Spotlight on Highway Safety

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Autonomous Vehicles Meet Human Drivers:

Traffic Safety Issues for States

Prepared for
Governors Highway Safety Association

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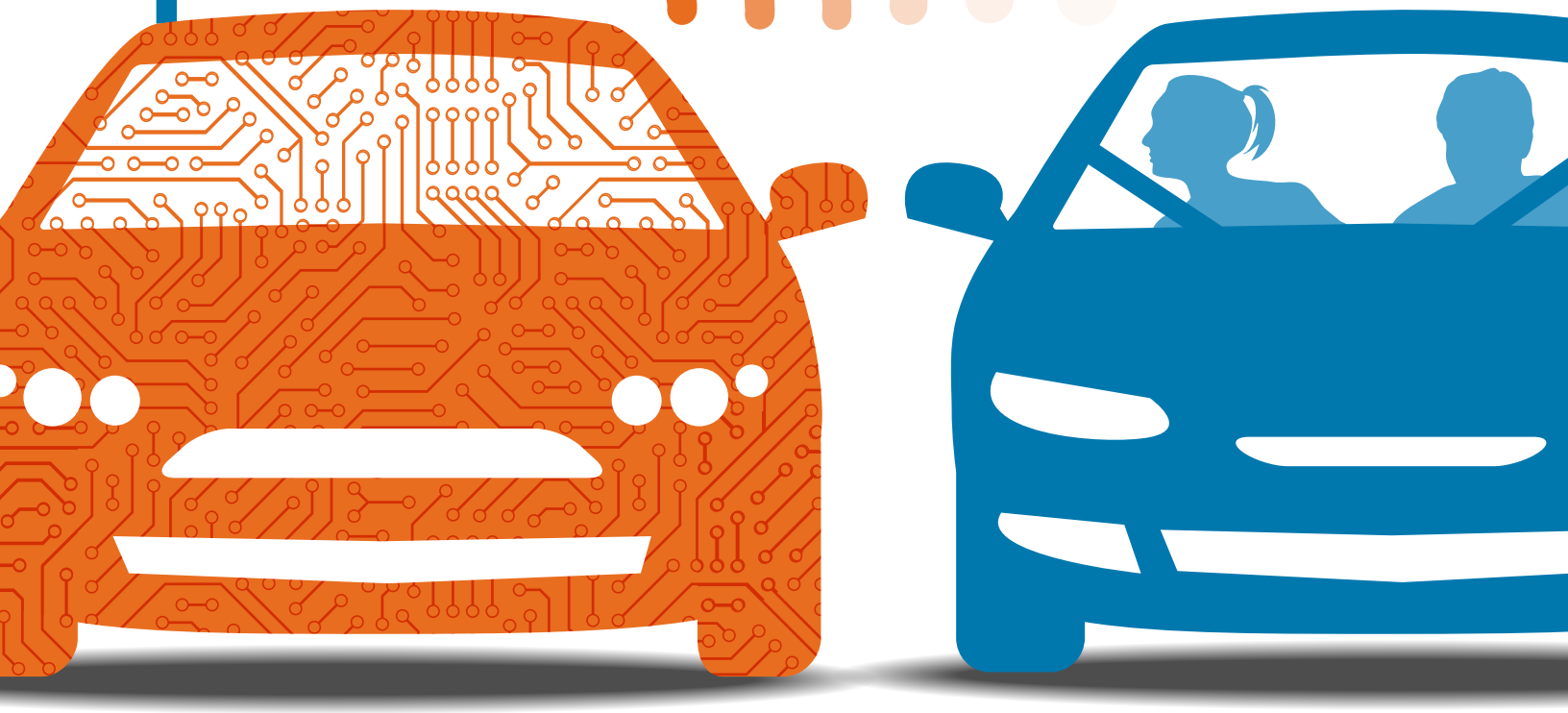

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ACKNOWLEDGMENTS

This report would not be possible without the knowledge, wisdom, and cooperation of many people with whom the author consulted. While the report's facts, conclusions, and recommendations are based on these conversations and on the extensive AV literature in the references, the author bears sole responsibility for them and for any errors of fact and judgment.

Jonathan Adkins, GHSA Executive Director, and Kara Macek, GHSA Senior Director of Communications and Programs, oversaw this report.

Russ Martin, GHSA Director of Government Relations, Madison Forker, GHSA Communications Coordinator, and Amadie Hart, GHSA Communications Consultant, reviewed the report.

Special thanks to Jana Simpler, Delaware Office of Highway Safety Director, and Rhonda Craft, California Office of Traffic Safety Director, for their review and expert advice.

Creative by Tony Frye Design.

INTRODUCTION

States must take the lead in dealing with the many traffic safety issues that a mix of driver-operated and autonomous vehicles will bring.

Fully autonomous vehicles – cars and trucks that can drive themselves, without a human at the controls – are coming soon. In fact, they already are on the road. Google's test cars have logged two million miles, though with a driver at the wheel to take over if needed. Fifteen companies are testing autonomous vehicles in California as of October 2016. In August 2016, Uber began offering autonomous vehicle rides in Pittsburgh, again with a backup driver. Tesla has sold tens of thousands of cars with a driver assistance feature misleadingly called Autopilot. An autonomous vehicle that can be driven by a quadriplegic is being tested. Autonomous vehicles likely will be available for sale across the country in a very few years and will make up a substantial portion of the vehicle fleet in the foreseeable future. Most vehicles on the road today already have some autonomous features such as crusie control and electronic stability control.

Autonomous vehicles will change our lives in many ways. Drivers can use their time in a car to use the internet, read, work, eat, or sleep. Autonomous vehicles can provide transportation for those who cannot drive themselves. An autonomous car can take someone to work and then return home by itself to take children to school. In urban areas, if an autonomous car can be summoned when wanted, there will be little need for some individuals to own a car. Congestion should decrease; far less parking should be needed; land use patterns likely would change.

