

CONNECTED AND AUTONOMOUS VEHICLES

A Policy Review

PURDUE POLICY RESEARCH INSTITUTE

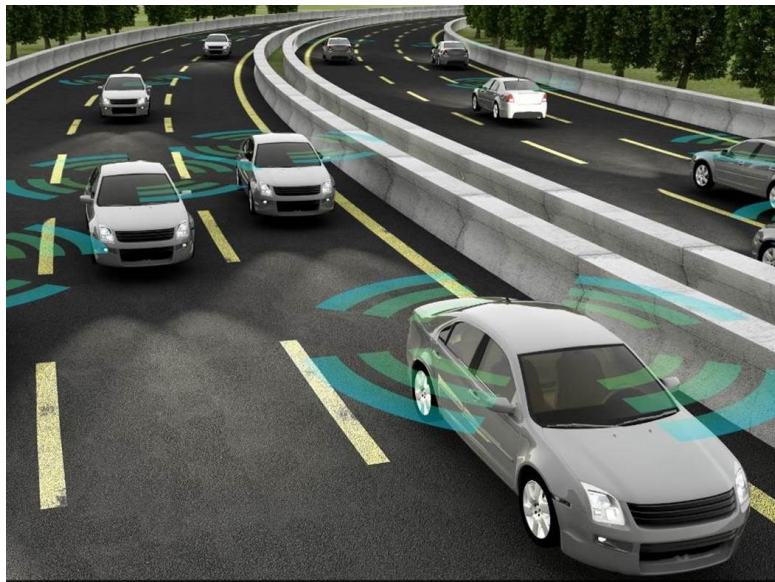


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Introduction

Connected and autonomous vehicles (CAV) have become a focal point for the automotive and technology industries, as industry giants like Apple, Waymo, Ford, Nissan, and Tesla have invested more than \$80 billion dollars in the last three years towards the development of this transportation technology (Kerry & Karsten, 2017). Many vehicles on the road already have some automated functions, and new forms and degrees automated technologies will be adopted more widely in the next five years. Widespread, successful adaptation of fully autonomous vehicles may not be as imminent, but with industry giants already testing driverless cars on the streets from San Francisco to Beijing, it is important to consider the issues that such vehicles present for law, society and policy. Societal reaction to these technological developments could hamper the growth of new technologies and endanger global competitiveness and security.

Supporters of this new technology argue that it will improve safety by reducing accidents and improve mobility for elderly and disabled people. They also cite a likely reduction in environmental degradation that could result from increased ridesharing and reduced emissions. Opponents worry about devastating impacts on the workforce, unanticipated dangers, new types of safety concerns and thorny ethical issues. Both supporters and opponents point to the ways that government action on this issue will shape national security, safety, and global competitiveness. Though government response in this area is slow in comparison with the rapid pace of technological development, the number of new policy initiatives directed at autonomous vehicles is increasing at both the state and national level. These efforts create both incentives and barriers to technological development. This paper identifies the range of the ethical, legal and social issues that this new technology presents, and briefly outlines the variety of policy responses aimed at addressing this new technology at state and federal levels, noting both policy action and policy silences on the issues. We also briefly canvas some of the approaches to the technology taken by other national governments, such as Japan, China and Germany. This work concludes by considering possible implications of these policy and technological developments.

Overview of Ethical, Legal and Social Issues

Connected and autonomous vehicles present a wide range of ethical, legal and social issues, only some of which are or should be addressed by public policy. Some may be questions of individual or corporate ethical behavior or policy, and some may relate to broader social or global transformation beyond the scope of action for local policymakers. Still, canvassing these issues shows the range of questions that could be addressed by policymakers at various levels, and presents the context of the broader issues and trends associated with this technology- a context that

is critical for a deeper understanding of the potential impact of the technology. These issues include:

- Privacy,
- Security,
- Insurance and liability issues,
- workforce and infrastructure,
- Safety,
- Mobility, and
- Algorithm ethics.

The sections below explain how each of these issues is related to autonomous vehicles.

