GHSA
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The States' Voice on Highway Safety

PREPARING FOR AUTOMATED VEHICLES: TRAFFIC SAFETY ISSUES FOR STATES

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Contents

About this Report

This report was prepared by Dr. James Hedlund under contract with the Governors Highway Safety Association (GHSA), the national association of state and territorial highway safety offices that address behavioral highway safety issues. Funding was provided by State Farm®. The report was guided by an advisory panel of experts from the states, transportation safety organizations, automakers, and automated vehicle developers.

The report provides references to research, survey findings, position papers, government documents, news media, and other resources on automated vehicles that have appeared in the last four years. It includes information obtained by GHSA from a survey of State Highway Safety Offices. It does not attempt to be a complete review of the extensive and rapidly-changing information available on automated vehicles.

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Executive Summary

Automated vehicles will bring new and perhaps unanticipated traffic safety issues to states, the District of Columbia, and the territories. This report outlines these issues and discusses how law enforcement and State Highway Safety Offices (SHSOs) should prepare for them. The report's recommendations to states are summarized below. They apply largely to Automated Driving System (ADS) vehicles: those capable of operating without driver control for at least brief periods under certain conditions and which are classified as Level 3, 4, or 5 by the Society of Automotive Engineers (SAE) and the National Highway Traffic Safety Administration (NHTSA).

MANAGEMENT

State policy and activities should seek to encourage responsible ADS testing and deployment while protecting the public safety. Activities should include those below. See AAMVA (2018a), Hill et al. (2018), and NHTSA (2017) for additional discussion.

- Develop a state ADS testing and deployment plan.
- Designate the state's lead agency for ADS testing and deployment.
- Establish a broad and inclusive automated vehicle task force. SHSO and law enforcement representatives should be task force members.
- Become and remain informed on automated vehicle developments.

TRAFFIC LAWS

States should review all traffic laws for changes needed to accommodate ADS testing, both with and without a test driver, and ADS deployment. Some laws that may need to be created or modified are listed below. ULC (2018) suggests specific language, with options, for many law additions and revisions. The forthcoming National Cooperative Highway Research Program report (NCHRP, 2018) should provide additional information.

- A law specifically authorizing driverless Level 4 and 5 ADS operation. Smith (2014) argues that such a law may not be required, but states may wish to consider one and use it to place any requirements on Level 4 and 5 ADSs.
- Laws requiring or assuming that a licensed driver is present in each vehicle.
- Laws establishing legal responsibility for a driverless Level 4 or 5 ADS.
- Laws regulating the remote control of an ADS.
- Distracted driving laws, in particular for drivers of Level 3 vehicles who may be required to take control quickly, including laws on the use of cell phones and other electronic devices.
- Impaired driving laws.
- Following too closely laws. Scribner (2016) reviews each state's laws as it would affect ADS platooning.
- Laws regarding other road user behavior near ADSs.

AUTOMATED VEHICLE TESTING

States should encourage ADS testing while retaining enough control and oversight to protect the public. AAMVA (2018a) and NHTSA (2017) provide specific guidance. Activities should include:

- Establish conditions under which ADSs may be tested, including authorization to test, requirements for testing organizations, requirements for test vehicles and test vehicle drivers, liability and insurance for test vehicles, testing locations and conditions, and reporting.
- Determine whether traffic law changes or exemptions are needed for testing.
- Coordinate all testing with law enforcement and local government in testing locations.
- Actively inform the public and the media about ADS testing, especially in testing locations.
- Maintain effective high-level oversight of all testing.

AUTOMATED VEHICLE DEPLOYMENT

States must prepare for ADS deployment. AAMVA (2018a) provides detailed guidance. Specific activities should include the following.

- Establish ADS vehicle licensing and registration requirements. Issues to consider include identifying a vehicle's ADS level and ADS features relevant to traffic safety, identifying software updates that change a vehicle's ADS level or features, and establishing a method for law enforcement and first responders to determine this information quickly and easily.
- Establish or coordinate programs to educate ADS owners and drivers, other road users, and the public about ADS operations. Partnerships, including ADS manufacturers and dealers, commercial ADS operators, law enforcement, and organizations involved in highway safety, will be critical in developing and disseminating accurate and consistent information.
- Incorporate ADS information into state data, including vehicle registration, traffic violation, crash report, and perhaps driver license systems. Issues to consider include identifying ADS vehicles by level and operational design domain (ODD: the conditions under which the vehicle can operate without a driver) and identifying whether an ADS involved in a traffic violation or crash was under vehicle or driver control.
- Determine who – law enforcement, insurers, others – should have access to data generated by an ADS and how that access should be granted.
- Establish law enforcement policies and procedures regarding ADS operations, including how to identify and communicate with an ADS on the road and at a crash scene. Train all patrol officers in these policies and procedures.
- Determine if vehicle insurance requirements should be adjusted in any way for ADSs.

Preparing for Automated Vehicles: Traffic Safety Issues for States

The year is 2023. Some automated driving system (ADS) vehicles are on the road: vehicles that can operate without driver control under certain conditions. An officer is called to a crash scene. A car with an ADS had struck a pedestrian. The car had a single occupant, sitting in the driver's seat. The occupant and the pedestrian were both injured but not seriously. The occupant was unbelted. He said he was riding home from a night at the bar. He failed a field sobriety test. The pedestrian was crossing the road mid-block, not at a crosswalk. He said that he thought that the car was ADS-equipped so expected it to stop for him. Also, he had signaled to the person in the driver's seat that he wanted to cross and believed that he had signaled for him to go ahead. But the car didn't slow down when he stepped off the curb.

FIGURE 1: WHO IS AT FAULT?

AVs, especially ADSs, promise to increase mobility, in particular for those who cannot drive, and reduce traffic crashes enormously, as **over 90% of crashes involve driver error.**

The officer has many questions. Can he tell that the car was ADS-equipped? Was the car operating automatically at the time of the crash or was the driver in control? Had the car informed the driver that the driver should take control? If the car was in control, should the driver be charged with impaired driving and failure to wear his seat belt? Why did the pedestrian think that the car was equipped with an ADS? Why did he think that it would stop for him even though the car had the right-of-way? Why did he think the driver signaled to him to cross? And why didn't the ADS recognize the pedestrian and immediately stop? Ultimately, who or what was at fault: the car, the driver, the pedestrian, or all three?

This is a preview of what's coming, and coming soon, as automated vehicles enter the fleet. They are called by various names, including autonomous vehicles, vehicles with automated systems, and self-driving cars. In this report, an automated vehicle (AV) is a vehicle with any automated feature and an automated driving system (ADS) vehicle is an AV capable of operating without a driver in control for at least brief periods under certain conditions. The next section gives more detailed definitions and classifications.

AVs, especially ADSs, promise to increase mobility, in particular for those who cannot drive, and reduce traffic crashes enormously, as over 90% of crashes involve driver error. But they also raise important traffic safety concerns that states must address, especially during the many years ahead when AVs and ADSs will share the road with vehicles driven by humans.

This report should help states understand and address these concerns. It's written for state Departments of Transportation (DOTs), Departments of Motor Vehicles (DMVs), and highway safety offices (SHSOs). It concentrates on the behavioral traffic safety issues relevant to SHSOs, especially those involving law enforcement and public education. It does not discuss in detail

AV technology, driver licensing, vehicle registration, liability and insurance, or the access to and use of data produced by AVs. It does not address the many other areas affected by AVs such as infrastructure, employment, commuting patterns, and cybersecurity.

The report presents basic information about AVs, outlines their behavioral traffic safety issues, and describes what states should and should not do to encourage AV development and implementation while protecting public safety. The report is arranged in the following sections:

1. AV and ADS definitions and descriptions. The levels of automation; how a completely driverless vehicle works.
2. AV and ADS status, plans, and projections. What's here now; what's coming; scenarios for ADS penetration into the vehicle fleet; what the public thinks about AVs and ADSs.
3. Behavioral traffic safety issues of AVs and ADSs. The hybrid fleet of AVs, ADSs, and vehicles driven by humans; interactions with other road users; what the public should know about how AVs and ADSs operate.
4. What states should do to prepare for ADS testing and deployment. Current state activities and laws concerning ADSs, management structure, traffic laws, vehicle registration and identification, driver licensure, law enforcement issues, crash response and investigation, how to inform the public about AVs and ADSs, liability and insurance, access to data produced by AVs and ADSs.
5. What national organizations are doing and should do to assist states.
6. Sources of additional information.

This report includes information available as of June 2018. A new AV or ADS development, announcement, projection, or story appears almost daily, so the report will lack the most recent information by the time you read it. But the issues that AVs and ADSs raise regarding traffic safety, regulations and policy, law enforcement, public education, and overall management will remain. States that haven't begun to address them should begin now. Even states with extensive AV and ADS planning and testing may find a few things in this report that they should consider. All states should account for the rapidly-changing AV and ADS landscape by staying informed of new developments and by being flexible to accommodate the unanticipated.

