Beyond Speculation 2.0

An Update to Eno's Action Plan for Federal, State, and Local Policymakers

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Eno Center for Transportation

Beyond Speculation 2.0: Automated Vehicles and Public Policy

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About Eno

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1.0 Introduction

Technology continues to alter how people and goods move. One innovation that has the greatest potential to upend traditional travel is the automation of driving. Automated vehicles (AVs) could completely transform mobility networks, dramatically improve safety, reduce emissions, and provide access and mobility to underserved parts of society.[1] The proliferation of AVs could also lead to more suburban sprawl, congestion, greenhouse gas emissions, and higher costs. Putting the right public policy in place now will help ensure that the transportation system of the future is safer, equitable, and more efficient.

In recent years, automated and semi-automated driving technologies have progressed significantly. Some automated features, such as lane centering and adaptive cruise control, are available on cars and trucks on the lot today and more advanced automotive technologies are currently being tested on public roads. Although there is much speculation about when fully automated vehicles will be widely and commercially available, there is no question about the impressive speed of recent development.

Meanwhile, the emerging AV industry is asking policymakers to adapt domestic frameworks to address the demands of AV sales and ensure U.S. competitiveness in the global market.[2] This includes updating regulations, funding research and development, and investing in infrastructure. Crafting policy and investment plans that can adapt to a changing environment poses significant challenges for public officials at all levels of government. Nevertheless, it is important to consider the policy implications for AVs now as test vehicles with automated driving systems are already sharing public roads with drivers. Infrastructure updates, such as well-maintained pavements, striping, and signage, can facilitate technological benefits and increased safety.

This paper updates Eno's 2017 *Beyond Speculation* and discusses the current and future state of AVs, as well as the existing, proposed, and expected implications for federal, state, and local policy. It does not intend to summarize all the research nor provide new analysis of the potential implications of AVs. The goal is to provide an overview of the current policy arena and posit concrete and substantive recommendations for policymakers to responsibly test and deploy AVs on public roads.

The overarching aim of federal- and state-level policy on AVs should be to ensure public safety, to provide consistent frameworks for developers, and to create an environment where rules can adapt to unknown future outcomes. Given that AVs are still in the development phase, governments must take a performance-based approach instead of imposing strict technical requirements. The federal government has a clear role in regulating the safety of automated driving systems. States and local governments have more flexibility in the areas they have traditionally managed, such as roadway design, rules, and licensing, and may choose to pass laws or take executive actions, while others prefer to not take any steps. While each method comes with certain tradeoffs and pitfalls, each government must decide what is right for their own constituents. Within a broad framework, the following items outline specific steps or considerations of any approach.

2.0 Key Concepts for Automated Vehicles

Automated vehicles are complex and changing rapidly, presenting three major public policy challenges.

First, the definition of an AV is not singular. The federal government currently defines "levels of automation" that describe the respective roles and responsibilities of human and AV systems when performing a specific driving task. While these established levels provide a useful baseline for categorizing the levels of vehicle autonomy, they demonstrate that an "automated vehicle" can mean many different things.

Second, private industry—not government—leads research and development, which gives policymakers the critical role of continuing to foster this innovation while ensuring public safety. Local, state, and federal authorities must strike a delicate balance with the private sector as well as reckon with intragovernmental conflict regarding the particular protection of interstate commerce.

Lastly, highly automated vehicles (HAVs, or SAE Level 3, 4, and 5) do not yet exist. There are some Level 2 automated driving features available on the market today (such as Cadillac's Super Cruise), and there are some HAVs in testing or limited pilots (by many major automakers as well as technology firms like Waymo and Uber). However, experts disagree on when HAVs will be mature and market-ready. Therefore, developing a policy framework at any jurisdictional level for this unproven technology is a daunting task.

2.1 Defining "Automated Driving"

When discussing AVs, it's important to note that the vehicle is not the object of automation – the driving is. Today, an increasing number of features on vehicle models are automating the task of driving.[3] These include:

- Adaptive cruise control, that automatically adjusts vehicle speed to maintain a safe distance from vehicles ahead;
- Lane centering systems, that automatically ensure a vehicle stays in its lane (unless a turn signal is on in that direction) and/or warn a driver when they veer out of their lane;
- Parking assist systems, that allow vehicles to maneuver themselves into parking spaces;
- Level 2 systems that combine one or more automated features to steer, accelerate, and brake on certain roadways under human driver supervision

either in the vehicle or remotely. This feature is currently offered by a select number of manufacturers such as Mercedes-Benz, BMW, Tesla, Cadillac, and Lexus;[4]

- Countermeasures for Level 2 features such as technology that monitors the driver, such as hands-on-wheel sensors and/or driver gaze observations to dissuade distracted operation.

These features correspond to a specific "level of automation" on the National Highway Traffic Safety Administration (NHTSA) classification system for AVs.[5] That system, which was adopted based on the Society of Automotive Engineers (SAE) International classifications, defines six different levels of vehicle automation referenced throughout this paper (Table 1).

Table 1: Classification System for Vehicle Levels of Automation

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	**You <u>are</u> driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You <u>are not</u> driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **OR** brake/acceleration support to the driver	These features provide steering **AND** brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering **OR** • adaptive cruise control	• lane centering **AND** • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Source: SAE International, J3016: Levels of Driving Automation, 2018

Despite their prevalence and importance to AV policy, the SAE Levels of Automation have caused significant confusion for policymakers, practitioners, and the media.[6] For example, users of Tesla's Autopilot, a Level 2 system, frequently assume that the car is "full self-driving" and does not require constant monitoring.[7]

The “levels” of automation are perceived as a hierarchy, where one is inherently “better” or even “more automated” than the other. Instead, they are best thought of not as levels, but as classifications, and the classifications apply to a system, not a vehicle. A sports car could be Level 1 when the owner wants to drive it personally and could also be switched into Level 3 highway cruise mode when the owner sits stuck in traffic. A Level 4 system is not inherently “better” than one at Level 2. For example, a Level 4 system might be operable only on a small stretch of roadway under ideal weather conditions, but a Level 2 system functions on a million miles of roadways. The levels are simply different ways of defining the roles of the human and the automated driving system (ADS) in vehicle control.

SAE released two revisions (in 2016 and 2018) to its original 2014 J3016 document, in part to help clarify some of the aforementioned confusion.[8] The classification structure has not been changed, but updates add new terms and definitions and provide clarification to address changes to the AV development environment. For example, the 2018 revision addressed how remote drivers fall into different classifications depending on their task. Additionally, by its nature, some of the definitions include subjective or vague terminology such as “appropriate time” and “timely.”

While imperfect, and sometimes confusing, nobody has been able to develop a competing classification system that defines the legal roles and responsibilities of the human driver and the system as well as the SAE levels have to date. A true understanding of the levels of automation will help policymakers make clear decisions about what and how to regulate.

2.2 Commercial Availability of AVs

Level 1 features comprise the majority of driving automation technology in use today. Several luxury car brands, such as Tesla, Mercedes-Benz, and Cadillac also include Level 2 features. There are no market-ready vehicles with HAV (Levels 3, 4, or 5) technology as of the publication of this paper.

Table 2 shows a selection of the diverging opinions forecasting when vehicles with higher levels of automation will reach the market. Commercial deployment might be less groundbreaking than it appears to policymakers. For example, companies are setting the targets for what they consider a “minimum viable product.” While a vehicle might have a Level 3 or 4 feature, it might have an operational design domain (ODD) that is limited to well-maintained Interstate highways during clear weather conditions. Such a feature could be commercially viable, but it would have a relatively small effect on the overall transportation system.

As with many new technologies, the market and the public often believe the technology will enter the mainstream quickly and dramatically change markets and human behavior. Even over the course of one year, many researchers and companies have changed their expected rollout dates for Levels 4 and 5 AVs. Government agencies debating major policy overhauls and large investments in resources should remain cautious in the face of inflated hype surrounding AVs.

Table 2: Expected U.S. Commercial Availability of Highly Automated Vehicles, by Selected Organizations

	Organization	2016/2017 Predictions	2018 Predictions	Automation Level
Vehicle Manufacturer	BMW	2021[9]	Unchanged	Levels 4 and 5
	Daimler	2020-2025[10]	Unchanged	Levels 4 and 5
	Fiat-Chrysler Automotive	2021	2023[11]	Level 4
	Ford Motor Company	2021 (Ridehailing)[12]	Unchanged[13]	Level 4
	General Motors/Cruise	2019 (Ridehailing)[14]	Unchanged	Unspecified
	Tesla	2017[15]	2019[16]	Level 4
	Toyota	2020 (Highways)[17]	Unchanged	Level 4
	Volvo	2020[18]	2021[19]	Level 4
TNC/Tech Company	Zoox	2020[20]	2020[21]	Levels 4 and 5
	Google/Waymo	2020[22]	Unchanged	Level 4
	Uber	2019 (Ridehailing)[23]	2021[24]	Unspecified
Market Research Firms	ABI Research	2021[25]	Unchanged	Levels 4 and 5
	his Markit	2020[26]	2019 (Ridehailing) 2021 (Personal)[27]	Levels 4 and 5

Sources vary. See endnotes.

2.3 Shared vs Personal AV Business Models

The rapid development of AV technology has already started shifting the business models of automotive mobility. Some developers are focusing their initial deployment efforts around a shared fleet of vehicles rather than individual ownership. Examples include Waymo's deployment of self-driving fleets in Arizona; Honda's investment in General Motors-acquired Cruise; and Uber's collaboration with Volvo. To recoup their significant development costs, firms could charge for automated driving services rather than selling a one-time product. The shared fleet approach will allow companies to retain control of the vehicle for necessary maintenance, and potentially cultivate greater public acceptance of the futuristic technology before individuals are in a position to make a large capital purchase for personal ownership.

Shared fleets could also reduce demand for parking, and therefore free up more available public space for economic and social benefit. On the environmental side, as long as AVs are widely adopted as both electric and shared vehicles, studies estimate that by 2050 decreased energy use, decreased CO2 emissions, and decreased cost of vehicles and infrastructure would save about $5 trillion per year.[28] Policymakers need to consider both types of ownership-use models as they plan and develop future laws and regulations around AVs. The recommendations in this paper can apply to both the private and fleet ownership models.

AVs as EVs

In 2018, most AVs being tested were electric or hybrid. Even without market-ready AVs, the share of plug-in electric vehicles sold in the United States has been steadily rising—reaching 1.2 percent of all light-duty vehicles sales in 2017. Hybrid vehicles, on the other hand, have teetered back and forth between 2.0 percent and 3.2 percent market share since 2007. However, the total number of hybrid vehicles sold has increased every year.

