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Automated Vehicle Policy and Technology: The Potential to Intersect with Shared Use Mobility Services

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Abstract

This paper reviews national and state level policies regarding the introduction and use of automated vehicles in the United States, and recommends policies going forward. Virtually none of the recommended policies has been implemented to date, but some are urgently needed before automated vehicles become widespread. These include restrictions on the use of internal combustion engines in AVs, and monetary or regulatory measures to discourage low (and zero) occupancy vehicle driving as well as general increases in vehicle travel, along with measures to ensure that commercial use of automated vehicles is compatible/complementary with transit system use. General restrictions on private ownership of AVs may be needed at least for a period of time to ensure that they enter service as societally beneficial vehicles. So far existing policies are focused mainly on the legality of different levels of automation and various efforts to ensure a safe introduction of AVs. A few states (such as Michigan) are now encouraging introduction of AVs by reducing restrictions. These can be important steps but fall far short of what is needed.

1. Introduction

Automated vehicles (AVs) have begun to emerge in the US market, and other parts of the globe. Their emergence has been coupled with a discussion of how they fit into existing transportation systems. This discussion has begun to largely revolve around two possible futures that are, in many ways, at odds. In one possible future, AVs are primarily used for on-demand ride services, and what's more those rides may be shared among multiple passengers simultaneously. In this future travelers adopt a different culture of transportation, and utilize many modes of travel, including autonomous vehicle systems that are well integrated with alternative modes such as transit, and bikeshare. In the alternative future, ownership of AVs will be similar to current personal vehicle ownership, and exclusive use of each vehicle will belong to one individual or household. In this future, the use of AVs is expected to increase VMT, as commutes become more amenable to multi-tasking and thus longer. At the same time, AVs may be sent off long distances to find parking, circle the block to avoid parking, or if fuel costs remain negligible, run errands with no need for efficiency.

The differences between these two possible futures depends largely on how AVs are owned, and how they are used. There are certainly a number of potential outcomes, and there are several factors that will determine which flavor of AV use comes to dominate in the next ten years, and what our transportation system looks like thirty years from now. In this report we consider automated vehicles in the context of emerging transportation services such as on-demand ride services and shared ride systems. We investigate policy solutions that address the potentially disruptive outcomes of these services and technologies, and incorporate relevant social goals. Specifically, we focus on policies to reduce transportation emissions and provide equitable transportation access, and emerging policies around the allowance/support of increasingly connected and automated vehicles. We examine the potential impacts of policies that incentivize the use of lower-emission vehicles and pooled ride services such as Lyftline with drivers or automated vehicles, and policies that facilitate improved access in underserved areas.

In the next two sections, we provide a background on the current issues related to automated vehicles, and a brief overview of automated vehicle technology. In section 4 we discuss current state and federal policies in the US. Section 5 covers consumer perceptions and relevant issues in travel behavior. Section 6 gets in to the connection of automated vehicles with shared use mobility, and in section 7 we close with a presentation of some potential directions forward for automated vehicles.

2. Background

The discussion related to automated vehicles is centered on a set of key topics, each of which relates to the two possible futures noted above to varying degrees. Automated vehicles may provide opportunities to improve transportation safety, and access and to reduce associated externalities, but they may also lead to worsening congestion and urban sprawl, and possibly lower vehicle occupancy rates, and higher per-capita vehicle miles travelled (VMT). Additional concerns include privacy, as connected vehicles may transmit sensitive information, or become targets of hacking. Some worry about job loss in transportation industries; bus and taxi drivers, freight delivery, etc. Lastly, there is concern that the costs of these vehicles will make them unattainable for most, or that families will sacrifice other needs or freedoms in order to pay for their own automated car. There are also logistic and legal obstacles, like insurance and liability. The future of transportation, with automated vehicles depends largely on how these considerations are addressed, and how quickly the technology becomes available.

SAFETY

Automated vehicles are heralded as a much safer alternative to human drivers. The computers that drive these vehicles do not get tired, are not distracted, and process more information, and more quickly than humans. These features, along with the expectation that these vehicles will communicate with one another about road conditions, traffic, landscape features, and appropriate responses is expected to vastly reduce transportation related fatalities. There is not a lot of debate about the potential for safety improvements, however there are questions about the rollout of different technologies and how different levels of automation affect safety.

One of the greatest uncertainties related to automated vehicle safety is driver reengagement. Currently, outside of testing, no vehicles are fully automated; meaning there are no vehicles that can take over all functions of driving with no input from a human driver. The current technology coupled with most existing state level policies, require drivers to stay engaged with the driving task. However, because the combined features available today do allow the driver to disengage, specifically during highway travel, there are anecdotes of "drivers" engaging in other tasks while behind the wheel and relying on the combined use of features like lane-control and variable speed cruise control. These features keep the vehicle following the lane and the vehicle in front at a specified distance (rather than a set speed). While there are few incidents reported of the AV systems failing in these situations, the primary concern is not related to the capabilities of the automated vehicles themselves, but rather the human driver's ability to re-engage with the driving task, and how quickly one is able to provide adequate attention to safely retake control of the vehicle in moving traffic. It is for this reason, that Google X's Chris Urmson urges the skipping the development of partially automated vehicles, and work towards fully driverless cars (Urmson, Chris 2015).

EMISSIONS REDUCTIONS

There is uncertainty about whether automated vehicles will increase or reduce greenhouse gas emissions. This partially depends on whether or not these vehicles will be electric, but is also related to how they are used, and the associated VMT. Some suggest that since the electric power systems are more compatible with the technologies that drive automated vehicles, they will likely be electric. There is a trend towards increased electricity in the transportation sector that also suggests a much higher percentage of vehicles, including AVs, will be electric in the not too distant future. Electrification will reduce emissions from travel, but there are other potential ways for automated vehicles to contribute to emissions reductions. If the highest levels of automation are achieved, some safety features and equipment will no longer be necessary, and this will make vehicles lighter, and more energy efficient. Further, regardless of whether AVs are shared vs. individually owned, programming can keep them driving more smoothly, under speed limits, with fewer stops and starts, all leading to a more efficient use of fuel. Automated vehicles could be "eco-drivers" by default.

There will be additional emissions reductions when there are higher proportions of automated vehicles on the road, and vehicle to vehicle communication (often referred to as connected and autonomous vehicles). Connected vehicles will be able to share information about their speed, braking and upcoming hazards, allowing vehicles to travel more closely behind one another, and providing the added benefit of 'drafting', where each vehicle pulls along the one behind it. At the same time, all of this communicating will prevent frequent stops and starts, and allow traffic at large to flow more smoothly. All of this could contribute to substantial emissions reductions.