1. Definitions and Descriptions

AV TERMINOLOGY AND LEVELS

An automated vehicle (AV) can perform some functions of a human driver. The simplest functions are controlling speed or lane position on the highway. A fully automated vehicle, or a self-driving car, can operate without any human control or even monitoring under certain conditions.

The Society of Automotive Engineers (SAE) and the National Highway Traffic Safety Administration (NHTSA) define six levels of automation (SAE, 2018; NHTSA, 2017). 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-keeping assistance, in some situations. The driver must monitor the vehicle and road at all times, with hands on the steering wheel and feet on or near the pedals, and must be ready to take control at any moment.
- **Level 2** – partial automation. The vehicle can take control of both the vehicle's speed and lane position in certain conditions, for example on controlled access highways. 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 quickly at any moment.
- **Level 3** – limited self-driving (conditional automation). The vehicle can be in full control in certain conditions, 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 quickly when informed.
- **Level 4** – full self-driving under certain conditions (high automation). The vehicle can be in full control for the entire trip in these conditions and operates without a driver.
- **Level 5** – full self-driving under all conditions (full automation). The vehicle can operate without a human driver and need not have human occupants.

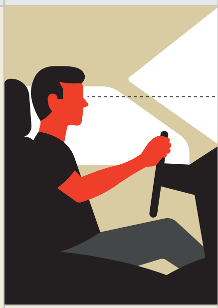
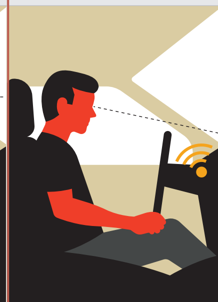
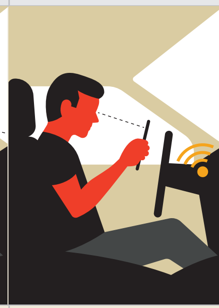
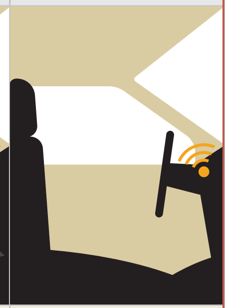
NHTSA and SAE refer to vehicles at Levels 3-5 as having Automated Driving Systems (ADSs). AAMVA (2018a) uses the term Highly Automated Vehicle (HAV) instead of ADS.

The conditions in which a Level 3 or 4 ADS can operate without a human driver are called the vehicle's Operational Design Domain (ODD). The boundaries of an ODD may include physical limits (for example, within specified geographic areas), road type (only on limited access highways), road conditions (not on icy or snow-covered roads), light conditions (only in daylight), weather (not in heavy rain or snow), and more.

These AV level definitions raise two important points. First, the public and the popular press probably assume that the terms self-driving cars or automated vehicles refer to a full Level 5. But most AVs for the foreseeable future will be Levels 2 through 4. Perhaps they should be called "occasionally self-driving." Next, the boundaries between Levels 2, 3, and 4 are not well understood outside of the expert community (Roy, 2018). Some AVs on the road or in development have been informally called Level 2.5.

Most AVs for the foreseeable future **will be Levels 2 through 4**.

FIGURE 2: AV TERMINOLOGY AND LEVELS

				Automated Driving Systems (ADS)		
	Level 0 No Automation	**Level 1 Driver assistance**	**Level 2 Partial automation**	**Level 3 Limited self-driving (conditional automation)**	**Level 4 Full self-driving under certain conditions (high automation)**	**Level 5 Full self-driving under all conditions (full automation)**
Vehicle	No automation.	Can assist driver in some situations.	Can take control of speed and lane position in certain conditions.	Can be in full control in certain conditions and will inform the driver to take control.	Can be in full control for the entire trip in these conditions and can operate without a driver.	Can operate without a human driver and need not have human occupants.
Driver						
	In complete control at all times.	Must monitor, engage controls, and be ready to take over control quickly at any moment.	Must monitor and be ready to take over control quickly at any moment.	Must be ready to take control quickly when informed.	Not needed	Not needed

As AV development continues, NHTSA and SAE may modify these definitions. It's useful to think of Levels 2-4 combined as vehicles that can operate without a driver in control of speed and lane position under certain conditions, with varying amounts of driver monitoring required. As the level of automation increases, the vehicle can control itself in more conditions, for longer periods of time, with less need for driver monitoring.

Levels 2-4 present important safety issues. Some drivers of Level 2 vehicles may not monitor the vehicle and road constantly, as they should. Level 3 drivers must be ready to shift quickly from complete disengagement to complete control when notified by their vehicle. A Level 4 vehicle may have a trip planned entirely within its ODD but may need to leave its ODD to complete the trip because of a roadway closure or a sudden change in the weather, at which point a driver would be required.

An AV at any level is a combination of hardware and software. The hardware is the physical vehicle; the software is the computer brain that controls some or all of the vehicle's operation. Level 1 software is relatively simple, as it only monitors the vehicle's speed or lane position and adjusts the throttle or the steering as needed. Level 5 software will be very complex, as it must monitor everything involved in driving, determine what to do next, and control the vehicle. This is extremely difficult because driving is an extremely complex task. While driving often is monotonous and repetitive, unexpected situations occur suddenly. A driver must observe, interpret, and take immediate appropriate action in response to a continually changing environment of other vehicles, pedestrians, bicyclists, animals, objects in the road, potholes, traffic signals, and more. To illustrate this complexity, the computers in current luxury vehicles, at most Level 2, have up to 100 million lines of computer code while a Boeing 787's computer has 6.7 million lines of code (GAO, 2016; Litman, 2018). Level 5 software will be even more sophisticated.

This combination of hardware and software means that an AV may not perform in the exact same way from one day to the next. Software can be updated quickly via the internet. For example, on October 19, 2016, Tesla announced that all Teslas produced after that date would have all the technology needed for Level 4 self-driving, though the software would not be activated (Tesla, 2016a). And just as drivers learn from their driving experiences, so will AVs. States cannot register an AV once and assume that it will maintain the same capabilities over its lifetime.

Users also may be able to engage or disengage their vehicle's AV features, just as drivers today can activate or deactivate the cruise control. Users of Levels 3-5 vehicles may be able to shift between automated and manual operation. An AV level describes the largest degree of automation of which the vehicle is capable, not the level that applies to any trip or trip segment.

Users also may be able to **change their vehicle's AV level**, just as drivers today can activate or deactivate cruise control.

ADS OPERATIONS

A Level 5 ADS and a Level 4 within its ODD operate using a series of four steps, repeated many times each second. This description is taken from Waymo (2017), but the framework is similar for all ADS developers (see for example General Motors [2018]).

Locate. The ADS memory contains a detailed three-dimensional map of all roadways within its ODD. The map includes road profiles, curbs and sidewalks, lane markers, crosswalks, traffic signals, speed limits, signage, fixed objects, and other relevant features. This is not a simple GPS map but is developed specifically for ADS operation. The ADS uses its sensors to determine its precise location on this map.

Scan. The ADS sensors scan the roadway and surrounding areas in all directions for objects around the vehicle: other vehicles, bicyclists, pedestrians, animals, objects in the roadway, potholes, temporary signage. They interpret any traffic controls including traffic light color or railroad crossing gates and signals. The scanners' range extends for hundreds of yards.

Predict. The ADS predicts the path of every movable object based on its current location and its previous movements and speed. The predictions take into account how other objects may be affected by roadway features or conditions, such as traffic signals or a vehicle in the travel lane. These predictions are updated many times each second.

Act. The ADS then chooses its trajectory and any speed or steering adjustments needed for this trajectory.

Repeat. Run the same four steps continually.

Many ADSs rely on GPS technology and exchange map data and other information with remote servers using telematics communications. ADSs in the future may be able to acquire even more useful information by communicating with other vehicles or with the environment. Vehicle to vehicle (V2V) communication may allow all vehicles to move in a coordinated fashion, reducing stop-and-go congestion and emergency maneuvers. Vehicle to infrastructure (V2I) communication may allow vehicles to anticipate traffic signals and roadway condition changes. Extensive V2V and V2I research and demonstration programs are underway (USDOT, 2018a), but the schedule for large-scale implementation is uncertain.

V2V or V2I implementation will not change the fundamental structure of ADS operations or the traffic safety issues ADSs pose. From the ADS point of view, all that's important is that the ADS gets the information it needs from some combination of its own sensors, other vehicles, or the infrastructure.