Infrastructure for EV charging is becoming increasingly common, mostly spurred by manufacturers. Supporting a large influx in the number of EVs on the road, at the scale anticipated to accommodate electric AV fleets, would necessitate increased EV infrastructure. This infrastructure could develop from either private or public investment. This paper recognizes the importance of EVs in their relationship to AVs, but it is beyond the scope to develop policy recommendations explicitly for electric vehicles.

Oak Ridge National Laboratory, Transportation Energy Data Book. Ed. 36,, August 2018.

2.4 Connectivity

Connected vehicles are inherently different from AVs but are often discussed in the same policy setting. Connected vehicles (CVs) have the ability to communicate with each other (vehicle-to-vehicle or V2V), with infrastructure (vehicle-to-infrastructure or V2I), and potentially with any other user or element of the transportation system (V2X). Vehicle autonomy means that the vehicle can drive itself without connected input from its surroundings, but the combination of connected functions can enhance vehicle automation. While AV technology is not dependent on CV technology (or vice versa), both technologies are quickly developing in parallel and in concert with each other.[29] Connectivity in AVs could accelerate their deployment and more fully unlock the benefits of driverless technology such as increased safety and efficiency.[30]

CV technology communicates directly with other vehicles and infrastructure about vehicle data related to speed, location, trajectory, and other operational variables, potentially enabling better management of traffic flow with the ability to address specific problems in real-time.[31] Connected technologies enabling the transfer of these data introduce new opportunities for cybersecurity challenges that must be addressed, but have the potential to increase both safety and throughput on the roadway. According to the U.S. Department of Transportation, ubiquitous V2X technology could eliminate 80 percent of unimpaired crash scenarios and could save tens of thousands of lives each year.[32] But in order to come to fruition, V2X needs to be standardized for communication and public sector investment in infrastructure.

The CV policy debate centers around connectivity, as vehicle connectivity has the most theoretical benefit if all vehicles operate on the same standard and use the same base technology. Governments have developed standards and deployed pilots for dedicated short-range communications (DSRC) that permit two-way medium-range wireless connectivity similar to Wi-Fi. U.S. DOT is currently piloting a CV program with three sites intended to understand how best to implement CV technology in a variety of scenarios across the country.[33] New York City, Tampa, and Wyoming are part of the ongoing study, which includes investments in V2I technology with DSRC-enabled cars. The federal agency has not yet completed the operational phase of the pilot, but preliminary models and interoperability tests already offer a perspective into how signals and vehicles can be upgraded to communicate key information about vehicle position and roadway conditions.

On December 13, 2016, U.S. DOT issued a Notice of Proposed Rulemaking (NPRM) to mandate DSRC communication technology for V2V applications (V2I and V2X are not considered in the proposal) in all light-duty vehicles by 2023.[34] The rule would require CV technology in all vehicles, focusing on DSRC-based communications, but also including options for non-DSRC technologies that meet performance and interoperability standards.[35] Public comment on the rule closed on April 12, 2017. U.S. DOT has made various statements in 2018 reinforcing their support of a reserved spectrum and their commitment to remain technology neutral in guidance and regulations.

More recently, 5G technology has advanced to a level that has convinced some transportation professionals to advocate for cellular V2X (C-V2X) instead. Regardless of whether it relies on DSRC or G5, governments are poised to invest billions in V2I technology that will remain in place for decades. Some manufacturers and telecommunication companies suggest that DSRC is already outdated and planning and decision-making agencies and manufacturers should focus regulations and plans around 5G cellular C-V2X technology instead.[36]

Automotive and tech industry support for C-V2X technologies has expanded in recent years, as evidenced by the growing testing and stated interest and support for C-V2X implementation. For example, in 2016 eight industry companies founded the 5G Automotive Association (5GAA), and membership has since grown to 108 transportation and technology companies. The 5GAA believes that the FCC restrictions on the 5.9 GHz wavelength band should be opened up to allow C-V2X communication as well as the currently permitted DSRC communication for intelligent transportation systems.[37] They recently petitioned the FCC to grant a waiver for C-V2X implementation in a portion of the allocated 5.9 GHz spectrum, signifying a growing desire for 5G-based connected vehicles.[38]

Other ongoing and completed federal efforts that support sophisticated research and development, such as the U.S. Department of Defense Advanced Research Projects Agency's (DARPA) Grand Challenges (beginning in 2004) and its Urban Challenge (in 2007), have played a key role in catalyzing the development of self-driving vehicle technologies, companies, and workforce.[39]

3.0 The State of AV Policy Today

Policy development tends to be reactive. When William P. Eno proposed his "rules of the road" in the early 1900s, he was developing policy to fix congested and chaotic streets.[40] Policymakers today have the opportunity to shape the transportation landscape before the arrival of AVs. This process has already started, with federal guidelines and state-based legislation laying the groundwork for a national system.

The traditional federalist roles in automotive policy have not changed much over the past half-century. The federal government has been responsible for federal motor vehicle safety standards (FMVSS) that regulate the design, construction, and performance of vehicles. The federal government also supplies capital funding to states and localities to build and improve roadways, with requirements for consistent markings and engineering standards.

States and localities control a much larger portion of the policy framework. Their roles include building, maintaining, and owning the roadways. They set the rules of the road, control traffic law enforcement, and regulate the sale and ownership of vehicles. They also have jurisdiction to set insurance rates, assign liability for crashes, and set requirements for vehicle registration and driver licensing.

AVs' most plausible change to the established structure involves the licensing of the driver. Policymakers are struggling over how to regulate "licensing" a non-human operator. Absent federal standards, some states have moved forward by either banning robot drivers or regulating the standards for the AVs, while others are not taking any action. AV developers see this as a threat to the industry, because a patchwork of standards could make the systems inoperable across state boundaries as well as impracticable from a business standpoint.

3.1 The Federal Automated Vehicles Policy Statement

NHTSA released the first version of their Federal Automated Vehicles Policy Statement (FAVP) in September 2016, and replaced the document with a second version, FAVP 2.0 *Automated Driving Systems: A Vision for Safety*, the following year.[41] The statements were written in consultation with industry stakeholders including automakers, technology firms, state government officials, and experts in the field, with incorporation of feedback from public comments. U.S. DOT released the 3.0 version of the FAVP, *Preparing for the Future of Transportation: Automated Vehicles 3.0,* in October 2018 to augment, not replace, 2.0. FAVP 3.0 includes further guidance for actual implementation of AVs than was laid out in previous

FAVPs and integrates guidance for trucks, buses, and other modes beyond passenger vehicles.[42] While these documents are neither binding nor comprehensive, the voluntary guidance establishes a foundation from which industry leaders and the federal government can collaborate on developing AV policies.

The FAVP seeks to assuage industry concerns surrounding the lack of legislative and regulatory certainty for AVs. It provides guidance to manufacturers testing and developing AVs on public roads, clarifies the roles of the federal and state governments in regulating vehicles, their use and associated operations, and outlines NHTSA's existing and potential enforcement mechanisms. NHTSA received over 1,000 formal comments each on the first and second versions of the document.[43]

In FAVP 2.0, NHTSA encourages AV developers to publish Voluntary Safety Self-Assessments (VSSA) that describe how they address the safety aspects of their AVs and best practices in the industry and at their own companies. According to NHTSA, the VSSA is a method for AV developers to provide concise information to the public about 12 aspects of their AVs and how they are developed:[44]

- System Safety
- Operational Design Domain
- Object and Event Detection and Response
- Fallback (Minimal Risk Condition)
- Validation Methods
- Human Machine Interface
- Vehicle Cybersecurity
- Crashworthiness
- Post-Crash ADS Behavior
- Data Recording
- Consumer Education and Training
- Federal, State, and Local Laws

The guidance emphasizes the "voluntary" nature of this assessment, with that word appearing no fewer than 45 times in the 2.0 document. To date, 12 companies have submitted VSSAs, including Apple, AutoX, Ford, GM, Mercedes-Benz/Bosch, Navya, Nuro, Nvidia, Starsky Robotics, Uber, Waymo, and Zoox.[45] Of the VSSAs submitted, none include a quantitative assessment of safety elements or outcomes. While 2.0 does recommend safety and risk assessment for various ADS tasks, vehicle design, and software, they do not include this in the VSSA template.

The second part of the FAVP 2.0 discusses best practices for state highway officials. It provides no real concrete recommendations but gives states many things to consider should they decide to regulate AVs. U.S. DOT breaks down the areas of state-level action recommended for consideration into seven categories:

1. Administrative: Consider creating an ADS technology committee, a designated lead agency, and allowing applications and permits for AV testing.
2. Standardizing application for tests on public roads: Require AV developers to submit a safety and compliance plan.
3. Permission to test AVs on public roads: Lead this effort and involve law enforcement.
4. Specific considerations for test drivers and operations: Require that testers follow traffic rules, licensed drivers are in control at all times, and AV testers report crashes to the state.
5. Considerations for registration and titling: Consider specific title and registration tags for ADS vehicles, either for new vehicles or those that have been upgraded.
6. Working with public safety officials: Consider training public safety officials to understand ADS and coordinate with neighboring states.
7. Liability and insurance: Begin to consider how to allocate liability and assign who should carry insurance among ADS owners, operators, passengers, manufacturers, and other entities when a crash occurs.[46]

3.0 emphasizes a multi-modal approach and increased safety guidance. It doubles down on the VSSA process established in 2.0 in lieu of legally binding federal safety standards. The new version holistically addresses automation issues across all surface transportation modes. Whereas 2.0 was almost exclusively about the NHTSA and self-driving cars, the new document strings in commercial vehicles, intermodal facilities, mass transit vehicles, and their operating agencies within U.S. DOT.

