Review of Automated Vehicle Technology: Policy and Implementation Implications

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16. Abstract

The goals of this project were to undergo a systematic review of automated vehicle technologies with a focus on policy implications, methods of implementation, regulation by states, and developments occurring on legal fronts, ultimately creating a set of policy recommendations and questions for further research.

This report provides recommendations for the state of Iowa over the next five years:

- Encouraging automation by preparing government agencies, infrastructure, leveraging procurement, and advocating for safety mandates
- Adjusting long range planning processes by identifying and incorporating a wide range of new automation scenarios
- Beginning to analyze and, as necessary, clarify existing law as it apples to automated driving
- Auditing existing law
- Enforcing existing laws
- Ensuring vehicle owners and operators bear the true cost of driving
- Embracing flexibility by giving agencies the statutory authority to achieve regulatory goals through different means, allowing them to make small-scale exemptions to statutory regimes and clarifying their enforcement discretion
- Thinking locally and preparing publically
- Sharing the steps being taken to promote (as well as to anticipate and regulate) automated driving
- Instituting public education about automated vehicle technologies

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Executive Summary

The field of automated vehicle technology is rapidly developing. While it will likely be many years before self-driving cars are commercially viable and used by the general public in a wide range of conditions, technological advancements are speeding along the automated technology continuum toward this destination. Vehicles with automated vehicle technologies promise to have significant benefits for society, including dramatic decreases in car crashes, injuries and deaths, increased mobility, increased road efficiency, and better utilization of parking and lands.

As testing on public roads is necessary for automated vehicles to reach maturity, it is essential to examine basic policy issues now so that the most effective planning can be done in Iowa and to ensure safety of the general public.

The goals of this project were to undergo a systematic review of automated vehicle technologies with a focus on policy implications, methods of implementation, regulation by states, and developments occurring on legal fronts, ultimately creating a set of policy recommendations and questions for further research.

Automated vehicle require the integration of sensor data along with the complex decision making algorithms along with the ability to quickly respond to changing roadway conditions. To create a fully automated vehicle, all of these technologies must seamlessly work together.

While automated vehicle technologies have the potential to substantially benefit mobility, policymakers are only beginning to deal with the tremendous challenges they introduce. Currently there is no federal law specific to automated vehicles and only a few states have adopted legislation explicitly addressing automated driving. While well intentioned, these laws have the potential to unintentionally establish additional hurdles to testing or deployment, thus creating a confusing and incompatible patchwork of regulations. Additionally, since technology is changing so rapidly, legislation can become obsolete quickly. Conversely, in 2014 Johnson County, Iowa became the first municipality to encourage vehicle testing as an economic development initiative by advertising its lack of restrictive legislation on the testing and operation of automated vehicles on public roads. Strong relationships with municipal governments, the Iowa DOT and law enforcement enhance communication.

This report provides recommendations for the state of Iowa over the next five years in regards to automated vehicle policy development. These administrative, planning, legal, and community strategy recommendations for government agencies include:

- Encouraging automation by preparing government agencies, infrastructure, leveraging procurement, and advocating for safety mandates
- Adjusting long range planning processes by identifying and incorporating a wide range of new automation scenarios

- Beginning to analyze and, as necessary, clarify existing law as it apples to automated driving
- Auditing existing law
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- Ensuring vehicle owners and operators bear the true cost of driving
- Embracing flexibility by giving agencies the statutory authority to achieve regulatory goals through different means, allowing them to make small-scale exemptions to statutory regimes and clarifying their enforcement discretion
- Thinking locally and preparing publically
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Introduction

The field of automated vehicle technology (AVT) is rapidly developing. While it will likely be many years before self-driving cars are commercially viable and used by the general public in a wide range of conditions, technological advancements are speeding along the automated technology continuum toward this destination.

AVT promises to have significant benefits for society including, most notably, dramatic decreases in car crashes and automobile deaths. While crashes have been gradually declining, in 2014 more than 32,000 people were killed in motor vehicle crashes on U.S. roadways, with an additional 2.3 million injured (NHTSA, 2015a). This is in addition to the estimated 55% of crashes that go unreported (NHTSA, 2015b). Human error accounts for the vast majority of crashes -- 95% of total crashes today (NHTSA, 2008). AVT therefore has the potential to substantially reduce crashes by removing the human error component.

Additionally, automated vehicles are also expected to increase mobility for certain populations such as the blind or disabled, decrease fuel consumption and emissions, likely reduce congestion, and improve land use. Thus AVT is expected to provide benefits to safety, mobility and sustainability, three major transportation issues.

This report builds on previous work completed by The University of Iowa, first reviewing the levels of automation and providing a brief review of developments in AVT. Case studies of a number of different vehicles either on the market or under development are presented, including: GM Super Cruise, the Volvo Drive Me project, and the Google self-driving car.

Figure 1. Cadillac models later this decade will include Super Cruise, an automated system that controls the car but requires the driver to monitor the environment. (Photo / General Motors)

An in-depth legislative review discusses the current legislation adopted by six states and Washington D.C. There are no federal laws specifically regulating AVT or automated vehicles. However, the National Highway Transportation Safety Administration (NHTSA) has created recommendations for state legislation. The current state legislation is compared with these recommendations.

During this project, The University of Iowa partnered with Professor Bryant Walker Smith from the University of South Carolina, whose research focuses on risk (particularly tort law, product liability, and state and municipal liability), technology, and mobility, to create recommendations that the state of Iowa can take now to encourage the development, deployment, and use of AVTs and automated vehicles. (Professor Smith provided policy analysis; he did not provide legal advice. This report summarizes the analysis he presented to the Iowa DOT and that he details in a forthcoming paper.) The outcome of this review is a set of recommendations that will help pave the way for safe and legal use of vehicles with automated technology in the state of Iowa and, ultimately, fully automated vehicles. Additionally, a set of research questions are proposed that highlight some of the most important unanswered questions about the deployment of automated vehicles on Iowa roads.

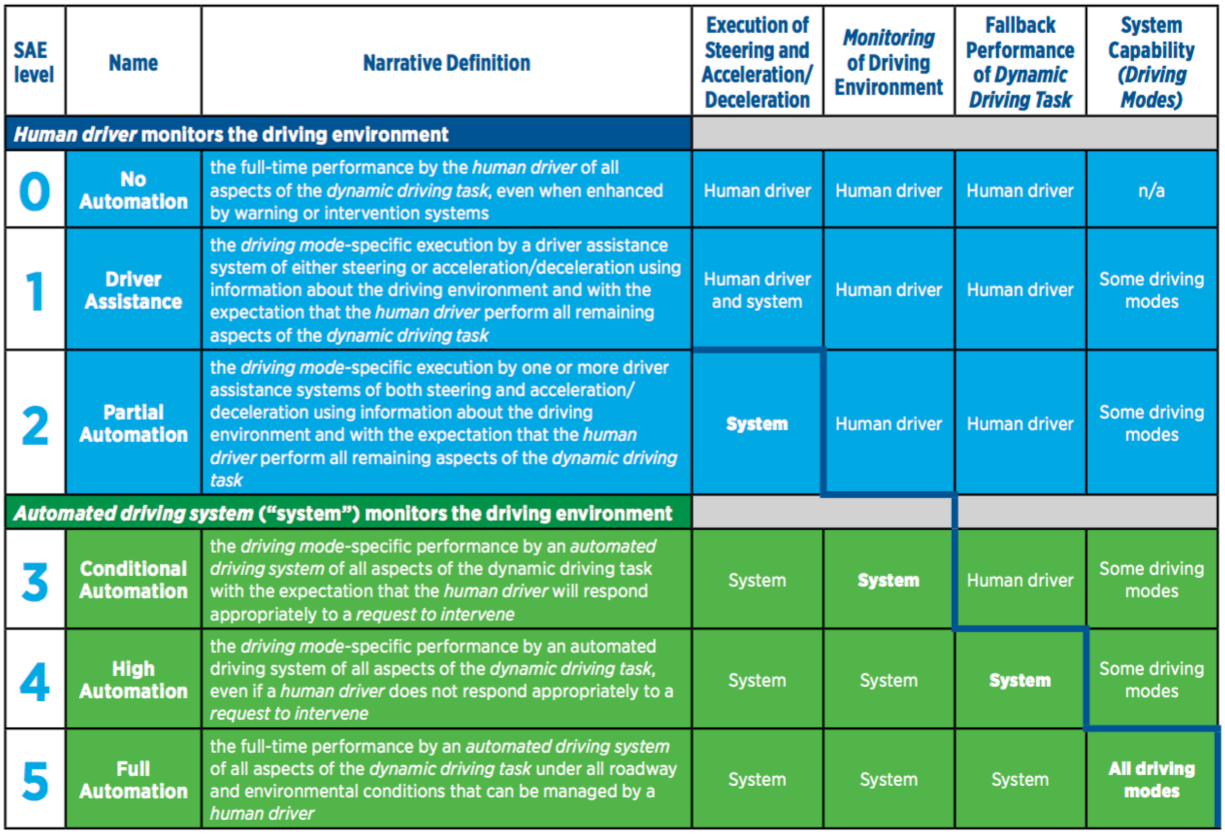
It is important to note the difference between the terms “automated” and “autonomous” in this report. NHTSA now prefers the term automated to autonomous, as it is inclusive of a range of automation levels (Schwarz, 2013). This report uses the term automated vehicle technologies (AVTs) to refer to the technologies with varying degrees of automation that will one day result in a fully automated vehicle.

I. Levels of Automation

Every modern vehicle has some degree of automation, including cruise control, electronic stability control, and even automated headlights and windshield wipers. As cars become more advanced, it has become common to specify distinct levels of automation. Both the NHTSA and the Society of Automotive Engineers (SAE), in separate but parallel development efforts, have published definitions of the levels of vehicle automation to provide a basis for communication of different concepts. The levels range from Level 0, “no automation” (conventional, fully human-driven vehicles) to Levels 4 or 5, “full automation” (may require no driver at all) based on functional aspects of technology. The SAE defines six distinct levels while the NHTSA defines five.