Privacy

Connected and autonomous vehicles will likely operate using highly sophisticated on-board computing systems which will have the ability to transfer enormous amounts of vehicle data to the manufacturer, as well as other vehicles, including the transportation history, current and future location, travel routes, and personal information of the vehicle passenger(s). Without the ability to transmit this information through the connected and autonomous vehicle system, the vehicles would not be functional or capable of operating without human intervention, as proposed (Hubaux, Capkun, & Luo, 2004). It is also possible that these vehicles will employ biometric data, such as fingerprint or retinal scans, for security. This data would be stored in the vehicle database, available to a variety of parties with access. The federal or state registration of the vehicle might also allow government entities to access this information (Lin, 2013; Petit & Shladover, 2015).

Without legal intervention, it is not clear who would own this information, or who would have the ability to extract it and view it for any use. Solutions to these privacy concerns are both technical and legislative. Infrastructure design and safeguarding measures can be put into place to protect data, but the key element for privacy control and protection of vehicle passengers and owners will be creating laws that make any breach of data or misuse of data illegal.

Security

Connected and autonomous vehicles will be vulnerable to security breaches, such as hacking. While it is not likely that an “unhackable” system will be developed, a requirement for a multi-tiered verification system and a series of redundancy checks can help avoid malevolent intrusions into both vehicles and infrastructure systems (Berman, 2015; Lin, 2013; Petit & Shladover, 2015).

Insurance and Liability

Connected and autonomous vehicles present several issues for insurance and liability structures. In theory, the driver/passenger of the vehicle will not be able to influence the “decisions” made by the vehicle, so it is not clear who (driver, manufacturer, algorithm designer) will be considered liable in the case of an accident caused by computer error or failure.. Accidents will result from programming bugs, computer error, and machine faults. Algorithms can be designed to ensure the vehicle will always make decisions that would protect the passenger from liability (Goodall, 2014), but protecting passengers from liability may not result in the most ethical decisions, posing legal problems for multiple stakeholders (Campbell, Egerstedt, How, & Murray, 2010; Kalra, 2017;

Schellekens, 2015). Manufacturers and lawmakers have suggested a “black box” mandate, similar to that of an aircraft, to record the state of the automobile at the time of the accident to more clearly assign liability, but questions arise to feasibility and cost viability (Burianski & Theissan, 2017). Some experts say that “pay-per-ride” insurance may be available for ride-sharing in autonomous vehicles, or that the risk liability may be spread evenly between manufacturers and passengers, similar to states that currently employ “no-fault” accident liability assignment. Recasting questions that pertain to liability in the case of the operation of CATV will involve both government and insurance industry actors.

Infrastructure and Workforce Impact

The infrastructure updates required to support a CATV environment would be large scale and likely expensive. Roadways would need to become wirelessly connected, allowing the vehicles to communicate with stop lights, stop signs, and other traffic signs, as well as to take on weather conditions and other information. Connected and autonomous vehicle infrastructure will also need to support communication between vehicles. The cost of these kinds of upgrades to the national transportation infrastructure in the United States is not known or fully understood, but is expected to be extremely high (Greenblatt & Shaheen, 2015). Roadway engineers, such as those at 3M, note that this kind of large-scale change will have to be incremental, and a possible way to reduce costs would be to overlay communicative technologies onto existing roadway signage and infrastructure. However, this approach must account for mixed traffic, where the infrastructure supports both autonomous and non-autonomous vehicles, and will require several layers of redundancy built in to account for errors and failures within the CATV environment. It is possible that the initial infrastructure challenges may inhibit industry growth in the early stages of adoption, especially if policy mandates that autonomous vehicles be compatible with the roadways on which they travel.

It is not known how the proliferation of these vehicles will affect other industries, such as the taxicab industry, public transportation, or the freight trucking industry. It is estimated that a shift to automated semi-trucks and taxicabs would result in job loss for over four million workers in the US (Kalra, 2017; Solutions, 2017). Current research is underway to estimate the economic impact on the service industry and workforce, but some experts caution that the impact could not be immediately felt, but instead could be seen generationally as the technology becomes more widespread over the course of several decades. This extended timeline may provide the opportunity for would-be truck drivers to vocationally train elsewhere to minimize impact (Solutions, 2017; Veryard & Daniel, 2017).