Echoing the second section of 2.0, the 3.0 document encourages state governments to think twice before regulating AVs: "State legislatures may want to first determine if there is a need for State legislation. Unnecessary or overly prescriptive State requirements could create unintended barriers for the testing, deployment, and operations of advanced vehicle safety technologies."[47]

In terms of specific actions, the AV 3.0 summary document outlines a number of next steps that U.S. DOT will undertake:

- Structuring a proposed collaborative AV safety research program based on public comment on a NHTSA-released Advance Notice of Proposed Rule Making.
- Changing the definition of "operator" by asking for public comment on which of its standard regulations will need to be revised to make it clear that the "operator" of a commercial motor vehicle is not always required to be human.
- Changing NHTSA standards to allow cars without driver input. (Because the eventual manufacture of Level 4 and 5 AVs may not require those features, the 3.0 document notes that current safety standards make it illegal to sell cars that lack driver input features like steering wheels, brake and throttle pedals, and mirrors.)
- Fast-tracking the NHTSA exemption process.
- Awarding $60 million in grants for AV testing.
- Updating the Manual on Uniform Traffic Control Devices to reflect changing technology for vehicle-to-infrastructure and vehicle-to-vehicle systems. (The Manual is the official compilation of national standards for all traffic control devices, including road markings, highway signs, and traffic signals.)
- Releasing automated transit bus guidance from the Federal Transit Administration. (FTA has already released the Strategic Transit Automation Research Plan.)[48]
- Evaluating port access and truck queueing from the Maritime Administration and the Federal Motor Carrier Safety Administration.
- Studying workforce impacts in coordination with the Labor, Commerce, and Health and Human Services Departments.[49]

The AV industry's reactions to the FAVP fall into three general categories. The first was disagreement with the inclusion of Level 2 vehicles in the safety assessment letter (SAL) in 1.0. SAE does not categorize Level 2 vehicles as "Highly Automated" (see Table 1), and Level 2 vehicles are already operating on roads today, creating confusion as to who should submit documentation for that technology and when. FAVP 2.0 resolved that confusion by recommending VSSAs for only Level 3 and up. Many comments on 2.0 from automakers acknowledged this, but also contended that the NHTSA descriptions of the levels of automation did not match the SAE descriptions. The FAVP 3.0 adopted more precise SAE language.

A second concern with 1.0 was with the purpose of SAL itself. For NHTSA to evaluate the letters, AV developers claimed that they would need to disclose propriety information about their system design to federal regulators. This would include trade secrets and other confidential data that could be subject to public access. 2.0's update and VSSA template assuaged those concerns about data, but commenters provided mixed feedback on the omission of certification, ethics, and cybersecurity elements. This did not change in 3.0. Comments from states and other organizations on the 2.0 document addressed other elements of safety assessment, suggesting that there should be demonstrable, measurable safety standards.

The third major concern with 1.0 was regarding its implied recommendation that states formally adopt the NHTSA policy, rendering the voluntary guidance compulsory. Writing a SAL for each state would be burdensome to AV developers and, they claimed the effort would not be very productive for safety.[50] The 3.0 version emphasizes coordination between states and the federal government in an attempt to decrease state regulations and responsibilities.

3.2 Federal Legislation

Aside from the FAVP, the federal government has not passed any policies or laws directly pertaining to automated vehicles except for a few minor demonstration projects and research. Both chambers of Congress have developed bills to address and expand the regulatory authority of the federal government with respect to automated vehicles. The House of Representatives passed the Safely Ensuring Lives Future Deployment and Research In Vehicle Evolution (SELF DRIVE) Act by voice vote on September 6, 2017. Meanwhile, the Senate Commerce Committee passed the American Vision for Safer Transportation through Advancement of Revolutionary Technologies (AV START) bill with bipartisan support. However, it did not pass the full Senate prior to the end of the 115th Congress. The 116th Congress is expected to pursue similar legislation.

Federal AV legislation aims to address three main components. The first is to direct NHTSA to develop federal motor vehicle safety standards (FMVSS) for HAVs. All vehicles must comply with FMVSS, but current standards pose a hindrance to the commercial realization of AVs. For example, FMVSS set standards for controls, displays, and ways the operator interacts with the vehicle. But many current regulations will not work for dynamic, software-based vehicle control. Creating FMVSS for ADS-operated vehicles will require a rethink of how FMVSS are structured.

While NHTSA is already in the process of doing this, legislation with deadlines and assessments could help streamline the process. NHTSA's current authority includes preemption of state and local governments to regulate the design, construction, and performance of motor vehicles (something that has been long established in federal automotive policy). Just as they have now, NHTSA would have the authority to regulate, recall, and continually assess automobiles, including those equipped with

ADS technologies, as part of a national framework for AV safety. States and localities would reserve their existing responsibilities for certain licensing, use, liability, and legal policies.

Second, the proposed Senate bill also provided an expanded number of exemptions from FMVSS. Currently, automobile manufacturers can apply to be exempt from FMVSS (eliminating, for example, the steering wheel and brake and accelerator pedals) up to 2,500 vehicles sold. Manufacturers must prove to NHTSA that their vehicle is as safe or safer than a compliant design to receive an exemption. Under AV START, the exemption cap would have been incrementally increased to 80,000 vehicles.

Federal policy would also bridge the gap while NHTSA developed full FMVSS by requiring ADS manufacturers to submit a detailed Safety Evaluation Report (SER) to NHTSA prior to deployment. Clarifying rules for liability, data sharing, cybersecurity, and interim safety evaluation reports were all aspects of AV START, and likely will be major portions of future legislation.

3.3 State Policies

States are moving to more clearly define AV requirements, regulations, and infrastructure investment schemes. In general, states have taken one of four approaches to AV policy.[51]

The first approach is "hands off", when states do not have any regulations or laws that specifically pertain to AVs. Not that they are unaware of the changing environment, but many states are instead working to craft laws or waiting to see how the market evolves in the rest of the country. While this leaves any AV subject to existing traffic and motor vehicle laws, it does not explicitly prohibit their operation so long as a licensed human driver is in control.

The second approach is when states explicitly express interest in AVs but have not passed any laws directly related to testing and deployment. Through executive orders, states like Arizona have started to set up self-driving vehicle oversight committees and research teams at their respective state departments of transportation (DOTs). Virginia's governor issued a 2015 "executive proclamation" that supports AV research and the testing conducted in partnership with Virginia Tech. Virginia also created the Virginia Automated 20xx Working Group to bring state-level policymakers and officials together in order to create a state strategic plan for AVs.[52] North Dakota established a legislative management study of AVs.[53]

These groups work to inform lawmakers and other state officials on when and how to craft state laws or investments for AVs.

But these states have been known to move quickly and modify their approaches over the course of a few years. Georgia's Joint Autonomous Vehicle Technology Study Committee evaluated the issues facing AV technology through three public hearings involving academics and industry experts. The committee's final 2014 report advised the Georgia state legislature to refrain from passing any legislation until the technology had matured. It stated: "To recommend any changes to our current system at this time would be putting the proverbial cart before the horse."[54] However, the state has since decided to move forward on implementing official AV policies by enacting a law that allows for fully driverless AVs.[55]

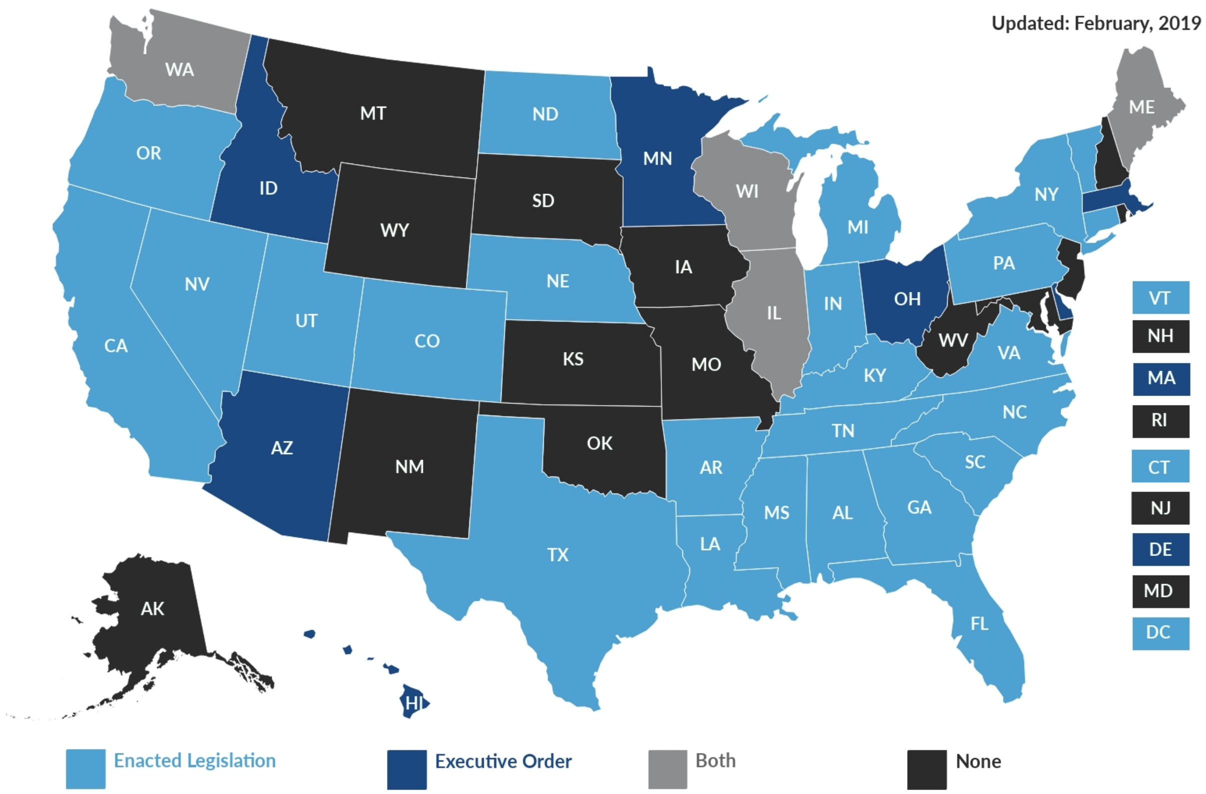
The third approach includes states that explicitly allow for AV testing. This is most common among states that have AV laws and includes Michigan, California, Utah, Nevada, and Tennessee. California requires licensing with the state and regular reporting of any system problem or incident. Tennessee set up a framework for the state to begin charging a per-mile fee on AV driving.[56] Michigan passed AV legislation that allows for testing on public roads, truck platooning, and legalized self-driving ridesharing in the state.[57] Utah authorized the state U.S. DOT to conduct a connected automated vehicle (CAV) testing program on platooning applications.[58] In most of these cases, AV developers must obtain a state-approved permit that requires them to report their safety infractions to the state government.

The fourth approach includes states that explicitly allow HAVs to be deployed beyond the testing phase. Florida was one of the first states to pass an AV policy and, along with Georgia, Nebraska, Tennessee, and California, it is one of only five states to specifically allow for the operation of driverless vehicles. Under Florida's current framework, AVs can operate on public roadways without a human physically present in the vehicle. The only requirement is that if the system fails, the vehicle and software must be able to inform an operator within the vehicle, or via remote, and safely bring itself to a stop. The District of Columbia and many states also allow for fully automated vehicles, as long as a human operator is present in the driver's seat.[59]

As of October 2018, 41 states and Washington D.C. have proposed or enacted self-driving laws (Figure 1).[60] This has created a patchwork of state regulations, which allows policymakers to learn and compile lessons from various approaches, but also troubles many AV developers.