These outcomes are not inevitable though. AVs will not necessarily be electric, and policy makers do not currently appear willing to support the development of vehicles without human-operated safety equipment like steering wheels and brake pedals. Thus the weight and driving patterns of autonomous vehicles may not be different from conventional vehicles for some time. Some of the other potential benefits depend on programming, which may or may not be manipulated in ways that promote eco-driving, and if left to individual owners, there could be a wide variety of settings used in practice.

ACCESS AND MOBILITY

Another expected benefit from automated vehicles is improved access and mobility for those who are not able to drive themselves, or who will benefit from the assistance provided by automation. These groups may include the elderly, disabled and vision impaired, and others for whom driving is not possible. Indeed, there is some evidence that ride-hailing services such as Uber and Lyft already offer these benefits to some of these communities. Indeed, if AVs are operated in fleets, and under shared use models, there may be benefits for many individuals to use them; even more than current on-demand ride-hailing services, since with truly driverless cars, the costs are greatly reduced.

Some also wonder about those who have limited transportation access for other reasons. The US is not known for good public transportation, and the expense of vehicles leaves a portion of the population without convenient and reliable transportation. On-demand ride services, and shared automated vehicles have the potential to fill in some of these gaps in public transportation, and improve transportation access for these groups. However, because automated vehicles will likely remain one of the most expensive vehicle options on the market; the more automated features, the more expensive the vehicle, these vehicles will not likely be available to everyone for private individual ownership. So, if they are not operated in shared fleets, or if the cost savings are not great enough for these vehicles to be a good option for on-demand ride service providers, vehicle automation will do little to help fill in the service gaps for disabled groups nor groups in areas with poor transportation access.

LAND USE AND SPRAWL

Vehicle automation may lead to longer commutes and worsening urban sprawl. Automated vehicles could allow one to sleep, read the news, watch TV, catch up on work, or possibly eat dinner, or do a little yoga… the possibilities are almost endless, and would make travel time more useful, at least for some. Though not all see travel time as a waste, and some do enjoy driving in and of itself, there is the possibility that automation will lead to more comfortable commutes, and in turn longer commutes and worsening sprawl; this has a number of negative impacts, including conversion of natural areas and agricultural lands, increased separation and segmentation of communities, and potentially the degradation of downtown areas. If AVs are electric, there may be limited impacts to emissions, but if they are not, these impacts would be exacerbated by worsening emissions. If AVs result in higher VMT, and people spend more time on the road we will surely see worse congestion.

There are also potential positive land use changes associated with AVs. If AVs are largely used in shared models, it is expected to result in reduced parking needs in urban areas. Areas currently devoted to parking could be converted to infrastructure for walking and biking, sidewalk cafes or other types of public spaces. Parking requirements facing developers could also be reduced for shopping centers, apartment buildings and employment centers, freeing up space for other uses, including open space, parks, denser development patterns and/or a more balance mix of uses with employment centers located closer to residential areas.

VEHICLE OCCUPANCY, VMT, AND CONGESTION

One of the great benefits of automated vehicles may be the owner or user's ability to summon the vehicle when needed, and send it off on its own to find parking. However AVs are used, there will likely be some travel that has no passengers. If AVs are shared, they could pick up and drop off passengers one after another, with little to no zero-occupancy travel. At the other extreme, no-passenger trips could involve individually owned AVs driving back to an owner's home after a morning commute, only to return (empty) to pick up the owner at the end of the day; essentially doubling VMT. While this would depend on gas prices and parking costs, there would likely be some commuters for whom this would be the lowest cost solution to parking. If there is a substantial number of empty vehicles on roadways, mixing in with regular traffic, there could be greatly worsened congestion and associated emissions.

ECONOMIC IMPACTS

One of the most often cited potential economic impacts of automated vehicles is the loss of jobs in the transportation sector; this could range from taxi drivers to truckers and many positions in between that require a human to control a vehicle as their primary job. The loss of these jobs could leave to dramatic increases in unemployment. It is also possible that as labor costs drop, so do the prices on consumer goods. Perhaps we ought to imagine a future where machines and robots do all the work, and humans are free to pursue out individual interests.

Another economic impact expected to result from the increased use of automated vehicles is loss of revenue from transportation infractions and parking fees. This would result because automated vehicles are expected to follow regulations consistently at all times, whereas human drivers do not. Speeding tickets, and other fines would go away, such as those for driving under the influence. At the same time, parking fees and parking ticket revenues would likely decrease, as automated vehicles could simply not park, and drive around the block while waiting for a passenger, or drive away from dense urban areas with high parking costs, and park in lower cost or free areas. If automated vehicles are shared, these fees would also go away, as there would be limited need for parking. The loss of revenues from traffic and parking violations would further reduce funds available to maintain transportation infrastructure, and provide transportation services. However, with good planning and pricing, these impacts could be minimized.

PASSENGER INTERESTS

What will it take for automated vehicles to be widely adopted? Are consumers even interested and willing to ride in automated vehicles? According to a recent report and study by the Boston Consulting Group, in collaboration with the World Economic Forum, most people would be willing to take a ride in a fully or partially automated vehicle (Boston Consulting Group 2016). In the same report, 43% of respondents reported not needing to find parking as a main reason to use automated vehicles. Multitasking while riding was a close second, with 40% of respondents selecting this as a main benefit (Boston Consulting Group 2016). A second similar international study found that respondents expected to engage in various tasks while a driver or passenger, with increasing likelihood for more automation, other than listening to the radio. Some of the highest reported activities, for fully automated vehicles included “Phoning”, “Eating”, “Passengers” and “Observing” (Kyriakidis et al. 2015). In another look at the perceived benefits of survey participants noted safety, amenities, and convenience most frequently as the most attractive features of self-driving cars (Howard and Dai 2013).

At the same time, the top two concerns about automated vehicles were not feeling safe (50%) and wanting to be in control (45%) (Boston Consulting Group 2016BCG 2016). In another study, the participants selected hacking and misuse as well as safety and legal issues as their highest concerns (Kyriakidis et al. 2015). Howard and Dai (2013) find that respondents selected control, liability, and cost among the least attractive features of self-driving cars. Many individuals are willing to use AVs, though there are a number of concerns that have been expressed. Perhaps comfort will increase as more people know someone who has ridden in, or owned some form of automated vehicle.