Safety

Industry experts estimate that the implementation of CATV could reduce automotive fatalities from human error, especially drunk driving, to less than 10% of the current rate. However, the likely error/failure rates and degradation styles of CATV technology are not known, and these errors will likely require human takeover. Current research has done little to investigate how to genuinely reengage human passengers for takeover in the event of automation failure. Human takeover of failing or disengaging automation has been shown to be infeasible and unsafe if the humans are passive or unengaged (Hancock & Parasuraman, 1993; Landry, 2014; Merat, Jamson, Lai, Daly, & Carsten, 2014; Metzger & Parasuraman, 2005; Parasuraman & Riley, 1997; Prevot, Homola, & Mercer, 2008), and little forward progress has been made by industry to address this

issue (Ayre, 2017). Additionally, the rate and mode of CATV automation failure are not known, so it is not possible to determine if the tradeoff between fewer accidents from human error and CATV technology failure is acceptable.

Current industry trends suggest that connected and autonomous vehicles would not operate outside their specific domain (a specialized “autonomous vehicle operating zone”), or could even be restricted to use within geo-fenced areas. Proposed and enacted policy for testing, at both the state level and at the national level elsewhere, currently restrict vehicles to operating within specified operational domains (Burianski & Theissan, 2017; Soliday, Sullivan, Ober, & Hatfield, 2018). This approach may minimize human/computer interaction and takeover issues, if they arise only in more limited or controlled areas. Additionally, systematic approaches to technology design, such as multiple layers of redundancy and user interface design, are also possible solutions. Such designs may help to reinforce the driver’s need to pay attention, and they may be able to incorporate information about surrounding traffic attributes and the state of the vehicle operations to support possible driver reengagement.

Mobility

Autonomous vehicles have the potential to facilitate the mobility of both older adults who may no longer be able to drive but who nevertheless wish to age in place. Older adults who can no longer drive often rely on friends and family for transportation. They might also contemplate moving into an assisted living facility to meet their transportation needs even if they wished to live more independently for other reasons. Autonomous vehicles may also be useful for disabled individuals who are unable to drive and therefore rely heavily upon demand-response transportation that is often expensive and unreliable. A lack of reliable transportation can be a barrier to work for disabled people. The vehicle technology discussed here may help increase the community mobility of both of these populations, but secondary issues (e.g., meeting the needs of riders with mild cognitive impairment, dementia, increased fragility, or other assorted sensory and/or mobility impairments) may complicate a smooth or immediate transition to driverless vehicles at least for older adults (Bradshaw-Martin & Easton, 2014; Reimer, 2014)

Algorithm Ethics

As in other applications of automated decision making, the prospect of driverless vehicles raises ethical questions about how algorithms should be designed. Perhaps the most widely cited piece on algorithmic ethics as they apply to autonomous vehicles concerns how a computer would decide to balance passenger safety and the possibility of hitting pedestrians or other cars in an effort to avoid harming others (Bonneton, Shariff, & Rahwan, 2015). This dilemma raises challenging questions about how to incorporate ethical considerations into the design of the algorithms determining the operation of driverless vehicles. If consumers prefer to preserve their own safety or that of their families more than they wish to minimize harm to others, even when this is generally agreed to be an ethically less preferable outcome, it presents a dilemma for those charged with developing the algorithms that make these decisions. Algorithm programmers must incorporate these ethical issues into vehicle programming, but if they design an algorithm that preserves human life over passenger safety, as most ethical analysis suggests should be done,

potential consumers or passengers may reject the vehicle or prefer a model with a less ethical algorithm. Additionally, if such algorithms are developed using machine learning, discovering the balance of ethical considerations encoded in these algorithms may be challenging. Machine learning works in a way scientists cannot predict, so the ethics of these internal algorithms may not be known (Knight, 2017).