The first state to enact legislation authorizing the operation of AVs was Nevada in 2011. The law defined "autonomous vehicles" and directed the state's department of motor vehicles (DMV) to adopt rules for license endorsement, operation, insurance, safety standards, and testing.[61] Since then, 25 states have enacted AV legislation: Alabama, California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Michigan, Mississippi, Nebraska, Nevada, New York, North Carolina, North Dakota, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Vermont, and Virginia, as well as the District of Columbia. Most of these laws passed in 2017 and 2018.

Figure 1: Status of State Legislation and Executive Orders Related to Automated Driving



Source: National Conference of State Legislatures; The Center for Internet and Society; and individual state-legislation[62]

The enacted laws vary in scope, rules, and extent, and create a medley of frameworks to which AV testers must adapt. Florida passed a law in 2012 and another in 2016, eliminating the driver requirements for automated vehicle testing and expanding AV operation on public roads. North Dakota requires its state DOT to study use data from AVs traveling on its highways, and Utah, Connecticut, and Florida also have study requirements accompanying their laws.[63] Tennessee set up a framework for the state to begin charging a per-mile fee on AV driving. Michigan passed comprehensive AV legislation in a series of six bills between 2013 and 2016 that allow for testing on public roads without a driver, truck platooning, and legalized self-driving ridesharing in the state.[64]

In 2015, the governor of Arizona issued an executive order for various agencies to support the testing and operations of AV and encouraged universities to launch pilot programs for AVs.[65] He followed up with a 2018 executive order requiring federal safety standard compliance. A Massachusetts order created an AV working group to craft legislation and a Memorandum of Understanding (MOU) agreement for companies to sign before testing on state roads.[66] A March 2018 executive order in Minnesota established a Governor's Advisory Council requiring bicameral and bipartisan membership.[67] Most recently, the outgoing Illinois governor signed an executive order in October 2018 initiating an AV initiative under the state U.S. DOT that includes AV development, testing, and deployment requiring an in-vehicle operator and a registration system.[68]

Problems with legal patchworks and attempts to harmonize AV regulations are not limited to the United States. In November 2016, Australia's National Transport Commission (NTC) published national guidelines on AVs in an attempt to establish a consistent regulatory environment across the country. Then, in May 2018, state and territory ministers of the Transport and Infrastructure Council approved a set of NTC policy recommendations toward a national, uniform approach to AV legislation, including clarification to ensure some legal entity would be responsible for automated operations.[69]

In March 2016, the United Nations Economic Commission for Europe updated the UN 1968 Vienna Convention on Road Trafficking, which harmonizes regulations for use of roadways across Europe and with other cross-continental signing parties, to allow for AV technologies in real traffic.[70] These intergovernmental and international efforts continue. The UN Economic Commission for Europe Sustainable Transport Division oversees a world forum for the harmonization of vehicle regulation, and a subsidiary working party on automated/autonomous and connected vehicles (GRVA, abbreviation of the French name) was created in June 2018.[71]

4.0 Implications and Recommendations for Policymakers

With so much uncertainty regarding AVs in terms of their specific capabilities and timeline, policymakers need to take a performance-based approach that enables responsible AV deployment, regardless of when or how the technology eventually takes shape. These policies should be focused on creating an environment where firms can deploy technologies that provide benefits to society and consumers, while also protecting the general public interest and safety.

The following recommendations address some of the most important areas of AV policy and can help guide safe, efficient, and sustainable deployment.

4.1 Definitions

Policymakers should adopt current (and future) SAE AV definitions, and use them when developing AV policies.

Policymakers and media should think of the SAE levels as "classifications" rather than hierarchical levels.

From a legal standpoint, the SAE and NHTSA classification scheme for defining AVs and their system capabilities defines who or what is in control of the vehicle. Standard, deliberate definitions of hardware, software, and use, including types of technology, vehicles, operating modes, and communication are necessary to develop clear, effective policy. Consistency is also important for national compatibility in the market. These definitions may create confusion in the media and among consumers but are important to adopt for clear public policy.

Some states have created unique definitions for AVs that are inconsistent with NHTSA/SAE language. For example, Michigan defined an "automated motor vehicle" as any motor vehicle with automated technology installed that allows it to be operated without any control or monitoring by a human driver. Vehicles with active safety or operator assistance systems like adaptive cruise control, lane-keeping assistance, and lane departure warnings were not included in Michigan designation, unless one or more of those technologies allowed the vehicle to operate itself without control or monitoring by an operator.

Tennessee's law defines "autonomous technology" (a different term than Michigan) as systems with the capability to drive a motor vehicle without the active physical control or monitoring by the operator. It breaks down autonomous technology into two types that each require state certification before testing: Operator-Required Autonomous Vehicle (ORAV) and Non-Operator Required Autonomous Vehicle (NORAV).[72]

The differences in these definitions create confusion and apprehension among AV developers as they work to create vehicles that can travel across state boundaries. The NHTSA/SAE classification provides a uniform system for designating the levels of vehicle automation, which allows lawmakers and regulators to precisely define how their rules apply to different automated systems, rather than trying to recreate categories that might not line up in other jurisdictions. AV developers have the responsibility to ensure that consumers and the media understand the capabilities of their AV system, regardless of its level, and to clearly communicate those capabilities to them prior to and during use.

4.2 Liability

States should extend liability to AV operators, owners, passengers, manufacturers, and other entities when an AV crash occurs.

Federal regulators should set a standard for human-machine interface and responsibility to ensure clarity in liability for vehicle operations.

Some of the most challenging issues facing policymakers deal with how to assign liability for collisions and insure against damages in a driverless or quasi-driverless world. Driving liability currently applies to the operator of the vehicle, which has always meant the human behind the steering wheel. Now, experts are suggesting that this risk should shift from the human driver to software developed by the vehicle manufacturer and technology providers.[73]

There is not yet a precedent where the automated system has been held liable for a crash, although pending lawsuits might change that.[74] States have long governed product liability, but without uniformity from state tort laws or consistent and updated regulations from the federal level AV companies are unsure about the liability for use of their products. Further, insurance providers may not know whom to hold liable for crashes and will want access to vehicle and user data that can assist with determining fault. A shift in the responsible driving party calls attention to the need for more clarity in the legal framework. Barring a change to the current legislative structure, this clarity will develop as cases emerge in each state forcing a precedent to work from.

In most existing cases, the assignment of responsibility—and therefore liability—is straightforward. For example, when driving under Level 1 automation, which includes cruise control that exists on most cars, the human driver is clearly responsible for driving the vehicle. The opposite is true at the other end of the scale: in Level 4 or 5 automation the driver is not responsible for intervening and taking back responsibility in any situation.[75]

The ambiguity arises in Levels 2 and 3. In these cases, the automated driving features can maneuver the vehicle in most instances but require the human driver to ultimately be in control. In Level 2, where the system conducts both steering and acceleration/deceleration functions, the driver is expected to continually monitor and is responsible for the system's performance while engaged (unless the system forces this through driver monitoring such as hands-on-wheel sensing and/or driver gaze monitoring). For example, if the system does not detect a problem in the roadway, it is the human driver's responsibility to take control immediately and avoid the crash. In Level 3, the vehicle's driving system is monitoring the environment, but if it detects a scenario that it cannot navigate, it warns the human driver and control is transferred back to the human.

Monitoring and scanning a roadway while traveling at high speeds requires focus, attention, and short-term memory, even for routine driving situations. A study found that the average person needs at least 17 seconds to regain full focus of a roadway environment before they are ready to regain control of a vehicle.[76] While that study had a small sample size and therefore is not conclusive, the findings clash with the expectation of Level 2 and 3 responsibilities. Recent observations of how humans act behind the wheel of Level 2 vehicles (such as Tesla's Autopilot feature) indicate that it is easy to lose focus.[77] A news article from early 2017 reported that the Ford Motor Company found their engineers routinely falling asleep during testing, despite alarms designed to keep the trained professionals alert.[78] Ford refuted this claim, but the company did note that high-level automated driving does provide a "false sense of security" and represents a conundrum for the industry.[79]

Critics of AVs argue that crashes in 2017 and 2018 involving vehicles in high automation modes proved that the technology is not yet ready to be deployed, despite evidence that AVs could be much safer than human drivers.[80] The first non-operator fatality involving a vehicle operating in automated mode occurred March 18, 2018 when an Uber vehicle in self-drive mode with an operator in the driver's seat struck and killed a pedestrian walking with her bicycle across a road. The sensor input and identification software did not allow for timely correct identification of the pedestrian, and automatic emergency braking was not enabled. Uber quickly reached a settlement with the family of its victim within the month of the crash.[81] The National Transportation Safety Board's preliminary May 2018 report found that the Volvo test vehicle's automated emergency braking system was disabled while computer controls were activated, and the human safety driver at the wheel did not respond in time to avoid collision.[82] The full investigation is ongoing.

Research shows that there are real-world benefits to crash avoidance technologies. A forward collision warning system that includes automatic braking can cut front-to-rear crash injuries by 56 percent.[83] Rear automatic braking cuts backing crashes by 62 percent.[84] However, according to a RAND study, AVs need to drive "hundreds of millions of miles" to scientifically definitively prove they are safer than human drivers.[85] The Insurance Information Institute states, "there will still be a need for liability coverage, but over time the coverage could change…as manufacturers and suppliers and possibly even municipalities are called upon to take responsibility for what went wrong."[86]

At the federal level, NHTSA legally defines a vehicle's driver as whatever—as opposed to whomever—is doing the driving.[87] But federal regulations still require all vehicles to have hand and foot-controlled brake pedals and parking brakes.[88] NHTSA's new guidelines provide auto manufacturers with the option to design a vehicle without these constraints, but they need to receive a temporary exemption from the FMVSS (per Title 49 of the Code of Federal Regulations, Part 555), which has, in the past, been limited to 2,500 vehicles per year over two years.[89]

4.3 System Safety Certification

Congress should pass legislation directing NHTSA to issue new, performance-based safety standards for automated driving systems.

Policymakers should work with NHTSA to ensure consistent, national safety standards for freight and passenger commercial AV certification that protect all roadway users.

NHTSA should continue to study and formally regulate appropriate "transition" parameters to give control back to human drivers before disengaging Level 3 AV systems.

NHTSA, not individual states, should be responsible for certifying the technology used to drive AVs to ensure that they can safely operate in the

conditions for which they are designed. State governments have a role in ensuring that ADS-operated vehicles follow the rules of the road but regulating safety at the state-level requires careful action and harmonization with federal guidelines. If done correctly, a federal performance-based approach to certification can allow for effective safety oversight while allowing for innovation in technologies by not prescribing specific elements or methods.