But all vehicles on the road will not be autonomous for a very long time, perhaps never. Until then, autonomous vehicles must share the road with vehicles driven by humans. How can this be done safely? States are responsible for safety on the roads – for licensing drivers, registering vehicles, and establishing and enforcing traffic laws. So states must take the lead in dealing with the many traffic safety issues that a mix of driver-operated and autonomous vehicles will bring. In particular, states should help educate the public about the benefits that autonomous vehicles will bring and the risks that they may present, educate drivers of semi-autonomous vehicles about their driving responsibilities, and educate all drivers about how to share the road safely with autonomous vehicles.

This report should help states understand and address these issues. It's written for state Departments of Transportation (DOTs), Departments of Motor Vehicles (DMVs), and State Highway Safety Offices (SHSOs). It begins with background information: a description of the various levels of autonomous vehicles, a summary of what's on the road now and what's coming soon, results from surveys of public knowledge and attitudes regarding autonomous vehicles, and projections of autonomous vehicle sales and use. Next, it describes the key topics that states must address to manage traffic safety in a world with both driver-operated and autonomous vehicles. The report then summarizes what some states already have done to address autonomous vehicles. Finally, the report suggests what all states can and should do to prepare for autonomous vehicles and to assure that traffic safety is at the forefront of all autonomous vehicle discussions.

There is extensive information on autonomous vehicles in scientific journals and in the popular media, with something new appearing almost daily. This report captures the most important points for states and provides references for more information. It concentrates on traffic safety issues, especially the issues when driver-operated and autonomous vehicles share the road. It does not discuss in any detail many other issues raised by autonomous vehicles such as insurance and liability, infrastructure changes, and autonomous vehicle technology, communications, and security.

BACKGROUND

Fully autonomous vehicles can operate without any human control or even monitoring.

What is an autonomous vehicle?

A vehicle is autonomous if it can perform some functions of a human driver. Autonomous vehicles properly should be called automated vehicles; more precisely, vehicles with some level of automated driving capacity. Fully autonomous vehicles can operate without any human control or even monitoring – they can drive themselves and have been called driverless or self-driving. This report refers to vehicles with any level of automation as autonomous vehicles (AVs), a term frequently used in state laws (Novakowski et al, 2015), or as AVs at certain levels as defined below. The Society of Automotive Engineers (SAE, 2016) provides a thorough discussion of automated vehicle terminology.

SAE and the National Highway Traffic Safety Administration (NHTSA) define five levels of AVs (SAE, 2016; NHTSA, 2016a, p. 9). In brief:

- **Level 0 –** no automation: the driver is in complete control of the vehicle at all times.
- **Level 1 –** driver assistance: the vehicle can assist the driver or take control of either the vehicle's speed, through cruise control, or its lane position, through lane guidance. The driver must monitor the vehicle and road at all times and must be ready to take control at any moment, with hands on the steering wheel and feet on or near the pedals.
- **Level 2 –** occasional self-driving: the vehicle can take control of both the vehicle's speed and lane position in some situations, for example on limited-access freeways. The driver may disengage, with hands off the steering wheel and feet away from the pedals, but must monitor the vehicle and road at all times and be ready to take control at any moment.
- **Level 3 –** limited self-driving: the vehicle is in full control in some situations, monitors the road and traffic, and will inform the driver when he or she must take control. When the vehicle is in control the driver need not monitor the vehicle, road, or traffic but must be ready to take control when required.
- **Level 4 –** full self-driving under certain conditions: the vehicle is in full control for the entire trip in these conditions, such as urban ride-sharing. The vehicle can operate without a driver in these conditions; the driver's only role is to provide the destination.
- **Level 5 –** full self-driving under all conditions: the vehicle can operate without a human driver or occupants.

NHTSA (2016a, p.10) refers to Levels 3-5 as Highly Automated Vehicles (HAVs) and denotes the situations in which a Level 2-4 AV can operate without a human driver as the vehicle's Operational Design Domain (ODD). Levels 2 and 3 present important safety issues. Some drivers of Level 2 vehicles may not monitor the vehicle and road as they should. Level 3 drivers must be ready to shift quickly from complete disengagement to complete control.

As of August 2016, 33 corporations around the world were working on some aspect of AVs.

What AVs are on the road now or being tested?

Level 1 driver assistance has been available for many years. Cruise control was offered in the 1960s, electronic stability control in the 1990s, and various lane-keeping and lane departure warning systems in the 2000s. Electronic stability control is standard on model year 2012 and later passenger vehicles.

Level 2 partial self-driving features are now available. Perhaps the best example is the Tesla Autopilot, installed via a software update to 60,000 vehicles in October 2015. A car with Autopilot can manage its speed, stay within a traffic lane, change lanes, and park itself (MIT, 2016). While the driver is warned to keep his or her hands on the steering wheel at all times (Tesla, 2016), "Tesla customers, delighted, posted videos of themselves on the highway, hands free, reading the paper, sipping coffee, and even, once, riding on the roof," treating the vehicle as a Level 3 (Bradley, 2016). Many manufacturers offer a combination of adaptive cruise control, which automatically adjusts the vehicle's speed to maintain a safe distance from vehicles ahead, and a lane-keeping or lane departure warning system (Mays, 2016).

Levels 3 through 5 vehicles are being tested extensively. Google's AV test fleet has driven almost two million miles (Dwoskin and Fung, 2016) and Google is now testing AVs with no steering wheel or floor pedals (Halsey and Laris, 2016). In September 2016 Uber began offering rides in fully automated cars in Pittsburgh, though the cars are supervised by an engineer in the driver's seat (Bhattarai, 2016). They are not foolproof yet: one of their cars was observed turning the wrong way into a one-way street (Griswold, 2016). Apple is working on AV technology (Fingas, 2016), as are several traditional automobile manufacturers (Economist, 2016, Sept. 24). As of October 2016, all AV testing in the United States has a test driver in the vehicle who can take control if needed (Prince, 2016). Volvo began testing self-driving cars in Gothenberg Sweden in September 2016 (Anderson, 2016) and in 2017 will test in London (Topham, 2016).

In October 2016, an Otto self-driving 53-foot semi-trailer containing 2,000 cases of beer drove 120 miles from Fort Collins to Colorado Springs with the driver in the sleeper berth for the majority of the trip (della Cava, October 2016). In November, another Otto truck drove 33 miles between Dublin and East Liberty, Ohio, with no involvement from the driver (Trucker News Services, 2016).