Policy Action on Autonomous Vehicles: State, Federal and International Policy

In the United States, there has been little policy action on most of the issues outlined above. The National Highway and Safety Administration has released federal guidance for these systems (see A Vision for Safety 2.0 for most recent guidelines), and it defines different suggested safety guidelines for different levels of automation. In general, however, governments have done little to address the ethical, legal and social issues identified above. The policy vacuum at the federal level has left the US states to offer guidance in their individual jurisdictions, resulting in a wide variety and degree of policy responses to automated vehicle testing and driving. Also, governments in other countries have taken up some of these issues, offering potential models for action-or lessons about what to avoid. These initiatives are described briefly here. In the sections below, we first review the idea of levels of automation (a concept that undergirds much policymaking on CATV) before turning to an overview of state (with particular attention to Indiana), federal and international policy initiatives.

Levels of Automation

Discussions of policy on autonomous vehicles often refer to their level of automation, which is conventionally defined as ranging from 0 to 5. Level 0 automation is described as a vehicle with no automation where the human driver performs all functions. Level 1 automation is considered a “driver assistance” level, where automation can assist with some functions (cruise control, for example), but the human driver still handles accelerating, braking and monitoring surrounding environments. Level 2 automation is considered partial automation, where automation can assist with steering the wheel or acceleration, but the driver is still responsible for all safety-critical functionality, including monitoring the road and surroundings. Level 2 automation is where most new vehicle technologies in the market stand today. Level 3 automation is defined as conditional automation, where the vehicle can handle driving without any input from the human driver under certain conditions or in specified operational domains. However, the driver is expected to intervene at any moment and is still responsible for being aware of his/her surroundings. Level 3 and above vehicles are not yet available for commercial purchase. Level 4 automation is considered high automation, where the vehicle is capable of all functions of driving, but still within specified design domains, or specific areas where autonomous driving is deemed allowable. When the vehicle is engaged in level 4 automation, the driver is not expected to be asked to intervene or take over until it leaves the design domain, and attention to surroundings is not required. Level 5 automation is a fully autonomous vehicle where no human attention or driving functionality is required whatsoever and can handle all traffic scenarios that occur without any intervention. Level 5 autonomous vehicles would be considered a complete form of autonomy (Fagnant & Kockelman, 2015).

State Action

State action on autonomous vehicle technology has picked up considerably over the past few years, with more states considering legislation every year since 2012 (National Conference of State Legislatures 2018). In 2018 so far, 98 bills have been introduced in 28 states. In 2017, legislation was introduced in 33 states. To date, the vast majority of states (at least 41) have considered official action on autonomous vehicles. Still, to date, only slightly more than half of state governments (27) have acted, with 21 states passing regulations through the legislature and six more where governors have enacted executive orders (AZ DE HI MA WI WA). State laws cover a wide range of issues not currently addressed in federal legislation, including liability, commercial trucking, and platooning (National Council of State Legislatures, 2018). Some states clearly aim to make testing of autonomous vehicles on the roads easier, while others view such testing primarily as a threat to safety. Some of the states where research on these technologies has been most advanced (California, Michigan, Florida, Georgia) are also those where policy development is keeping pace with innovation (Hubbard, 2018; Legislatures, 2018).

Indiana Legislative Initiatives

On January 19, 2018, the Indiana House of Representatives introduced House Bill No. 1341 aimed at setting guidelines for autonomous vehicle testing and usage within the state. This bill legislates policy over automated driving systems (Level 3 automation) and automated vehicles (Level 4 and 5 automation). Automated functions that do not fall into this jurisdiction are currently employed technologies, such as adaptive cruise control, blind spot detection, collision avoidance or detection, parking assistance, lane keeping assistance, and so on.

Bill 1341 indicates that anyone operating a level 3 vehicle must hold a valid driver's license, but level 4 and 5 vehicles only require that someone with a valid driver's license is inside the vehicle, not necessarily operating it, while traveling on a public road outside of a specific operating domain. Any and all autonomous vehicles, regardless of level, intended for driving or testing on any public road within the state must be registered within the state bureau of motor vehicles and display a notation that outwardly indicates the vehicle's autonomous status to other drivers.