AV developers are designing products that drive themselves on roadways all over the country. Therefore, the federal agency should assume responsibility for certifying the safety of the technology underlying interstate driving. The ADS certifications will require specific standards that may change according to the level of automation and its operational context. This system would apply whether an individual owns the vehicle or the vehicle is part of a fleet.

Technology-driven vehicle certifications can be temporally or geographically limited or could allow for operation anywhere and anytime. Regardless, in order for the technology to become certified, AV firms could demonstrate to NHTSA that their technology meets a certain safety standard, such as a driving record that is comparable or better than an average or better-than-average human driver.[90] However, this is a challenge due to the lack of standardization in safety evaluation of human divers. The current climate of nationwide media reactions to all safety incidents related to automated vehicles technologies shows that the public is holding the technology to a much higher standard than human drivers. Some certification process is necessary to protect all users of public roadways. While protection of pedestrians and cyclist is implied, NHTSA needs to explicitly require that certification systems include their safety.

ADS certifications should take into account both level of automation and operational design domain when necessary. The certification of ADS is proposed as follows (when applicable):

- **Level 0 and 1**: Traditional human driver licensing requires the driver to be alert and in control of the car at all times when using features such as adaptive cruise control, lane assist, and electronic stability control. No change required to the current licensing or liability arrangement.
- **Level 2:** The human driver has the required role of supervising the ADS in real time and intervening, with or without warning, as needed to maintain safe vehicle operation. As a matter of safety, Level 2 features, which provide both lateral and longitudinal vehicle motion control support to the driver

while engaged, must include a driver monitoring and enforcement system that ensures that the driver continues to supervise and monitor the environment. The technology developer should demonstrate that it can safely deny system operation if the driver appears to lose focus.

- **Level 3:** NHTSA must certify all Level 3 driving systems and create standards for the transfer of control from the ADS to the human driver. Under Level 3, the ADS controls all aspects of driving with the expectation that the human driver will respond appropriately upon a system's request to intervene. Preliminary studies and anecdotal evidence indicate that human drivers, even those with extensive training, lose focus easily in Level 3 test vehicles, and require a transition period to fully regain awareness.[91] NHTSA needs to continue their existing analyses that estimate the appropriate amount of time and alert type required for a human driver to regain focus as well as appropriate parameters to allow a driver to relinquish control. Human drivers can manually take control at any point.
- **Level 4:** NHTSA must certify Level 4 driving systems. This should also include any remote-controlled operation of the vehicle. There does not need to be a licensed human driver in the vehicle if only operating in its certified driving environment. For level 4 driving systems that operate the vehicle for only part of any given trip (e.g., only on freeways in dense traffic), NHTSA should require the presence of a licensed human driver at all times.
- **Level 5:** NHTSA must certify Level 5 driving systems. This should also include any remote-controlled operation of the vehicle. There does not need to be a licensed human driver in the vehicle.

Certification performance metrics and standards should continue to explicitly preempt a patchwork of state laws and regulations pertaining to the design, construction, and performance of all motor vehicles, including those equipped with driving automation technology. While the proposed certification system is built around the adopted SAE levels of automation, NHTSA should be open to additional considerations as the certification process evolves. During the initial certification process, it will be important for NHTSA to work with AV companies to address issues with version control of software, over-the-air updates, and recertification. NHTSA issued a final rule in 2018 to streamline the process for manufacturers to petition for exemptions from FMVSS.[92]

Manufacturers can only sell vehicles that NHTSA has determined are in compliance with FMVSS or that qualify for an exemption. As FMVSS evolve, further study will inform new standards relating to AVs. A 2015 report and a later 2018 NHTSA study on human factors in level 2 and 3 AVs address the importance of alerts including visual, aural, and haptic feedback as well as design specifications for them.[93] However, evidence from other tests suggests that human-ADS interface needs substantially more research.

As NHTSA has historically overseen regulations on hardware and manufacturing, the certification process for AV software will require the right balance of technical expertise and flexibility to accommodate new designs and updates. As with conventional vehicles, states will remain responsible for licensing of human drivers, registering vehicles, and enforcing road safety.

4.4 State Testing Permits

States should design balanced reporting and permitting requirements for AV tests that meet state needs for transparency and safety but are not too bureaucratically cumbersome and do not reveal proprietary corporate information.

States should understand that legislation or regulatory action do not necessarily attract or deter AV testing. AV testing engages an entire ecosystem of automakers and/or technology firms, research institutes, and localities engaged in the field. States have an advantage when they collaborate with other state and federal authorities.

The overarching aim of state-level regulations for AVs is to (1) ensure public safety, (2) provide consistent frameworks for developers, and (3) create an environment where rules can adapt to the unknown future outcomes. Given that AVs are still in the development phase, there is no "one size fits all" approach to state-level AV regulations. Some states might choose to pass laws, others might choose to take executive actions, and others will prefer to not take any steps. While there can be pitfalls in any of these methods, state governments must decide what is right for their own constituents. Motor vehicles by their very nature are designed to traverse jurisdictional boundaries. Given the uncertainty of technological development, it behooves states to collaborate with each other and with federal authorities to craft policies that are at least compatible.

States are feeling pressured to proactively pass AV laws that govern the safety and regulatory environment in which the technology would operate. A primary impetus for these statutes is to promote AV testing and development in order to bolster an AV economy in their state. While AV laws are intended to help create a more consistent and welcome environment for AV developers, practice shows they might not achieve their stated purpose.

Despite copying portions of California's AV laws, Tennessee does not (yet) have a robust AV testing industry in the state. Nor do burdensome reporting requirements prompt companies to leave a particular state. California and Michigan have unique competitive advantages on the national stage including varied climates, a skilled workforce, preexisting automotive and high-tech industries, and hundreds of academic institutions. AV technology is still in development and, despite its high visibility in the national media, it remains both geographically and financially concentrated in Michigan, California, and Arizona (although growing in other states such as Florida, Massachusetts, and Nevada). The existing facilities and qualified workforce in places like California and Michigan have given them a structural advantage that keeps AV companies testing there, even given the more stringent reporting requirements compared to other states where testing is allowed.

Since AVs of Level 3 and 4 are still in the development phase, existing state legislation aims to regulate and set safety oversight for vehicle testing. Some state AV laws require testers to get state permits and report to the state before, during, and/or after testing. Not every state has the same requirements, and overdesign of the reporting requirements can both dissuade widespread testing and create problems when test vehicles cross state boundaries. While this is an annoyance during testing, it will be even more problematic for future commercial applications.

In California, each AV must be registered and permitted with the state's DMV prior to operation on public roads. Registration documents must include a written description of the automated technology and features integrated into the vehicle, as well as the range of its automated capabilities. Testers must also conduct pre-permit, off road testing to simulate real world design domains and through this test must "have been reasonably determined to be safe."[94] These permits last for two years. The California DMV established fees to recover the costs of processing initial applications and renewals, requesting additional vehicles and/or test drives, and modifying an existing permit.[95] A law passed in 2018 updates the requirements, and allows for driverless operations so long as the tester has a remote driver capable of taking over control of the vehicle when necessary.[96] Companies testing without a driver must submit a $5 million Autonomous Vehicle Manufacturer Surety Bond or, if they can prove a net worth of over $5 million, they can submit a Certificate of Self-Insurance instead.

Manufacturer applications in California must certify that their AVs comply with the applicable FMVSS and are equipped with the following features:

- An easily-accessible mechanism to engage and disengage the AV system
- A visible display inside the vehicle that indicates when the AV system is engaged or disengaged
- An alert system that notifies the operator when a system failure is detected
- A law enforcement interaction plan for vehicles without drivers
- Mechanisms for mitigating risk in the event of a system failure that either:
    - Allow the operator to immediately take manual control of the vehicle; and/or
    - Stop the vehicle when the driver does not or cannot take control in the event of an emergency
- A failure alert system that allows the driver or remote operator to take immediate manual control in more than one way (e.g., using the brake, accelerator, or steering wheel).[97]

Under California's enacted regulations, only employees, contractors, or other persons designated by the AV manufacturer can conduct the tests in cars with in-vehicle operators. The regulations require manufacturers to develop and maintain training programs for their AV test drivers. As of October 2018 there are 60 AV permit holders in California including Waymo, which is the only manufacturer also holding a permit approved for driverless, remote operator testing.[98] Furthermore, each AV must have a data recording system that captures and stores sensor data for at least 30 seconds before a collision. These data must be stored in a read-only (un-editable) format.

During testing, the regulations require manufacturers to record every instance of disengagement of the automated system (i.e. when the AV system is turned off and control is handed back to the human operator), as well as collisions. The California DMV makes these "disengagement reports" publicly available online.[99] These reports summarize disengagements, including the total number and the circumstances surrounding them. The DMV website published 2017 disengagement reports for 20 AV developers, each with hundreds of individual instances.[100]

Similar to California, manufacturers in Tennessee are also permitted to test Operator-Required Autonomous Vehicles (ORAVs) on public streets and highways after obtaining a permit from the Department of Safety. In fact, aside from their inconsistent definitions of AVs, portions of Tennessee's 2016 laws that relate to AV testing are identical to California's 2012 AV laws. As in California, if any company was to begin testing in the state, it would need to obtain a permit from the state and verify that its AVs are capable of safe operation. By copying California's legal language, Tennessee facilitated the consistency of requirements for testing and reporting, but this does not mean that all states will or should take the same approach.

Michigan has similar (but not identical) testing laws to California and Tennessee. Manufacturers are required to submit proof of insurance and obtain special license plates from the state before driving. Throughout testing, an employee of the manufacturer must be either present in the vehicle or monitoring it remotely and remain prepared to immediately take over control.[101] Furthermore, the regulations exempt AV operators from the statewide prohibition on using cell phones while operating a motor vehicle, foreseeing a future where humans are freed from driving.

The rules in Arizona for AV testing are simpler and much more permissive than they are in California, Tennessee, and Michigan. While Arizona has not enacted any AV legislation, a 2015 executive order directs the U.S. DOT, Department of Public Safety, and all other state agencies to "undertake all necessary steps to support the testing and operation" of AVs. The order outlines several "rules" for AV testing and operation, including one that the vehicles can only be operated by an employee of the AV developer (with a valid driver's license), who is responsible for and must monitor the vehicle's movement. The AV developer must have a proof of financial responsibility, and the U.S. DOT director can add additional rules necessary to allow testing on public roadways.

While the AV industry has helped to write state AV laws and regulations, it does not always support the outcome. The Coalition for Safer Streets, an industry-led AV advocacy group, expressed concerns over the requirement in California and other states for manufacturers to submit annual reports on every single unplanned disengagement of the automated system.[102] But the private AV industry is not opposed to states requiring permitting or reporting generally, particularly in the case of collisions.