2. Automated driving system vehicle development status, plans, and projections

ADS DEVELOPMENT STATUS

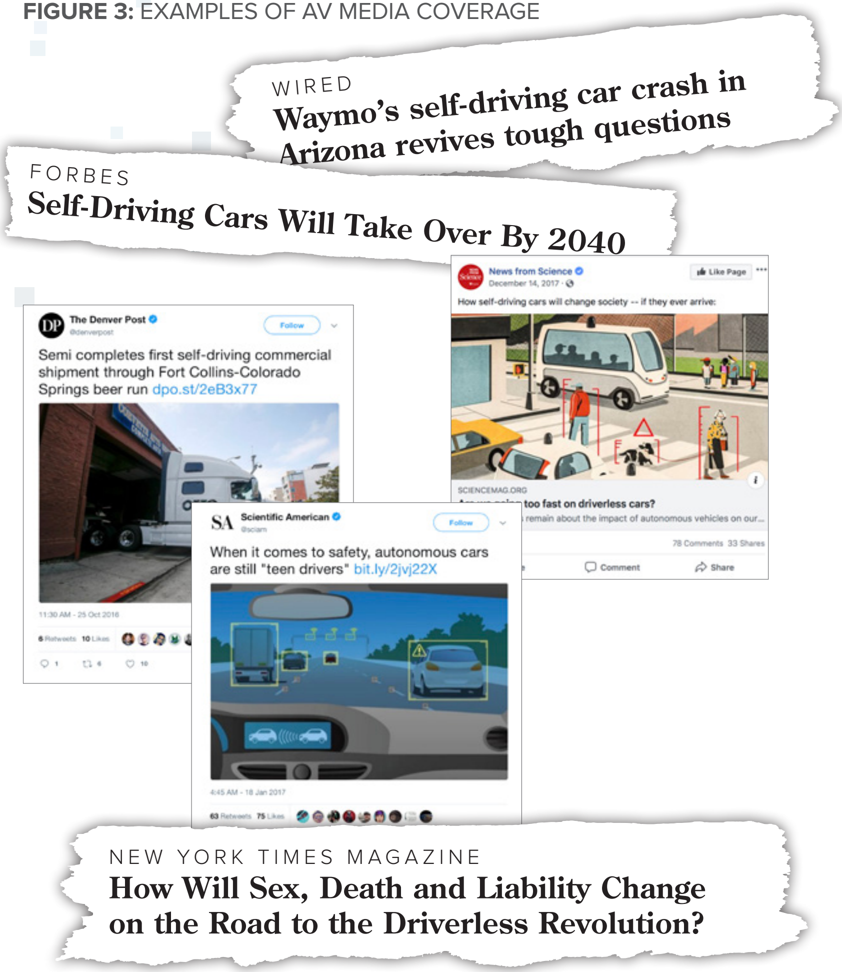
AV development and testing is advancing very rapidly, as shown by the following examples.

- Over 50 companies are testing ADS vehicles that can operate without a driver in control in certain conditions.
- Waymo's test fleet had logged more than 7 million miles on public roads by June 2018 (Waymo, 2018a).
- Uber's 100 minivans have driven more than 1 million miles (Johnson, 2018) and Lyft has 30 minivans in its Las Vegas test fleet (Moon, 2018a).
- All new Tesla vehicles are advertised to have the hardware needed for Level 3 or 4 self-driving (Tesla, 2018).
- Several other companies have announced plans to sell or operate fully driverless vehicles in some markets within a few years.

AV testing in California has been both extensive and well-documented. As of June 2018:

- 54 companies had valid AV test permits (CA DMV, 2018a).
- Over 400 test vehicles were registered (Richter, 2018).
- The DMV had received 66 AV crash reports dating back to October 2014 (CA DMV, 2018b).
- Testing without a backup driver was now allowed and Waymo had applied for a permit for driverless testing (Richter, 2018).

FIGURE 3: EXAMPLES OF AV MEDIA COVERAGE



ADS INTRODUCTION FORECASTS

ADSs will be introduced into the vehicle fleet in two ways. First, vehicle manufacturers will continue to add new features into many or all of their Level 1 or 2 vehicles. Some provide information to the driver and some control the vehicle's acceleration, braking, or steering. Recent driver information features include forward collision warning, obstacle and pedestrian detection, and lane departure warning. Vehicle control features include adaptive cruise control, automatic emergency braking, and automatic parallel parking (NSC, 2018). Vehicles with new automated features likely will be Level 2 and may reach Level 3.

Next, ADS vehicles at Levels 4 and perhaps even Level 5 will be available soon. The first users likely will be businesses, not individuals, in one or more of the following settings:

- Low speed shuttles within enclaves such as campuses or retirement communities or other limited geographic areas;
- Commercial trucking, which may include truck platooning with at least some driverless trucks in the platoon
- On-demand ride services such as Uber and Lyft, perhaps within dedicated geographic areas (tests are underway);
- Commercial operations on specific private roadways dedicated to ADS vehicles.

Recent announcements and predictions of when ADS vehicles will be available are listed below (Driverless Future, 2018; Walker, 2018). Many announcements use somewhat imprecise language such as "self-driving" but most probably refer to Level 4 vehicles.

2018

- May Mobility began commercial ADS operations in Detroit to transport close to 18,000 employees of Quicken Loans between their offices, parking sites, events, and other downtown destinations (Frost, 2018).
- NuTonomy will begin self-driving taxi services in Singapore.

2019

- Baidu predicts that a large number of Level 4 or 5 cars will be on the road.
- VW predicts that some Level 4 or 5 cars will be on the road.
- Delphi and MobilEye announced that they will offer a Level 4 system for use in a variety of cars.

2020

- Audi, Honda, Hyundai, and Renault-Nissan plan on offering self-driving cars.
- Ford and General Motors both predict that self-driving cars will be on the road.

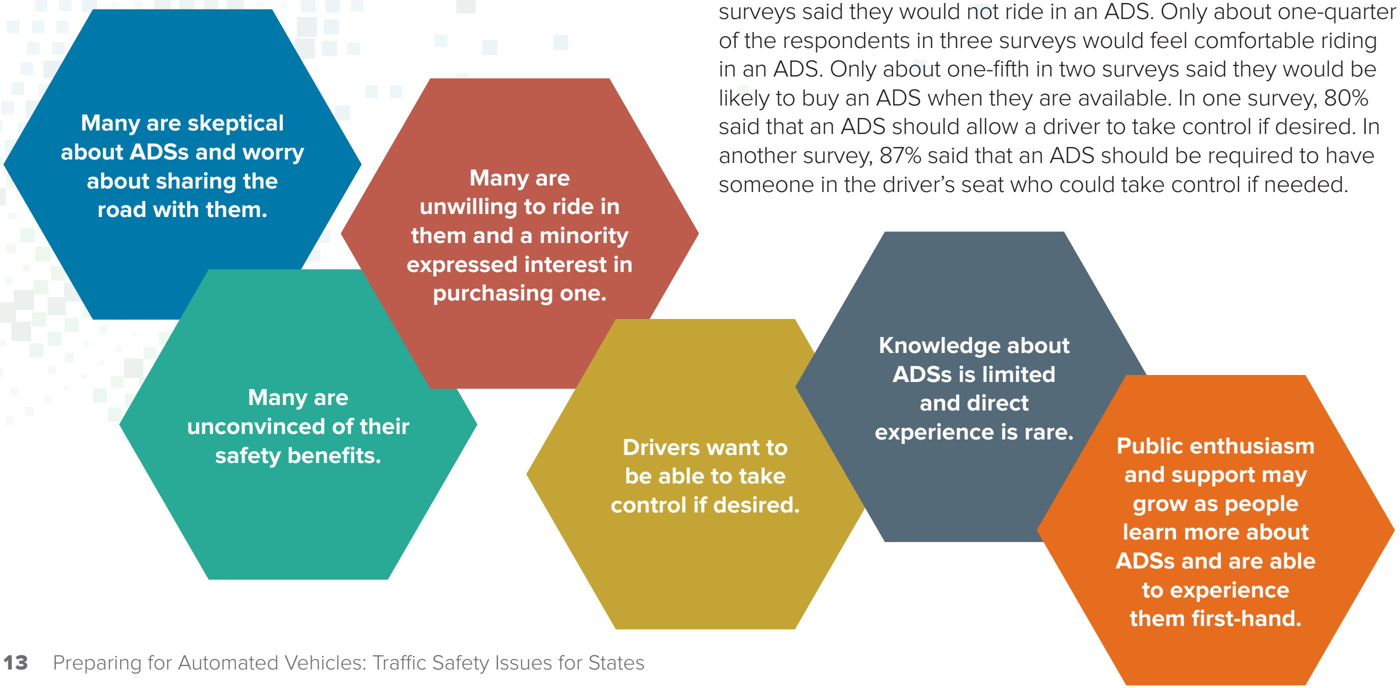
2021

- Ford plans on offering fully self-driving vehicles, without steering wheels or pedals, targeted to fleets providing mobility services.
- BMW plans on offering a self-driving electric vehicle, the BMW iNext.
- Volvo plans on offering self-driving vehicles.
- Fiat-Chrysler predicts that self-driving cars will be on the road.

These of course come from the ADS developers and may be overly optimistic. Nevertheless, it's likely that by 2022 some Level 4s will be in use in some settings and perhaps offered to the public. In contrast, Toyota is concentrating on adding features to its Level 2 vehicles to make them safer and easier to drive rather than pushing hard to offer Level 4s (Economist, 2018). Other manufacturers will do both: continue to improve their Level 2s at the same time as they are developing ADSs. In addition, companies may begin offering aftermarket kits that add sensors, other hardware, and software to Level 2 vehicles to raise them to a Level 3 or even 4 (Ohnsman, 2016).