From the perspective of the driver, there is a key distinction in experience between SAE Level 2 (where the human driver performs part of the dynamic driving task) and Level 3 (where the automated driving system performs the entire dynamic driving task). The following discussion will use the SAE taxonomy, and the levels shall be denoted by the abbreviations L0, L1, L2, L3, L4 and L5.

A brief overview of how the responsibility for the driving process is distributed between the vehicle and the driver is outlined in Figure 2. In L0, the driver is in complete and sole control whereas, at the other end of the spectrum in L5, the vehicle is fully automated and the experience of all occupants is that of a passenger. Vehicles with L5 automation may also be referred to as fully automated, or self-driving, vehicles. Detailed descriptions of SAE AVT levels can be found in Appendix 2 (http://www.sae.org/misc/pdfs/automated_driving.pdf).



SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 2. SAE levels of automation (http://www.sae.org/misc/pdfs/automated_driving.pdf)

All major automobile manufacturers have demonstrated research vehicles with advanced (though generally supervised) automation, but not all are actively working toward marketing one. Many technical challenges have yet to be solved; one model estimates it will take another ten to 20 years for the technology to achieve the desired level of consistency necessary for commercial viability and thus mainstream use across a wide range of driving environments (Moore & Lu, 2011).

On the other hand, gradual improvements in technology are resulting in L2 and, potentially, L3 vehicles coming to market. The number of driver-assist features (outside AVT) available on cars continues to grow, including features such as automated emergency braking and automated pedestrian collision warning systems. AVT is also expected to have a major impact on mass transit; and the first L4 systems may be low-speed urban transit vehicles.

II. Automated Vehicle Technologies (AVTs)

AVTs are in a rapid state of development. Low-level automated features (L1, L2) already exist on some vehicles, with higher-level AVT on the horizon for consumers. This section includes a short review of the state-of-the-art AVTs; including how connected vehicle technology cooperates and complements automation. AVT falls roughly into the categories of: perception (achieved through various sensors and the fusion of their data), planning (carried out using some form of artificial intelligence algorithm), and execution (exerted through actuators).

Radar

Radar-equipped vehicles emit radio waves that bounce off of objects and return to a receiver, allowing the estimation of distance, and sometimes heading, to an object. Short-range radar (SRR) detects the distance of nearby objects within a range of up to 20 meters. Typically implemented with a single antenna, SRR cannot detect angles and must be paired with other sensors such as cameras to provide that information. SRR is used with systems such as park assist and collision and blind spot warning.

Long-range radar (LRR) can measure the distance of an object in the path of the vehicle up to 150 meters with an angular resolution of two degrees. Such radar technology is often implemented to give directionality to the sensing capability. LRR is used in long range sensing applications like ACC by measuring the distance to a vehicle in front of the car and the speed of that vehicle.

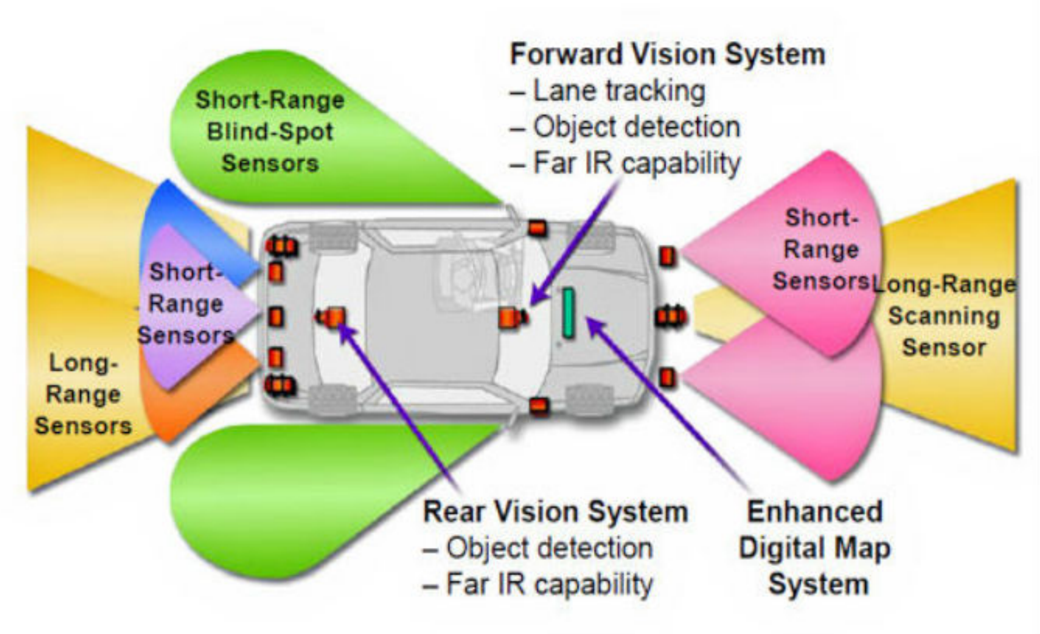


Figure 3. Depiction of long and short range radar, location on most vehicles, and areas of detection.

Ultrasonic Sensors

Used in backing, parking assist, lane keeping, and ACC features, ultrasonic sensors send out high frequency sound waves that measure echoes to determine the distance of an object.

Figure 4. Ultrasonic sensors

Global Positioning System (GPS)

In clear weather and in the absence of tall buildings, civilian GPS technology utilizes satellites to provide location within five meters (16 feet). Functionality can be affected by weather or large buildings. The resolution of such systems is quickly shrinking down for commercial (non-military) applications. While still expensive, one centimeter resolution will be will begin to become more common in the coming years.

Dedicated Short Range Communications (DSRC)

Used to communicate directly with other vehicles (V2V), as well as with stationary roadside units (V2I), DSRC is a wireless communication protocol used in connected vehicle technology that is suitable for safety systems like collision warning. Combined with cellular infrastructure, it provides comprehensive connectivity to vehicles for safety, navigation, and infotainment systems. DSRC can supplement traditional sensors by adding a form of sensing that is not limited to line-of-sight.

Cameras

Crucial to AVT, cameras detect color and boundaries, enabling the recognition of lane lines on roads and the reading of signs. Paired with the right software, sensors, boundary classification allows vehicles to identify types of objects such as cars, trucks, motorcycles, pedestrians, emergency lights, etc. Cameras cannot measure distance directly, unless used in pairs for stereo vision, and thus must be paired with other sensors. However, cameras can easily measure rates of change between objects ahead, like whether a driver is gaining on a slower moving vehicle, pedestrians, or bicycles. Considered an essential part of AVT, cameras can deliver spatial and color information that other sensors cannot (Schwarz et. al, 2013). Most simply, camera systems place boxes around targets and measure the change in size for collision warning/avoidance.

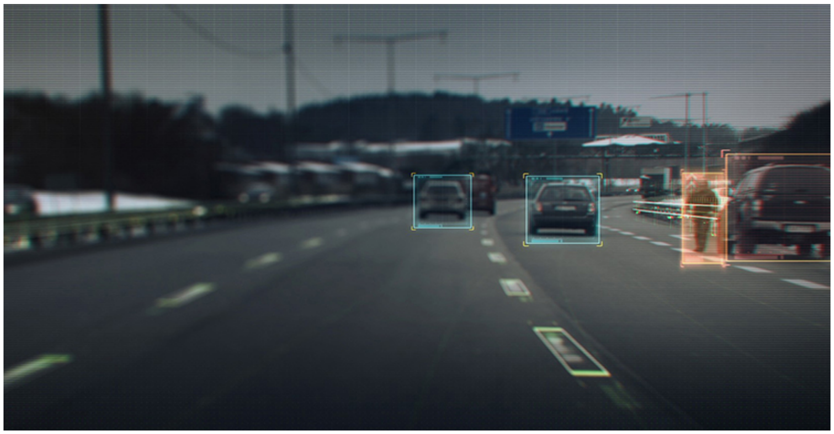


Figure 5. Camera images are analyzed by software to recognize distinct features. Integration with radar allows the car to identify which objects are moving with the flow of traffic or not threats (blue) and which are not (red). A lane marker is highlighted in yellow (from Volvo XC90).

LiDAR

LiDAR (light detection and ranging) functions similarly to sonar in that it emits and measures laser signals that bounce back to calculate the distance of objects around the vehicle. LiDAR is the only sensor that can measure accurate angles in horizontal and vertical dimensions, enabling it to generate 3D data that is accurate within two centimeters. This data is then integrated with 2D GPS map data to allow vehicles to navigate their environments.

LiDAR is also used for aerial surveying and is crucial in producing high-resolution maps necessary for automated vehicles to function.

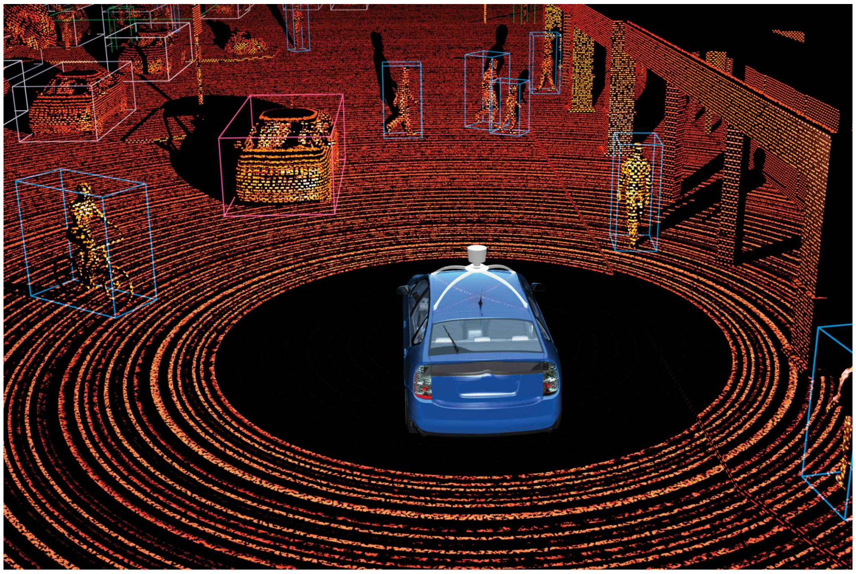


Figure 6. LiDAR scan of the environment taking more than a million measurements per second and forming a high-resolution map of the car's surroundings (Google).