4.5 Local AV Pilots

States should allow specific pilot programs for driverless AV testing through partnerships with AV developers, localities, and research groups.

Testing advanced AV capabilities without human drivers requires special authorizations and permission to pilot on public roadways. While self-driving vehicles are still years away from full deployment, cities across the world have initiated pilot programs for AV shuttles and testing for true driverless vehicles. Ongoing pilots of low speed automated shuttles exist in more than ten locations in the United States, including:

- Dublin, CA – EasyMile
- San Ramon, CA – EasyMile
- Gainesville, FL – EasyMile
- Jacksonville, FL – EasyMile, Navya
- Weymouth, MA – Polaris GEM
- Ann Arbor, MI – Navya
- North Kingstown, RI – May Mobility
- Detroit, MI – Polaris GEM
- Las Vegas, NV – Navya ARMA
- Greenville, SC – Local Motors, Cushman Shuttle
- Arlington, TX - EasyMile[103]

On September 29, 2016, California Governor Jerry Brown signed AB 1592 into law, which authorizes the Contra Costa Transportation Authority (CCTA) to conduct a pilot project for testing automated vehicles without human operators.[104] The five to 10-year program aims to increase regional economic competitiveness; improve safety, mobility, and the environment; and create a world-class test bed.[105] Prior to testing, the CCTA and/or the private entity conducting the test must submit a detailed description to the California DMV. The program description must certify that the vehicle has been tested under controlled conditions to ensure it is capable of safe operation. Furthermore, the City of San Ramon and other local authorities with jurisdiction over the testing area must approve of the testing, environmental, traffic, and speed conditions under which the AV will operate. The law restricts the vehicles to operating at less than 35 miles per hour and only within the designated areas and clear weather conditions. CCTA met all of the requirements, including a FMVSS waiver for the EasyMile vehicle, and began testing of low speed automated shuttles on public roads in 2018.[106]

Michigan has several additional minimum standards that AV developers must meet prior to beginning pilots. This includes self-certifying that they have logged at least one million miles of driving with the automated driving system engaged, self-certifying that they meet all FMVSS, and providing proof of insurance for no less than $10 million. To prevent local barriers to entry, cities are prohibited from imposing local fees or regulations on AV pilot projects until after December 21, 2022.[107]

For freight applications, Michigan companies are able to capitalize on AV capabilities by operating platoons on streets or highways for entities provided that they submit plans for general platoon operations with the state police and state

DOTs. If neither department rejects those plans within 30 days, the entity is allowed to initiate platooning tests and demonstrations.[108]

4.6 Cybersecurity

Congress should define AV developers' roles and responsibilities for crashes that result from a cybersecurity breach.

Congress should explicitly require the AV industry to protect the privacy of vehicle owners and users.

Congress should explicitly require the AV industry to develop a plan to respond to cybersecurity breaches.

States and cities should update laws that prohibit and punish any deceiving or disabling of AV communications.

The rise of automated and connected vehicle technologies raises concerns with respect to malicious access to driving systems and what could result from such an attack. In some cases, driving software could be illegally accessed and repurposed to cause crashes. An example of car hacking made news in July 2015 when two "white-hat hackers" (professionals who break through security in order to expose weaknesses) remotely disabled a Jeep's engine and brakes.[109] Although Fiat Chrysler Automobiles has since faced NHTSA and FTC enforcement action and has addressed the vulnerability, this type of occurrence could become a greater danger as more vehicles rely on outside digital connections. Other potential disruptions include signal jammers and other types of interference that can disable or confuse the sensors on cars.

If there is a breach to a personal computer or corporate network, there may be a loss of personal information, financial data, or corporate trade secrets but likely not of the user's life. Hacking into vehicles could be disastrous for safety. It is impossible to create a system that is un-hackable, and any security breach of an AV system is a criminal offense. Nevertheless, as a matter of public safety and ensuring consumer acceptance, AV developers face a high bar of accountability for securing their systems.

The automotive industry launched the Automotive Information Sharing and Analysis Center (Auto-ISAC), a non-profit forum for sharing cyber threats and vulnerabilities across its membership to address emerging threats and vulnerabilities with AVs.[110] In January 2016, the organization released a set of guidelines for technology developers to increase the safety of their systems.[111]

In late 2016, NHTSA released voluntary guidance for technology developers on cybersecurity for modern motor vehicles.[112] The following recommendations cover areas that AV developers need to focus on during the design process: secure development practices, information sharing, disclosures of vulnerabilities, incident response, and self-auditing. The guidelines reiterate fundamental cybersecurity precautions that emphasize restricting access to critical components in connected vehicles and establishing strong boundaries between the vehicles' communications and driving systems. Congress reiterated this responsibility in both the House's SELF DRIVE Act and the Senate's AV START Act, which would have required manufacturers to develop, maintain, and execute a cybersecurity plan as well as set requirements for recovering from cybersecurity incidents expeditiously.[113]

NHTSA took an important first step in establishing federal guidelines to secure connected vehicles and protect drivers' privacy.[114] But in order to guarantee that AV technology firms are taking cybersecurity seriously, they should be held responsible in the case of a crash caused by a security breach. As software continually updates, manufacturers should be allowed to update over the air or require vehicles to be serviced immediately for safety concerns, or they could disable the semi- or fully-automated features until the consumer updates or fixes the vehicle. If a vehicle owner declines to update or fix their vehicle, then the AV developer should deny them AV services.

States should update their laws to prohibit mischievous or nefarious activities that can interfere with the safe operation of AVs. This can encourage an environment for safe AV testing and eventual deployment, and in the meantime, make roadways better and safer for all road users. With the number of testing centers across the county growing, state and local DOTs should begin to work closely with them to identify necessary updates of traffic laws that optimize the roadway for safe mobility regardless of travel mode.

4.7 Data Management and Sharing

Human owners or operators of vehicles with automated systems should have access to vehicle data when they are liable in the event of a crash.

Cities and states should work with the AV industry to establish model data sharing agreements to enhance local transportation planning and operations.

In terms of data ownership, multiple parties might want access to data collected by an AV, including the automaker, the technology developer, the human occupant, urban planners, the vehicle owner, and various other commercial entities. These data can be extremely valuable to businesses and public entities, including mapping data, traffic data, and travel data showing where the user spends time and money.[115]

Operational data could also aid in determining fault in the event of an incident, providing police and injured parties with a detailed analysis of a crash. New vehicles are already equipped with event data recorders (EDR) that provide operational information when involved in a crash with standardized data reporting requirements. Current laws state that all EDR data belongs to the vehicle owner and can only be accessed with consent or through a court order.[116] However, depending on the ownership model of AVs, it is unclear who owns what and who has the legal access to the information in question. The National Association of City Transportation Officials advises that the federal government explicitly define exactly who owns what data and in what scenarios they are required to share it. [117]

Vehicle manufacturers or AV technology firms should retain ownership of the data produced in the vehicles during any operation when their software is collecting data. But private firms must be required to share that ownership with a human operator if s/he is in control of the vehicle at the time of a crash. For example, if a Level 2 driving technology expects the driver to be liable in the case of a crash, then the data must be fully shared between the technology firm and the car owner. However, if an AV is liable for a crash, and the human occupant is not expected to have any driving responsibility, then the AV firm responsible for the driving task would exclusively own the data. If an incident occurs on a public roadway, companies should be required to provide data to government and law enforcement officials to prove fault in the case of a crash or other incident where there is loss of property or personal injury.

Manufacturers must protect the privacy of the vehicle owners, and companies should not be allowed to distribute personal identifiable information about vehicle owners or occupants without their approval and knowledge. As in accordance with current laws, data sharing agreements should adhere to policies that maintain user anonymity and protect company trade secrets. Consumers should be informed of data ownership rules prior to car purchase or use. In 2014, automakers acknowledged the importance of transparency, data management, and data sharing options with their broad statement of commitment to privacy principles.[118]

AVs need to operate on public roads, and the agencies that manage traffic and conduct maintenance on these roads can benefit from a wealth of travel information from the vehicles that use them. Data sharing agreements would provide beneficial updates on road conditions and traffic flow to drivers and agencies; it could be used to improve planning, emergency response, and congestion mitigation. These data need to be scrubbed of personally identifiable information and information that might competitively disadvantage the technology firms.

4.8 Infrastructure Investment

Cities and states should use AVs as a way to galvanize support for robust state of good repair programs that target unsafe roadways and work zones across the state.

Federal investment programs should target "fix it first" rather than system expansion.

AV technology and public roadways are intrinsically linked. Although the technological development has largely been a private sector effort, successful deployment requires access to good public roadways, traffic signals, and signage that create a workable driving environment. As the technology currently exists, AVs are limited to operating on well-maintained roads with clear lane markings.[119]

AV developers are not counting on massive, coordinated public investment for full functionality of their systems. Instead they are developing advanced methods that work within the existing roadway environment. Thus, maintaining traditional infrastructure that serves all road users—regardless of levels of automation or connectivity—remains the best use of public funds. In addition to clear lane markings, pavement should be uniform and without potholes, traffic signals should be functioning properly and easily visible, and signs should be clearly legible and visible from the roadway.[120]

To this end, a "fix it first" approach to infrastructure investment will likely prove to be both prudent and cost-effective in the long run. By prioritizing maintenance of existing roads and infrastructure, a state will be able to ensure the long-term health of its transportation network. Federal funding programs should encourage these investments both for the benefit of current road users and in anticipation of future AV deployments, particularly since AVs could expand roadway capacity without physical expansion.

However, it is unrealistic to expect states to update every roadway to have very high-quality pavement, signage, and striping and maintain them consistently. AVs need to be able to operate safely regardless of the road condition but targeting state of good repair funds to roadways with safety problems, or to high-risk areas such as work zones, can be a good place for states to start. (See funding recommendations on Section 4.10)

4.9 Connected Vehicles

The Federal Communications Commission should maintain the existing 5.9 GHz spectrum for connected vehicles and transportation safety applications.

NHTSA should continue to work closely with the automotive industry on standards for V2V and V2I communications.

States and local governments should initiate pilots of DSRC and 5G wireless CV technologies, particularly when a private entity is willing and able to support the pilot financially.

States and cities should incorporate CV and AV technologies into their public vehicle fleets during turnover and monitor the performance of the technologies.

Although connected vehicles and AVs are fundamentally different things, many in the industry believe that AVs must be connected in order to speed the deployment and unlock the full benefits of driverless technology.[121] CV technology communicates directly with other vehicles and infrastructure about vehicle data related to speed, location, trajectory, and other operational variables, potentially enabling better management of traffic flow with the ability to address specific problems in real-time.

