficient and safe fashion as possible."

Responsibilities

"*Revolutionary* – As we transition to a more automated system of vehicles, I think that our responsibility may shift a bit more to providing something special or specific to enhance AV operation… For my career and the one following behind, we will always have to consider the human driver."

"*Revolutionary* – Responsibilities: The change in the customer—we have functioned in data silos; we need to get out of viewing our data as something different and held close to the vest. We need to move to radical transparency in data. We want to let [the] world know what we know and harvest what [the] world knows about our roads. Feel one influencer on the current highway funding crisis is that the consumer senses that highways as currently configured and operated are highly inefficient. Highway costs exceeded inflation. What we offer in terms of experience—like what was offered to your grandparents. Same old same old. How can we offer folks a greater experience? Higher speeds, greater reliability. Hand-free driving so you can do other things makes the experience better. Inherently good for customer. For toll authority—preserve how we can charge people for what they can get free. Toll authorities could be in vanguard because change to offer premium experience. Capital cost savings. Billion less we have to borrow and pay off by raising people's tolls."

"*Revolutionary* – Will have to develop ITS architecture that is independent of other things. Will need to be more interactive with other systems and vehicles using the network."

"*Revolutionary* – That could happen? Needing person to understand technology. Where we put our emphasis—more staff on maintenance and operations than transit planning—or freight planning. Aging—human services transportation and paratransit—glaring inefficiency perhaps cost savings."

"*Evolutionary* **–** As long as your foundation is attracting customers—you'll strive to provide the most advanced, stress-free travel. Expected to be at forefront of technology esp. managed lanes, expected to maintain speed, pass a lot of traffic. Like it did when we went all electronic. In our strategic plan. There may be some safety aspects such as speed, ice, and snow. It may be you're done with gantries traditional tolling infrastructure. Now you're communicating with automated vehicles as opposed to currently millions and millions of dollars of infrastructure."

"*Revolutionary* – Depending on how these develop we may not be responsible for operating our lights. We are responsible for assigning priority at intersections and doing traffic zones, etc. However, that responsibility could shift if we don't keep up with what is happening. We could fundamentally change if the signals go away. If that happens we would likely still be responsible for assigning ROW at intersections. This could all change from a reliance on physical infrastructure to a data-intensive infrastructure. However, I don't know what that looks like. When someone is driving, they exert operational control (speed, brake) and tactical control (where to go, etc.). Operational control will be handled by OEMs and such, and agencies could take more control of tactical space."

Organizational Structure

"*Revolutionary* – Inevitably, we are going to see that our field technicians are going to have to be far more competent than we've had previously. Before, they needed to know concrete, how to dig a hole, and some minor electrical work. They will still need to know that, but also be computer programmers, diagnostics, and much more electronics vs electrical oriented. The job will have to transform, or we will have to create a new position to do this job. I'm pushing our technicians to adopt new skills. These new skills are very high salary, however. This will be a hard sell, especially up the chain of command. How do I change the job and change the perception of the job?"

"*Revolutionary* – Couple of changes. Data becomes front and center of what we do. Mine the data about our customers, their movement, incidents on the roadway. Approach capacity by looking at more than concrete. Start making the tradeoff between concrete and technology as ways to offer customers a premium highway transportation experience. Now divorced. IT department focused on desktops and toll collection. Operations—focused on concrete. Make assessment tech versus concrete."

"*Revolutionary* – No change in structure. There will be tweaks in the skill sets of their people. They will be more operations focused but will need that expertise in the existing structure."

"*Revolutionary* – Nothing at this point—flat organization. Planners engaged with policy makers."

"*Evolutionary* – Add or enhance operations side with car to infrastructure type staff. No radical change necessary. You still have fundamentals of finance, engineering, operations, communications."