Indeed, all of these concerns related to automated vehicles could be problematic if they are not addressed with timely and appropriate policies. There is great uncertainty related to these technologies, and the outcomes will depend on how the technology progresses, the development of a shared use transportation culture, and the implementation of sound policy and regulations.

3. Automated Vehicle Technology: Development and Classifications

EARLY DEVELOPMENT OF VEHICLE AUTOMATION

Vehicle automation has been introduced in a number of science fiction scenarios, and some features of automation are well integrated into airplanes, and some transit systems, but it has not been close to a reality in cars until very recently. Early development grew out of university robotics labs at University of California, Berkeley and Carnegie Mellon University. UC Berkeley's PATH program developed an automated vehicle that used magnets in the roadway as early as the 1980s. In 1997, PATH hosted a demo in Southern California, with a platoon of eight automated vehicles maneuvering while drivers "waved their hands to show that they were not doing the steering." (Shladover 2007). Around the same time in 1995, a team at Carnegie Mellon University developed automated vehicle technology and completed "No Hands Across America", an automated vehicle trip from Pittsburgh to San Diego. The project website reports that the vehicle was "driving autonomously 2800 of the 2850 miles across the country" (No Hands Across America 1995).

Early attempts to stimulate research and development of automated vehicles in the US came from the Defense Advanced Research Projects Agency (DARPA) challenges. DARPA is the research and development branch of the Department of Defense. DARPA conducted three challenges from 2004 to 2007 in Southern California and Nevada. The first challenge, called the Grand Challenge, required vehicles to leave from Barstow, California and "…automatedly navigate a 142-mile course that ran across the desert to Primm, Nev." None of the entrants successfully completed the course. The most successful competitor made it only 7.5 miles. (DARPA 2014). The Second Grand Challenge took place just eighteen months later, on a 132-mile course in southern Nevada. First prize went to Stanford University, and their entry "Stanley". Four other teams were also successful.

The third DARPA challenge, the Urban Challenge took place a few years later, in 2007 in Victorville, California. This course was different from the course in the two Grand Challenges. The vehicles had to navigate a simulated urban environment, including weaving in and out of traffic, correctly passing through four-way stop intersections. The course also included thirty manned vehicles to increase the density of traffic on the roadway during the contest. Six teams completed the course, with Carnegie Mellon University taking the grand prize.

The vehicles in the DARPA challenges were able to navigate the courses without additional input. The rules state, "Vehicles may be tele-operated for staging purposes, but during demonstration or testing all processing and navigation must be done by systems aboard the vehicle. Cooperation of any kind among vehicles during the site visit, NQE or the UFE events is prohibited" (DARPA 2007). Thus, fully automated or truly driverless vehicle technology was demonstrated during the DARPA Urban Challenge. However, the vehicles took a long time to execute the challenges, and the vehicles were single proto-types of what will need to become widely available in order to have a substantial impact on transportation.

LEVELS OF AUTOMATION

Today, vehicle automation is progressing to varying degrees, across a number of startups and vehicle manufacturers. In the next section, we discuss policies related to automation, and it is important to note here, that the policies generally include definitions, for terms such as autonomous vehicle, automated driving system and others. Though federal policy identifies levels of automation, there is little consistency across industry, government, and other interest groups related to the use of different terms, and how they correspond to these levels of automation.

The National Highway Traffic Safety Administration uses the following definitions of the levels of automation (NHTSA 2016):

> Note on "Levels of Automation" There are multiple definitions for various levels of automation and for some time there has been need for standardization to aid clarity and consistency. Therefore, this Policy adopts the SAE International (SAE) definitions for levels of automation. The SAE definitions divide vehicles into levels based on "who does what, when."4 Generally:
>
> • At SAE Level 0, the human driver does everything;
>
> • At SAE Level 1, an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task;
>
> • At SAE Level 2, an automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task;
>
> • At SAE Level 3, an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests;
>
> • At SAE Level 4, an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions; and
>
> • At SAE Level 5, the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

The classifications listed above describe what vehicles at different levels of automation are capable of doing, but it is of course the underlying technology that enables the vehicles to have these capabilities. Some of the most important features of the technology include sensing the environment and surroundings, and processing the information in order to perform the correct vehicle actions. Thus, the sensors, and the decision making components of the vehicles are integral to its function and ability to achieve the desired outcomes, such as getting passengers where they want to go, avoiding collisions, and obeying relevant traffic laws. The technologies required for monitoring the environment include cameras, light- or sound-sensing technology such as radar or lidar, and GPS potentially in combination with internal navigation systems (maps that are stored locally within the vehicle and can help with navigation when temporarily disconnected from GPS).

Commercially available vehicles currently go up to level 2 and 3. Fully automated vehicles; at level 4 may be operating as test vehicles, and these technologies are improving all the time. It is not the purpose of this report to describe the details of each company's current technology, nor do we expect to find such information publicly available. Here, we assume that the various levels of automation will be available at some point in the future, and frame our discussion in terms of expectations related to full automation.

4. Current policies covering automated vehicles

The state of automated vehicle technology, and the related policies have been piggybacking, and leapfrogging all over the place. The technologies are nascent, and until recently, existing transportation policy said nothing about vehicle automation. One recent article even goes to great lengths to describe why the vehicles are "probably legal", but that it could be contested for a variety of reasons (Smith 2014). Things are changing quickly, and Smith's article is potentially out of date, just a few short years later. However, some of the key points made about relevant terminology and its legal interpretation offer a good starting point for the discussion of relevant policies. For example, legally, what does it mean to be the driver of a vehicle; what does it mean to be in control of the vehicle?

Who is the driver, is a key consideration since the driver is assumed to be responsible for what the vehicle does. In the US, this could be the person who is sitting in the driver's seat, and possibly sets the route, or at least the destination, and provides some input to the vehicle to operate in the automated program.

While automated vehicles are not expressly prohibited, there may be instances, specifically in state regulations that inadvertently limit the use of automated vehicles, or some of their features, because of existing regulations such as keeping a hand on the steering wheel, or not following the vehicle in front of you too closely (Smith 2014).

First, we describe the current federal policy related to automated vehicles. This is followed by a brief description of existing state policies, and a discussion of how AVs are considered at the local level.