What AVs are coming and when?

There's broad consensus that Level 3-5 AVs will be commercially available to some buyers within five years. They may be operating on the road if appropriate laws and regulations are in place. Recent predictions come from Baidu (by 2019), Ford (by 2020), and GM (by 2020) (Driverless Future, 2016).

On August 16, 2016, Ford announced its plans "to have a high-volume, fully autonomous SAE Level 4-capable vehicle in commercial operation in 2021 in a ride-hailing or ride-sharing service" (Ford, 2016). The vehicle will not have a steering wheel or pedals (Golson, 2016).

Plans and activities from other companies include (Driverless Future, 2016, unless otherwise cited):

- Fully autonomous vehicles from Tesla by 2018, Volkswagen by 2019, Toyota by 2020, and BMW by 2021. On October 19, 2016, Tesla announced that all Teslas produced after this date will have all the technology needed for Level 4 self-driving, though the software has not yet been activated (Tesla, October 2016).

- NuTonomy's self-driving taxis in Singapore began trial operations in August 2016 (Liang and Durbin, 2016). NuTonomy plans to have AV taxi fleets in 10 cities by 2020.
- Delphi and MobilEye plan to have a fully autonomous system on the market for use in a variety of cars in 2019.
- Secretary of Transportation Foxx stated in 2015 that he expects AVs to be in use all over the world by 2025.

GM plans to make its first autonomous vehicle electric, likely the 2017 Chevrolet Bolt EV, "and nearly anyone will be able to experience it through Lyft." While GM has not made a public announcement, a GM official says that "this is all coming much faster than people anticipate" (Szymkowski, 2016).

The Central North America Trade Corridor Association is working to create a corridor that will allow autonomous vehicles for commerce along US 83 from Canada through North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas to Mexico (CNATCA, 2016).

As of August 2016, 33 corporations around the world were working on some aspect of AVs (CB Insights, 2016).

What does the public think about AVs?

Five recent surveys examined the public's knowledge of and attitudes toward AVs. The surveys were conducted in the United States by Kelly Blue Book, State Farm, Schoettle and Sivak, and Vox and in Canada by the Traffic Injury Research Foundation. The Appendix summarizes each survey's methods and results.

Surveys show considerable skepticism about AVs currently, sometimes with twice as many negative responses as positive.

While the five surveys asked different questions phrased in different ways to different respondent pools, the results overall are quite consistent. They show considerable skepticism about AVs currently, sometimes with twice as many negative responses as positive. Survey respondents were generally unenthusiastic about AVs and doubted that AVs would improve safety. Only one-sixth said they were willing to ride in an AV today and one-third in the next ten years. Only one-quarter to one-third of the respondents said they would be comfortable riding in an AV, with about twice as many not comfortable. Only about one-fifth of respondents said they are likely to buy an AV, at least immediately.

Respondents had a strong preference for AVs that allow drivers to take control of the vehicle when they wish.

The public's views on new technology can change quickly. AVs today may well be similar to automobiles a century ago or smart phones only 10 years ago: a new technology with a few ardent supporters and many skeptics initially but which quickly became both acceptable and highly desirable. As Henry Ford is purported to have said regarding automobiles (probably incorrectly), "If I had asked people what they wanted, they would have said faster horses." Also, today's teenagers are more accepting of AVs: in the Kelley Blue Book survey, 48% of respondents age 12-15 said they would be comfortable riding in an AV compared to 36% of all respondents.

What will influence AV sales and travel?

Fully autonomous cars offer many potential advantages (Anderson et al., 2016; Cox Automotive, 2015; Isaac, 2016; Litman, 2015; Fagnant, 2015 and others):

- **Increased safety:** may eliminate many of the crashes caused by human error, estimated at 94% of all crashes.
- **Improved mobility:** for those who cannot drive, including elderly, disabled, and youth.
- **Reduced parking needs:** passengers can be dropped off at their destinations without needing a nearby parking space.
- **Relaxed drivers:** drivers can rest, work, or entertain themselves during a trip.
- **Increased car-sharing:** reduced need for individually-owned cars.
- **Increased road capacity:** through vehicle platooning (traveling very closely together), more predictable traffic flow, and reduced congestion.

However, AVs raise some serious questions (Isaac, 2016; Litman, 2015, and others):

- **Costs:** AVs initially will cost several thousand dollars more than comparable non-AV vehicles and maintenance costs also will be higher.
- **AV Safety:** AVs may cause or contribute to some crashes because they may not be able to analyze and react appropriately to every potentially risky situation in the same way that a human driver would.
- **Human driver safety:** Drivers will need to learn how to interact with AVs, both when they are driving a Level 2-4 AV and when they are driving a vehicle that's on the road with AVs.
- **System failures:** what happens if an AV's computer system fails partially or completely?
- **Ethics:** how would an AV choose between alternatives that risk the AV and its occupants and those that risk others – for example, if a dog runs into the road, will the AV strike the dog or crash the vehicle into a tree?
- **Liability:** who's responsible for a crash in which an AV is at least partially at fault: the "driver," the vehicle manufacturer, the software provider, or some combination?
- **Security:** can an AV's data system be protected against hackers?
- **Data privacy:** will an AV's travel data be accessible by others?
- **Travel:** AVs may encourage more vehicular travel, for example through longer commutes.
- **Infrastructure issues:** will AVs encourage modifications to roadways and parking areas that may affect pedestrian, bicycle, and transit travel?

Respondents to a survey listed the following factors that would encourage or discourage them from purchasing a fully autonomous vehicle (Cox Automotive, 2016, only responses of more than 25% listed).