It's notable that these predictions do not mention Level 3. Primarily because of the safety issues of Level 3s discussed in Section 3, it's likely that many manufacturers will not offer Level 3 but will move directly from Level 2 to Level 4 or 5 (Gain, 2017; Munster, 2017; Rechtin, 2017; Walker, 2018, Waymo, 2017).

FIGURE 4: WHAT DOES THE PUBLIC THINK ABOUT ADSs?



PUBLIC ATTITUDES REGARDING ADS

At least nine surveys from 2016 through June 2018, eight in the United States and one in Canada, investigated the driving public's knowledge of and beliefs about ADS vehicles. The Appendix summarizes each survey's methods and key results.

While the surveys asked questions phrased differently to adults selected in different ways, the results overall are quite consistent. More respondents were worried than enthusiastic about the prospect of ADSs. They were fairly evenly divided when asked if ADSs would be safer than human drivers or if ADSs would reduce crash injuries and fatalities. About half the respondents in four surveys said they would be concerned or feel less safe if ADSs were sharing the road and about half of respondents in five surveys said they would not ride in an ADS. Only about one-quarter of the respondents in three surveys would feel comfortable riding in an ADS. Only about one-fifth in two surveys said they would be likely to buy an ADS when they are available. In one survey, 80% said that an ADS should allow a driver to take control if desired. In another survey, 87% said that an ADS should be required to have someone in the driver's seat who could take control if needed.

Another survey was conducted in spring 2017 in Pittsburgh. It used a convenience sample of 321 Bike Pittsburgh members and 798 members of the Pittsburgh general public. Uber began testing ADSs in Pittsburgh in August 2016, so these respondents knew about ADSs both from news sources and first-hand experience: 43% of member respondents and 46% of the general public had interacted with an ADS while walking and 41% of members and 35% of the public while riding a bicycle. In contrast to the national surveys, 72% of members and 62% of the public believed that ADSs would reduce injuries and fatalities. And while 42% of Bike Pittsburgh members felt safe sharing the road with ADSs, only 18% felt safe sharing the road with human drivers.

These surveys show that many people are skeptical about ADSs, worried about sharing the road with them, unconvinced of their safety benefits, and unwilling to ride in them. But knowledge about ADSs is limited and direct experience is rare: about two-thirds of respondents in two surveys said they know little or nothing about them and only 11% in another survey had ridden in one. The Pittsburgh survey results suggest that public enthusiasm and support will grow as people learn more about ADSs and are able to experience them first-hand. See also Hutson (2017) for some current research on strategies to increase consumer confidence in ADSs.

Public enthusiasm and support will grow **as people learn more about ADSs** and are able to experience them first-hand.

ADS PENETRATION FORECASTS

Predictions of ADS sales and share of the vehicle fleet abound, produced by news outlets, market research firms, and the automotive and tech industries. There's general consensus that there will be several million Level 4 vehicles on the road by 2025 and that they will no longer be rare by 2030. Beyond that, predictions vary considerably. For example, Munster (2017) expects that over 94% of vehicle sales in 2040 will be Level 4 or 5 while Littman (2018) estimates about 50%.

ADS sales will be driven by several considerations.

- Consumer attitudes: While Level 4 and 5 vehicles offer substantial benefits, many drivers are currently skeptical of them.
- Price: Vehicles are expensive and last many years: the average age of cars on the road in 2018 was 12 years (Ratchet+Wrench, 2018). Many drivers may prefer to keep their present vehicle for several more years rather than invest in a new Level 4 or 5, which will cost several thousand dollars more than a conventional vehicle and will also be more expensive to maintain.
- Regulation: ADS sales may require state laws and regulations to allow them.
- Market for commercial applications: trucking companies and ridesharing providers may seek to purchase ADSs.

Littman (2018) projects the combined Level 4 and 5 share of vehicle sales and vehicles on the road over the next 40 years, based on a detailed analysis of driver attitudes regarding ADSs, implementation patterns of previous vehicle technology such as automatic transmissions and air bags, and ADS price.

FIGURE 5: PREDICTIONS OF SALES, VEHICLES ON THE ROAD, AND TRAVEL FOR LEVEL 4 AND 5 VEHICLES

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%

Source: Littman (2018)

It's clear from all predictions that **AVs and ADSs will share the road with vehicles driven by humans** for many years.

3. Behavioral traffic safety issues posed by automated vehicles

AVs and ADSs raise important traffic safety issues related to their operators and passengers, other road users, law enforcement, and crashes. States must understand the issues and must determine what actions they should take to address them.

AUTOMATED VEHICLE PERFORMANCE

Any discussion of ADS safety issues must begin with a basic understanding of what it means for an ADS to perform safely. This is far different than for a non-automated vehicle, which can be thought of as a piece of hardware. Its safety is regulated by the Federal Motor Vehicle Safety Standards (FMVSS) which set requirements in three broad areas: crash avoidance (100-series standards), crashworthiness (200-series), and post-crash survivability (300-series) (USDOT, 2018b). A vehicle can demonstrate that it meets these standards by how it is designed and how it performs in a small number of compliance tests. Its safe performance on the road is largely determined by the driver, as shown by the fact that more than 90% of traffic crashes involve driver error.

An AV, in particular an ADS, adds software to the hardware and takes on some or all of the role of the driver. It's impossible to test how an ADS will react to every conceivable driving situation that may pose a safety risk. NHTSA recognizes this, and has stated that it does not intend to mandate the equivalent of the FMVSS to regulate the driving competency of ADSs. Instead, it recommends (but does not require) that ADSs have a process to assure that they meet a set of 28 "core behavioral competencies" adapted from research by California Partners for Advanced Transportation Technology (PATH). Each competency describes a common driving situation to which an ADS must respond. Examples include "Detect and respond to (speed limit changes, stopped vehicles, traffic signals)," "Navigate (an intersection, a parking lot)" and "Yield to (pedestrians, law enforcement)." NHTSA clearly does not regard this list as exhaustive: "the full complement of behavioral competencies a particular ADS would be expected to demonstrate and routinely perform will depend upon the individual ADS, its ODD, and the designated fallback (minimal risk condition) method" (NHTSA, 2017). Waymo tests at least 19 additional competencies. See Waymo (2017) for the NHTSA-recommended competencies and the Waymo additions.

ADS developers train their software in stages: basic development, then extensive simulation, then testing on closed course test tracks, then testing on public roads with a test driver to take control if needed. After enough experience, and when authorized by the state, some ADSs will be deployed. Then they inevitably will meet driving situations for which they have not been specifically trained.

It's **impossible to test how an ADS will react** to every conceivable driving situation that may pose a safety risk.

The bottom line for states is that an ADS is like a human driver in some respects. Drivers must pass a license exam which tests a minimal set of driving skills and safe driving judgments in a somewhat artificial setting. An ADS should have extensive training and experience, so that it can meet a set of behavioral competencies, but cannot guarantee that it will perform safely in every driving situation. As they gain driving experience, both human drivers and ADSs will encounter situations for which they are not prepared. Each driver will learn from his or her individual experience. ADSs also will learn, and artificial intelligence techniques will allow ADS software to “learn” rapidly from the collective experience of all ADS vehicles using the same software platform (General Motors, 2018; Waymo, 2017).

With this in mind, consider the following brief list of traffic safety issues that AVs and ADSs may pose. Some are covered by the core behavioral competencies and have been thoroughly considered by some AV and ADS developers while others are not.

AUTOMATED VEHICLE ISSUES

Traffic laws and traffic flow: ADSs to date are programmed to obey traffic laws such as speed limits except when necessary for occupant or other road user safety. But human drivers often do not, for example on limited access highways where prevailing speeds often exceed the posted speed limit by at least 10 mph. How will an ADS balance the need to match the traffic flow and minimize risky speed differentials with the requirement to obey the speed limit?

Local practices: Some driving practices differ across the country. Consider the “Pittsburgh left”: the custom in Pittsburgh and a few other cities to allow the first left-turning vehicle stopped at a traffic light which turns green to turn before oncoming vehicles enter the intersection (Wikipedia, 2018). Social customs and communications that govern giving right-of-way to pedestrians vary. State and local laws also vary with respect to who has the right-of-way in crosswalks in different settings, and even in the definition of a crosswalk (PBIC, 2017). How will ADSs adapt to these practices?

FIGURE 6: LICENSURE AND PERFORMANCE: HUMANS VS. ADSs

	Human Driver	ADS
Pre-“License”	■ Supervised practice driving on public roads and driver education to learn basic skills ■ License exam ■ On-the-road exam to test judgments in a test environment	■ Basic development ■ Extensive simulation ■ Closed course testing ■ Supervised testing on public road
Gain driving experience from unanticipated situations	Each driver learns from individual experiences	Artificial intelligence techniques will allow ADS software to “learn” rapidly from the collective experience of all ADS vehicles using the same software platform

Decision rules: Emergency situations sometimes require a choice between bad outcomes. If a dog runs into the road, does the ADS hit the dog or steer off the road into a tree? What if a child runs into the road? Emergency situations for human drivers may not be emergencies for an ADS because their sensors and predictions should detect the dog or the child and react to it long before a human driver would. But an ADS will need to deal with some situations for which it has no experience or training and will need some decision rule framework to do this. This in turn involves ethical considerations. For example, it has been proposed that an ADS always should protect its occupants rather than anyone or anything outside the vehicle in situations requiring an ethical choice (Roy, 2016). Such situations have been called the Trolley Problem (see also Spangler [2017]). Is this the appropriate strategy?