Testing standards for manufacturers are also determined. All vehicles must adhere to posted federal and state traffic laws, regardless of automation level. Additionally, vehicles cannot operate on public roads unless the road has conformed to the needs of the autonomous vehicle and is compatible with the individual system. Details of specific compatibility are not outlined, but an example could be that stoplights must be configured to transmit their signal and intent to autonomous vehicles wirelessly. If the federal government has not released standardized safety guidelines, any vehicle wishing to operate in Indiana must obtain an exemption to bypass current safety standards from the state of Indiana to decide roadworthiness and safety confidence. For example, any company wishing to test an autonomous vehicle on the road in Indiana today must submit an application for exemption from meeting current roadworthiness standards, as no autonomous vehicle standards have been created to date.

Regardless of federal safety mandates, all autonomous vehicles wishing to operate on state roads, including commercial trucks, must obtain permission from the state government. Manufacturers or testers must, along with all other provisions outlined above, show proof of financial liability, submit an operational protocol which indicates specifically when and where the road test of the vehicle will be carried out and must submit proof that the vehicle is as safe as a motor vehicle operating with level 0 automation. Additionally, any operation that involves platooning of vehicles must also meet this series of requirements and seek exemption from the state, regardless of automation level.

Level 4 and level 5 vehicles have additional specific requirements for operation, including having an occupant who has been trained to use the vehicle, supervises the automation responsibly, and is capable of appropriately intervening in the event of failure or departs from its operational design domain. Waivers are possible to circumvent these standards, specifically if the operation is limited to a contained date, place and time (Soliday et al., 2018).

Critics of this bill say that the requirement to have a licensed driver within the vehicle at all times discriminates against the elderly and disabled, and manufacturers suggest it will be difficult to gain exemption for testing, as it will be challenging to prove the safety level at least matches that of a level 0 automated vehicle. Additionally, innovators and manufacturers balk at the concept that each vehicle must apply for a testing exemption individually, rather than one application for a group of vehicles (Miley, 2018).

United States Federal Policy: AVSTART Bill

Until now, federal action on automated vehicles has consisted of NHTSA guidelines. The AVSTART bill is the first federal bill introduced in the United States Congress that aims to regulate autonomous vehicles. The AVSTART bill addresses vehicles at levels 3, 4, and 5 of automation, and begins by clearly outlining when and where federal policy preempts state policy. Federal policy and safety standards take precedent in autonomous vehicle design, construction, and performance. In addition, safety evaluation reports from manufacturers must be submitted to federal agencies. State law still presides over the sale, distribution, repair and service of autonomous vehicles, as well as licensing requirements. However, states may not discriminate in licensing for autonomous vehicles based on disability. In addition, it is clearly stated that compliance with the regulations outlined in the AVSTART bill does not eliminate manufacturer liability for any kind of damages, accidents or other injury that could result from the use of their autonomous vehicle.

The main purpose of the AVSTART bill is to address the design of safety standards for autonomous vehicles. It mandates safety standards requiring that any equipment necessary to perform the dynamic driving task are rewritten without reference to the human driver to accommodate current and future iterations of CATV. For example, current safety standards reference the distance from the steering wheel to the human driver. However, for autonomous vehicles, this will not be applicable as level 5 autonomous cars may not have a steering wheel and there will be no human driver. Therefore, without rewriting the standards, all level 5 vehicles would be out of specification. The bill also highlights safety standard compliance procedures, or how to address the lack of such standards in the case of emerging technologies. Testing guidelines

are loosely described, mandating that only employees or agents of the manufacturer can test autonomous vehicles and that the test vehicles may not be sold or leased to anyone at all upon completion of testing. Manufacturers must also submit appropriate identification information following a submission procedure similar to current procedures for non-autonomous vehicles. This identification information includes the identity of the manufacturer and their previous record of safety standard compliance. This background information can be taken into account while their autonomous vehicle testing application is under review.