Factors that would encourage purchase:

- Price in respondent's price range: **53%**
- AVs are demonstrated to be safe: **51%**
- Insurance rates would decrease: **35%**
- Ability to try an AV without fully committing to buying one: **30%**
- Tax breaks: **28%**
- AV is standard in the vehicle they want: **28%**

Factors that would discourage purchase:

- Too expensive to buy: **50%**
- Too expensive to repair: **48%**
- Fear of AV computer system failure: **47%**
- Fear of AV computer system being hacked: **44%**
- No option for driver to take control: **43%**
- More confident in their ability to drive than in AV's ability: **38%**
- Concerns about interactions between AVs and driver-operated cars: **37%**
- Fear of AV not communicating well: **37%**
- Would not be able to fully relax when AV is in control: **27%**

Three themes jump out. First, cost is critical. Second, uncertainty about AV performance lies behind many of the discouraging responses. This will be overcome only after AVs demonstrate that they perform reliably and safely, preferably allowing potential purchasers to get first-hand experience with them. Finally, many drivers would prefer a vehicle that can be operated either autonomously or by a human driver. Manufacturers understand this desire (Schultz, 2016).

AVs offer substantial benefits to manufacturers. They will be a new product, a disruptive technology that eventually could make traditionally driven cars almost obsolete, in the same way that smart phones have almost completely replaced older cell phones. Manufacturers can be expected to promote AV sales vigorously as soon as they have a safe and reliable product to offer.

On the other hand, vehicles are expensive and last many years: the average age of cars on the road in 2015 was 11.5 years (Culver, 2015). Many drivers may prefer to keep their present vehicle for several more years rather than invest in a new and costly AV.

What are current AV sales and travel projections?

Experts agree that it likely will be years before Level 4 or 5 AVs make up a substantial portion of the vehicle fleet. Isaac (2016) reports that the consensus of researchers is that Level 4 or 5 AVs will not be ubiquitous on roadways until 2025 – 2040 (and some believe even later). Lari reports that some observers estimate limited availability of Level 4 or 5 AV cars by 2020, with wide availability to the public by 2040. Based on Highway Loss Data Institute data on the time it takes promising safety features to reach 95% of the on-the-road fleet, IIHS estimates that if Level 4 or 5 AVs were mandated today it would take at least 25 years before 95% of the vehicles on the road were AVs (Rader, 2016).

Littman (2015, Table 7) makes specific projections of Level 4 and 5 AV penetration into the vehicle fleet based on consumer attitudes, implementation patterns of previous vehicle technology (automatic transmissions, air bags, and others), and price.

Table 7

Stage	Decade	Vehicle Sales	Vehicle Fleet	Vehicle Travel
Large price premium	2020s	2-5%	1-2%	1-4%
Moderate price premium	2030s	20-40%	10-20%	10-30%
Minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all vehicles on road	???	100%	100%	100%

Some experts believe that the first extensive AV uses may be for trucks on limited-access highways, ride-sharing in urban areas, public transportation on restricted roadways, and/or valet parking (Isaac, 2016; Nowakowski et al., 2015).

States should begin planning now to deal with the traffic safety issues presented when autonomous and driver-operated vehicles share the roads.

What are current state laws regarding AVs?

It is generally held that AVs can operate legally in most, if not all, states without any explicit authorizing legislation (Smith, 2014). Some restrictions may apply. For example, New York law requires drivers to keep at least one hand on the steering wheel while the vehicle is in motion (Sloane, 2016). No state has enacted a law prohibiting AV testing or operations.

As of December 2016, nine states and the District of Columbia have enacted laws regarding AVs and another two states have executive orders in place. Summaries may be found in NCSL (2016), Sloane (2016), and Weiner and Smith (2016), each of which is updated regularly.

- California, the District of Columbia, Florida, and Nevada laws authorize AV testing and operations under specified conditions.
- Michigan and Utah laws authorize AV testing under specified conditions.
- Louisiana's law defines "autonomous technology." North Dakota's law authorizes an AV study, but the study was not funded and has not been conducted. Tennessee's law establishes a certification program for AVs. Virginia's law allows the viewing of a visual display while a vehicle is being operated autonomously.
- Arizona's executive order requires the Department of Transportation to take steps necessary to support AV testing and operation on public roads.
- On Oct. 20, 2016, Boston Mayor Walsh and Massachusetts Governor Baker signed a pair of executive orders to create regulations and guidelines for testing AVs in Boston (Graham, 2016).

In 2016, 16 states considered legislation regarding AVs (NCSL, 2016).

Conclusions

There are two important conclusions for states from all of the above.

- Some Level 4 and 5 AVs – fully driverless vehicles – will be on the road within five years.
- There will be a mix of autonomous and driver-operated vehicles on the road for at least 30 years and perhaps forever.

States should begin planning now to deal with the traffic safety issues presented when autonomous and driver-operated vehicles share the roads.

WHAT ARE THE AV PRIORITIES FOR SHSOs AND DMVs?

Both AV testing and AV commercial and private operations will bring two broad challenges to states. The long-run challenge is to develop and manage a surface transportation system in which most vehicles are AVs. This raises many infrastructure issues, such as road design and traffic signals, that are outside the scope of this report. The short-run challenge is to manage a world with a mix of driver-operated and autonomous vehicles, from Level 1 through Level 5, on the road at the same time. A key question is to attempt to anticipate how AVs will change behavior, both for AV drivers and those interacting with AVs: other drivers, motorcyclists, bicyclists, pedestrians, and other road users. For example, a recent study suggests that drivers may take advantage of AVs by driving aggressively around them (Price, 2016).

This section provides a brief discussion of several key topics that DMVs and SHSOs will need to consider as they address these challenges.

The short-run challenge is to manage a world with a mix of driver-operated and autonomous vehicles.

AV Testing

The final stages of AV testing take place on public roads, not on test tracks. States should welcome the opportunity to encourage AV development and the benefits AVs will bring. The challenge is to protect public safety during the testing period.

While it is probably true that AVs can operate legally in all states without any law changes (Smith, 2014), states may wish to establish AV testing requirements and monitor testing performance. NHTSA's model policy (2016a, p. 41-43) suggests that states require each organization wishing to test to submit an application to the state that identifies each test vehicle and test operator, provides information on the organization's safety plan, and establishes that the organization has appropriate insurance in the event of a crash. The organization should specify the conditions under which AVs will be tested: which local jurisdictions, which roadways, which weather conditions. States may wish to establish reporting requirements that document what testing has occurred and any crashes, injuries, or other incidents that occurred during testing.