Recognition and reaction: Human drivers recognize and react to many unofficial and non-standardized cues: obeying directions from police and bystanders, exchanging signals from other drivers at a four-way stop as to who should go first, determining when something in the road is an obstacle to be avoided and when it is not, identifying temporary signage, and more. How will ADSs recognize such cues and react to them?

System failure: An ADS will continually check to be sure its software is operating properly and that it remains within its ODD. If a problem is detected, the ADS directs itself into a Minimal Risk Condition (MRC), probably by stopping in a safe location. How will this be done in risky situations, for example in heavy traffic on a high-speed road?

System security: An ADS must be designed with extensive cybersecurity measures to protect itself against hacking. Still, it's likely that at least some ADS systems will be targeted. How can a hacked ADS be detected and stopped?

AV DRIVER ISSUES

It will be critical to educate AV drivers and owners about their vehicle's capabilities and how the vehicle interacts with its driver and occupants. Many drivers and owners of today's Level 1 and 2 vehicles likely do not understand what their vehicle or other newer vehicles can do: see for example the 40 different safety features listed at mycardoeswhat.org (NSC, 2018). More advanced Level 2s and Level 3s will raise the need for good education. The typical current system is woefully inadequate. A new owner's discussion at a dealership often takes only a few minutes and covers only a few vehicle features while the ever-thicker owner's manual often goes unread.

But even with more effective driver training it's highly likely that some drivers will not use ADSs properly.

Level 2 drivers: Level 2 drivers are expected to monitor the road themselves and decide when to take control. But, of course, they may not, as experience with Tesla's Level 2 Autopilot shows. While the Tesla owner's manual says the driver must keep his or her hands on the steering wheel at all times (Tesla, 2016b), "Tesla customers, delighted, posted videos of themselves on the highway, hands free, reading the paper, sipping coffee, and even, once, riding on the roof" (Bradley, 2016). In the widely-reported 2016 Tesla fatal crash, the driver had his hands off the steering wheel for more than 36 out of 37 minutes of travel and ignored the car's warnings before he crashed broadside into a semitrailer (Shepardson, 2017). In a second fatal crash in 2018, the driver's hands were off the wheel for six seconds before he crashed into a median (Wootson, 2018). The Institute of Transportation Engineers position statement on connected and automated vehicles concludes that Level 2 vehicles "requiring driver monitoring have not been proven safe for use on the open road" (ITE, 2018).

Level 3 drivers: The challenge of driver behavior response becomes more acute at Level 3. When the vehicle is operating automatically the driver need not even monitor the road but must be prepared to take control quickly when notified by the vehicle. It's likely that some drivers will talk on their cellphone, work or surf the web on their laptop, eat, or doze. It may take 10 seconds or longer for an inattentive driver to become fully alert and take control (Gain, 2017). Distracted driving by current drivers already is a major cause of crashes: NHTSA estimates that 9% of traffic fatalities involve distracted driving (NCSA, 2017). A Level 3 ADS creates conditions that encourage distracted driving. As noted previously, some ADS developers believe that the risks of Level 3 are sufficiently high that they do not plan to offer them but will move directly to Level 4. States may wish to consider whether specific training should be required for drivers of Level 3 vehicles to be sure that they understand their responsibilities.

Level 2 vehicles, especially as they include more driver assist features, and Level 3 vehicles present very real risks of driver distraction and driver response. How can they be deployed safely and how can their drivers be trained?

Level 4 drivers: Level 4 presents a different driver issue. The vehicle can drive itself within its ODD, so need not even have a driver. But what if the vehicle leaves its ODD, for example due to a sudden ice storm? Then the ADS software takes over and directs the vehicle into a Minimal Risk Condition, probably stopping in a safe location. But if there's no driver, what happens next, especially if the only passengers are children or persons without a driver's license? Level 4 also presents both opportunities and challenges regarding impaired drivers. Can a Level 4 vehicle legally serve as a designated driver to carry passengers home from the bar? Would its occupants be subject to impaired driving laws?

Drivers who override an ADS: Current ADS test vehicles are programmed generally to obey traffic laws. But it's likely that at least some Level 4 or 5 vehicles will be able to be driven manually as well as automatically. Drivers of these vehicles may shift to manual operation and speed, run red lights, or generally drive unsafely. One cannot assume that a Level 4 or 5 will be driven as it's programmed, and this may impact their anticipated safety benefits.

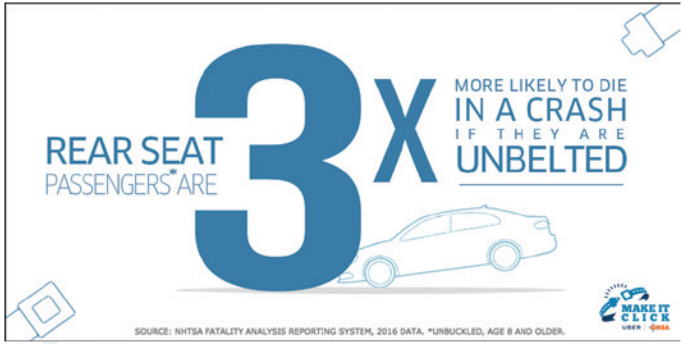
A **Level 3 ADS** creates conditions that can **encourage distracted driving.**

AV PASSENGER ISSUES

Belts and belt use laws: Will Level 4 and 5 passengers be belted? Fully automated vehicles are being promoted as offices, dining rooms, gyms, bedrooms, and the like, with the tacit assumption that adult belts won't be used. This raises several issues. What's the definition of seating position for Level 4 and 5 vehicles, especially Level 5 vehicles without a steering wheel and pedals? Will all seating positions be equipped with belts? Will FMVSS belt requirements be changed for Level 4 and 5 vehicles? Will states wish to apply their belt use laws to Level 4 and 5 vehicles? If so, will they need to be modified to account for belt availability and seating position? Will Level 4 and 5 passengers feel so safe that they ignore any belt use laws? Will the use of Level 4 and 5 ADSs for ridesharing exacerbate the current low belt use in rear seats, especially for passengers in taxis and on-demand ride services?

Child restraints: Will child restraints be necessary in Level 4 and 5 vehicles? If so, will the vehicles accommodate them with secure latches and proper orientation? Will child restraint use laws still apply, either without change or after modification?

Communication with the vehicle: How will safety communications from passengers be prioritized within a Level 4 or 5 ADS? Should all passengers be permitted to communicate with the vehicle? If so, how does the vehicle decide among conflicting instructions? What about unsupervised minor passengers?



OTHER ROAD USER ISSUES

Communication: How will an ADS communicate its intentions to other drivers, bicyclists, and pedestrians? Human drivers use direct eye contact, hand signals, and flashing headlights to send various messages. What will an ADS do? ADS developers are considering various strategies, for example signals from flashing lights (Fingas, 2017). Similarly, how will other road users communicate with an ADS? For example, can a driver at a four-way stop indicate that an ADS on the intersecting road should proceed through the intersection first? PBIS (2017) discusses ten issues involving AV interactions with pedestrians and bicyclists including accurate detection and communication, right of way issues and safe passing of bicyclists

Taking advantage of an ADS: If pedestrians know that ADSs will stop for them, they may constantly jaywalk. Some have predicted that this could seriously disrupt traffic flow in city centers (Hurley, 2017).

Criminal behavior: Criminals could block an ADS, knowing that it will stop for them, and rob its passengers. Criminals could use a driverless ADS to deliver drugs, stolen goods, or even a bomb. Routine traffic stops have helped solve many unrelated crimes. These interactions will drop substantially for ADSs that regularly obey traffic laws.

LAW ENFORCEMENT ISSUES

Identifying an ADS: Will officers need or be able to identify an ADS on the road, determine its automation level, and determine if it is within its ODD? Officers may need to do this quickly to manage a mix of ADSs and other vehicles.

Communicating with an ADS: How can an officer direct an ADS to do something, such as change its speed or direction or to pull over and stop? Will an ADS react appropriately to an officer's hand signals or an enforcement vehicle's siren or flashing lights? What if an officer directs an ADS to do something contrary to traffic control devices or traffic laws, such as to proceed through a red light or cross a double yellow line?

Communicating with ADS occupants: How will an officer interact with occupants of a driverless Level 4 or 5 ADS within its ODD?

Crash investigators may be able to **extract data** from AVs to reconstruct pre-crash events more quickly and accurately, **but may need assistance to access the data.**

Crash response: How will crash response procedures differ for ADSs? For example, how will officers assure that an ADS at a crash will not move until authorized? How can an officer disable and restart the automated features? Waymo has developed a law enforcement emergency response guide describing how its test ADSs will respond to police, paramedics, or firefighters, and how those officials should interact with Waymo's ADSs (Moon, 2018b; Waymo, 2018b).