Because safety standards are not yet broadly established, the sale of any commercially produced autonomous vehicle is not allowed without special evaluation of their safety measures. Manufacturers may apply for exemptions from the prohibition against commercial sales under the AVSTART bill if they meet certain safety requirements and are considered roadworthy. Specifically, manufacturers must submit a safety report for all vehicles for which this sales exemption is requested. This safety report must be submitted to the federal government and must provide aggregate results of any significant deviation from previous testing results or the level of safety provided by current, non-autonomous vehicles, regardless of whether or not is more or less safe. The Bill does not specify the particular metrics on which this comparison of safety is to be based.

The safety evaluation portion of the sales exemption application is to be judged with respect to a series of considerations/dimensions, including assurance that the system performs in the intended manner, mitigates all unreasonable risk due to malfunction, and is capable of accurately sensing objects such as motorcyclists, bicyclists, and animals. Data recording is also mandated and systems must be capable of recording automation failures and performing causal analysis. Systems must also be capable of sharing data with other entities in order to analyze failures and accidents. Cybersecurity is briefly mentioned, insofar as it is mandated that any risk or intrusion must be communicated to the driver or passenger in the vehicle and that the knowledge of vulnerabilities in the manufacturing process and supply chain must be protected.

The human-machine interface is discussed at length in the AVSTART bill, specifying that the driver or passenger must be informed that any and all automated functions are being performed properly. Any interfaces must be designed to address disabilities including audio and visual impairments. For Level 3 automation, driver reengagement, or the ability for human drivers to take the driving task over from the automation at any time, is addressed as mandatory, but details of the reengagement methodology are not included.

The AVSTART bill also addresses that each vehicle must be proved to be crashworthy in all seating configurations, and vehicles must comply with applicable traffic laws. While it is not outlined specifically which traffic laws must be obeyed, it is possible that vehicles will not be programmed to exceed posted speed limits, cross double-yellow lines under any circumstances, or otherwise engage in common (if strictly speaking illegal) activity. This mandate could result in highly brittle and awkward traffic flows, especially if autonomous vehicles are traveling on the same roads as non-autonomous vehicles. The bill also requires that these vehicles be able to adapt in the event of unexpected changes to the operational design domain, such as traffic light failures or damaged pavement markings.

The bill initiates the formation of a series of safety committees to study a variety of topics related to CATV, including system safety, automated steering and braking, crashworthiness, event data recording, vehicle communication with infrastructure, accessibility for the elderly and disabled, and potential conflicts with existing motor vehicle safety standards. These working groups should also address how vehicles communicate with passengers, the mode and rate of failure, operational boundary responsibilities, the possibility of cyber hacking, and other ways that human interaction could change the functional behavior in unintended ways.

Consumer education is also addressed, requiring these working groups to identify the types of education and responsible marketing strategies for the general public surrounding connected and autonomous vehicles. Consumers should be informed about the safety of an autonomous vehicle as compared to a non-autonomous vehicle with respect to crashes, fatalities and injuries.

Cybersecurity is mentioned in the AVSTART bill, but does not address specific ways to manage or mitigate issues. However, it does mandate that experts investigate the issue and develop a plan to address issue detection, response, and recovery. The ownership of data is not explicitly spelled out, but the bill does determine that no ownership can be determined until a committee is formed to determine the best legal approach for addressing privacy.

The AVSTART bill also addresses the need to understand the impacts of CATV on society, specifically in terms of urban sprawl, rural areas that may get “left out” or excluded from connectivity, the impact to public transportation systems, traffic congestion, how weather changes impact the vehicle’s ability to drive, and energy consumption. This is done by suggesting working groups or research groups be formed to investigate and address these issues.

The AVSTART bill does not address commercial vehicles in any way, due to teamster and union pressure. Reports indicate that labor unions have urged lawmakers to “put the brakes” on self-driving car legislation and that professional drivers, such as taxi and truck drivers, fear job loss in the wake of CATV implementation (Beene & Widelson, 2017). The bill does not address these workforce and potential job loss issues in any way.