FEDERAL POLICY

The federal policies on automated vehicles provide background and guidance on a number of issues related to automated vehicles and make suggestions for state level policy. The National Highway Safety Administration put forth the following summary in a fact sheet on the policy:

Components of the Policy:

- Vehicle Performance Guidance for Automated Vehicles: The guidance for manufacturers, developers and other organizations outlines a 15 point "Safety Assessment" for the safe design, development, testing and deployment of automated vehicles.
- Model State Policy: This section presents a clear distinction between Federal and State responsibilities for regulation of HAVs, and suggests recommended policy areas for states to consider with a goal of generating a consistent national framework for the testing and deployment of highly automated vehicles.
- Current Regulatory Tools: This discussion outlines DOT's current regulatory tools that can be used to accelerate the safe development of HAVs, such as interpreting current rules to allow for greater flexibility in design and providing limited exemptions to allow for testing of nontraditional vehicle designs in a more timely fashion.
- Modern Regulatory Tools: This discussion identifies potential new regulatory tools and statutory authorities that may aid the safe and efficient deployment of new lifesaving technologies.

The policies also distinguish between the role of the federal government, largely focused on the vehicles, and the technologies and safety features of vehicles, versus the role of state governments, which deal with operation of vehicles within each state, including licensing of drivers and vehicles – and classification of such licenses. The guidelines for the state policy suggest a number of areas to be covered:

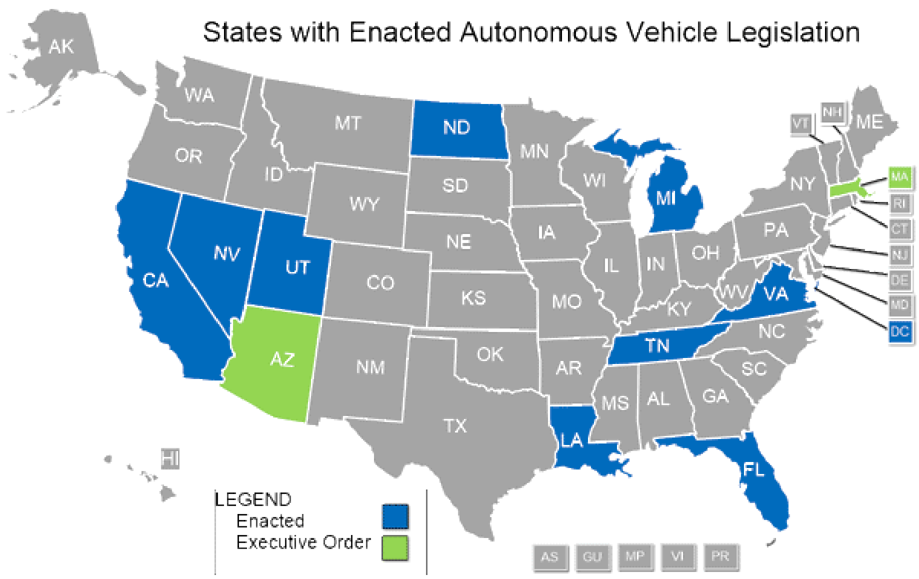
- Administrative structure and processes that States can set up to administer requirements regarding the use of public roads for HAV testing and deployment in their States;
- Application by manufacturers or other entities to test HAVs on public roads;
- Jurisdictional permission to test;

- Testing by the manufacturer or other entities;
- Drivers of deployed vehicles;
- Registration and titling of deployed vehicles;
- Law enforcement considerations; and
- Liability and insurance.

STATE POLICY

Few states have successfully passed legislation related to the certification, testing and operation of automated vehicles. The current policies largely address the points noted above, from NHTSA. The National Conference of State Legislatures keeps track of state level regulations and the introduction of legislation at the state level that has not passed. The map below, shows the states that had automated vehicle policies in place, as of January 2017.

Figure 1: States with Automated Vehicle Legislation



Source: National Conference of State Legislatures; [www.ncsl.org (accessed January 31, 2017)](http://www.ncsl.org)

The number of states with legislation and/or regulations related automated vehicles is growing, and even those with legislation on the books as early as a few years ago, continue to update their rules and allowances for automated vehicles. For example, Michigan first passed legislation in 2013, but then in 2016 four new bills were passed related to automated vehicles. Reviewing the proposed legislation on the NCSL website also indicates that many states have some legislators actively trying to pursue rules related to autonomous vehicles; many have failed in the state legislatures, but others, for example in Massachusetts, New Jersey, and New York are in committees.

Table 1 highlights some of the key aspects of the policies that have been enacted thus far. Typically, states have passed legislation that defines autonomous vehicles, automated mode, driving tasks and other related terms. In addition, many of the state level policies set forth insurance and liability responsibilities, and identify agencies responsible for introducing regulations and permitting processes. Most state policies initially only allowed for vehicle testing, and required an individual be ready to take over the vehicle if any problems arose. Some states are beginning to relax these requirements, and allow vehicles to operate outside of testing, and in some cases, without a human operator ready to retake control.

Table 1: State Legislative Actions on Automated Vehicles

State	Key Legislative Actions
California	• Sets definitions, provides rules for automated vehicle testing on California roadways. • Outlines liability requirements for manufacturers and third parties and necessary driver qualifications, reporting requirements and the types and classes of vehicles that are permitted for autonomous driving. Qualifications for drivers, and testing permits. Reporting requirements for accidents and other events with the automated vehicles when on the road. • Another piece of California legislation, passed in September 2016 permits the testing of vehicles that do not have a steering wheel, brake pedals, nor an operator; if the testing occurs in specific areas of Contra Costa County, and vehicle is moving less than 35 mph. (CA Legis. Senate 2012, CA Legis. Assembly 2016)
Florida	• Defines terms, sets requirements for certification and registration. • Requires indicators within the vehicle that show when the automated system is engaged, and mechanisms to alert the driver when there are issues with the system. Or the vbehicle must be able to come to a stop on its own. • April 2016 revisions: “deleting a requirement that a human operator be present in an autonomous vehicle for testing purposes”. All language related to testing is removed from the legislation. • Permits the driver to watch “moving video displays” while in such vehicles. (FL Legis. House 2012, 2016)
Louisiana	• Legislation is limited to the definitions of terms related to automated vehicles and various modes of operation. The regulation does not currently go beyond this, but perhaps it will in the near future. (LA Legis. House 2016)
Michigan	• Defines “Automated motor vehicle”, and “Automatic Mode” • Changes the definition of the term operate • Allows automated vehicles to operate on Michigan roadways, solely for testing. • Sets requirements for license plates, and registration, drivers of automated vehicles, who can operate the vehicle, and in what ways. • Provides guidance on liability: “257.817 – Manufacturer immunity: “A manufacturer of automated technology is immune from civil liability for damages that arise out of any modification made by another person to a motor vehicle or an automated motor vehicle, or to any automated technology, as provided in section 2949b of the revised judicature act of 1961, 1961 PA 236, MCL 600.2949b.” • December 2016 updated legislation: “The four-bill package, championed by lawmakers as the first of its kind, would allow automated vehicles to be driven on roads in the state for any reason, not only while being tested. Supporters, including such automakers as General Motors Co. and Ford Motor Co., say the legislation is necessary to establish Michigan as a leader in the nascent industry.” (Vanhulle 2016). This legislation also approved a large test area for AVs; the American Center for Mobility. This will cover 330 acres, in a test track near Ypsilanti, at a former GM facility. It is possible that this area will become a national test ground for AV technologies (Vanhulle 2016)