Other road user behavior toward ADSs: How can officers influence other road users' behavior so that they do not take advantage of an ADS, such as pedestrians jaywalking in front of an ADS or drivers at an intersection or a parking lot not allowing an ADS to proceed? Will new public outreach or even enforcement efforts be needed?

Changed nature of traffic enforcement: Routine traffic patrol activities should change substantially. With a mix of ADSs and driver-controlled vehicles, enforcement must deal with the interactions between ADSs, other vehicles, and other road users. This may increase the need for patrol officers. On the other hand, if all vehicles on some roadways are ADSs, there should be few traffic violations and crashes. This will have a substantial impact on traffic law enforcement and adjudication, with a reduced need for patrol officers; fewer citations, fines, and fees; and fewer court cases.

Use of ADS vehicle data: Law enforcement may be able to use data produced by AVs to monitor traffic and detect and respond to problems. Crash investigators may be able to extract data from AVs to reconstruct pre-crash events far more quickly and accurately than at present. Insurers likely will wish to use ADS vehicle data to resolve claims. But these data may not be readily accessible without assistance from AV service providers.

AV EFFECT ON CRASHES

AVs and ADSs should reduce traffic crashes, injuries, and fatalities substantially in the long run. But it's impossible to estimate with any confidence their near term effects, for several reasons. The preceding discussion only suggests some of the traffic safety issues that they raise. Solutions may not be developed for some time. ADSs may increase vehicle travel as they allow children, the elderly, and the disabled to travel without a driver and allow drivers to use their time on the road more productively. More travel would produce more crashes. On the other hand, ADSs may reduce or even eliminate driving by persons impaired by alcohol, drugs, distraction, or fatigue.

Only **one thing is certain: there will be crashes, injuries, and fatalities involving AVs,** especially for the many years ahead **when ADSs will share the road** with vehicles driven by humans.

Only one thing is certain: there will be crashes, injuries, and fatalities involving AVs, especially for the many years ahead when ADSs will share the road with vehicles driven by humans. As of June 2018, three fatalities involving AVs had been recorded in the United States. In both Tesla Level 2 fatalities the driver failed to monitor the road and take control of the vehicle as Level 2 drivers are expected to do. In March 2018 an Uber test vehicle in Phoenix AZ struck and killed a pedestrian who stepped in front of it. The Uber's test driver failed to react in time to prevent the crash. Uber executives stated that the vehicle's self-driving system detected the pedestrian in its path but decided that "it didn't need to react right away" (Meyer, 2018). Waymo's test vehicles have been involved in more than 30 minor crashes in California, most of which were caused by other vehicles (Marshall and Davies, 2018). AV technology will continue to improve; the actions and reactions of the humans inside or sharing the road with AVs will continue to be fallible.

The transportation community is considering these developments in a complex debate about how and when ADSs should join the vehicle fleet. ADSs must demonstrate safe driving performance before they are allowed on the road. An argument can be made that ADS deployment is justified in terms of traffic safety overall if it reduces crash rates by as little as 10% (Kalra and Groves, 2017). But ADS crashes and fatalities can have a chilling effect on ADS development and deployment: Uber stopped all ADS testing after the Phoenix fatal crash (Johnson, 2018) and closed its Arizona test operations, though it plans to resume testing in other locations after the Arizona crash investigation is complete (Randazzo, 2018). Gradual ADS deployment in controlled commercial settings should help improve ADS performance and increase public support for ADSs.

4. What states should do to prepare for automated vehicle testing and operations

About 20 states and the District of Columbia are participating in the testing and deployment of fully automated vehicles – Level 4 and 5 ADSs – through authorizing legislation, task forces, and/or studies. The remaining states are only observing. They should become involved, soon, to begin setting the policy groundwork that will be needed when Level 4 and 5 ADSs appear on their roads.

Each state's goal should be to encourage responsible ADS testing and deployment. The SHSO's role is to protect the public's safety. More specifically, the SHSO should participate in considering traffic law changes to accommodate ADS vehicles, help educate the public about ADSs, work with law enforcement to address the issues ADSs will bring, and assist their DMV in the challenges of identifying and registering ADSs.

SHSOs should **participate in considering traffic law changes** to accommodate ADS vehicles, **help educate the public** about ADSs, **work with law enforcement** to address the issues ADSs will bring, and **assist their DMV** in the challenges of identifying and registering ADSs.

This section first summarizes current state activities and legislation regarding ADSs. It then provides specific guidance for states and SHSOs on how to address the behavioral traffic safety issues outlined in the previous section. Some states already have taken some of these actions. Five publications will be especially useful.

- AAMVA's guidelines for motor vehicle administrators and law enforcement on ADS testing, registration and licensing, driver licensing, and law enforcement considerations (AAMVA, 2018a).
- The National Governors Association's issue paper with recommended policy guidance for governors on ADS testing and deployment (Hill et al., 2018).
- NHTSA's technical assistance to states on ADS legislation and policy, contained in NHTSA's ADS policy 2.0 (NHTSA, 2017). Version 3.0 is scheduled for release in 2018 and likely will contain new information relevant to states.
- The forthcoming NCHRP report on traffic law changes necessary to accommodate ADSs (NCHRP, 2018).
- The Uniform Law Commission's draft Highly Automated Vehicles Act (ULC, 2018).

CURRENT STATE ACTIVITIES REGARDING ADS TESTING AND OPERATIONS

GHSA conducted a brief survey of SHSOs in the 50 states and the District of Columbia in February 2018 regarding their AV and ADS activities. GHSA received received 35 responses. Seventeen of the 35 respondents reported that they are actively encouraging AV development and testing in some way; 6 are observing AV development while the remaining 12 indicated no involvement with AVs. Ten reported ADS testing underway and another 10 indicated that some testing may begin sometime in 2018. Twenty-one of the 35 reported that there was a state AV task force; the SHSO was a task force member in 13 and was not a member in 8. Law enforcement definitely was involved in some way in AV testing or task forces in 11 and may be involved in 3 others.

Many of the 16 states that did not respond to the survey likely have little or no AV activity. That means that fewer than half the states currently encourage AV development and testing and fewer than half have an AV task force.

STATE LEGISLATION

As of June 2018, 37 states and the District of Columbia had enacted legislation or issued executive orders relating to AVs.

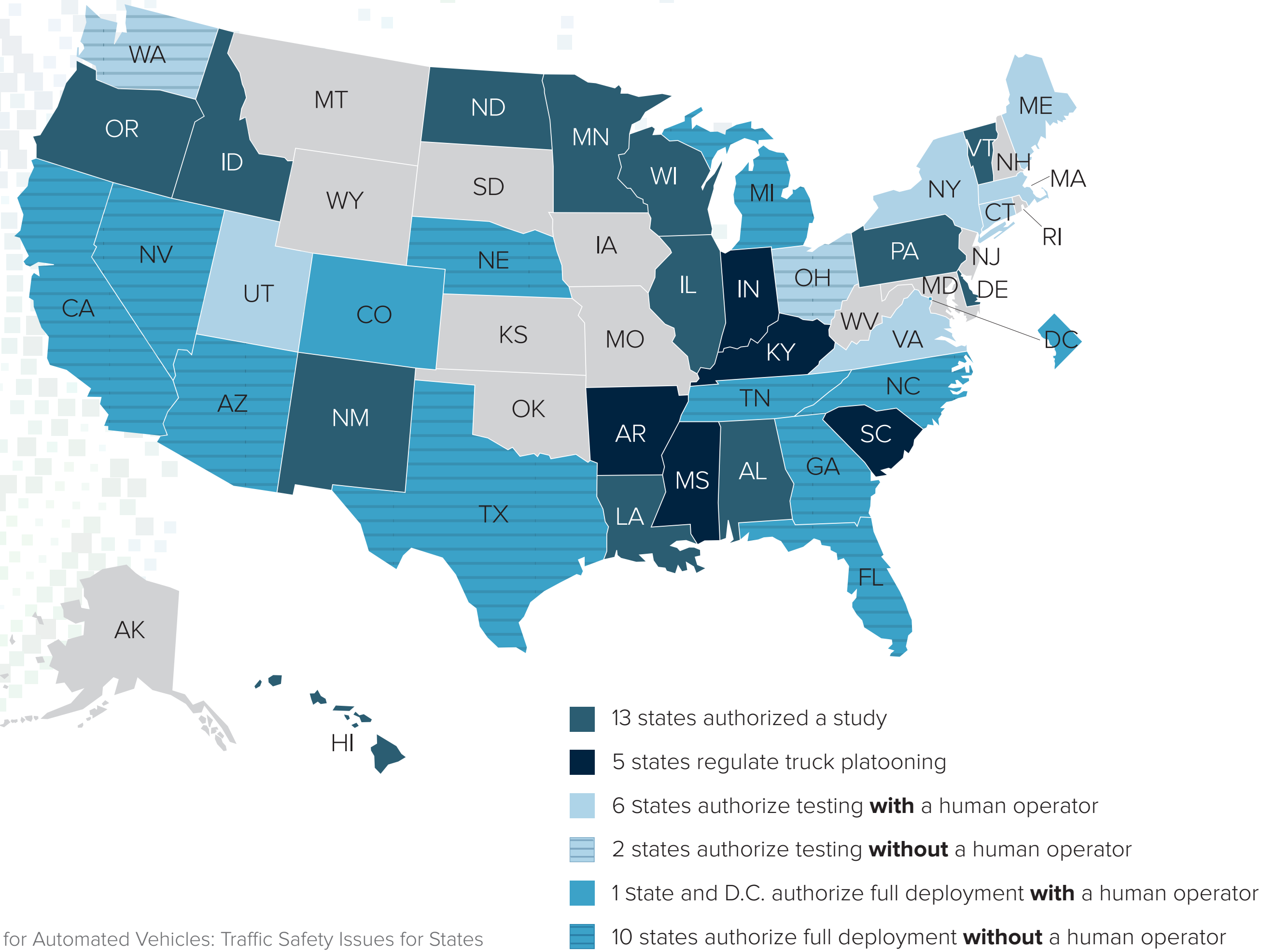
- 13 states simply authorize a study, define key terms or state contacts, or authorize funding.
- 8 states authorize testing.
- 11 states and the District of Columbia authorize full deployment.
- Of the 19 states authorizing testing or deployment, 12 states now allow testing or deployment without a human operator in the vehicle, although some limit it to certain defined conditions.
- 5 states regulate truck platooning.