Overall, the AVSTART bill outlines an approach to research on and design of safety standards that would allow connected and autonomous vehicles to be developed and sold in the United States without compromising the current level of traffic safety. This bill has not yet been brought up for a vote. It is currently being held up by three senators who are requiring that the bill address more thorough safety measures and standards, mandate functionality for driver take-over at all times regardless of level of automation, and provide more thorough policy guidelines for cyber security. However, it is widely expected that, even without these changes, the Bill will likely pass if called to a vote.

As this suggests, then, this bill is comprehensive in addressing the full range of ethical, legal and social issues we outlined at the beginning of this paper. In addition, some critics say the policy worry that this policy, even as written, will not address the rapidly emerging technology in this area. Still, the framework presented by the Bill represents the first foray into this area, and federal action is welcomed by many industry players who hope it will bring uniformity to a wide range of state actions. At the least, if it becomes law, the legislation will provide a predictable legal

framework within which manufacturers can prepare roadworthy vehicles within the next three to five years (Thune, Blunt, Peters, & Stabenow, 2017).

Policy Developments in Autonomous Vehicles: An International Scan

The United States is not the only country working to enact public policy to support the innovation of connected and autonomous vehicles. Germany has set forth the most expansive public policy on autonomous vehicles, addressing testing, programming design and even some ethical considerations. A German policy similar to the AVSTART bill in the US has been released, setting forth guidelines for traffic compliance, a mandate for a black box within the vehicle to record the actions of both the system and the human, and a requirement that the vehicle allow the human passenger/driver to take control of the vehicle at any time, even within the designated operational domain. This policy also requires the vehicle to warn the driver if it is outside of its intended design domain and to provide sufficient lead time for the driver to take control when transitioning back to manual mode (or experiencing system failure) (Burianski & Theissan, 2017). Critics of the German legislation have warned that the definition of “sufficient lead time” can be challenging for the industry to comply with, as the definition of “sufficient” is vague with no industry accepted definition. Additionally, previous research has suggested that human takeover from automation cannot be done in a safe or sufficient amount of time, further complicating the ability to comply with this mandate (Hancock & Parasuraman, 1993; Parasuraman & Riley, 1997). This requirement may slow down the innovation of level 4 and 5 autonomous vehicles (Levine & Kahmann, 2018).

The federal government in Germany has also released a report from an ethics commission regarding the programming of autonomous vehicles in regards to human life and how the computers judge its value. This report states that no vehicle may harm a human life if any other option is available, such as property damage or harm to animals. It also states that in the event of inevitable human harm, the computer may not discriminate by age, race, gender, and other descriptive characteristics. This report even suggests that searching for features that would be specifically characteristic of a race, gender, age, etc. would be considered discriminatory and will be considered illegal. The ethics commission also outlines that humans must not be considered a piece of the system, and programming must reflect that human life is precious. The report goes further into data ethics and privacy rights, laying out rules mandating that every user must individually consent to having his or her vehicle data sent to a third party for use (*Ethics Commission for Automated and Connected Driving*, 2017).

The development of the first set of ethical guidelines for programming of autonomous vehicles has been received positively throughout the public sphere. However, critics of these guidelines warn of regulatory overreach, worrying that it will stifle innovation. In particular, the vague language of these guidelines could make manufacturers reluctant to bring CATVs to the market in Germany, as it can be challenging to prove compliance, especially with machine learning deployed in the vehicles. Machine learning can complicate compliance with these guidelines, as the programmers and manufacturers do not have control over machine learning mechanisms, and cannot guarantee how the computer will make decisions (Levine & Kahmann, 2018).

Other European countries have set forth some guidelines about data privacy and testing, but none as robust as Germany. Some believe the EU will follow the German example and adopt similar policy in these areas, while the UK is likely to set their own less stringent guidelines (Emirates, 2017).