	• These updates also allow for on-demand services to be operated using autonomous vehicles. (MI Legis. Senate 2013a, 2013b, 2016a, 2016b, 2016c, 2016d).
Nevada	• Enables testing and operation of automated vehicles. (Testing only permitted thus far). • Requires the Department of Motor Vehicles to adopt regulations authorizing the operation of autonomous vehicles on highways within the State of Nevada. • Requires DMV to adopt regulations to establish a driver's license endorsement for operation of autonomous vehicles. • Defines automated vehicle: a motor vehicle that uses artificial intelligence, sensors and global positioning system coordinates to drive itself without the active intervention of a human operator. (NRS 482A.030) • Sets requirements for human operators in test vehicles, and conditions for operation and testing on state roadways. • Outlines liability requirements and responsibilities. (NV Legis. Assembly 2011, NV Legis. Senate 2013)
North Dakota	• Sets up a program for the testing of automated vehicles, but the legislation also includes language on the operation of vehicles in the state • Rules *will* be developed for the operation of automated vehicles on North Dakota highways and roadways; they are not yet allowed. (ND Legis. House 2015)
Tennessee	• Initial legislation prohibits local governments from independently enacting rules related to automated vehicles; leaving the regulation of AV certification and operation to the state government. • Allows visual displays to be used in autonomous vehicles, when they are integrated in such a way that they are immediately disabled when autonomous operation is suspended. • Sets requirements for testing and operation of autonomous vehicles. • Imposes a use tax on autonomous vehicles, to be distributed among the state's general fund, the state's highway fund, counties and municipalities. (TN Legis. Senate 2015, 2016)
Utah	• Requires a study of current regulations, and best practices the federal policy related to AVs, and the current safety and other considerations, and a timeline for this report to be completed and presented. • Permits transportation agencies to contract with others for vehicle testing, though the rules for testing are not included in current legislation. • Additional legislation relaxes safe following distances for connected vehicles, which are being tested. (UT Legis. House 2015, 2016)
Virginia	• Allows viewing visual displays while a vehicle is operating autonomously – no additional legislation. (VA Legis. House 2016)
Washington DC	• Defines automated vehicles, and drivers • Sets regulations for the conditions under which an automated vehicle can be operated; however not clear if there is a set of licensing either for the vehicles, or for the drivers/operators. • Addresses liability for conversion of existing vehicles and original manufacturers. (District of Columbia 2012)

LOCAL POLICY

At the local level, there has been limited activity related to automated vehicles. Regional and Long-range Transportation Plans do not mention automated vehicles, much less provide planning or policy suggestions for how to deal with them at the local level, save one that mentions them, without including policy (Guerra 2015). In an interview-based study Guerra (2015) reports that MPO interviewees are reluctant to incorporate automated vehicles into planning efforts primarily because of the great uncertainty about how the technology will progress, what consumer responses will be, and what the federal and state policies might be related to these technologies. Other reasons that planners at the local level have not addressed these technologies include: they are too far removed from the things that planners do, namely decide to what infrastructure projects to allocate funding. At the same time, MPO interviewees noted that there are a number of other potential "game changers" that could also have large impacts on the future of transportation and local transportation planning, so they must divide their resources among several potentially impactful issues (Guerra 2015).

Policy makers and planners from the cities interviewed by BCG report that they expect individual privately owned cars to be banned from city centers with increasing regularity, beginning in the next 10-15 years (Boston Consulting Group 2016).

FUTURE POLICY LANDSCAPE

What will automated vehicle policy look like in the future? It is plausible that as companies develop new technologies, they will work to legalize their introduction. Smith (2016) describes a set of steps ranging from preparing government, and evaluating relevant existing laws, to collaborating with private developers and communicating with the public, all with the aim of supporting or promoting the development and deployment of automated vehicles. The idea that the development of these vehicles and related policies should be encouraged stems from the safety benefits they are expected to extend, and the anticipated advances that might be best incorporated into regulatory efforts, rather than a wait-and-see approach.

Thus far, policy related to the testing and use of AVs has not stemmed from environmental nor equity concerns. The potential long term impacts of AVs are the focus of discussions among transportation experts, planners, and environmental advocates, however; policy is largely focused on how to introduce the vehicles onto roadways without sacrifices to safety or security. Perhaps it is not yet time to address the environmental and equity implications of autonomous vehicles, but if policy makers don't take action soon, when will it be too late?

5. Automated Vehicles and Shared Use Mobility

With or without drivers, positive impacts of on-demand ride-hailing on environmental sustainability are expected to occur through reductions in VMT, congestion and related emissions. On-demand ride-hailing services provide the potential to improve access, reduce the cost of travel, and reduce the environmental impact of transportation, mostly by reducing dependence on carbon-intensive single-occupant vehicles and by providing new choices and greater flexibility. The best model of positive impacts involves high load factors, use of low-carbon vehicles, and increased use of conventional bus and rail transit and bikes by providing first and last mile connections.

AVs in the context of shared use mobility make sense because as vehicles become more automated, all drivers can become passengers, and at the same time, the companies offering on-demand ride services will benefit greatly as they will no longer have the expense of drivers. Indeed, one component of Lyft's partnership with GM is the development of AVs to deploy in their services, and Uber has partnered with Carnegie Mellon University, and is currently running a small fleet of AVs on the streets of Pittsburgh, in Uber service. The State of Michigan recently passed legislation allowing for the operation of on-demand services with autonomous vehicles, taking one step closer to making on-demand ride services with automated vehicles a reality.

There is some evidence that early on-demand ride-hailing and other shared use transportation services facilitate positive sustainability outcomes. For example carsharing participants own fewer vehicles than others (Martin et al. 2010), and that those who use ride-sourcing services may have lower VMT (Rayle et al. 2014), less dependency on automobile travel, and in some cases reduced levels of vehicle ownership (Dutzik et. al 2013). Those who use on-demand ride-hailing services also tend to use transit (American Public Transportation Association 2016).