On the other hand, a bill introduced in the Minnesota Senate in March 2018 would ban the use of self-driving cars indefinitely (Satter, 2018). See IIHS (2018) for key features of the laws or executive orders in the states authorizing testing or deployment and NCSL (2018) for key features and links to all AV-related bills and executive orders. (See map on following page)

FIGURE 7

Laws and Legislation relating to AVa

AS OF JUNE 2018



MANAGEMENT

States should establish an ADS management structure to develop policy and activities encouraging ADS testing and deployment while protecting the public safety. Activities should include the following. See AAMVA (2018a) and NHTSA (2017) for additional discussion.

- Develop a state ADS testing and deployment plan.
- Designate the state's lead agency for ADS testing and deployment.
- Establish a broad and inclusive automated vehicle task force. SHSO and law enforcement representatives should be task force members.
- Become and remain informed on automated vehicle developments. Key information sources are listed in the final section of this report.

It's important that ADS activities and the automated vehicle task force include a broad range of disciplines and organizations. The behavioral issues that ADSs will present to SHSOs result from how ADS vehicles perform and how they interact with the infrastructure, employment, cybersecurity, and many other areas. Inclusive and collaborative planning and programming will pay substantial dividends. In particular, ADS manufacturers and dealers are essential to keep SHSOs informed about their activities and plans. In return, SHSOs can help manufacturers and dealers interact with law enforcement, media, and the public as they begin ADS testing and deployment.

Federal and state regulatory roles are stated clearly in NHTSA (2017): NHTSA regulates vehicle safety, through the FMVSS and vehicle safety recalls, while states register and title vehicles, license drivers, establish and enforce traffic laws, and regulate vehicle insurance. AVs blur these boundaries somewhat because a Level 4 or 5 vehicle within its ODD needs no driver. But the state roles remain. In particular, states should not attempt to regulate ADS vehicle and software design and performance, and indeed they lack the resources and technical expertise to do so even if they wanted to. That's NHTSA's role. In particular, states cannot and should not attempt to guarantee that each ADS on the road is performing satisfactorily. NHTSA (2017) provided voluntary guidance for ADS developers on 12 ADS safety elements that developers should address and gave developers a template for a voluntary safety self-assessment to document that they have addressed these elements. As of June 2018, Waymo (2017) and General Motors (2018) have released safety reports.

As of June 2018, bills were under consideration in both the United States House (H.3388) and Senate (S.1885) that would limit state actions to regulate AV performance. It's uncertain whether either bill will be enacted before the next Congress takes office in 2019.

TRAFFIC LAWS

States should review all traffic laws for changes needed to accommodate ADS testing, both with and without a test driver, and ADS deployment. Some laws that may need to be created or modified are listed below. ULC (2018) suggests specific language, with options, for many law additions and revisions. NCHRP (2018) should provide additional information.

- A law specifically authorizing driverless Level 4 and 5 ADS operation. Smith (2014) argues that such a law may not be required, but states may wish to consider one and use it to place any requirements on Level 4 and 5 ADSs.

- Laws requiring or assuming that a licensed driver is present in each vehicle, especially for Level 2-3 AVs in which a licensed driver may be called upon to take control.
- Laws establishing legal responsibility for a driverless Level 4 or 5 ADS.
- Laws regulating the remote control of an ADS.
- Distracted driving laws, in particular for drivers of Level 3 vehicles who may be required to take control quickly, including laws on the use of cell phones and other electronic devices.
- Impaired driving laws.
- Following too closely laws. Scribner (2016) reviews each state's laws as it would affect ADS platooning.
- Laws regarding other road user behavior near ADSs.

States should **consider laws requiring or assuming that a licensed driver is present in each vehicle**, especially for Level 2-3 AVs in which a licensed driver may be **called upon to take control.**

AV TESTING

The final stages of AV testing take place on public roads. States should welcome the opportunity to encourage responsible AV testing. Their challenge is to protect public safety during the testing period. The three documented AV fatalities and the publicity and reactions they produced emphasize how important safety is to AV development and testing.

Requirements for and oversight of AV testing in the states that authorize it currently range from substantial to minimal. NHTSA (2017) suggests an intermediate level including requirements for a formal application to test, test driver qualifications, liability, insurance, and reporting. AAMVA (2018a) provides explicit recommendations in these areas. That level is quite appropriate. Minimal requirements may not protect public safety while AV developers faced with extensive and burdensome requirements will test in other states.

States should manage ADS testing through the following activities:

- Establish conditions under which ADSs may be tested, including:
  - Authorization to test,
  - Requirements for testing organizations,
  - Requirements for test vehicles and test vehicle drivers,
  - Liability and insurance for test vehicles,
  - Testing locations and conditions, and
  - Reporting.
- Determine whether traffic law changes or exemptions are needed for testing.
- Coordinate all testing with law enforcement and local government in testing locations.
- Actively inform the public and media about all aspects of ADS testing, especially in testing locations.
- Maintain effective high-level oversight of all testing.

AV DEPLOYMENT

States must prepare for ADS deployment. AAMVA (2018a) provides detailed guidance. Specific activities should include the following.

- Establish ADS vehicle licensing and registration requirements. Issues to consider include the following.
  - Identifying a vehicle's ADS level and ADS features relevant to traffic safety,
  - Identifying software updates that change a vehicle's ADS level or features,
  - Establishing a method for law enforcement and first responders to determine this information quickly and easily.
- Establish or coordinate programs to educate ADS owners and drivers, other road users, and the public about ADS operations.
  - ADS owners and drivers must be fully informed about their vehicle's capabilities and requirements and their responsibilities.
  - The public must be informed about how and where ADSs will be deployed, how they operate, and how other road users should act near an ADS.
  - DMV driver license examiners and driver education instructors must be fully informed about ADS operations and the training necessary to operate them and must include this in their activities.
  - For each of these, partnerships including ADS manufacturers and dealers, commercial ADS operators, law enforcement, and organizations involved in highway safety will be critical in developing and disseminating accurate and consistent information.
- Incorporate ADS information into state data, including vehicle registration, traffic violation, crash report, and perhaps driver license systems.
  - Identify ADS vehicles by level and ODD.
  - For violations and crashes, identify whether the ADS was under vehicle or driver control. For crashes, the 2017 Fifth Edition of the Model Minimum Uniform Crash Criteria (MMUCC) includes three variables under DV1. Motor Vehicle Automated Driving Systems:
    - Crash investigators are instructed to record whether the vehicle has any automated features; if so, then record the vehicle's AV level and what level was engaged at the time of the crash (MMUCC, 2017).
  - Determine who – law enforcement, insurers, others – should have access to data generated by an ADS and how that access should be granted.
- Establish law enforcement policies and procedures regarding ADS operations, including how to identify and communicate with an ADS on the road and at a crash scene. Train all patrol officers in these policies and procedures.
- Determine if vehicle insurance requirements should be adjusted in any way for ADSs.

States should **establish law enforcement policies and procedures** regarding ADS operations and train all patrol officers in these policies and procedures.

5. What national organizations are doing and should do to assist states

National organizations can, should, and must help states navigate 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.

AGREE ON COMMON DEFINITIONS AND TERMINOLOGY FOR AV LEVELS AND FEATURES

The proliferation of terms for AVs and ADSs and their various features creates confusion rather than clarity. Tesla's Autopilot is a good example: while it's only a Level 2, the name implies at least Level 4. SAE (2018) requires 35 pages to present accurate and precise language. NHTSA and the manufacturers, perhaps with SAE, should agree on and publicize clear, concise, and accurate definitions and terminology that can be understood easily by consumers as well as experts.