In 1999, the Federal Communications Commission (FCC) allocated part of the electromagnetic spectrum for a system called dedicated short-range communication (DSRC). DSRC refers to close-range communications channels that vehicles use to communicate with each other. But with the explosive growth of mobile and wireless devices, the current available spectrums are crowded, and telecommunications providers sought to expand into the spectrum currently reserved for connected vehicles. In September 2018, the FCC ruled to expand the spectrum available for 5G, streamline federal state, and local review for small cell deployment, and further incentivize new network and connectivity technologies.[122]

Movement on CV technology is still split between DSRC and cellular technologies, as technological capabilities, coordination, and public sector investment all progress. As a result, the wireless industry is now being pitted against some members of the automotive industry on whether this allocation would jeopardize the safety of connected vehicles.[123] Regardless, reserving the spectrum is important to keep all options open for these technologies as they develop alongside AV technology. Reserving the spectrum will prevent crowding of the existing network for CVs and AVs to use seamlessly.

In order to realize the full benefits of CV technology, NHTSA and the automotive industry should continue to collaborate through industry organizations like SAE to set standards for V2X. This would maintain a universal language for all vehicles to use, regardless of manufacturer (e.g., a Honda Accord must be able to communicate with a Ford Fusion). These standards should also address cybersecurity issues and other ways that vehicles can communicate safely and securely.

States, universities, and localities are already testing CV capabilities on public roadways. In 2016, Sunnyvale, California entered into a partnership with Nissan, Savari, and the University of California, Berkeley to install V2X-enabled roadside units across nearly 4.5 square miles and three public intersections. The city intends to use information collected through this test program to optimize traffic light timing.[124]

The Virginia Connected Corridors initiative facilitates the real-world application and deployment of 5G CV technology. The state is using more than 60 roadside equipment units and is also implementing connected applications using the corridor, including traveler information, enhanced transit operations, lane closure alerts, and work zone and incident management.[125]

In Michigan, the Ann Arbor Connected Vehicle Test Environment (AACVTE) began when U.S. DOT and the University of Michigan Transportation Research Institute (UMTRI) launched its predecessor, the Safety Pilot Model Deployment in 2012. This three-year, $30 million research project included over 2,800 vehicles and 73 lane miles of connected infrastructure along the roadway.[126] In the coming years, AACVTE will expand this deployment by leveraging funds from the Federal Highway Administration (FHWA), the state of Michigan, academic institutions, the city of Ann Arbor, and the private sector. The larger deployment will amount to a 27-square mile test zone throughout The City of Ann Arbor, including 45 street locations, 12 freeway sites, and up to 5,000 equipped vehicles.[127]

Monitoring and measuring the benefits, costs, and other factors of CV pilots will be vital to informing the ensuing policy debate and ensuring that the government sets the right standards for interoperability and makes the right investment decisions for the technology.

4.10 Funding

Congress should authorize a pilot for a per-mile charge fee system on vehicles that are operating on Level 3 or higher.

U.S. DOT and state DOTs should support research for different approaches to implementing and using a vehicle miles traveled (VMT) fee on AVs as a way to (1) create a new revenue stream for state transportation investment and (2) encourage the responsible use of AVs on public roadways.

The direct infrastructure costs associated with the operation of AVs presents a unique funding need for infrastructure improvements and regulatory oversight. Conveniently, AV technology also opens up an opportunity to implement a fair and straightforward per-mile charge or vehicle miles traveled (VMT) fee.

Unlike traditional car purchases where there is an initial vehicle sale and little business interaction afterward, transportation today is more often being sold as a service.[128] The computerization of driving will require constant updates and refinements to ensure that vehicles can operate in an ever-changing environment. Recent partnerships between automotive manufacturers and transportation network companies (TNCs), such as Uber and Lyft, point to a future where technology firms will be selling Levels 3, 4, and 5 automated driving as a service, charging by the mile or per trip. All this indicates that companies are laying the groundwork for a per-mile charge, and governments could take advantage of this new business model to fund public infrastructure investments.

Given that the technology is nascent and limited as an advanced or luxury feature, now is the time to implement a system that can be used to support future infrastructure programs. Congress should establish a VMT-based charge on AVs overseen by U.S. DOT. The fee could charge differently by mile and be designed to account for differences in vehicle types and other variables such as time of day. Although it is a revenue stream related to use, manufacturers or technology firms should pay the VMT charge to the government, not the driver or car owner, for only the portions of the trip that are completed under automated operation.[129]

At the start, the VMT rate can be set at a nominal $0.01 per mile. This small charge will not dissuade early adopters. Level 1, Level 2, and test vehicles should be exempt. In fact, the $0.01 per mile rate is similar to current federal fuel tax rates. Current federal fuel taxes raise approximately $34 billion annually, and if all vehicles paid a penny per mile fee, the net receipts would total $32 billion.[130]

The VMT charge may not create a particularly robust revenue stream at first, but could net about $320 million annually, if 1 percent of all driving is done in Level 3, 4 or 5.[131] The funds should support a new federal transportation infrastructure grant and be targeted to investments that improve the safety and reliability of AVs, including state of good repair programs and connected infrastructure deployment. In the future, this pricing could be indexed, supplemented by additional state fees (much like the current fuel taxes), and varied based on vehicle type. For example, the cost of a light duty vehicle on a public road is different than that of an 18-wheeler, and the VMT fee structure could accommodate those differences.

Although this proposed fee would specifically apply to AVs, AV developers are not necessarily against implementing a VMT fee on their vehicles. Policymakers need to be mindful of market distortions related to a VMT fee and should consider using discounts or other incentives to encourage the beneficial adoption of AV technology.

State work on a VMT fee has already begun: irrespective of AVs, Oregon has a pilot project to test the replacement of its state gasoline tax with a VMT fee.[132] In 2016 Tennessee passed a law that would specifically charge a VMT for AVs. Although it has yet to be implemented, the revenue generated from the charge would be allocated to state, county, and local governments' transportation funds.[133] The federal government's 2015 reauthorization Fixing America's Surface Transportation (FAST) Act set aside $25 million for VMT research.[134] The U.S. DOT can use this money to begin testing a VMT fee system for AVs before they become more prevalent on the roadways.

In 2016, Tennessee passed a law that would specifically charge a VMT for AVs at a rate of $0.01 per mile for two-axle vehicles and $0.026 per mile for more than two axles. Although it has yet to be implemented, the state will divide the revenue generated from the charge between the state general fund, state highway fund, counties, and localities according to a statutory formula.[135]

4.11 Planning

Cities, counties, metropolitan planning organizations (MPOs), and state DOTs should examine and include the potential impacts of AVs on regional transportation systems in their long-range plans.

States and cities should implement strategies now to mitigate negative externalities of AVs.

AVs have the potential to enhance mobility and decrease congestion. Some research indicates the number of cars per household could drop by 43 percent in a shared AV scenario.[136] Shared AVs offer a potential solution to parking and other urban problems that presently stem from widespread individual car ownership. Those unable to drive (i.e. the disabled and elderly) could newly access vehicles to travel directly to their destinations.

Yet, research suggests that fully deployed AVs will make driving cheaper and easier, which could result in large increases in vehicle miles traveled and thus lead to detrimental effects on congestion, air quality, and sprawl.[137] Planners are increasingly worried about the negative effects of AVs on the transportation system as a whole, including "zombie" cars waiting for passengers that circle blocks with nobody on board.[138] Luckily, even today, strategic interventions can reduce the incentives for inefficient utilization of AV technologies.

Planners need to emphasize policies that encourage sharing. A shared fleet of AVs—in combination with public transportation—could sustain current levels of mobility using only 10 percent of the vehicles currently on the road today.[139] To achieve this, AVs would be shared simultaneously by several passengers thereby reducing the need for private vehicle ownership and decreasing congestion.[140] In this model, individuals would not own and use personal AVs but, instead, AVs would function like a fleet of self-driving taxis to be hailed as needed, which could reduce the total vehicle miles traveled.[141] AVs also present a major opportunity for fleet turnover, thus an equally large opportunity to clean the nation's transportation fleet if the new vehicles are electric.

Shared travel can be encouraged through new infrastructure or policies before commercial AV deployment. Strategies such as high occupant vehicle lanes can create priority access for carpoolers, though must be implemented with care to achieve the desired outcomes without negative externalities.[142] Investing in high quality transit system, including priority lanes for buses, are ways of encouraging shared rides. Employers can provide financial benefits to commuters that carpool.

Reducing parking needs will also help encourage sharing. Eliminating parking minimums and increasing the artificially low cost of on-street parking can encourage shared ownership. Less parking demand would also free up curb space for multimodal uses, including possible AV pick-ups and drop-offs, making the streets more efficient and safer. One expert estimates that in many cities up to 45 percent of traffic is caused by people looking for a place to park.[143] A shared-use model could ease the search for parking and also reduce greenhouse gas emissions.[144]

Strategies to reduce "zombie" AV trips and shared trip deadheading involve pricing. States and localities could experiment with additional charges for deadheading AVs traveling without a passenger. Conversely, pricing could be applied as an incentive. For instance, in AVs operating with three or more passengers, the car might operate at a reduced fee. Variable pricing could create scenarios in which empty AVs are discouraged and shared vehicles are incentivized. Using scenario planning to examine possible outcomes based on different policy decisions, consumer behavior, and technological accomplishments can help planners properly account for AVs when modeling future conditions.

Planning organizations play a critical role in designing and monitoring the long-term outcomes of regional transportation networks. As agencies develop long-range plans, they should work collaboratively with policymakers and other stakeholders to identify how AVs help or hinder to achieve their goals for accessibility, air quality, and land use development. But planners should recognize that they are already well equipped to reduce the negative externalities of the transportation network.

4.12 Traffic Laws

Identify current state and local laws that might be in conflict with the capabilities of future commercial-ready AVs. Proactively modify those laws so that they allow for permitted or certified AV systems, while still requiring safe human operation.

Current national, state, and local laws can conflict directly with the nature of AVs. For example, Falls Church, Virginia's vehicle code reads: "No person shall operate a motor vehicle upon the streets of the city without giving full time and attention to the operation of the vehicle."[145] This well-intended traffic code, which is common in cities, directly conflicts with the ultimate goal of AV developments: to reduce the need for humans to drive.