These early studies of on-demand ride services suggest that they can affect shifts towards more sustainable transportation patterns, including reduced household vehicles, and VMT. However, on-demand ride-hailing services also have the potential to increase auto travel, VMT and possibly congestion; if there is a tendency to replace transit trips with on-demand ride-hailing. Thus, in order to achieve the best sustainable transportation outcomes incorporating on-demand ride-hailing, policy intervention is likely necessary. The authors of TRB Special Report 319 call on policy makers to "formulate public policies and regulations designed to steer the development of innovative services to improve mobility, safety, and sustainability." (Taylor 2016 p. 102).

The on-demand transportation services industry is also very creative and innovative, and some industry practices may be good resources in the development of sustainable transportation policies for on-demand ride-hailing. For example, the two largest companies, Uber and Lyft, both offer services described as ridesplitting: a form of ridesharing but where a single driver picks up separate passengers on the same trip, with possibly separate origins and destinations.

Ridesplitting can reduce total VMT, decrease the number of vehicles on the road, improve the efficiency of drivers' time, and reduce costs per passenger, all without substantially impacting the convenience of the service. Though ridesplitting may not have been introduced with sustainable transportation goals in mind, it has the potential to be part of the means for improving the sustainability impacts of on-demand ride-hailing. To the extent that service providers see ridesplitting as desirable for their business, there is an alignment of business models and the public interest. Policy can be used to enhance this alignment.

Current trends in automation, largely focused on partial automation and traditional models of car ownership and use, do not suggest we will arrive at a shared system of automated vehicles in the near term. Indeed, some authors suggests we will live in a world of privately owned partially automated vehicles for many years to come. It will be years before these vehicles are replaced by fully automated and shared vehicles operating in possibly publicly owned, or publicly accessible, fleets (Grush 2016).

On the other hand, near term future scenarios with AVs and shared use could align with sustainable transportation goals. Even if some AVs are owned and used by individuals or households, those same vehicles could be sent out during the times they are not needed, to offer rides to others, and the owners could partially offset the costs of the AV, while at the same time providing a benefit to the public, and likely contributing to reductions in transportation emissions. Or, most AVs could operate as shared vehicles/on-demand ride services. It is likely impossible to avoid some level of zero-occupancy travel with automated vehicles, however integrating shared use mobility with automated vehicles can likely reduce the level of zero-occupancy travel.

Given that the operators of on-demand ride services are likely to incorporate AVs to the greatest extent allowable and feasible, the policy considerations for improving environmental and equity outcomes, should ask how to increase the use of shared use mobility alternatives, including the operation of AVs as shared use services, *rather than* individually owned and operated vehicles. The types of policies that would achieve this shift must promote shared use mobility alternatives, incentivize the most environmentally beneficial aspects of shared use mobility, and discourage the potential downsides of individual use of autonomous vehicles. Some potential policy avenues include promoting shared use mobility, incentivizing the positive outcomes of automated vehicles, and penalizing the potential negative outcomes. In section 6 we explore potential policy options related to these and other aspects of automated vehicles and sustainable and equitable transportation.

6. Policy for Addressing Environmental Impacts of Automated Vehicles

There is much uncertainty about the future rollout of automated vehicle technologies, however one thing we do know is that their production is not waiting for anyone. Policy makers are working to catch up with the vehicles that have been introduced thus far, and early adopters are purchasing and using partially automated vehicles in ways that may or may not be recommended by manufacturers. It is quite possible that federal and state policies will continue to play catchup with industry advancement, and input. The discussion among transportation experts, and planners surrounding vehicle automation involves a number of issues related to environmental, economic, safety and other concerns, however, aside from safety, policies related to automated vehicles do not address these topics. It is not likely that a comprehensive set of policies addressing all of these issues will be in place in the near future, if at all, though there are a number of potential policies that could help to reduce the anticipated environmental impacts of automated vehicles (especially when fully automated vehicles are widely available).

We expect a reduction in the environmental impacts of automated vehicles from policies that support shared use of autonomous vehicles, aim to reduce per-capita VMT, and increase the use of electric and alternative fuel vehicles. A number of policies could support these outcomes. In this table we present some potential policies to achieve these outcomes; policies are differentiated between the goal, whether they target the vehicle, or its use, and whether they are regulatory of market based. Any combination of these policies, or others may help to best reduce the environmental impacts of automated vehicles. Below we discuss a number of these policy options in more detail.

TABLE 2: Policy Possibilities for Automated Vehicles

Goal	Target	Regulatory	Market Based
Promote Shared Use Mobility	Vehicle/ Tech Based	Restrict private ownership of AVs; ensure safety/security of passengers through design standards	Fee for non-commercial (e.g. individual) purchase of AVs
	Use Based	Restrict application of light-duty (e.g. 4/5 passenger) AVs in situations that may compete with public transit. Encourage TNCs to partner with transit agencies to integrate services	provide incentives for shared trips and/or tax single occupant trips provide incentives for connecting to transit systems Allow use of certain public infrastructure/parking for AVs operating in fleets Auction permits for providing service to disabled populations in specific areas
Minimize Increases in Per-capita VMT		Ban non-commercial AVs entirely, or from commercial centers	VMT fee for individually owned/operated AVs or for zero-occupant travel miles

		Require AVs to be used in ride-splitting services like Lyftline or UberPool	Provide some public infrastructure for ride-splitting services
Increase Electrification of AVs	Vehicle/ Tech Based	Mandate all AVs are electric or other ZEV/alternative fuel vehicles	Extra credits for AVs that are electric or vice versa (e.g. in ZEV mandate) Extension of existing EV purchase incentives and rebates to AVs Provide funding for research and development
	Use Based	Restrict ICE AVs (or all ICEs) from preferred parking, roads, zones	Tax systems based on fuel/energy type, CO2 emissions that clearly make ICE AVs disadvantageous. Could be linked to occupancy taxes/incentives

PROMOTE SHARED USE MOBILITY

The use of shared use mobility will likely continue to grow as the industry gains recognition and the services are adapted to new markets. Both Uber and Lyft have partnered with health care and other special interest groups to provide service specifically for medical appointments and other similar types of travel. Shared use mobility is also being promoted through a number of programs linking on-demand ride services to public transportation, through subsidies of trips originating or ending at transit stops. These programs are expected to increase the use of on-demand ride services and the use of transit, while also improving accessibility (typically for specific locations). There has been little publicly reported evaluation of these programs to date, though their rapid adoption throughout the US may be evidence that those who have implemented them are sharing success stories.