Nowakowski et al. (2015) discuss other issues a state should consider during AV testing: test driver selection and training, the testing organization's safety culture and record, whether test vehicles should be marked or otherwise identified, what crashes or incidents should be reported, and what information should be reported for testing overall and for crashes and incidents. The Department for Transport (2016) describes the British AV testing requirements.

As of December 2016, California, the District of Columbia, Florida, Michigan, Nevada, and Utah have enacted laws that authorize AV testing under specified conditions.

- California's and Nevada's AV testing laws, regulations, application procedures, and news may be found at https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/bkgd and http://www.dmvnv.com/autonomous.htm, respectively.
- Florida's procedures as of 2014 are described in FL (2014). Florida does not require an application or otherwise regulate AV testing aside from requiring that the operator of the AV being tested is an employee, contractor, or other person authorized by the manufacturer. The operator must be able to take control at any time. The AV must have a visual indicator inside the vehicle to show when it is in autonomous mode and must alert the operator if there is a technology failure.

AV Operations

Many questions should be considered before commercial or private AV operations begin. Some of the more obvious and important ones are discussed in this section.

AV certification. Before AVs can operate, states must assure that they will operate safely. AV safety includes two components. First, an AV must operate properly and safely on the roads when all its hardware and software are functioning as designed. Second, it must be able to deal safely with hardware or software failures. Nowakowski et al. (2015) call these two components behavioral competency and functional safety, respectively. Both are vehicle technology issues which NHTSA should regulate, not the states. A method is needed to certify that a vehicle meets acceptable standards in each. It is far from clear what an acceptable level of safety would be or how to develop and implement certification standards and procedures to provide this level of safety. In addition, NHTSA is reviewing the existing Federal Motor Vehicle Safety Standards (FMVSS) to determine where revisions may be needed to accommodate AVs (Kim, Bogard, et al., 2016).

AV registration and titling. Level 3-5 AVs, which do not require a human driver for an entire trip or a portion of a trip, should be identified in the vehicle's title and registration. NHTSA (2016a, p. 44) suggests that states add a new data field and code these vehicles as HAVs. States may wish to provide more detail by identifying AVs at each level and by identifying their ODDs - the situations in which they can be operated without a driver. States may wish to do the same for Level 2 vehicles: the Tesla incident noted previously shows that they sometimes can be operated as if they were Level 3. States also should establish procedures for modifying the title and registration of vehicles if additional or improved software upgrades an AV to a higher level.

In its policy, NHTSA (2016a, p. 44) states that it should issue regulations on the labeling and identification of HAVs (Levels 3-5).

AV drivers. Level 5 AVs do not require a human driver under any circumstances: passengers do not require driver training or licensing. Level 2-4 AVs require human drivers under some circumstances so must have at least one properly licensed driver (Level 4 vehicles require a licensed driver only when they are driven outside their ODDs). In addition, states may wish to require Level 2-4 AVs to carry at least one driver who has been trained in that AV's operation (Nowakowski et al., 2015). This training is vehicle-dependent, so states will need some way of assuring that Level 2-4 owners and drivers know their vehicle's capabilities and limitations and have been appropriately trained. States may wish to record this AV training as an endorsement on the driver license. This knowledge and training also will be required when a Level 2-4 vehicle is sold to a new owner or when software changes modify the vehicle's capabilities or limitations.

Laws on AV operations. Fully autonomous Level 4 and 5 AVs raise several issues if they were to operate within current traffic laws. These include:

Who's the driver? Current state laws explicitly state or implicitly assume that each vehicle has a driver. Some laws require the drivers to do certain things, for example to present the driver's license and vehicle registration when requested by a law enforcement officer. New York requires the driver to always have at least one hand on the steering wheel.

Many states have distracted driving laws requiring the driver to be fully attentive at all times or prohibiting cell phone use or texting while driving. AVs at Levels 4 and 5, and to some extent at Level 3, do not require constant driver attention and will encourage cell phone use and texting.

All states prohibit driving while impaired by alcohol or drugs. But a Level 4 or 5 AV could transport impaired drivers safely within its ODD.

Many drivers exceed the posted speed limit in certain situations. What will AVs do?

Law compliance: many traffic laws prohibit certain actions but common-sense exceptions are both recognized and encouraged. For example, it is illegal to cross a double yellow center line. But if a vehicle on a two-lane road is parked in the travel lane and the road is clear ahead, common sense suggests that a car may cross the double yellow line and pass the stopped vehicle (NHTSA, 2016a, p. 26). States should attempt to understand how AVs will resolve these conflicts.

Speed limits present an interesting challenge. Many drivers exceed the posted speed limit in certain situations, for example on interstate highways or rural two-lane roads with little traffic and clear sight lines. What will AVs do? If they are programmed to obey the speed limit scrupulously then they will frustrate many following drivers. If they are programmed to exceed the speed limit then they are programmed to break the law consistently.

Google's California AV fleet obeys all traffic laws, including speed limits. This practice has raised problems, for instance when an AV tries to merge onto a busy highway with traffic moving well above the speed limit (Naughton, 2015). It also has produced a number of minor crashes in which the AV was not at fault (Schoettle and Sivik, 2015b).

Several efforts are underway to document how current state laws may need to change to accommodate AVs.

- Scribner (2016) addresses the specific issue of vehicle platooning, which is prohibited in many states by following-too-closely laws. He provides a comprehensive overview of following-too-closely laws and regulations and suggests specific changes for each state.
- Under National Cooperative Highway Research Program (NCHRP) project 20-102(07), Implications of Automation for Motor Vehicle Codes, the Virginia Tech Transportation Institute (VTTI) will review how each state's motor vehicle laws and codes may need to be reconsidered to accommodate AVs and will develop guidance for state DOTs, DMVs, and SHSOs on law and regulation changes (NCHRP, 2016). The project's final report is due in February 2018.
- An AAMVA-NHTSA working group with representatives from several states reviewed the NHTSA model policy (NHTSA, 2016a) and is at work on model laws and regulations.

Traffic control devices, especially at intersections, pose another challenge. For example, consider what happens when four vehicles arrive at the same time at a four-way stop-controlled intersection. Human drivers decide who goes first with a combination of eye contact, hand signals, and vehicle movements, but automated vehicles will be challenged to negotiate such situations. Traffic controls are on AASHTO's Connected/Automated Vehicle Research Roadmap (Schladover and Gettman (2015) but the proposed project is not yet funded (http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3824).