DEVELOP MODEL STATE LAWS AND REGULATIONS

The Uniform Law Commission's draft law (ULC, 2018) and the AAMVA Guidelines (AAMVA, 2018a) provide excellent starting points for identifying laws that may need to be modified or replaced and options to be considered. NCHRP (2018) should provide additional information. National organizations, including NHTSA, AAMVA, AASHTO, and GHSA, may wish to discuss a coordinated approach to state laws and regulations. ADS technology and software are changing very rapidly, so that laws and regulations should be flexible enough to accommodate unforeseen new ADS developments.

DOCUMENT THE TRAFFIC SAFETY ISSUES THAT AVS LIKELY WILL PRODUCE

Much AV research and development has concentrated on the technology of AVs and on policy and liability issues rather than on behavioral highway safety concerns. 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 thoroughly 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 EDUCATION MATERIALS

Education on AVs will be critical. States should educate the public about the benefits that they will bring and the risks that they may present, educate operators of Level 2-4 vehicles about their driving responsibilities, and educate all drivers about how to share the road safely with automated vehicles. States also should educate law enforcement, first responders, elected officials, state agencies, the driver education community, and the media about AV issues.

National development will produce greater consistency of messages across the states. States then can adapt the materials and messages to their individual circumstances. It's also far more efficient to develop key information strategies, message points, and materials once rather than 51 times. NHTSA, AAMVA, GHSA, and ADS developers and manufacturers all have roles, together with representatives from the states.

ESTABLISH REGULATIONS TO IDENTIFY AVS IN DATA SYSTEMS

Regulations or recommendations are needed for identifying AVs, or at least Level 3-5 ADSs, consistently in the various state data systems: vehicle title and registration, driver licensing, and crash data. States cannot develop accurate and consistent data systems without a standard method of identifying AVs. Many data systems take a long time to change. The sooner regulations or recommendations 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 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.

States **should educate the public about AV risks and benefits**, educate operators of level 2-4 AVs about their responsibilities, and **educate all drivers about sharing the road with AVs**.

DEVELOP MODEL LAW ENFORCEMENT GUIDANCE AND MATERIALS

Law enforcement will need information and training to address many ADS issues. As with public education, it would be both useful and efficient to develop model materials and training that can be used or adapted to fit local needs. Waymo's emergency response guide (Waymo, 2018b) is an initial example of one part of what's needed. IACP and NSA could take the lead, in partnership with manufacturers, NHTSA, AAMVA, and GHSA.

ESTABLISH CONSISTENCY ACROSS THE STATES

It's in everyone's interest that AV policies and laws are consistent across the states. They need not be identical, but sufficiently consistent that an AV can travel across state lines. Traffic laws provide the model: while each state has slightly different laws, such as speed limits on interstate highways, their basic structure and content are similar. NHTSA should work with the states through AAMVA, AASHTO, GHSA and other groups to promote consistency.

PROVIDE A COMPREHENSIVE AV DEVELOPMENT AND IMPLEMENTATION PLAN

The Government Accountability Office (GAO) reviewed USDOT's AV activities. It recommended that USDOT develop and implement a comprehensive plan for its AV initiatives (GAO, 2017). Such a plan could include most if not all the activities listed above. It may be part of NHTSA's version 3.0 of its AV policy, which it plans to release in 2018.

6. Sources of additional information

Key sources of additional information are listed below. See the References for detailed citations and weblinks.

Automated Driving Systems: A Vision for Safety (NHTSA, 2017) is Version 2.0 of NHTSA's policy framework for ADSs. It discusses 12 ADS safety elements that developers should satisfy. It lays out the federal and state roles in regulating ADS development, testing, and deployment and provides recommendations to states on ADS program administration and ADS testing, registration, and titling. Version 3.0 is scheduled for release in 2018.

Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles (AAMVA, 2018a) provides specific recommendations on ADS program administration and ADS testing, registration, titling, insurance, driver licensing, driver training, and law enforcement considerations.

State Public Safety and Autonomous Vehicle Technology (Hill et al., 2018) provides policy guidance from the National Governors Association for governors and states on ADS program policy and management.

ULC (2018) discusses traffic law issues related to ADSs and suggests specific legal language, with options. NCHRP (2018) should provide additional information. Scribner (2016) addresses the specific issue of vehicle platooning.

Two ADS developers, Waymo (2017) and GM (2018), have released safety reports. These reports document how these developers' ADS vehicles work and how they have addressed NHTSA's 12 safety elements.

AAMVA's Autonomous Vehicle Information Library (AAMVA, 2018b) contains links to hundreds of AV research studies, news stories, laws and policies, and presentations.

NHTSA's website *Automated Vehicles for Safety* (NHTSA, 2018) contains links to NHTSA's policy framework and other ADS documents.

Several websites provide regular AV news, including the daily ITS America SmartBrief, the weekly TU-Automotive brief, and the monthly CAV News Digest (contact marketing@econolite.com for more information).

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Appendix: Public attitudes regarding automated vehicles

At least ten surveys from 2016 through June 2018, nine in the United States and one in Canada, investigated the driving public's knowledge and beliefs about ADS vehicles.

GENERAL PUBLIC SURVEYS:

- AAA: (AAA, 2018). A national telephone survey of 1,004 adults conducted in December 2017.
- AHAS: Advocates for Highway and Auto Safety (AHAS, 2018). A survey of 1,005 adults conducted in December 2017.
- AIG: American International Group (AIG, 2017). A national online survey of 1,000 adults conducted in August 2017.
- JDP: J.D. Power (Westenberg et al., 2018). A survey of more than 1,500 owners of model year 2013-2018 personal vehicles.
- KBB: Kelly Blue Book (2016). A national online survey of 2,264 residents ages 12-64 conducted in May 2016.
- Pew: (Smith and Anderson, 2017). A survey of 4,135 adults conducted in May 2017.
- 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.
- TIRF: Traffic Injury Research Foundation (Robertson et al., 2016). An online survey of 2,662 Canadian drivers ages 16-93 conducted in April 2016.
- V: Vox (Morning Consult, 2016). A national survey of 2,102 registered voters conducted in August 2016.

GENERAL PUBLIC SURVEY RESULTS:

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

1. What's your knowledge of or experience with ADS vehicles?
    a. KBB: 60% know little or nothing about them.
    b. Pew: 65% know little or nothing about them.
    c. State Farm: 89% had never ridden in one.
2. What's your attitude toward ADS vehicles?
    a. Pew: 40% enthusiastic, 54% worried.
    b. V: 34% excited about wide use of ADSs, 57% worried.
3. Will ADSs reduce crashes and fatalities?
    a. Pew: 39% yes, 30% no.
    b. V: 35% yes, 46% no.
4. Would an ADS operate more safely than a human driver?
    a. AIG: 39% yes, 27% no.
5. Would you feel concerned, or less safe, if you shared the road with an ADS while you drive your car?
    a. AAA: 13% feel safer, 46% less safe.
    b. AHAS: 34% not concerned, 64% concerned.
    c. AIG: 42% not concerned, 41% concerned.
    d. Pew: 48% safe, 52% unsafe.

6. Would you ride in an ADS?
    a. AAA: 63% would be afraid to ride in one, down from 78% in early 2017.
    b. JDP: 47% yes, 46% no.
    c. Pew: 44% yes, 54% no.
    d. TIRF: 17% would use an ADS if one were available today, 75% would not use.
    e. V: 33% would be likely to ride in one in the next 10 years, 46% not likely.
7. How comfortable would you be riding in an ADS?
    a. AAA: 28% would trust an ADS.
    b. SF: 27% would be comfortable riding in an ADS, 42% would not be comfortable.
    c. TIRF: 22% would find them very relaxing, 41% very stressful.
8. Would you buy an ADS?
    a. KBB: 16% would buy an ADS as soon as they are available, 35% would wait until they were more comfortable with ADSs, 49% would never buy or buy only if there were no non-ADS cars.
    b. SF: 21% would be likely to buy an ADS, 51% would not.
9. 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.
10. Should an ADS allow a driver to take control if desired?
    a. KBB: 80% yes.
11. Should an ADS be required to have someone in the driver's seat who can take control if needed?
    a. Pew: 87% yes.

PITTSBURGH SURVEY

Another survey (WPRDC, 2017) was conducted in spring 2017 in Pittsburgh, where Uber had been testing ADSs since August 2016. It used a convenience sample of 321 Bike Pittsburgh members and 798 members of the Pittsburgh general public.

PITTSBURGH SURVEY RESULTS

1. Have you interacted with an ADS while riding your bicycle?
    a. Yes: 41% of members, 35% of public.
2. Have you interacted with an ADS while walking?
    a. Yes: 43% of members, 46% of public.
3. Do ADSs have the potential to reduce injuries and fatalities?
    a. Yes: 72% of members, 62% of public.
4. Do you feel safe sharing the road (asked only of members)?
    a. With ADSs: about 42% of members.
    b. With human driver vehicles: about 18% of members.

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