"*Revolutionary* – I could see you having a group that works with AV and CV companies. We sort of do that now. The city manager has an open data initiative, and we are trying to get signal timing data out there. The new position could be a liaison to facilitate deployment, which would require a different skill set. They would need to know the needs of the city but also the needs of the industry. That will help to identify optimal solutions. Organizational structure would likely be the last thing to change on the public sector side."

INTERVIEW QUESTION 8

Ask Questions of Scenario <u>Most Likely</u> (circle):
Revolutionary Scenario Evolutionary Scenario

8. *Are there any policies or planning actions that your agency could implement to prepare for this scenario?*

Responses from State DOTs

"*Evolutionary* – Really don't know today. It's something definitely we want to start thinking about. What we tell people is we're in a wait and see mode. We're going to wait for feds to tell us what we need to do. Wait for standards before making big changes. Keeping an eye on what other states are doing, esp. like Michigan which has more going on in CV than other states."

"*Note*: Would not choose a scenario – Those are two of the areas we have identified as needing to be addressed. The policy and legal framework will need to be developed. The planning process will need to change also. We will see some major changes. We don't know how to do that yet but we will need to come up with answers.

[City] has incorporated AV into their scenario planning. It is called Plan 2040. We have had talks with our planning staff about updating our highway plan and this is one of the things we will be addressing moving forward: incorporating AV and CV. Don't know how to do it yet. We will be updating our state ITS plan to integrate AV and CV into that which will then feed regional and local plans."

"*Evolutionary* – They partnered with [university] to do an analysis with a timetable for implementation by 2040. The working group mentioned earlier is doing a Strategic Plan for implementation as well."

"He feels AV is likely to be revolutionary and CV will be evolutionary. Not sure as yet—that is one thing that their Exploratory Committee will be doing."

"*Evolutionary* – I think we're doing a good job of staying on top of policy—working with DMV looking at policy in state legislation what would need to be changed. [State DOT] needs to continue with ongoing education and awareness building among all agencies. But [state] doing a good job—also had discussions with rail and transit and office of attorney general, secretary of technology. One thing that would change would be to have dedicated staff—rather than spreading across current functions. Policy is one thing, then regulatory and technology another thing. Governor sees this will drive business and economic growth. Think getting the conversations going now is what is needed. Continue to look and see as NHTSA and DOT make policy—what needs to be changed as the technology continues."

"He feels AV is likely to be revolutionary and CV will be evolutionary—They don't plan to implement any policies pertaining to AV/CV that might limit their ability to be flexible as technology changes. Changes in policy right now would be premature.

They did staff up their ITS group in anticipation of the implementation of these technologies."

"*Revolutionary* – We are, but are a little cautious. We are very sensitive to that, but are also exploring and understanding as well… What the technologies are, how they impact our policies, etc."

"*Evolutionary* – I can't really discuss policy.

In terms of planning, we need language in our planning documents. Our 25-year state plan has language but it was just thrown in. Other states have done better as these issues are accounted for in their near and midterm plans. We have a long way to go on that. Getting AV and CV into your planning documents ensures that money is programmed for that activity if it is needed in the future.

"*Revolutionary* – From a policy perspective we need to be looking at what technologies exist today, and as we continue to build and maintain the roadway system we need to make sure we have flexibility for the system to accommodate these systems. It is similar to what [state] is doing. If we are doing new traffic lights we should be looking to put in systems that accommodate future technologies; however, we don't want to invest in systems that will soon be out-of-date.

Planning: We just need to have people thinking about this, being engaged and proactively envisioning this through activities like [AV/CV initiative]."

"*Revolutionary* – Facilitating testing: We are very interested in partnering with the private sector. We could support a partnership."

"*Revolutionary* **–** Yeah, we're already doing that by focusing on commodity flow and movement. What goes to global markets? We have data across all three commodities moving across the state and the US. The second thing is… getting to enabling performance in terms of valuing mobility and outcomes. One of the inherent flaws in civil engineering school is that dealing with vehicles as volume/percent of trucks is how we normally make decisions about the system. It is not empirical to take into account what is in the vehicle. All vehicles do not have equal value. That is the biggest shift. Thinking about mobility and the value of the cargo? If 35% of my traffic is commercial, where is the threshold… for product movement? We are enablers, but also inhibitors."