Law enforcement. AVs raise many issues for law enforcement. These include:

- Officer safety: what aspects of AV operations pose new risks to officers?
- Identification: how can an officer easily identify an AV and determine its level? If a vehicle is a Level 3 or 4 AV, is it being operated without a driver within its ODD?
- Enforcement procedures: how should traffic stops and, if necessary, vehicle pursuit and intercept be conducted with an AV?
- Contraband and threats: how can officers deal with an unmanned AV suspected of delivering contraband, such as drugs, or threats, such as explosives?
- Interactions with other drivers (road rage): how can officers deal with drivers who become frustrated if AVs always obey the law, for example if they always obey the posted speed limit?
- Training: how should officers be trained to deal with these and other AV issues?

The officer's crash report should have an easy way for an officer to record a vehicle's AV capabilities.

Crash investigation. AVs will be involved in some crashes that law enforcement officers will investigate. For their own safety, officers should be able to determine easily if a crashed vehicle has any autonomous features that might affect their safety during the investigation.

The officer's crash report should have an easy way for an officer to record a vehicle's autonomous capabilities, or at least its AV level, and whether it was being operated driverless within its ODD. In 2016, the Model Minimum Uniform Crash Criteria (MMUCC), which develops model crash report data elements and coding for states, proposed two versions of an AV variable, one distinguishing no, partial, or full automation and one coding the SAE Level 1-5 (NHTSA Traffic Records Team, 2016). The MMUCC Expert Panel has taken this a step further and recommends one more variable that codes whether the vehicle's autonomous features were engaged at the time of the crash. NHTSA plans to hold a workshop annually at the Traffic Records Forum to reexamine the MMUCC AV data elements to see if they should be modified (Harsha, 2016).

In the future, officers may be able to extract data from an AV's computer system that can be very valuable for a crash report.

Data systems. AVs should be identified in state record systems: vehicle title and registration, driver licensing, and crash records, as discussed previously. It would be very useful if the same AV codes could be used in each system, or at the very least if the codes in each system could be easily mapped into the codes in the other systems. It would be even better if identical or consistent codes could be used in all states so that AV registration, driver license, and crash information could be shared easily.

Liability and insurance. AVs will be involved in crashes and likely will cause some crashes, as the widely reported Tesla fatality illustrates (Singhvi and Russell, 2016; Lambert, 2016). As discussed in NHTSA's model policy (2016a, p. 45-46), states first need to consider how to determine the AV's responsibility for a crash. Then they need to decide how the liability assigned to the AV is to be allocated among the AV's manufacturers, software providers, owners, operators (if an operator is in the vehicle), and others. While various strategies have been proposed, there is no consensus and discussions likely will continue for some time.

These liability issues will affect motor vehicle insurance policies, rates, and costs. Again, it's far too early to predict outcomes.

An important consideration in crash causation and liability is the set of decision rules an AV uses to decide what action to take in an emergency situation (NHTSA, 2016a, p. 26). How does the AV balance the safety of its occupants against the safety of other road users? If a dog runs across an AV's path and the only options are to strike the dog or to strike a roadside tree, what does the AV do? What if it's a child rather than a dog? Some of these ethical questions have no commonly-accepted answers: different drivers in these situations may choose different actions.

Vehicle inspection. As of October 2016, 16 states require periodic safety inspections and another 3 states require inspections when a vehicle is sold or transferred from another state (AAA, 2016). These inspections typically are straightforward checks of the vehicle's lights, brakes, and similar components in a garage. When AVs become operational, states must decide what to do about inspecting them (NHTSA, 2016a, p. 44). A safety inspection state could continue its current inspection procedures and not inspect any specific automation components, in the same manner that cruise control or other Level 1 features are not currently inspected. If a state chooses to inspect a vehicle's autonomous driving capacity it must determine what to inspect and must allow for the wide variety of automation levels and features across the manufacturers.

Coordination. For each of the above areas, it would be very useful if policies, regulations, and practices could be coordinated across the states. As stated in NHTSA's policy (2016a, p. 39), the goal is not uniformity, because each state must develop policies, regulations, and practices that best suit the state's individual characteristics. Rather, the goal is enough consistency that AVs can be sold and operated in each state and can move easily from state to state. Coordination also would allow information on AV operations to be shared easily among the states and to be aggregated nationally.

Speed limits provide an example of consistency without uniformity. Each state sets its own speed limits for its roads and informs drivers of the speed limit on each road. Drivers know that roads have speed limits and that the speed limit on a road may change when the road crosses a state border, so can adapt their driving speed accordingly.

Coordinated policies, regulations, and practices are strongly encouraged by AV manufacturers and by AAMVA, NHTSA, and other national organizations. They also can relieve states of the hard work of developing them individually. NHTSA's model state policy is an excellent first step in this coordination. Work is underway to develop model state laws. The subsequent national organization section discusses current coordination activities.

WHAT CAN SHSOs AND DMVs DO TO PREPARE FOR AVs AND BECOME ENGAGED IN AV ISSUES?

GHSA offers the following **five pieces of advice for states** as they grapple with the issue of AVs:

1. **Be informed.**
2. **Be a player in your state.**
3. **Understand the role of states.**
4. **Don't rush into passing laws or establishing regulations.**
5. **Be flexible – this is a new game.**

1. Be informed

AVs are coming soon. They likely will be on the road in many states by 2025. As discussed previously, AVs will bring profound changes to virtually every aspect of road transportation. While a few states actively encourage AV testing and operations, many states know little about AVs and have done little or nothing to prepare for them.

The most important thing all state DMVs and SHSOs should do is to become and stay informed on AV issues and developments (Isaac, 2016). As a first step, states should read NHTSA's policy (NHTSA, 2016a). The model state policy of Chapter II provides an excellent overview of the areas in which AV testing and operations will affect state DMVs, SHSOs, law enforcement, and DOTs.