Sensor Fusion

The integration of sensors and data are and important element of AVTs. Data from cameras, radar, LiDAR, and other specialized sensors (in in some instances map data) must be integrated in order to understand the roadway environment.

Mapping technologies

Having been used for many years in navigation systems, roads are now being remapped at a higher resolution and with more variables than ever before. New maps contain more information about road slope and width, lane markings, and traffic control devices, all of which are important for the safe operation of AVTs. As a type of input, digital maps are not limited by line-of-sight and have greater range than any of the traditional sensors.

While public attention focuses on the development of fully automated cars, the digital maps and infrastructure that enable them to function will have a wider impact that will be seen on all scales, as 3D mapping is central to implementing AVT.

HERE, formerly a division of Nokia, produces digital maps and navigation systems that run on four of every five vehicles with in-car navigation systems in Europe and North America. Starting in the summer of 2015, HERE began working towards standardization of how its technology collects data so it can be added to the cloud for the purpose of informing other vehicles operating on the same navigation systems. Updates now occur on a per minute basis, alerting drivers of traffic jams and obstacles. HERE is also working on high-definition 3D mapping and has mapped Berlin, Germany, as well as several of the major cities in Scandinavia. HERE acquired U.S. based Navteq in 2007 and now provides additional mapping, tracking, and traffic information services.

In the last year, Tom-Tom, a Dutch navigation company, partnered with Bosch to build navigation systems and AVTs for automakers worldwide. Bosch stated that it has no intention of creating automated vehicles but will create the technologies that enable them. This includes using LiDAR to create digital maps of the San Francisco area, sections of I-80, and Autobahn A8 in Germany.

Before deploying its automated vehicle research fleet, Google manually drove throughout Mountain View, California, to create digital maps of the city and completed the same process in Austin, Texas in preparation for testing. In Sweden, Volvo mapped the Ring Road freeway through Gothenburg in preparation for their 2017 DriveMe test-launch to consumers. The ride-sharing service, Uber, has expressed interest in automated vehicles and may make a significant impact in the near future by digitally mapping a city with LiDAR as drivers provide rides.

Route Planning and Navigation Algorithms

When paired with GPS and digital maps, route planning algorithms can select the shortest route to a destination, even accounting for heavy or blocked traffic and rerouting quicker alternate routes. Algorithms treat intersections, on-ramps, and exits as decision points and the roads that connect them as links. Fully automated navigation is more complex than choosing which roads to take, as AVTs must also perform lane-keeping and speed-keeping, the primary tasks of driving. Environmental information must also be used to plan a lane change or to take a turn smoothly enough to be comfortable and safe for passengers and cargo.

Localization, Object Detection, and Mapping

Vehicles must be able to simultaneously scan the environment, identify all moving objects, calculate their exact location, plan routes, and navigate. If a high resolution digital map is not available for their current location, they may have to provide the mapping functionality as well. The process of the vehicle knowing where it is and mapping the environment in real-time is referred to as Simultaneous Location and Mapping (SLAM). SLAM algorithms complete a vehicle’s picture of the environment (Schwarz et. al, 2013), involving all sensor technology on the vehicle; for automated vehicles to function, all sensor technology must be integrated.

III. Current Developments in Automated Vehicles

Forecasts for the deployment of automated vehicles predict many years yet before human drivers need not play a real-time role across a wide range of driving environments. The first applications will be very slow-speed vehicles in (e.g., 5-7 mph on non-public roads—like a Disney property). However, AVTs are rapidly developing and a great deal of research is being conducted. The latest industry developments in AVTs are discussed within this section.

A. Applications of AVT

Platooning

Platooning, an enhancement to ACC, utilizes radar and specialized computer hardware and software to allow vehicles to sync with one another on the highway. Once linked, the lead driver performs at least acceleration and deceleration of the following vehicle(s), greatly reducing lag in reaction time and allowing vehicles to follow at close distances to each other. This AVT increases fuel efficiency in both the lead and following vehicles by reducing wind drag. Platooning has obvious benefits for safety, mobility and sustainability, and there is a strong business case to implement it in commercial truck fleets.

In the U.S., the trucking industry will likely be the first adopter of this technology, due primarily to economics. In 2014, the trucking industry generated revenues topping $700 billion (American Trucking Association, 2015). However, although profitability has improved in the last few years, private trucking companies historically have thin profit margins relative to other industries; in 2013, the industry operated at about a 6% net profit margin (Sageworks, 2014). This is due, in large part, to $100 billion in fuel and $48 billion in crash costs.

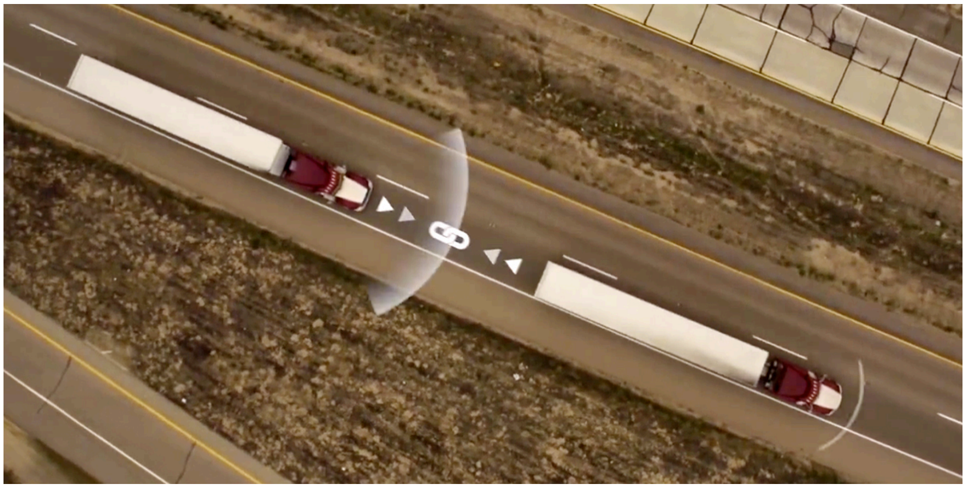


Figure 7. Two trucks demonstrating safe following distance with platooning technology.

In 2016, Peloton Technology, an American company, will begin equipping trucks with platooning technology. The system will electronically couple pairs of trucks through a combination of vehicle-to-vehicle (V2V) wireless communications, radar-based active braking systems, and proprietary vehicle-control algorithms. Through the direct V2V link, the rear truck will automatically react to acceleration or braking much more quickly than a human driver. Peloton's cloud-based Network Operations Center will continuously monitor individual truck safety and approve the linking of pairs of trucks on suitable roads and in appropriate weather and traffic conditions (Peloton, 2015). Peloton has performed studies demonstrating the significantly improved reaction times with synched vehicles in a platoon over both manual driving and ACC. In Peloton's version of platooning, rear truck drivers continue steering at all times, thus making it an L1 technology.

Figure 9 below compares the lag time between manual (human), automated (ACC), and coordinated (platooned) trucks. The top two bars show the considerable amount of time between the braking of a front truck and the rear (following) a human truck driver's perception, reaction, and brake lag. In the next set of bars, one can see that with an ACC "automated" system, though the perception and reaction times are diminished, there is still a lag in braking. However, the last set of bars shows the perception and reaction of coordinated, or platooned, trucks begins immediately, as soon as the front truck begins to brake, so there is little lag, thus allowing for closer following distances. Platooning eliminates the human component.

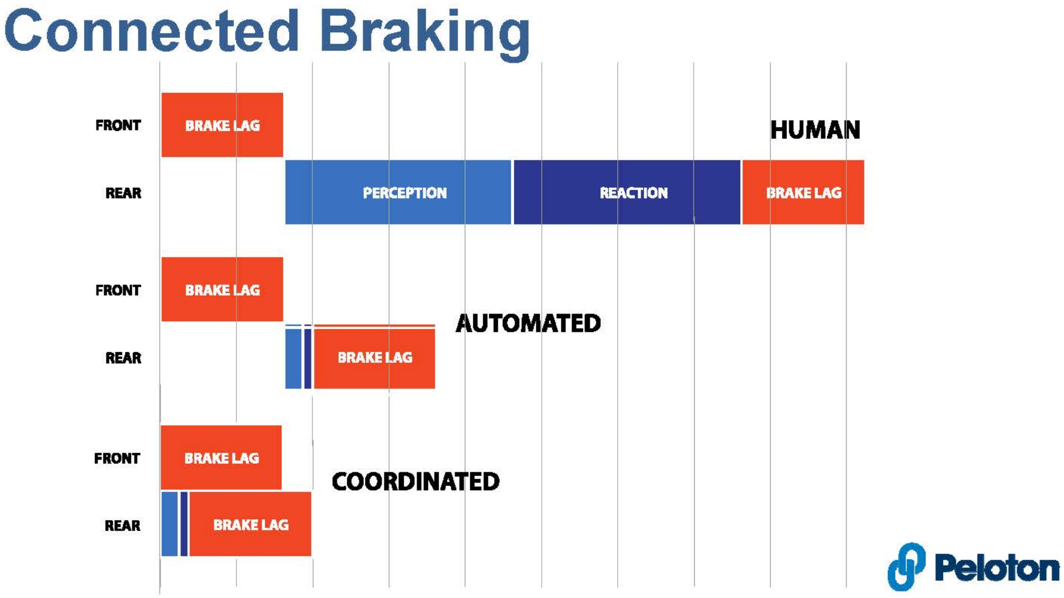


Figure 8. Peloton illustrates that the following vehicle begins braking even before the lead vehicle has signaled intent through brake lights.