For the most part the existing programs are pilot projects operating as public-private partnerships between transit agencies and ride service providers (including taxi companies). The private partners can benefit from these programs, since they may gain new customers. The primary investments from the private partners appears to be limited to any extra advertising and staff time to incorporate the specifics of each local pilot into the applications' programming. In some cases, these programs can provide cost savings for the public agencies involved. For example, for bus or transit routes in low density areas, or areas with low ridership, the lines may be replaced with on-demand ride services. The services would connect passengers to stops or routes with higher ridership. This is the case in the Pinellas Suncoast Transit Authority program Direct Connect.

While the introduction of these programs may be cost effective, there are a number of potential challenges. First, transit funding is not typically intended for this type of service. In addition, these types of programs may not be politically feasible, since public funds are used to pay for services provided by private companies. Another challenge for these types of programs lies in the limited power of the public agencies; the contracts are largely dictated by the private partners. This also leads to limited assessment, since data may not be shared with the public partners. Nonetheless, these programs are popping up in more and more locales, and do potentially show promise for a shift towards more shared use forms of transportation, which we expect to carry over to a system with higher levels of automated vehicles.

Additional benefits can come from integrating other shared use modes, such as bikeshare, at transit stops. This enables passengers to seamlessly transition from one mode to another, all within one trip. The primary challenge with the integration of multiple modes of travel is the payment process. The conveniences quickly become a hassle, if a passenger must have a separate account for each type of transportation, or each segment of a trip. This can be made much worse if the accounts require different cards, tickets, passwords, etc.

Other policy avenues to promote shared use mobility with automated vehicles might include mandates such as prohibiting the sale of automated vehicles to individuals, in order to limit the possibility that the use of automated vehicles would lead to longer commutes, increased sprawl, and potentially higher per-capita VMT. These outcomes would be similar if automated vehicles were mandated to be placed into fleets providing on-demand or other ride services. Other forms of public support for shared use mobility include allowing the use of public infrastructure, to increase efficiency and safety, or setting up publicly contracted systems to provide rides to disabled and elderly communities. All of these types of policy could contribute to increases in the use of shared mobility, and limit the congestion, emissions and other impacts that might otherwise become worse with the growth of automated vehicles on the road.

MINIMIZE INCREASES IN PER-CAPITA VMT

Increases in per-capita VMT are expected to result from the adoption of automated vehicles as commutes will become more comfortable. An added half an hour or more of travel may not be seen as problematic, or may even be a welcome chance to catch up on work, reading or other things. Per-capita VMT would also increase if automated vehicles travel extensively sans passengers. Reducing the potential for these outcomes, would help to minimize increases in per-capita VMT. One additional means to minimize these increases is to further the benefits of shared use mobility through ridesplitting, and the industry's "carpool" and "commute" services. The ride-hail industry's services called "carpool", or "commute" which are more like peer-to-peer ridesharing, may offer a means to reduce single-occupant vehicle trips.

All of these avenues could help to minimize any increases in per-capita VMT that result from the increased use of automated vehicles. The most streamlined approach is likely a per mile fee for automated vehicle use. The fee could be applied to all miles driven (as is the case in Tennessee's recent legislation), or specifically target miles that are travelled with no passenger. A policy applied to all miles, would address both the potential for individuals to travel further, with the comforts, and multi-tasking possibilities deriving from automated vehicles. A policy applied to only zero-occupant miles would aim to limit increases in VMT resulting from sending vehicles back home or to cheaper and farther away parking areas, or circling the block waiting for a passenger. A policy aimed at zero-occupant times would also promote efficiency in ride service providers, since they would be hit by both the lack of revenue, and the tax, any time a given vehicle was travelling with no passenger.

Either type of use tax could likely be easily implemented, and indeed will be implemented in Tennessee. Automated vehicles will already be monitored, and have other reporting requirements, for safety and liability purposes, so keeping track of the miles driven could be relatively easy way to reduce no-passenger travel with AVs. Policies like this are not very politically feasible, but may not have much cost as far as implementation; since there will already be many monitoring systems within the vehicle, tracking and reporting VMT on a monthly or annual basis would not require significantly more efforts from state DMVs.

Considering some of the other policies to minimize increases in per-capita VMT; ridesplitting is incentivized in and of itself. This service enables multiple rides to be simultaneously delivered by one vehicle. Savings is passed on to passengers who receive a discount of approximately 40% for splitting their ride. However, there is no incentive for the ride service providers to go further with this service. What's more, ridesplitting may be sensitive to whether the vehicles are automated or not. If automated vehicles are used in on-demand ride services and the cost savings (from no longer paying drivers) to the companies involved are passed on to consumers, there may be limited added benefit to price reductions from ridesplitting. Forty percent savings is substantial for a $10 ride but much less so, when the same ride (with no driver) is only $3.

INCREASE ELECTRIFICATION OF AUTOMATED VEHICLES

With the right mix of energy sources, electric vehicles and alternative fuel vehicles contribute much less to greenhouse gas emissions. Further electric vehicles remove local emission of criteria pollutants. If automated vehicles do typically travel more miles than human-operated vehicles, and no policies are in place to limit automated vehicle VMT, it may be even more important for automated vehicles to be electric, or alternative fuel. This could be accomplished through a mandate; all autonomous vehicles must be electric, or through some sort of incentive, such as fees for non-electric automated vehicles, or a continuation of existing incentives and subsidies for electric and hybrid vehicles, regardless of whether or not they are automated. One other avenue might be the ZEV mandate. Zero-emission automated vehicles could earn more credits than other zero-emission vehicles, since the potential impact (if automated vehicles tend to be drive more miles over a shorter period of time) could be greater.

Current subsidies are somewhat controversial, however, an extension or continuation of existing programs would likely be politically feasible, and have minimal new costs of implementation. Mandating that all automated vehicles are electric or alternative fuel would likely have more political challenges, and higher barriers to implementation. Such a policy would likely be limited to vehicles outside of testing, as there are currently automated vehicles being tested on roadways throughout the country powered by a mix of fuels. It may even be necessary for such a mandate to be ramped up over time, as vehicle manufacturers are not currently making projections and plans with such a policy in mind. This type of mandate would also need to be specific about what types of automation are targeted. Lower levels of automation that function largely as driver assistance are increasingly installed in all passenger vehicles, and as the technologies advance, more vehicles will have more automated capabilities. Thus, a mandate such as this must identify the specific functions of the automated technology that would require the vehicle to be electric or alternative fuel.