Next, DMVs and SHSOs should check regularly with key website pages that track and report on AV developments. These include the AAMVA and NHTSA websites for general information (http://www.aamva.org/Autonomous-Vehicle-Information-Library/ and http://www.nhtsa.gov/nhtsa/av/index.html) and the NCSL and Cyberlaw websites for information

on laws and regulations (http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx and http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action).

DMVs and SHSOs also can stay informed by tracking activities in one or more states where AVs are being tested. These include California, Michigan, Nevada, and Pennsylvania.

DMVs and SHSOs should consider designating an AV lead person with responsibility to monitor AV developments regularly and coordinate with each other, so that both DMV and SHSO management are informed of important new developments.

Finally, DMVs and SHSOs should meet regularly with any organization that is considering or currently developing or testing AVs within the state. Several states, including California, Michigan, Nevada, and Pennsylvania, do this already and find this coordination to be very valuable.

2. Be a player

AV development, testing, and implementation is being driven by the industries and companies involved. Without DMV and SHSO participation, AV technological and legal issues are top priority while public safety issues may not receive proper attention. To influence outcomes, be an active participant.

An excellent way to be a player is to join a state AV working group or task force.

An excellent way to be a player is to join a state AV working group or task force. This is the first recommendation of NHTSA's model state policy: that each state designate a lead agency for AV testing and that this agency form a task force that includes the DMV, SHSO, DOT, law enforcement, and others (NHTSA, 2016a, p. 40). An AV working group or task force with active SHSO participation is in place in only 6 of the 29 states responding to a brief GHSA survey; 3 other states have one but the SHSO is not actively involved in it. If one already exists in a state, the DMV and SHSO should join and serve as active members. If not, the DMV or SHSO should volunteer to form and manage one.

Start thinking now about how AVs may affect the areas for which DMVs and SHSOs are responsible. These include the areas discussed previously: traffic laws, law enforcement, crash investigations, and liability; driver training and licensing; vehicle registration and inspection; and data systems; see also the NHTSA model state policy. Also start thinking about what information should be presented to the public when AVs begin to be tested and when they begin to be operational and how this information should be provided.

Consider working with other states to develop consistent laws, enforcement policies, crash investigation protocols, data elements, driver training and licensing practices, vehicle registration and inspection protocols, and public education materials. National organizations will take the lead in some of these areas, as discussed subsequently.

States are encouraged to participate actively in NHTSA activities to develop and implement model state policy elements, individually and/or through GHSA and AAMVA (NHTSA, 2016a, p. 46). Participation can include responding to NHTSA's request for comment on the model state policy and on future NHTSA policy releases, either independently or through AAMVA or GHSA, and participating in NHTSA workshops and stakeholder meetings to further develop and refine state AV policy.

3. Understand the role of states

NHTSA's model guidance defines the federal and state roles for drivers and vehicles very clearly (NHTSA, 2016a, p 38). The federal role is to ensure that vehicles are safe. NHTSA does this by establishing and enforcing the Federal Motor Vehicle Safety Standards (FMVSS), investigating vehicle defects, and arranging for or ordering recalls if needed. The

Laws or regulations formed in haste may hinder rather than help AV testing and implementation.

state role is to license drivers, register vehicles, establish and enforce traffic laws, regulate motor vehicle insurance and liability issues, and conduct vehicle safety inspections if desired (NHTSA, 2016a, p 38).

AVs will blur these distinctions. There is no human driver in a Level 4 or 5 vehicle. This means that NHTSA's vehicle safety regulations must assure that Level 4 and 5 vehicles operated without a driver or a human monitor will operate safely, obey traffic laws, and respond appropriately in the event of a crash.

States should not attempt to regulate AV techology but should defer to NHTSA (NHTSA, 2016a p. 37). In fact, states are prohibited from setting vehicle standards unless they are identical to an existing FMVSS. States may wish to establish various criteria for AVs, for example to specify how AVs are to comply with speed limits and whether and when speed limits may be exceeded. It is then up to NHTSA to assure that the AVs will comply with any performance criteria. States will have quite enough to do with other AV issues: leave vehicle and technology regulation to NHTSA.

4. Don't rush

Many states wish to encourage AV testing and eventual implementation. As part of this encouragement, states may be tempted to establish AV laws or regulations quickly. They should resist the temptation. Before considering AV laws or regulations, states should be thoroughly informed on what laws or regulations may be needed and on how other states have dealt with these issues. Laws or regulations formed in haste may not be thought out well, may in fact hinder rather than help AV testing and implementation, and may soon be out of date. AV technology and capabilities are being developed rapidly, so that laws and regulations must deal not only with current AVs but must accommodate future changes as much as possible. And remember that model laws and regulations are being developed. Better to wait for them, so that all states begin with a common AV law and regulation structure, than to rush into a patchwork of inconsistent laws and regulations that will delay AV implementation.

5. Be flexible

AVs are disruptive technology which will change surface transportation dramatically. And AV technology is developing quickly. Nobody can foresee all the ways in which DMVs and SHSOs will need to change to encourage AVs and to maximize their benefits for mobility and safety. As they address AVs, states should remain flexible so that they can adapt to new AV developments and technology and learn from the experiences of other states.

WHAT CAN NATIONAL ORGANIZATIONS DO TO HELP STATES PREPARE FOR AVs?

National organizations can, should, and must help states deal with the issues of AV testing and operation outlined above. Without national organization help, states inevitably will waste resources to produce a patchwork of laws, regulations, policies, and practices. Some national organization efforts are discussed previously. This section summarizes them and suggests additional areas in which national organization help will be valuable.

Develop model state laws and regulations.

Efforts here already are underway. An AAMVA-NHTSA working group with representatives from several states reviewed the NHTSA model policy (NHTSA, 2016a) and is at work on model laws and regulations. GHSA and NCSL are represented. NHTSA's strategic plan (2016b) states that NHTSA will establish a work plan to produce a model state policy.

Document the traffic safety issues that AVs likely will produce.

AV research and development has concentrated on the technology of AVs and on policy and liability issues. Highway safety is rarely considered. But AVs will produce new highway safety risks, especially during the long transition period when there are large numbers of both AVs and driver-operated vehicles on the road. Level 3 AVs may pose particular risks as drivers can disengage but will be required to take control quickly when requested.