Peloton has shown that fuel usage in a two-truck platoon drops by 4.5% for the lead truck and 10% for the following truck based on testing conducted by the North American Council for Freight Efficiency and trucking fleet C.R. England (Peloton, 2015). For large commercial fleets, savings stand to be worth billions of dollars a year. Peloton's current focus is on trucks, but their patent covers the same application on personal vehicles as well.

The European Union (EU) funded Safe Road Trains for the Environment (SARTRE) is approaching platooning from the standpoint of environmental benefit. While the U.S. will initially focus on trucks, SARTRE is pushing to implement the technology on trucks and personal vehicles alike. In this version, L3 and L4 capabilities allow drivers of the following vehicles to completely disengage from performing the real-time driving task.

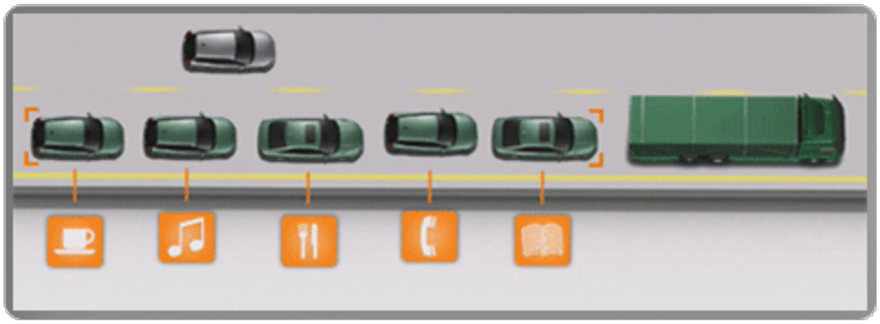


Figure 9. This slide by Volvo, demonstrates a road train in which multiple cars follow a lead truck. The icons below each vehicle indicate what a person behind the steering wheel can do with during this time.

The L2/L3 platooning technology offers even greater potential benefits in the form of fuel economy, crash reduction, and enhancement of experience for following vehicle drivers. The additional push from the EU to bring this to market for environmental reasons indicates that this may be a key automation technology in Europe over the next five years.

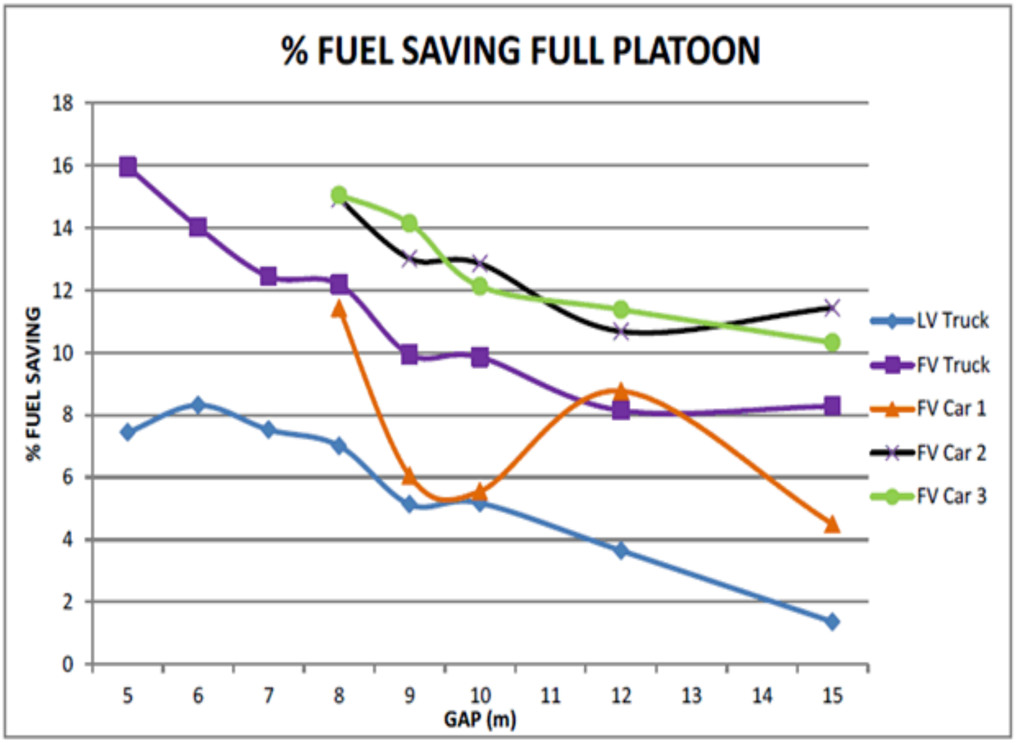


Figure 10. Results of fuel economy study released by SARTRE. The road train in this study constituted two trucks at the front followed by three cars. LV is the lead vehicle and FV is any following vehicle.

It should be noted that this particular technology may eventually appear under a variety of names, depending on the use, including terms like “drafting”, “road train”, “link”, “synchronize” and “coordinated braking.”

B. Automated Vehicle Developments

Public Transit – Europe

Since 1999, the EU has tested fully automated fleets in major European cities. The current project, CityMobil2, is designed to test, demonstrate, and highlight the capabilities of AVT in augmenting existing mass-transit systems. The vehicles employed are small, lightweight, and move at slow speeds. Bus lines tend to move along major roads within cities.

Figure 11. The CityMobil2 buses can hold up to eight people at once and are narrower than even most small European cars.

Successful demonstrations in multiple cities across Europe have increased public awareness and acceptance of fully automated transit options. Fleets such as these are likely to be piloted in the U.S. in airports or on large campuses. These vehicles are examples of level 4 automation.

GM Super Cruise – Highway Automation

In 2017, GM will launch a Super Cruise feature on the 2018 Cadillac CTS that combines ACC and lane following (centering), utilizing radar, ultrasonic sensors, cameras, and GPS map data. It will be the first personal vehicle marketed in the U.S. with V2V communication. The Super Cruise feature is for highway driving only and can only be activated under certain conditions. The GM Super Cruise feature constitutes an L2 technology; in press releases, GM has stressed the importance of the driver continuing to watch road conditions and to be ready to resume actively steering and braking at all times. The GM Super Cruise feature has already been tested on public roads.

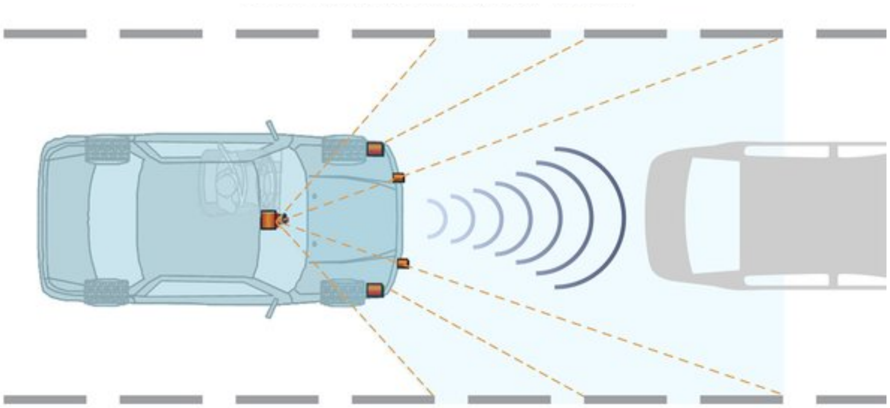


Figure 12. Image released by GM illustrating the use of cameras, radar and ultrasonic sensors to track lane markers and the vehicle directly ahead.

Volvo DriveMe

In 2017, Volvo will begin a pilot program in Gothenburg, Sweden to demonstrate the capabilities of L4 automation on select “certified” highways. The automation is only enabled on these select roads that have good roadway paint and have a 3D map. The Swedish government can also send a signal to the vehicles in the case of weather or other conditions to suspend the automation.

Figure 13. Volvo is actively advertising that drivers can completely disengage from all aspects of the driving task when the highway automation feature is activated.

The test involves 100 Volvo XC90 models driven by customers (instead of test engineers) who will purchase a two-year lease for the price of a regular XC90. Black box recorders will transmit data to Volvo in real time.

Once the XC90’s automated vehicle mode is turned on, drivers will be able to completely disengage from actively driving. The cars use cameras, LiDAR, radar, sonar, and digital maps to enable lane centering, ACC, and the ability to operate in stop-and-go highway traffic. Volvo’s promotional videos state that the technology is so reliable, the driver can focus on something else without having to pay attention to traffic and show a driver texting, taking notes, and reading a paper.

To function, DriveMe program vehicles must be able to access 3D cloud-based maps of “certified” highway in the Gothenburg area. Road certification is a two-step process that includes:

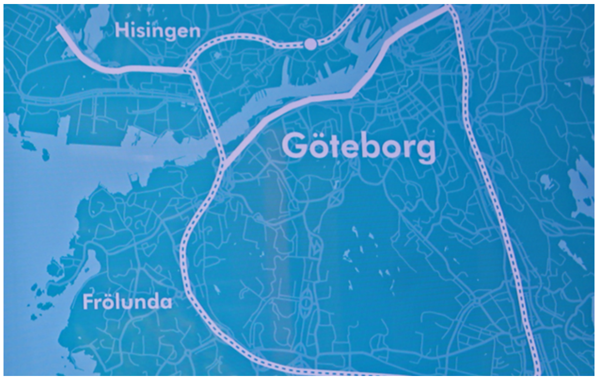


Figure 14. About 50km of highway around Gothenburg, Sweden has been certified for the DriveMe program

1) creation of a digital map that can be accessed via the cloud and 2) ensuring that all markers (painted lines, signs, etc.) are visible to the vehicle. There is constant V2I communication and construction and weather information is continuously updated. During inclement weather, the certification can be de-activated, disabling the automated highway function and requiring drivers to remain in control of the vehicle. When not on certified highways, drivers must actively drive the car.

Redundancy is used in all XC90 systems, ensuring that a single system failure does not result in a dangerous situation. In the event that a driver does not take control of the car when prompted or if an automated vehicle-vital system malfunctions, the car will pull itself over and come to a complete stop on specially designed turnouts.