"*Revolutionary* – Used possibility of AV/CV as argument for the sign inventory and sign refresh with geocoding. We're already spurred to think about what we need to do. In the existing regulations that allow testing, DMV initial recommendations now found to be untenable. We need to think about how these vehicles could operate on our streets—perhaps as an AV street with narrower lanes. A regulatory approach might be to incentivize purchases."

Responses from Other Agencies

"*Revolutionary* – I could see at the municipal level… making some changes to facilities to better work for AVs. As an example with the electric vehicle we have charging stations. Several places in town we had to figure out where to place the charging stations. I could see the same for AVs. We have narrow parking spaces for compact cars. I could see narrow spaces for AVs that are reserved for them that drop passengers off but don't require door swing area b/c the passengers have been dropped off already. Areas with restricted parking could improve by adopting something like this."

"*Revolutionary* **–** Consider whether we need to offer dedicated lanes during transition period. Managed lanes not favored by those of us who operate—whether necessary to do that? If we could double capacity in a lane with AV/CV then, it may be worth it. Our preference would be to have most of vehicle fleet turn over quickly—without us having to reconfigure roadway. I don't see us making a lot of tollway-specific rules. We are not going to get ahead of the state. It may be a lot of just watching patiently trying to measure benefits as tech takes over our system."

"*Revolutionary* – Yes, they need to get AV/CV on the planning radar. They need to educate officials and keep up with technology."

"*Revolutionary* – Last plan update 70 percent of funding going to maintenance and operations. More going to this to facilitate deployment. Economic development arm—citizen groups

working on economic competitive strategies. How is this region going to position itself for economic development of this technology?"

"*Evolutionary* – If you had more definition, there could be more thought invested during environmental process for a facility. How many lanes? When modeling can show you what that means for your schematic, environmental, alternatives. Now doesn't even really consider the technology issue. Weakest area that I can see."

"*Revolutionary* – Not that I can think of, other than working with industry. I ask these (private sector) guys how we can help and they really don't know. They don't know what is going to take off. We know some things are coming, and we are trying to make data (like signal) open to the industry. Once you know some things about the signal they can start preparing applications and such."

INTERVIEW QUESTION 9

Ask Questions of Scenario <u>Most Likely</u> (circle):
Revolutionary Scenario Evolutionary Scenario

9. *Is there anything that your agency could do to shape or influence the scenario coming to fruition?*

Responses from State DOTs

"*Evolutionary* – Getting involved with pilot projects, setting up test beds, getting involved with OEMs could definitely shape where this goes. Insert ourselves into the mix earlier rather than waiting."

"*Note*: Would not choose a scenario – Getting engaged nationally. [Name] serves on AASHTO committees and we have people involved in the CV Coalition. We are involved in a lot of national forums and research forums. We can't be involved with everything but we are trying to be involved strategically. We want to have a feel of the pulse of what's happening and be able to influence if we can. We want to make sure that we don't have one person as the expert on any one thing."

"*Evolutionary* – They partnered with [university] to do an analysis with a timetable for implementation by 2040. The working group mentioned earlier is doing a Strategic Plan for implementation as well. They also will continue to participate in national efforts and their working group."

"He feels AV is likely to be revolutionary and CV will be evolutionary—They are going to maintain their activities in national efforts, to make sure that they are part of a larger voice."

"*Evolutionary* – It is being involved now—we are being involved in CV pooled fund study—looking at issues that state needs to be aware of—AASHTO CV working group—involved in all the national groups that are looking at these issues. Feeding this information back to standards—tolling industry good model of what not to do—interoperability issues—need to define what the standards will be—I don't think we want it to be too slow—CV are building blocks for AV and we need to get CV happening now."