A "Traffic Safety Implications of Automated Vehicles" report that documents these issues could be useful in convincing state officials that traffic safety must be included in AV planning and that SHSOs must have a seat in state AV task forces or working groups. GHSA or NHTSA could take the lead in sponsoring such a report.

Develop model public education materials.

Public education on AVs will be critical. States should educate the public about the benefits that autonomous vehicles will bring and the risks that they may present, educate drivers of semi-autonomous vehicles about their driving responsibilities, and educate all drivers about how to share the road safely with autonomous vehicles. But it's far more efficient to develop key information strategies and message points once rather than 51 times. States then can adapt the materials and messages to their individual circumstances. National development also will produce greater consistency of messages across the states. NHTSA, AAMVA, and GHSA all have roles, together with representatives from the states.

Establish an AV clearing house.

The abundance of information about AVs, with something new appearing almost daily, makes it difficult for states first to learn the basic information they need regarding AVs and then to remain up-to-date on key developments. A comprehensive AV clearing house would be very useful. AAMVA's online library (http://www.aamva.org/Autonomous-Vehicle-Information-Library/) provides a vast amount of information, with links to over 100 AV research studies, news stories, laws and policies, and presentations. To help those with little knowledge of AVs it might be useful to add a basic overview of AVs – an "AV 101." NHTSA, GHSA, and other national organizations may be able to work with AAMVA to review the library from the perspective of their members and to identify and fill in any gaps.

Issue vehicle regulations and guidance promptly.

NHTSA's policy (2016a) discusses vehicle performance guidance quite extensively and lists 14 next steps that NHTSA definitely will do or plans to do to improve, expand, and oversee the guidance. NHTSA should move forward promptly with these activities.

Establish regulations to identify AVs.

One area where immediate action is needed is to establish regulations for identifying AVs, or at least Level 3-5 AVs, in the various data systems: vehicle title and registration, driver licensing, and crash data. States need to identify AVs in their data systems. They cannot develop accurate and consistent data systems without a standard method of identifying AVs. And data systems take a long time to change. NHTSA promised to issue these regulations (2016a, p. 44). The sooner they are issued, the better.

Involve law enforcement in AV discussions.

Law enforcement will be at the forefront of the traffic safety issues that AVs will introduce, but AV discussions to date have had little or no law enforcement involvement. The International Association of Chiefs of Police (IACP) and the National Sheriffs Association (NSA) should be invited to participate in national-level AV activities. State AV working groups and task forces also should have law enforcement representatives at the table.

FOR MORE INFORMATION

New information on AVs appears almost daily. Some useful information sources on key topics follow. Many are updated regularly.

States should begin by reading carefully NHTSA's Federal Automated Vehicle Policy (2016a), especially the Model State Policy of Chapter II.

For reasonably current plans from corporations involved in AV development and testing, see the Forecasts section in the Driverless Future website www.driverless-future.com/.

A large collection of information on AV news, laws, policies, and research is available from NHTSA (http://www.nhtsa.gov/nhtsa/av/index.html) and AAMVA (http://www.aamva.org/Autonomous-Vehicle-Information-Library/).

For state laws involving AVs see NCSL's Autonomous | Self-Driving Vehicles Legislation website http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx and the Weiner and Smith website http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action, both of which are updated regularly.

Nowakowski at al. (2015) have an excellent discussion of the issues states should consider in developing laws and regulations for AV testing and operations.

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APPENDIX: PUBLIC KNOWLEDGE AND ATTITUDE SURVEYS REGARDING AVs

Five recent surveys examined the public's knowledge of and attitudes toward AVs, four in the United States and one in Canada. The surveys' methods and results are summarized below.

The surveys:

- **KBB:** Kelly Blue Book (Cox Automotive, 2016). A national online survey of 2,264 residents ages 12-64 conducted in May 2016. The sample was weighted to Census figures by age, gender, ethnicity and region.
- **SF:** State Farm (2016). An online survey of approximately 1,000 drivers ages 18 and above who identified themselves as having some insurance and financial responsibility for their household, conducted in June 2016.
- **SS:** Schoettle and Sivak (2015a). A national online survey of 505 licensed drivers ages 18 and above conducted in June 2015.
- **TIRF:** Traffic Injury Research Foundation (Robertson et al., 2016). An online survey of 2,662 Canadian drivers ages 16-93 conducted in April 2016. The stratified sample was representative of Canadian drivers.
- **V:** Vox (Morning Consult, 2016). A national survey of 2,102 registered voters conducted in August 2016.

The results:

Selected responses from these surveys follow, grouped into seven broad areas. All questions refer to Level 4 or 5 fully autonomous vehicles unless noted otherwise. Responses of "don't know" or "no opinion" are not reported.

1. **What's your attitude toward AVs?**
   a. **V:** 34% say the prospect of the wide use of AVs makes them excited, 57% say it makes them worried.
2. **Will AVs reduce crashes and fatalities?**
   a. **V:** 35% yes, 46% no.
3. **Would you ride in an AV?**
   a. **T:** 17% would use an AV if one were available today, 75% would not use.
   b. **V:** 33% would be likely to ride in one in the next 10 years, 46% not likely.
4. **How comfortable would you be riding in an AV?**
   a. **SF:** 27% comfortable riding in an AV, 42% not comfortable.
   b. **SS:** 32% not concerned about riding in an AV, 68% concerned.
   c. **T:** 22% would find them very relaxing, 41% very stressful.
5. **Would you buy an AV?**

a. **KBB:** 16% would buy an AV as soon as they are available, 35% would wait until they were more comfortable with AVs, 49% would never buy or buy only if there were no non-AV cars.
b. **SF:** 21% would be likely to buy an AV, 51% would not.

6. **How much automation do you prefer?**
   a. **KBB:**
      i. 11% Level 1
      ii. 27% Level 2
      iii. 20% Level 3
      iv. 26% Level 5 with the option for a driver to take control if desired
      v. 13% Level 5
   b. **SS:**
      i. 44% no self-driving
      ii. 41% partially self-driving
      iii. 17% completely self-driving

7. **Should AVs allow a driver to take control if desired?**
   a. **KBB:** 80% yes.
   b. **SS:** 96% yes, 4% no.