Volvo plans to begin tests in other locations once the Gothenburg test draws to a close and has indicated a 2020 commercial release for this feature. Other OEMs like Tesla, Daimler and Nissan or planning similar implementation.

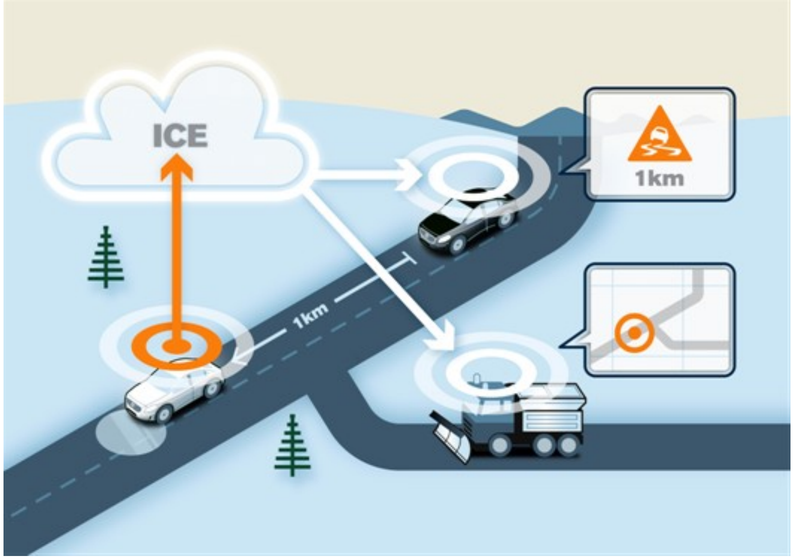


Figure 15. Illustration of V2I/V2V communication benefits of the Volvo DriveMe program.

Google Self-Driving Car

Google began development of its self-driving car in 2009 and currently has a fleet of more than 20 modified Lexus RX450h SUVs and 30 prototypes (vehicles designed from the ground up to be fully self-driving). These vehicles are currently on public roads in Mountain View, California, Austin, Texas, and Kirkland, Washington. During self-driving tests, engineers have been behind the wheel to provide feedback and to intervene, as necessary.

Both fleets utilize LiDAR, multiple cameras, LRR, SRR, and GPS. In the December 2015 Self-Driving Car Project Monthly Report, Google stated that the automated fleet had driven more than 1.3 million miles in automated mode, another 955,000 miles in Manual Mode, and were averaging 10,000 to 15,000 automated miles per week on public roads. To put this into perspective, a typical American drives approximately 13,000 miles per year, meaning that the Lexus RX450h SUV fleet has accumulated nearly 75 years of typical adult driving experience in just three years.

As a great deal of press coverage has been generated by the few crashes (17 in the six years of the project) involving the cars, Google has started publishing monthly reports covering the progress of the project and giving details of all crashes. In all but one instance, collisions involving Google cars were the fault of another vehicle. None of the crashes have been caused by the car itself (Google, 2015).

Laser
This sensor gives the vehicle a 360-degree understanding of its environment so the car can sense objects in front of, beside, and behind itself at the same time, all the time. The laser also helps the vehicle to determine its location in the world.

Safety drivers
Drivers also test the vehicles daily, reporting feedback on how to make the ride more safe and comfortable.

Processor
Information from the sensors is cross-checked and processed by the software so that different objects around the vehicle can be sensed and differentiated accurately, and safe driving decisions can then be made based on all the information received.

Position sensor
This sensor, located in the wheel hub, detects the rotations made by the wheels of the car to help the vehicle understand its position in the world.

Orientation sensor
Similar to the way a person's inner ear gives them a sense of motion and balance, this sensor, located in the interior of the car, works to give the car a clear sense of orientation.

Radar
This sensor detects vehicles far ahead and measures their speed so that the car can safely slow down or speed up with other vehicles on the road.

Figure 16. Google self-driving Lexus RX450h SUV

The milestone of driving more than million miles in automated – but supervised – mode is a positive indication of the development of AVT. Such automation still requires close supervision and safety drivers intervene when the automation fails to recognize a collision condition. Newer prototypes are a significant step in this direction as they are designed for passengers, not drivers, and are only equipped with steering wheels for the sake of testing (the steering wheels can be removed) Figure 17.

Figure 17. Highly autonomous L5 car designed by Google to function solely as a passenger vehicle.

These models are designed to go no faster than 25 mph and while the small size and low speed are not suitable for most work commutes, a highly automated vehicle capable of self-navigating on roads and widened sidewalks offers a great deal of social and economic benefit. A car of this type would represent a significant increase in quality of life for individuals who are unable to drive themselves.

Figure 18. Google has begun an awareness campaign demonstrating self-driving technology to likely early adopters who are unable to drive themselves. The man in this image is blind.

IV. Legislative Review and Legal Aspects

With every major commercial automaker engaged in AVT research and full-scale commercial introduction of automated vehicles estimated to potentially hit the market within the next 20 years, it is important for policymakers to understand the effects existing policies and laws are likely to have (Anderson et. al, 2014).

Every U.S. state has different laws shaped by legislators, regulators, and judges. These laws evolve both formally and informally. A key point is that since no change occurs in a vacuum, tomorrow's vehicles will face (and affect) tomorrow's laws (Smith, 2015).

In general, existing laws likely do not prohibit (but may complicate) automated driving (Smith, 2014a). Existing laws not specifically related to AVTs are important to consider, as they may treat technologies and applications differently. Two points are particularly key. First, details matter: New York, for example, uniquely requires a driver to keep at least one hand on the wheel when the vehicle is in motion, an action that may not be technically necessary with certain AVTs. Second, broader social context will shape many of those details: Whether a driver acts recklessly by closing her eyes in a fully automated vehicle during operation may depend on whether the relevant community, including police officers, judges, and juries, deems automation to be "good" or "bad." (Smith 2015)

New laws may likewise have a range of impacts. Certain laws already enacted have prohibited some forms of automated driving, established additional hurdles to testing or deployment, or imposed a superficial structure on existing law that confuses as much as it clarifies. The more meaningful legal review advocated in this report, however, could identify and then remedy lingering areas of legal uncertainty.

Historically, DMVs test and regulate the safety of drivers, relying on vehicle safety standards established by NHTSA, a federal entity. But AVTs are blurring the line between driver and vehicle and DMVs are now beginning to test and license self-driving vehicles (Anderson et. al, 2014). Currently, NHTSA has not established safety standards for self-driving vehicles but did publish a list of formal recommendations for vehicle technology on public roads in 2013 in order to encourage safe development and implementation. In January 2016, the DOT and NHTSA published an update to this statement that committed the DOT to creating automated vehicle guidance and model state policy within six months, which would offer a path to consistent national policy.

While the state of Iowa does not currently have legislation pertaining to automated vehicles, in July 2014 the Johnson County Board of Supervisors unanimously passed a proclamation encouraging automated vehicle testing as a public safety and economic development initiative (Iowa City Area Development, 2014). With this proclamation, Iowa is advertising its lack of restrictive legislation on the testing and operation of automated vehicles on public roads (O'Leary and Santana, 2014).

A. State Legislation

As of December 2015, six states (California, Michigan, Florida, Nevada, North Dakota, Tennessee) and the District of Columbia (DC) have passed legislation aimed at expressly regulating AVTs. In August 2015, Arizona's governor signed an executive order directing various agencies to take any necessary steps to support the testing and operation of self-driving vehicles on public roads and enabling pilot programs. Many more states are considering AVT legislation. In 2015, sixteen states introduced legislation related to AVTs, an increase from twelve in 2014, nine and DC in 2013, and six in 2012 (Weiner and Smith) (National Conference of State Legislatures, 2016). Within their legislation, Nevada, California, and Florida (and others) have expressly permitted, under certain conditions, the operation of self-driving, automated vehicles—largely in the context of "testing." California is the most advanced state relative to others as it goes further statutorily, but not regulatorily.

Rather than recognizing the various levels of automation as defined by NHTSA and SAE, laws in these states either consider vehicles automated or not. Under this approach, context determines whether the technology is defined as automated, though the dividing line likely falls between SAE levels 2 and 3 The following is a brief review noting the key aspects of legislation by the six states and DC. While the language and ideas between the laws are similar, none are identical.

Nevada

In 2011, the state of Nevada was the first to pass legislation regarding automated vehicles with Assembly Bill 511. Nevada's legislation broadly defines an autonomous vehicle as "a motor vehicle equipped with automated technology." It requires 'autonomous' vehicles to have a human operator but also states "a person is not required to actively drive." The legislation directs the Department of Motor Vehicles (DMV) to adopt regulations for license endorsement and operation, including insurance, safety standards, and testing (completed in 2012). Additionally, the legislation limits original manufacturer liability and requires proof of insurance (Nevada Legislature, 2011a). Senate Bill 313 in 2013 amends the legislation to require that the DOT shall establish a driver's license endorsement for the operation of an automated vehicle on Nevada highways. This endorsement recognizes the fact that a person is not required to actively drive an automated vehicle (Nevada Legislature, 2013).

Additional legislation related to automated vehicles, Nevada Senate Bill 140, enacted and chaptered in 2011, prohibits the use of cell phones and communications devices while driving, including texting and reading data. However, these activities are not prohibited for a person operating an automated vehicle (Nevada Legislature, 2011b).

Florida

Enacted in 2012, Florida House Bill 0599 and House Bill 1207 authorized the testing of vehicles equipped with automated technology and defined "autonomous technology" as technology installed on a vehicle enabling it to operate without the active control and continuous monitoring of a human operator. The legislation requires a licensed driver, unless on a closed course, to monitor the automated mode and intervene, when necessary. Drivers are limited to employees, contractors, and other persons designated by the manufacturer of the technology. Drivers must be able to disengage from automated mode and the technology must provide a visual indicator inside the vehicle when in automated mode and alert the operator to a technology failure. The legislation also directs the Department of Highway Safety and Motor Vehicles to prepare a report relating to the safe operation of vehicles equipped with automated technology on public roads (completed in 2014). Original manufacturer liability is limited and proof of insurance is required (Florida House of Representatives, 2012a and 2012b).