"He feels AV is likely to be revolutionary and CV will be evolutionary—They intend to stay active in national initiatives, and compete for V2I deployment funding."

"*Revolutionary* – Yes, from a structural standpoint we need to be sensitive to the technologies, and people will demand it. The DMV reports to the DOT, and we need to be responsive to

technology changes. Developing the roadmap, which will change, from a short term to medium or long term. How this fits into our long-range planning as well… How it affects travel behavior and how things operate in the future… Need to inform people in the agency and educate people to it."

"*Evolutionary* – We need to remain engaged in events like this symposium (*interview conducted in Ann Arbor*) to make sure that we know what is going on and that we have a voice in this development. We need to keep talking to AASHTO and USDOT about our state's needs in order to make sure our needs are being addressed. It's not that we are any different from other states, but we have an obligation, since we are on the front line, to tell AASHTO and DOT what we need."

"*Revolutionary* – Not sure it is the DOT's responsibility to shape. What we need to be doing is making sure policy makers know what is going on and educating the public. We need to remain engaged, and we need to be communicating with the private sector what our needs are and how the private sector might be able to fulfill those needs. For example, the freight sector is very important and freight movement is often hampered due to a lack of drivers. Our message to the industry is that we need to move more freight with less drivers, but we leave it to the industry to find the solutions. The industry needs to know what our challenges are."

"*Revolutionary* – We could be proactive legislatively, if we knew what it was that was going to happen. Second, I think we could provide testing and facilitate testing opportunities. However, that may be unrealistic because Utah doesn't have the capabilities. We are also a long way from the folks who are doing this."

"*Revolutionary* **–** My big issue is having a vision and focusing on the endpoint. Don't get stuck on the middle difficulties. Our endpoint is a significant number of self-driving vehicles. Having that vision will allow the organization to understand it."

Responses from Other Agencies

"*Revolutionary* – What I am doing so far is staying aware and informed as to what is going on and who the major players are. Anytime there is an opportunity for us to be a first deployer or test deployment, we try to get that. I know there is a call for federal projects on V2V or V2I technologies. TTI is very involved, but we proposed that a field deployment could be in [city]. Instead of splitting it up, they wanted to have one site in [state]. [City] is an advisor of that if [city] gets it."

"*Revolutionary* **–** Opportunity for highway authorities and state government to drive a grand bargain that we will support disruptive approach even though scary but you guys have got to deliver the capacity enhancement via reduced headways. We're getting major capacity benefits. We'll do our part to make sure legislature doesn't jump over the technology, keep fear mongering to a minimum.

To extent that there is a killer app on infrastructure side—so far—no one has said if you do X, we'll provide this app that will advance technology by 10 years. I hear the only things we need from your road operator are good pavement markings and lots of data. We can facilitate by running our roads and modifying them to make them readable and providing data."

"*Revolutionary* – So much relies on the private sector and the development of the technology. They need to have their Board members on board with AV/CV and well educated about it. Decision makers need to be knowledgeable."

"*Revolutionary* – Their agency

- Stay abreast of what is happening in the industry.
- We do have some very important companies and key players in this area—we could be more intentional about working with them.
- Intentional about looking at ways of deployment—military bases, retirement areas, 25 miles per hour or less versus the interstate. Looking at the land uses around the region for opportunities where L3 and L4 are deployed."

"*Evolutionary* – We could do some type of pilot of developers of technology on existing roadway facilities. Toll roads make it a bit easier—than a nontoll facility. Interstate highway system can't accept on any type of mass scale. Set aside on new facility—we are right now putting some right of way aside for sidewalks or bike ped. But could do that for AV development. Right now, befuddled on next move."

"*Revolutionary* – Make the data available and staying current on what's happening in the industry. They need to keep up to date on what is needed. We could advertise that we are 'open for business'. We just want to know what we can do to help. Nobody really knows what is going to happen, and we aren't going to make a big investment unless we know it's going to work. We will be approaching things incrementally."