There are many policy avenues that could help to reduce the environmental impacts expected to result from greater numbers of automated vehicles. While the majority of vehicles on the road will not be automated for what looks like a very long time, if policy makers are not actively anticipating and addressing the potential impacts of these vehicles they may lose the chance to avoid high levels of VMT, emissions, and congestion that could result from large numbers of automated vehicles on the roadways.

There is little uncertainty that automated vehicles will arrive. There is still time to shape how they will be used, who they will benefit and how their use will impact transportation access and environmental outcomes. With the right policies in place, perhaps we can steer this technology in the right direction.

References

American Public Transportation Association. 2016. Shared Mobility and the Transformation of Public Transit.

Boston Consulting Group, 2016. Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles.

CA Legis. Senate 2012. SB 1298. SB-1298 Vehicles: autonomous vehicles: safety and performance requirements. (2011-2012)

CA Legis. Assembly 2016. AB-1592 Autonomous vehicles: pilot project. (2015-2016)

DARPA. 2014. The DARPA Grand Challenge: Ten Years Later Autonomous vehicle challenge led to new technologies and invigorated the prize challenge model of promoting innovation 3/13/2014.

DARPA. 2007. DARPA Grand Challenge Urban Challenge Rules. October 27, 2007.

District of Columbia. 2012. District of Columbia Council Bill. Autonomous Vehicle Act of 2012.

Dutzik, Tony, Travis Madsen, and Phineas Baxandall. Fall 2013. A New Way to Go: The Transportation Apps and Vehicle-Sharing Tools that Are Giving More Americans the Freedom to Drive Less. U.S. PIRG Education Fund Frontier Group.

FL Legis. House. 2012. HB 1207. CS/HB 1207: Vehicles with Autonomous Technology

FL Legis. House. 2016. HB 7027. Department of Transportation

Grush, Bern, Grush Niles Strategic with John Niles (collaborating author) and Edgar Baum (contributing author). Ontario Must Prepare for Vehicle Automation Automated vehicles can influence urban form, congestion and infrastructure delivery. An independent research study prepared for the Residential and Civil Construction Alliance of Ontario (RCCAO). October 2016.

Guerra, Erick 2015. Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles. Journal of Planning Education and Research 1–15. Sage Publications.

Howard, D., & Dai, D. (2014). Public perceptions of self-driving cars: The case of Berkeley, California. In Transportation Research Board 93rd Annual Meeting (No. 14-4502).

Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). Public opinion on automated driving: results of an international questionnaire among 5000 respondents. Transportation research part F: traffic psychology and behaviour, 32, 127-140.

LA Leg. House. 2016. HB 1143. Motor Vehicles: Defines autonomous technology for purposes of the Highway Regulatory Act.

Martin, Elliot, Susan A. Shaheen and Jeffrey Lidicker. 2010. Impact of Carsharing on Household Vehicle Holdings Results from Borth American Shared-Use Vehicle Survey. Transportation Research Record: Journal of the Transportation Research Board. No. 2143, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 150–158.

MI Legis. Senate. 2013a. SB 169. Public Act 231 of 2013 (Effective: 3/27/2014)

MI Legis. Senate. 2013b. SB 663. Public Act 251 of 2013 (Effective: 12/27/2013)

MI Legis. Senate. 2016a. SB 995. Public Act 332 of 2016 (Effective: 12/9/2016)

MI Legis. Senate. 2016b. SB 996. Public Act 333 of 2016 (Effective: 12/9/2016)

MI Legis. Senate. 2016c. SB 997. Public Act 334 of 2016 (Effective: 12/9/2016)

MI Legis. Senate. 2016d. SB 998. Public Act 335 of 2016 (Effective: 12/9/2016)

National Conference of State Legislatures. AUTONOMOUS | SELF-DRIVING VEHICLES LEGISLATION. December 12, 2016. www.ncsl.org. Accessed February 2017.

NHTSA 2016. Federal Automated Vehicles Policy. Accelerating the Next Revolution In Roadway Safety. US Department of Transportation; National Highway Traffic and Safety Administration. September 2016.

ND Legis. House. 2015. HB 1065. AN ACT to provide for a legislative management study of automated motor vehicles.

NV Legis. Assembly. 2011. AB 511. Revises certain provisions governing transportation. (BDR 43-1109)

NV Legis. Senate. 2013. SB 511. Revises provisions relating to autonomous vehicles. (BDR 43-954)

No Hands Across America.1995. Trip Updates and Information; online at: http://www.cs.cmu.edu/~tjochem/nhaa/trip_info.html. Accessed December 2016.

Rayle, Lisa, Susan Shaheen, Nelson Chan, Danielle Dai and Robert Cervero. 2014. App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco. University of California Transportation Center Working Paper. November 2014.

Schladover, Steven E. Path at 20: Major History and Milestones. Intellegent Transportatoin Systems Conference, 2006. Published in: IEEE Transactions on Intelligent Transportation Systems (Volume: 8, Issue: 4, Dec. 2007) Page(s): 584 - 592.

Smith, Bryant Walker. 2014. Automated Vehicles Are Probably Legal in the United States, Tex. A& M L. Rev. 411 (2014)

Taylor, Brian and Transportation Research Board Committee for Review of Innovative Urban Mobility Services (2015). Special Report 319. Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services. 2016. The National Academies of Sciences.

TN Legis. Senate 2015. SB 598. AN ACT to amend Tennessee Code Annotated, Title 4;Title 5; Title 6; Title 7 and Title 55, relative to the regulation of autonomous vehicles.

TN Legis. Senate 2016. SB 2333. AN ACT to amend Tennessee Code Annotated, Title 55, Chapter 8 and Title 55, Chapter 9, Part 1, relative to motor vehicles equipped with autonomous technology.

TN Legis. Senate 2016. SB 1561. AN ACT to amend Tennessee Code Annotated, Title 47; Title 54, Chapter 1; Title 55 and Title 67, relative to autonomous vehicles.

UT Legis. House 2015. HB 373. Connected Vehicle Testing (2015 General Session)

UT Legis. House 2016. HB 280. Autonomous Vehicle Study (2016 General Session)

VA Legis. House 2016. HB 454 Motor vehicles; vehicles not to be equipped with televisions and video within view of driver. (2016 Session)

Urmson, Chris, 2015. How a driverless car sees the road. TED Talk; transcript available at: https://www.ted.com/talks/chris_urmson_how_a_driverless_car_sees_the_road/transcript?language=en. Accessed February 2017.