Similar to Nevada, Florida also permits the use of cell phones for those in automated vehicles.

California

In September 2012, California passed Senate Bill 1298 creating Vehicle Code 38750, establishing definitions and permitting the operation of automated vehicles for testing purposes on public roads under certain conditions (i.e. a properly licensed driver in the driver's seat who would be able to take over in emergencies). An "autonomous vehicle" is defined as any vehicle equipped with autonomous technology that has been integrated into the vehicle, with "autonomous technology" meaning technology that has the capability to drive the vehicle without the active physical control or monitoring by a human operator (CA vehicle code, section 38750). The legislation also required the adoption of safety standards and performance requirements developed by the Department of Motor Vehicles (DMV) (completed for testing in 2015; over a year overdue for general operation). Proof of insurance is required. Additionally, the legislation states that if the NHTSA creates conflicting regulations, the NHTSA vehicle-based regulations will supersede California law. (California Legislature, 2012). General operations regulation will stay with the state.

Washington D.C.

The Autonomous Vehicle Act of 2012 enacted and effective in April 2013, conditions the operation of autonomous vehicles on DC roadways on availability of a manual override feature and the presence of a driver seated in the driver's seat who is able to intervene at any time. An autonomous vehicle is defined as "a vehicle capable of navigating District roadways and interpreting traffic-control devices without a driver actively operating any of the vehicle's control systems." The legislation restricts conversion to recent vehicles and limits the original manufacturer's liability for any vehicle converted for autonomous purposes. The DMV was also directed to develop an autonomous vehicle designation and "safe driving protocols" (Council of the District of Columbia, 2013). Such 'safe driving protocols' were developed as part of impaired driving laws.

Michigan

Michigan Senate Bills 169 and 663, effective in 2014 and 2013 (respectively), expressly permit the testing of AVTs by certain parties under certain conditions. Automated motor vehicles are defined as those on which "automated technology has been installed…that enables the motor vehicle to be operated without any control or monitoring by a human operator." The legislation requires a qualified operator to be present during operation and limits the liability for original manufacturer and suppliers. By February 1, 2016, the legislation also requires the state DOT, with the Secretary of State, to submit a report recommending any additional legislative or regulatory actions that may be necessary for the continued safe testing of automated vehicles and technology (Michigan Legislature, 2013a and 2013b). The Michigan law also expressly prohibits all other operation of automated vehicles.

North Dakota

Through House Bill No. 1065, North Dakota enacted legislation in March 2015 providing for a study of laws that may need to be changed to accommodate the introduction or testing of automated motor vehicles. The legislation defines automated motor vehicles by the SAE standard as "the unconditional, full-time performance by an automated driving system of all aspects of the dynamic driving task." The study may also include research on the degree that automated vehicles could increase safety, reduce traffic congestion, and improve fuel economy (North Dakota House of Representatives, 2015).

Tennessee

Senate Bill 598, enacted by the State of Tennessee in April 2015, specifically prohibits local governments from banning the use of motor vehicles equipped with automated technology. Automated technology is defined as technology installed on a vehicle that has the capability to drive it "without the active physical control or monitoring by a human operator" (Tennessee Legislature, 2015).

Licensing

NHTSA recommends state legislation ensure that automated vehicle drivers understand how to operate the vehicle safely. Florida, California, and Michigan all require that automated vehicle operators be an employee, contractor, or other person authorized by the manufacturer.

Nevada has established a driver's license endorsement for the operation of an automated vehicle that recognizes the fact that a person is not required to actively drive an automated vehicle. Florida legislation states that the Department of Highway Safety and Motor Vehicles shall propose rules to establish a driver's license endorsement for residents to operate a vehicle with automated technology.

California and Michigan both give the license-granting department the discretion to arbitrarily limit the number of permits issued for testing self-driving vehicles on public roads. The permits take the form of a driver's license in California or a special license plate in Michigan. Both states require that these can only be issued to manufacturers of automated technology but neither state specifies that these manufacturers are testing their own technology. Both states specify that the issuing department have a process for manufacturers to apply to be recognized as a manufacturer of automated vehicle technology, and that the technology being tested meet as of yet unspecified safety conditions.

The Nevada DMV has also developed regulations outlining the issuance of testing licenses for automated vehicle technology. Testing applicants must provide proof of 10,000 hours of prior automated vehicle operation, statistics, and explanations of how the vehicle handles different traffic control devices, pedestrians/objects, speed variations, and various environmental types. Licensees are also required to submit a safety plan.

B. Federal Regulatory Recommendations

In 2013, NHTSA, the federal agency responsible for developing, setting, and enforcing Federal motor vehicle safety standards (FMVSSs), published a draft policy statement for drafters of state legislation and regulations governing licensing, testing, and operation of self-driving vehicles on public roads. In the absence of any specific federal laws, these recommendations were created to encourage the safe development and implementation of vehicles with higher-level automation. While NHTSA believes states are well suited to address issues like licensing and driver training, it has considerable concerns regarding detailed state regulation on safety of fully automated vehicles. Therefore, NHTSA recommended that states permit self-driving vehicles for testing purposes only (NHTSA, 2016).

NHTSA's recommendations, which all assume a human driver engaged in vehicle testing, are outlined below, followed with examples of how they are addressed by legislation in the six states and DC:

- Licensing drivers to operate self-driving vehicles for testing:
    - Ensure driver understands how to operate a self-driving vehicle safely

- State regulations governing testing of self-driving vehicles:
    - Ensure on-road testing of self-driving vehicles minimizes risk to other road users
    - Limit testing operations to conditions suitable for the capabilities of the tested self-driving vehicles
    - Establish reporting requirements to monitor testing

- Establishing basic principles for testing of self-driving vehicles:
    - Ensure process for transitioning from self-driving mode to driver control is safe, simple, and timely
    - Self-driving test vehicles should have the capability of detecting, recording, and informing the driver that the system of automated technologies has malfunctioned

    - Ensure installation and operation of any self-driving vehicle technologies does not disable any federally required safety features or systems
    - Ensure self-driving test vehicles record information about the status of the automated control technologies in the event of a crash or loss of vehicle control

- Authorizing the operation of self-driving vehicles for purposes other than testing is not recommended at this time

Testing

NHTSA recommends legislation ensure that on-road testing of self-driving vehicles minimize risks to other road users. Automated vehicles may be tested on public roads in California, Michigan, Nevada, and DC if there is an operator in the driver's seat and that individual is able to actively drive the vehicle, if needed.

For operation without the presence of a human driver, the California DMV may impose additional requirements to ensure safe operation. Florida law states that the vehicle may operate without the active control of a human operator, but the operation of the test vehicle must be continuously monitored in a manner that allows active control over the vehicle.

Developed by the state's DMV, Nevada's testing guidelines require two persons to be physically present in a self-driving vehicle while testing and each person must be trained in the operation of the automated vehicle, including the capabilities and limitations of the technology (Autonomous Vehicle Testing License, 2016).

Additionally, to test self-driving vehicles, both Nevada and Michigan require special license plates, as these provide clear visual indicators to other drivers that a vehicle may be operating in autonomous mode. Florida, another state with automated vehicle legislation, is considering this visual indicator but is unsure of the reduction in risk, as the state has more than two hundred specialty license plates (Florida Autonomous Vehicle Report, 2014).

Figure 19. Nevada autonomous vehicle specialty license plate

There are no limitations included within state legislation as to what public roadways or geographical locations autonomous vehicles may be tested on, nor are specific permissions of geographical locations required. However, the Nevada DMV testing guidelines require that a manufacturer desiring to test autonomous technology on public roadways complete an application process which requires a listing of specific geographic categories and environmental types of roads desired to test on, with all of Nevada's public roads being divided into six geographic categories (i.e. interstate highways, urban environments, residential roads, etc.) (Autonomous Vehicle Testing License, 2016).

Recording Information

NHTSA recommends legislation ensure self-driving test vehicles record information about the status of the automated control technologies in the event of a crash or loss of vehicle control. All sensory AVT that allows for a vehicle to function automatically collects data in real-time, allowing for event capture in the case of a crash. So far, only California legislation requires collision data to be stored. California Vehicle Code 38750 states that data from at least 30 seconds prior to a collision must be stored in a read-only format and retained until extracted, with the data being preserved for three years after the collision. These data collected by the AVTs must be disclosed by manufacturers to vehicle purchasers.

Transitioning from Self-Driving Mode to Driver Control

NHTSA recommends legislation that ensures the process for transitioning from self-driving mode to active driving in a safe, simple, and timely manner.

In California, Florida, and Nevada legislation, automated vehicles to be tested or operated on a highway within the state are required to be equipped with:

1. A means to engage and disengage the automated technology which is easily accessible to the human operator;
2. A visual indicator located inside the vehicle that indicates when automated technology is operating; and
3. A means to alert the human operator to take manual control of the automated vehicle if a failure of the automated technology has been detected and such failure affects the ability of the automated technology to operate the vehicle safely.

More generally, DC legislation requires that automated vehicles have a manual override feature that allows drivers to actively operate the vehicle at any time. Michigan legislation requires that the individual present within the automated vehicle has the ability to monitor the vehicle's performance and, if necessary, immediately actively operate of the vehicle.

C. Impending Federal Guidance

In January 2016, the DOT and NHTSA released an update to the Preliminary Statement of Policy Concerning Automated Vehicles. Recognizing the rapid development of AVTs and potential impending widespread deployment of automated vehicles, NHTSA committed to proposing best-practice guidance for establishing principles for safe operation of fully automated vehicles within six months. NHTSA intends to work with states to craft and propose the model policy guidance that will offer a nationally consistent approach to automated vehicles (DOT/NHTSA, 2016).

D. Civil liability and Insurance

With regard to anyone injured by an automated vehicle, provisions for insurance and liability have been included within some state legislation. The three states that address insurance requirements within legislation–California, Florida, and Nevada–all require an instrument of insurance instrument, proof of self-insurance, or a surety bond in the amount of $5 million. Michigan requires that, prior to research or testing of an automated vehicle or any AVT installed on an automated vehicle, the manufacturer shall submit proof that the vehicle is insured.