Eventually all states and localities will need to consider how their current traffic laws work within driverless vehicle capabilities and update them accordingly. Examples include:

- As of April 2018, talking on a hand-held cell phone while driving is banned in 17 states (including D.C.) and texting while driving is banned in 48 states (including D.C.).[146] As written, these laws would still not allow for phone use even if the vehicle were driving itself. This defeats one of the largest benefits of Level 4 and 5 AVs.
- Every state is responsible for licensing drivers, and every state requires that a licensed driver be present and operating the vehicle when it is in use. But if the future of cars is driverless fleets, there might not be a need for any person, licensed or not, to be in the vehicle or control.
- Many states have regulations about leaving vehicles unattended, including those that are idling. From a legal standpoint, this means that a person would need to "attend" to the vehicle at all times, which would not be required in Level 4 or 5 operation. Some states, like Virginia, caveat this and prohibit vehicles to be unattended only if "it constitutes a hazard in the use of the highway."[147]

These laws need to be reconciled with the changing nature of self-driving capabilities. By doing so, states can proactively address concerns, rather than letting incident-reactive laws and/or case law through an arduous series of court cases across the country determine the final outcome. According to some experts, it is not certain that a legal interpretation of existing laws would yield a favorable outcome for the AV industry, which has incited the companies to push for proactive policymaking when possible.[148] But repealing all existing traffic safety laws does not make sense either: human drivers should always have to abide by sensible traffic safety regulations, and updates should apply only to certified AV systems.

Tennessee's 2017 AV law begins to address some of the legal conflicts with AV driving. The law preempts localities from enacting policies that ban the operation of AVs, either intentionally or unintentionally. Further, it allows AV operators to use electronic display screens only when the automated mode is engaged.[149]

4.13 Workforce

The public sector should partner with universities and the private sector to implement targeted retraining or career development programs that proactively address and prepare for the adverse effects of automation.

By their nature, AVs are expected to eliminate or change the nature of skills needed for thousands of driver and maintenance jobs across the country. Bus drivers, delivery drivers, body shop staff, postal workers, truck drivers, and similar occupations represent four million jobs spread out across the country.[150] But if, when, and how automated driving systems will affect industry workers or replace humans behind the wheel is widely debated. If widespread deployment of Level 2 or Level 3 vehicle is successful, it could significantly reduce crashes, affecting the 915,000 workers employed in auto repair and maintenance jobs in the United States.[151]

The threat of substantial job losses or economic disruption, however, is a long way off. In the short and medium term, automation can help address some of the serious problems associated with professional driving, and over time, shifts in the job market may overcome much of the job loss. Some studies suggest that the unemployment rate will only fall 0.06 to 0.13 percent at the height of workforce disruption around the 2030s and that by 2050, economic benefits will soar and employment loss will minimize.[152] The rise of AVs could lead to the creation of new industries and new occupations. Examples of new industries that could emerge include maintenance workers for AV vehicles, remote operators for fleets of AVs, and individuals who will educate consumers, policymakers, and car distributors on the functions and limitations of AVs.

The trucking industry is grappling with a shortage of drivers. Automated trucks could create much safer and enjoyable jobs for the workforce, first by avoiding collisions and eventually by allowing truckers to avoid sitting for extended periods of time. More flexible work hours and technology-based driving might also attract younger or other underrepresented workers. Similar workforce improvements apply to public transit and taxi workers.[153]

AVs are by no means the first time that technology has disrupted regional economies. A state like Virginia once relied on coal miners, manufacturing in tobacco, furniture, and textiles to drive the state's economy. When those jobs disappeared, the state adapted and reinvented itself by incentivizing the growth of its technology industry—as other regions might need to do with automated vehicles. Industry is already proactively considering some of the issues surrounding automation and the workforce.[154] Governments too should nonetheless be proactive about addressing workforce concerns and preparing the workforce for the future.

4.14 Oversight Groups

States, cities, and AV test bed communities should create AV advisory committees of no more than 30 people that include representatives from various stakeholders such as state and local government offices, automotive manufacturers, AV technology firms, safety advocates, public transit industry, trucking industry, taxi industry, and other relevant experts. Industry associations or rotating seats would ensure that group sizes are manageable yet include perspectives from different organizations.

Stakeholder engagement before, during, and after testing and deployment is necessary to obtain crucial feedback and encourage smart AV policy. Engaging experts and decision-makers as well as potentially affected groups in committees and working groups can give populations a voice and add value to testing though expanded engagement. Engaging the general public can help utilize emerging technologies to fix existing problems in a community's transportation network. A 2018 Knight Foundation initiative funds AV pilot projects in five cities with the expressed objective of citizen engagement to address specific local concerns.[155]

Regardless of whether they pass AV laws or not, states are assembling stakeholder working groups to monitor and advise AV policy. For example, in August 2015 Arizona Governor Ducey issued an executive order establishing a Self-Driving Vehicle Oversight Committee. The committee is comprised of governor-appointed representatives from his office, the University of Arizona, and Arizona's Departments of Transportation, Public Safety, and Insurance.[156] This committee advises other public agencies on how to advance the testing and operation of AVs in the state.[157]

A number of other states have adopted a similar approach in establishing AV task forces, including Pennsylvania and Michigan, that are comprised of officials from a variety of public agencies whose operations may be affected by AVs.[158] Michigan established the Council on Future Mobility to recommend statewide policy changes and updates on an annual basis. The governor appoints individuals representing interests in local government, business, research, and technological AV development. The legislature also appoints representatives of the majority and minority parties from each chamber. State legislatures such as Georgia and Alabama have also established internal study committees.

If poorly designed or inconsistent with neighboring states, AV regulations at the state level can do more harm than good. Such laws do not necessarily guarantee safer AVs, nor will they necessarily attract significant AV developer investment.

Most states do not have any regulations or laws regarding AVs. While not passing state AV laws leaves any AV subject to existing traffic and motor vehicle regulations, it does not explicitly prohibit testing, provided there is a human driver in the driver's seat. These states are not unaware of the changing environment, but instead are waiting to see how the market evolves in the rest of the country and how more proactive states react.[159] Current laws exist to protect public safety, and that does not change under AVs

The ideal stakeholder advisory group consists of policymakers, regulators, lawyers, private AV developers, trade groups, community groups, environmental groups, and any others with a direct stake in the policy outcomes for AVs. The group should meet regularly—two to four times a year—and should provide guidance to policymakers on how to best integrate federal regulations with existing state and local laws in a rapidly changing technological environment.

4.15 Outstanding AV Issues

In absence of federal laws and regulations or when working to develop more permanent policies, states and cities should develop nonbinding "statements of principles" that address the following topics:

- *Privacy*. States and localities need to clearly delineate expectations about data ownership and access to the data in the case of a collision. Manufacturers must protect the privacy of the vehicle owners and companies should not be allowed to distribute personally identifiable information about vehicle owners or occupants without their approval and knowledge.
- *Cybersecurity*. States and localities need to proactively define AV developers' roles and responsibilities for crashes that result from a security breach and ensure that all AV developers are taking cybersecurity seriously.
- *Roadway safety*. States and localities should emphasize that AVs must be able to recognize, yield to, and share the roadway with all users of the roadway.
- *Consumer advocacy*. Consumers need to be aware of what their vehicle is capable of and what is it not. States and localities can set principles for consumer information for new and used cars with AV features. In addition, consumers should be informed of data ownership rules prior to purchasing an AV.
- *Data sharing*. States and localities should work with transportation service providers to create initial guidelines for data sharing that can set the stage for future data sharing agreements that can bring benefits to both public sector agencies and private companies.

The expectation of commercially ready AVs presents new challenges for policymakers in areas such as privacy, data sharing, consumer advocacy, roadway safety, and cybersecurity. However, AVs are still very much in their development phases, and it will be several years until the industry and the public fully understands what the implications are for data, cybersecurity, and safety. The federal government has taken only small steps to govern the system safety, and the Congress has not yet passed comprehensive AV legislation.

More than 70 percent of U.S. citizens indicated that they were "very concerned" or "moderately concerned" with AV system security from hackers.[160] Nearly the same amount voiced concern about privacy of location and destination tracking data.[161] States can demonstrate to the public and to the AV industry that they are taking these issues seriously by giving policymakers the flexibility to adapt in an unknown future.

4.16 Government Investment in Research

The federal government, states, and universities should fund academic research to understand the potential short-, medium-, and long-term effects of AVs on the transportation network, including the environment, social equity, and economic vitality.

Private sector initiatives and academic university research have led the way in AV development, mostly through a mixture of public and private funding. These range from private tech companies like Google and Uber; to automakers like Tesla, Audi, GM, and Ford; to universities like Carnegie Mellon and the University of Michigan. More than 250 companies are working directly or indirectly on AV technology, from sharing services to onboard hardware platforms.[162]

While the private sector has invested its resources into AV technology, universities can play an increasingly important role in understanding AV integration. This includes how AVs will interact with built environments, pedestrians, bicyclists, public transit, motorcycles, and every other roadway user. Information about how AVs will affect the transportation system is not being developed by the private sector, making it a natural fit for public investment.

Testing centers, technological research, and other innovative investments can help understand and accelerate deployment so the general public can maximize the safety, environmental, and social benefits that AVs can provide. In 2014, The Virginia Tech Transportation Institute received a federal grant for $25 million to research safety protocols for AVs. The study looks at AV electronics and potential cybersecurity risk, along with human interaction and reliability aspects of AVs.[163] State DOTs are also funding university-driven research, such as the Georgia DOT-funded research synthesis and roadmap development for AVs at the Georgia Institute of Technology and the joint FHWA and TXDOT funded project at University of Texas at Austin.

States and universities are also partnering to create AV testing centers. For example, in 2014 the Michigan DOT partnered with the University of Michigan Mobility Transformation Center to build a $6.5 million facility dubbed "Mcity" to test how vehicles perform in complex urban environments.[164] Testing centers do not necessarily have to be completely self-contained: states like Ohio and countries like Singapore and China have created "AV Zones" or "AV corridors" in industrial parks or managed freeways that serve to imitate the broad array of potential driving conditions without constructing new testing facilities.[165]

5.0 Conclusion

With the numerous issues around technology certification, liability, cybersecurity, data ownership, infrastructure funding, vehicle connectivity, environmental issues, and workforce development, AV policy is complex. The recommendations in this paper provide a clear and substantive framework for each level of government to use in order to support efficient, sustainable, and safe usage of this exciting technology.

Technology has always been an agent of change. Over the next decade, AV technology will rapidly alter the landscape of transportation. The implications will vary from insurance and certification, to infrastructure and the environment. As AV development continues to progress, appropriate and effective public policies are critical to managing safe deployment. Innovative and measured action now is necessary to lay the groundwork for the future.

Endnotes

[1] "Automated vehicles" is a broad term encompassing autonomous, self-driving, or driverless vehicles. It was first defined by the Society of Automotive Engine (SAE) and later adopted by the National Highway Traffic Safety Administration (NHTSA).

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