In Florida, after insurance is presented and title fees paid, the words “Autonomous Vehicle” will print on the vehicle’s registration certificate. California is also proposing to identify self-driving vehicles in a similar way registration cards and vehicle titles (Florida Autonomous Vehicle Report, 2014).

Civil liability concerns may – or may not – complicate the introduction of AVT (Anderson et. al, 2014). Liability is not an either/or proposition—multiple people can be sued and found at fault, andeach crash presents a unique set of facts (Smith, 2015). Just as it is today, determining liability in the event of an automated vehicle crash will be very fact specific (Smith, 2014b). In the event two vehicles crash, we need to ask about the circumstances (driver behavior, environment) to determine who is civilly liable. If an automated vehicle crashes, the same types of questions will likely be asked: What was the human supposed to be doing, if anything? Was the vehicle properly maintained? Was the vehicle used in the right environment? Did the manufacturer properly instruct and supervise the human user to the extent required? Did the vehicle make a mistake and, if so, what caused the mistake?

Florida, Nevada, Michigan, and DC all immunize original vehicle manufacturers from liability in any action involving injury caused by AVT equipment installed by a third party on that manufacturer’s original vehicle. Each of these states has minor variations in language but the overall liability protections are similar – and largely consistent with current common law. Michigan also extends this immunity to AVT manufacturers (subcomponent systems), not just vehicle manufacturers.

E. Other Legal Issues

It is inevitable that new technologies, especially those as complex as AVTs and self-driving cars, will face a host of legal questions. Aside from insurance and liability, data security, data ownership, privacy, and intellectual property are at the forefront of legal concerns.

Security for AVTs and self-driving vehicles falls into two categories: in-vehicle security (what exists to guard against tampering with a vehicle’s electronic and computerized systems) and “cyber” security (protections for V2V and V2I systems) (Garcia et. al, 2015). Automated vehicles could be vulnerable to different types of security attack and all security concerns that apply to the Internet would apply to in-vehicle communications (Anderson et. al, 2014). Hacking and malicious behaviors are concerns that have already been discussed and cited by lawmakers to defeat legislation permitting AVTs and self-driving vehicles. In the wake of the Boston marathon bombing, a bill seeking to establish a process for allowing the operation of automated vehicles died in committee, due to at least one representative’s concerns that the vehicles could be used as drones to deliver bombs for terrorists (LeSage, 2013).

Data ownership and privacy issues present an important policy gap (Anderson et. al, 2013). Vehicles equipped with AVTs are recording and store more data than ever before and that data, about both the vehicle and the driver, has a high value. For instance, insurance companies and retailers could be interested in driving habits. Under certain circumstances, law enforcement could have considerable interest in location data (Anderson et. al, 2013). Data about location and history could be used to discover information about personal lives and habits (Schwarz et. al, 2013).

Policy questions concerning data use and legal issues abound, including how long data from AVTs should be stored and maintained and by whom (Anderson et. al, 2014). As automated vehicle technology progresses, privacy issues will be at the forefront. Who owns the data generated AVT and does this data fall under current laws and court precedents, or will new laws and regulations be needed? (Garcia, Hill, and Wagner, 2015) Data issues and privacy concerns are an important policy gap policymakers need to address.

V. Policy Recommendations

The following recommendations were developed for Iowa governments to encourage the development, deployment, and use of automated road vehicles. The potential automated vehicle policy measures are divided into four categories: administrative, planning, legal, and community strategy recommendations. These recommendations are substantially similar to a forthcoming book chapter, Automated Driving Policy [Smith 2016] but include additional measures related to planning. That chapter in turn summarizes a longer policy paper, How Governments Can Promote Automated Driving, which is available at newlypossible.org.

A. Administrative Strategy Recommendations

Government agencies and other actors that constitute the bulk of the modern state can encourage automation by preparing themselves, preparing infrastructure, leveraging procurement, and advocating for safety measures.

Governments should provide their agencies the impetus, authority, and resources to prepare for and even promote automated systems. This includes identifying a single point person for automated driving at each level of government, advancing relevant agency expertise, ensuring that planning processes begin to account for automated driving, and developing break-the-glass plans for responding to early public incidents involving automated systems. These steps will require resources; preparing for automated vehicles involves issues that typically do not confront existing bureaucracies.

Governments should likewise prepare the physical and digital infrastructures that they manage. They should:

1. Prioritize the adequate maintenance of roadways (including pavement conditions and lane markings) to improve the real-life performance of early advanced driver assistance systems;
2. Ensure that policies on the design of transportation infrastructure (including traffic control devices) are clear, consistent across jurisdictions, and actually followed in practice to reduce the frequency with which automated systems must confront unusual roadway conditions;
3. Verify that construction crews and emergency responders follow relevant policies when working on or near active roadways to reduce unanticipated conflicts between automated vehicles and these personnel;
4. Standardize their management of road-and traffic-relevant data to make these data more accessible to digital mapmakers and other potential users;
5. Update existing vehicle registration databases with information about the automation capabilities of every vehicle so that police can readily distinguish between automated and conventional vehicles;
6. Coordinate with national authorities on V2V and V2I communications so that this infrastructure is available to those developers that wish to use it;

7. Encourage the deployment of robust wireless communications networks so that developers of automated systems can more reliably share data and updates with these systems after they have been deployed;
8. Make existing congestion management tools (including managed lanes) available for automation-related applications to encourage these applications; and
9. Emphasize neighborhood designs that are consistent with low vehicle speeds to provide roadway environments conducive to early driverless systems.

Governments should also cooperate with each other to increase demand for advanced driver assistance and automated emergency intervention systems by requiring or preferring these systems on vehicles that their agencies, their contractors, and their concessionaires purchase. In addition, state and local governments can push the federal government to move more aggressively in promoting and ultimately requiring more of these safety systems on new vehicles.

B. Planning Strategy Recommendations

The significant uncertainty surrounding automated driving, particularly the nature and timing of its impacts, makes transportation planning extremely difficult. Automated vehicles could conceivably lead to:

- Lower capacities (because of longer initial headways and less assertive behavior at intersections) or to higher lane capacities (because of reduced headways, smoother flows, shorter lag times at signals, and fewer crashes)
- Increased vehicle miles traveled (because travel is cheaper, trips are longer, other modes are less competitive, or vehicles have no occupants whatsoever) or decreased vehicle miles traveled (largely because ridesharing is more attractive and efficient)
- Increased pavement distress (as vehicles travel more frequently over a specific portion of the travel lane) or decreased pavement distress (as vehicles move more smoothly and avoid pavement deficiencies)
- Unexpected changes in more localized traffic patterns and behaviors as vehicles queue at major origins and destinations, make zero-occupancy trips in the nonpeak direction, or shift bottlenecks

This uncertainty has particularly significant implications for long-range planning, including demand models, infrastructure plans, alternative analyses, and financial projections. These exercises may fail to accurately predict the magnitude or even the direction of automation’s impacts. Moreover, their treatment of automation, or the lack thereof, may occasion increased scrutiny by other actors, including courts reviewing environmental impact statements or private investors evaluating infrastructure bond offerings.

Governments cannot resolve this uncertainty but they can begin to adjust their planning processes by identifying and incorporating a wide range of new automation scenarios. For example:

1. A metropolitan planning organization might consider the vehicle miles traveled impact of shifting half of trips on flights to less than 500 miles to single-occupancy motor vehicles;
2. A transit agency might consider the financial impact of shifting half of suburban bus trips to shared motor vehicles; and
3. A municipality might consider the congestion impact of shifting the origins or destinations of half of the trips from parking facilities to building entrances.

If appropriately qualified and contextualized, these stylized examples, among many others, can focus discussions of assumptions as well as impacts. Rather than relying on high and low estimates, governments might instead speak in terms of probabilities and magnitudes. Likely scenarios with significant impacts, for example, might justify more policy and planning attention than unlikely scenarios with minor impacts or even likely scenarios with minor impacts.

C. Legal Strategy Recommendations

Governments should begin to analyze and, as necessary, clarify existing law as it applies to automated driving.

A key initial step is to thoroughly audit existing law. This audit should complement the legal analyses that established developers of automated systems should also be expected to conduct. In contrast to the superficial "autonomous driving laws" passed by some states, an audit would attempt to identify every statute and regulation that could pertain to automated driving, including any that might restrict new kinds of vehicles, services, and products. This audit should give particular scrutiny to laws that deviate from actual reasonable practice, consider how enforcement discretion is and should be used to provide more practical flexibility than statutory language might suggest, and evaluate existing legal tools for regulating automated driving.

If the legal audit does identify a need to change or clarify existing law, governments should carefully pursue that change through legislative act, administrative regulation, executive order, legal interpretation, or policy statement. Policymakers should generally seek uniformity, particularly in the underlying legal frameworks that govern vehicles, drivers, driving, insurance, dealerships, and commercial vehicle operations. The use of standardized levels of automation (particularly those developed by SAE International) and the recognition of determinations made by regulators in other states could provide some of that uniformity. Specific changes might include declaring in good faith that automated driving is consistent with relevant conventions on road traffic, exempting the users of automated vehicles from prohibitions on the use of electronic devices, and establishing a clear legal distinction between driver and passenger.

In order to amplify the potential advantages of automated operation, governments should also enforce existing laws related to speeding, texting, driving while intoxicated, wearing a seatbelt, and maintaining a vehicle. Similarly, governments should make vehicle owners and operators bear the true cost of driving by raising fuel taxes, reducing parking subsidies, raising insurance minimums, and allowing or encouraging insurers to implement pay-as-you-drive and pay-how-you-drive mechanisms for pricing their consumer products.

More broadly, governments should embrace flexibility by giving agencies the statutory authority to achieve regulatory goals through different means, allowing them to make small-scale exemptions to statutory regimes and clarifying their enforcement discretion. (Demonstration projects for automated driving within the EU provide a useful model for these mechanisms.) Many agencies already have considerable authority to encourage or even regulate automated driving but they need flexibility and resources to appropriately use that authority.

D. Community Strategy Recommendations

The success of automated driving systems, particularly truly driverless vehicles that are initially restricted geographically, depends in part on how communities react to them. Governments can begin this conversation by thinking locally and preparing publicly.

A community that wants to attract or implement a truly driverless system should demonstrate that it is a strong candidate for such a system by developing a local plan for automated driving. This plan should identify specific needs and opportunities, especially sites such as airports, central business districts, retirement communities, large shopping centers, and areas dependent on last-mile transit routes. Such a plan could inform subsequent proposals to or even stimulate interest from developers of automated systems as well as a variety of state and federal agencies that may have funds available for transportation, community development, energy efficiency, and defense.

Communities should also identify both public and private networks of support for automation. The public network should reach from a state's governor down to local chiefs of police. The private network should involve key interest groups, companies, and even individuals who could advocate for, and possibly collaborate with, developers of driverless systems.

Governments should also begin to understand the broader implications of automation, including but not limited to automated driving. Investing now in structures to manage technology-induced unemployment or underemployment, shifts in land use in cities and within regions, and disruptions in established industries will help the public and private sectors prepare for potentially huge economic and social changes. Although automated vehicles are likely to be only one small part of these changes, these vehicles may also be one of the more prominent symbols of the next technological revolution.

Finally, governments should share the steps they are taking to promote (as well as to anticipate and regulate) automated driving. Knowledgeable point of contact, accurate websites, and ongoing contributions to the broader public discussion will be important in developing sound public policy, attracting initial deployments, building institutional credibility, and appropriately managing public expectations.

VI. Conclusions

Questions for further research are:

- For platooning to be allowed, do adjustments in laws need to be made for platooning trucks (i.e. closer following distances)?
- Are there any existing state of Iowa laws that complicate the use of automated vehicle technology?
- Is state level legislation needed to regulate automated vehicle technology? If so, what types of legislation would be most beneficial? And how can the legislation be written broadly enough so as not to have to be rewritten each time new or more advanced AVT is introduced?
- In July 2014, Johnson County, Iowa became the first municipality to officially encourage automated vehicle testing as an economic development initiative. In contrast to states that have passed specific legislation on automated vehicles, Iowa advertised its lack of restrictive legislation. Are there benefits (economic and beyond) to continuing with this less burdensome regulatory environment?
- What kinds of vehicles should be allowed (or disallowed) on Iowa roads and who should be allowed to operate them?

References

American Trucking Association. (May 11, 2015). *Trucking Revenues Top $700 Billion for the First Time According to New Report*. Retrieved from: http://www.trucking.org/article.aspx?uid=70210058-bb81-44df-a565-492f899fc139

Anderson, James M.; Kalra, Nidhi; Stanley, Karlyn D.; Sorensen, Paul; Samaras, Constantine; and Oluwatola, Oluwatobi A. (2014). Autonomous Vehicle Technology: A Guide for Policymakers. Retrieved from: http://www.rand.org/pubs/research_reports/RR443-1.html

Autonomous Vehicle Testing License. (2016). Nevada Department of Motor Vehicles. Retrieved from: http://www.dmvnv.com/autonomous.htm

California Legislature. (2012). Senate Bill 1298. September 25, 2012. Retrieved from California Legislative Information: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB1298

Council of the District of Columbia. (2013). Autonomous Vehicle Act of 2012. April 23, 2013. Retrieved from Council of the District of Columbia: http://dcclims1.dccouncil.us/lims/legislation.aspx?LegNo=B19-0931

Florida Autonomous Vehicle Report. (2014). Florida Highway Safety and Motor Vehicles. February 10, 2014. Retrieved from: http://www.flhsmv.gov/html/HSMVAutonomousVehicleReport2014.pdf

Florida House of Representatives. (2012a). House Bill 0599: Transportation and Mitigation Programs. July 1, 2012. Retrieved from Florida Senate: https://www.flsenate.gov/Session/Bill/2012/0599

Florida House of Representatives. (2012b). House Bill 1207: Vehicles with Autonomous Technology. April 16, 2012. Retrieved from Florida Senate: https://www.flsenate.gov/Session/Bill/2012/1207

Garcia, Dominie Ph.D; Hill, Chris Ph.D; Wagner, Jason. (2015). Revolutionizing our Roadways: Cybersecurity Considerations and Automated Vehicle Policy. January 2015. Retrieved from: http://tti.tamu.edu/policy/technology/revolutionizing-our-roadways/

Google Self-Driving Car Project Monthly Report. (November 2015). https://static.googleusercontent.com/media/www.google.com/en//selfdrivingcar/files/reports/report-1115.pdf

Iowa City Area Development. (2014). Proclamation Unanimously Approved on July 24, 2014.

LeSage, J. (2013). Fear of Robo-Cars Stalls Support for Driverless Cars in Oregon. April 4, 2013. Retrieved from: http://automotivedigest.com/2013/04/fear-of-robo-cars-stalls-support-for-driverless-cars-in-oregon/

Michigan Legislature. (2013a). Senate Bill 0169. March 27, 2014. Retrieved from Michigan Legislature: http://www.legislature.mi.gov/(S(rq4nx410b335vwatihvauwmt))/mileg.aspx?page=getobject&objectname=2013-SB-0169

Michigan Legislature. (2013b). Senate Bill 0663. December 27, 2013. Retrieved from Michigan Legislature: http://www.legislature.mi.gov/(S(l55kjkhe50tlg42qs1dn433q))/mileg.aspx?page=GetObject&objectname=2013-SB-0663

Moore, M. & Lu, B. (2011). Autonomous Vehicles for Personal Transport: A Technology Assessment. Social Science Research Network. Retrieved from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1865047

National Conference of State Legislatures. (January 9, 2016). Autonomous/Self-Driving Vehicles Legislation. http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx

NHTSA. (2008). *National Motor Vehicle Crash Causation Survey: Report to Congress.* Washington, D.C.: U.S. Department of Transportation.

NHTSA. (2013). U.S. Department of Transportation Releases Policy on Automated Vehicle Development. May 30, 2013. Retrieved from National Highway Traffic Safety Administration: http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

NHTSA. (2015a). *Traffic Safety Facts: 2014 Crash Data Key Findings*. Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/Pubs/812219.pdf

NHTSA. (2015b). *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*. Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/pubs/812013.pdf

NHTSA. (2016). Secretary Foxx Unveils Obama's FY17 Budget Proposal of Nearly $4 Billion for Automated Vehicles and Announces DOT Initiatives to Accelerate Vehicle Safety Innovations. January 14, 2016. Retrieved from National Highway Traffic Safety Administration: http://www.nhtsa.gov/About+NHTSA/Press+Releases/dot-initiatives-accelerating-vehicle-safety-innovations-01142016

Nevada Legislature. (2011a). Assembly Bill No. 511. June 17, 2011. Retrieved from Nevada Legislature: https://www.leg.state.nv.us/Session/76th2011/reports/history.cfm?ID=1011

Nevada Legislature. (2011b). Senate Bill 140. June 17, 2011. Retrieved from Nevada Legislature: http://leg.state.nv.us/76th2011/Reports/history.cfm?ID=324

Nevada Legislature. (2013). Senate Bill 313. July 1, 2013. Retrieved from Nevada Legislature: http://leg.state.nv.us/session/77th2013/reports/history.cfm?ID=759

North Dakota House of Representatives. (2015). House Bill 1065: An Act to Provide for the Legislative Management Study of Automated Motor Vehicles. March 23, 2015. Retrieved from North Dakota House of Representatives: http://openstates.org/nd/bills/64/HB1065/#billtext

O'Leary, Josh and Santana, Marco. (2014). Ready for a Joyride? Johnson County Oks Driverless Cars. The Des Moines Register. July 25, 2014.

Peloton. (April 2015). Five Fortune 500 Companies Invest to Bring Groundbreaking Truck Automation Technology to Market. http://www.peloton-tech.com/prapril2015/

Sageworks. (2014). U.S. Trucking Companies Deliver Sales, Profit Gains. February 28, 2014. Retrieved from: https://www.sageworks.com/datareleases.aspx?article=202&title=U.S.-trucking-companies-deliver-sales,-profit-gains&date=February-28-2014

Schwarz, Chris Ph.D; Thomas, Geb Ph.D; Nelson, Kory B.S.; McCrary, Michael B.S.; Schlarmann, Nicholas; and Powell, Matthew. (2013). "Towards Autonomous Vehicles." Final Reports & Technical Briefs from Mid-America Transportation Center. Paper 92. http://digitalcommons.unl.edu/matcreports/92

Smith, Bryant Walker. (2014a). Automated Vehicles are Probably Legal in the United States. Retrieved from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2303904

Smith, Bryant Walker. (2014b). CCTV: Bryant Walker Smith of Univ. of South Carolina Discusses Driverless Cars. November 21, 2014. Retrieved from: https://www.youtube.com/watch?v=8wyDUm338Y0

Smith, Bryant Walker. (2015). Automated Vehicle Liability. As presented at the TRB-AUVSI Automated Vehicles Symposium. July 22, 2015. Retrieved from: http://newlypossible.org/files/presentations/2015-07-22_TRB-AUVSI_Liability.pdf

Tennessee Legislature. (2015). Senate Bill 598: Motor Vehicles. May 6, 2015. Retrieved from the Tennessee Legislature: http://openstates.org/tn/bills/109/SB598/

Appendices

Appendix 1. List of Acronyms

ACC	Adaptive Cruise Control
AVT	Automated Vehicle Technology
DMV	Department of Motor Vehicles
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
GPS	Global Positioning System
IR	Infrared
LRR	Long Range Radar
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automated Engineers
SARTRE	Safe Road Trains for the Environment
SLAM	Simultaneous Location and Mapping
SRR	Short Range Radar
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle

Appendix 2. Society of Automotive Engineers (SAE) Levels of Automation Descriptions

http://www.sae.org/misc/pdfs/automated_driving.pdf