In terms of national governments, China and Japan are two other important actors to watch. These two countries are home to the major industrial innovators in the area of CATV in Asia. Both governments have taken a strikingly different approach than the approach adopted by Western nations like the US and Germany. Adopting industrial policy aimed at bolstering the automotive industries in their respective countries, both China and Japan have dedicated government resources to aid in the development and deployment of CATV. In 2014, the Japanese government invested nearly \$400 million US dollars in programs meant to revitalize the Japanese economy (Boyd, 2015), and the CATV automotive industry was a major benefactor of that investment. Citing safety concerns that could be alleviated with driverless vehicles, national pride, and the rapidly aging Japanese economy that will require advanced mobility, the government made a clear statement that Japan wanted to be among the first to showcase driverless technology on their streets, particularly at the 2020 Olympics in Tokyo (West, 2016). In 2017, the first Japanese government policy on CATVs was put in place to guide the testing of driverless vehicles on public roads. It includes the requirement that every vehicle submit an application to the government, specifying exactly when and where testing would take place. The policy involves local prefectural and city governments in managing the road tests themselves rather than leaving this to federal safety officials. These tests are not to take place near schools or during school hours, and all local residents in the area of the test must be notified before the test takes place (Juji, 2017).

A more wide ranging policy on safety standards for autonomous vehicles is expected in Japan later in 2018, but it is not expected to be as detailed as American and German measures. The Japanese government is also undertaking a series of research projects in 2018 and 2019 to investigate and address cybersecurity risks, including how to maintain security throughout the supply chain as various people in many places and industries will be privy to vehicle vulnerabilities (*Japan setting cybersecurity guidelines for autonomous vehicles*, 2017).

The Chinese government has outlined the importance of innovation in the automotive industries in the national priorities list released in 2015, and then again in the “Made in China 2025” policy released in 2017, which specifically outlines the goal of leading the world in artificial intelligence and CATV by the end of the next decade. An enormous amount of government support has gone into these industries over the past few years, and a series of policies introduced in 2017 aims to give the country a head start so they may surpass other nations in the race to introduce a driverless vehicle (Dai, 2018; Wang, 2017; West, 2016). First, Chinese policy has proclaimed that no foreign companies may test autonomous vehicles on their roads. Citing national security concerns due to the recording equipment on CATVs, all testing has been tightly monitored and controlled, even on closed tracks, and has been restricted to companies owned by Chinese nationals. This “Chinese only” policy for testing has inspired some companies in Silicon Valley to actually relocate their headquarters to China to circumvent this ban and test their vehicles on complex Chinese infrastructure. However, Chinese companies are currently allowed to test their vehicles in other countries, such as the US, and are even partnering with American technology companies to exchange their advanced algorithms for traffic data collected by US CATV

researchers. This exchange allows these vehicles developed by Chinese companies to “learn” faster, via machine learning and to base their algorithms on a more complex set of data from diverse traffic settings. Some industry experts suggest this may give these vehicles, and Chinese industry in general, a comparative advantage over companies in the rest of the world (Clover, 2017).

The second CATV policy introduced in China came in December 2017, outlining the first rules for testing autonomous vehicles on public roads in Beijing. The guidelines, which some say are more relaxed than Western testing guidelines, mandate that vehicles must be able to make turns at a specific angle, must be able to pass through tunnels and underpasses safely without losing connectivity, must have a certain amount of accident insurance and liability, and must have a human behind the wheel in the event that anything goes wrong. Tech analysts say that more cities throughout China are expected to adopt these public road testing guidelines in 2018. The Chinese transit ministry has also announced that several cities will become autonomous vehicle showcase zones over the next three years, noting that success in the area of CATV is a national priority (Dai, 2018).

Policy Silences and Policy Models

As noted, workforce issues are a major source of controversy in this area. Concerns about job loss are a serious source of political opposition to these bills (Beene & Edelson, 2017). This opposition is particularly strong as it applies to trucking and commercial operations. The House Energy and Commerce committee advanced legislation that included trucks in July 2017. The US Senate was also developing similar legislation with bipartisan support and strong support from automakers such as Ford and Tesla and technology companies such as Alphabet and Lyft. Nevertheless, by January 2018, trucking and commercial aspects were excluded from the AVSTART bill primarily due to pressure from unions and teamsters (Beene & Widelson, 2017). Other nations that have focused on autonomous vehicles policy, such as China, Japan, and Germany, have also left workforce issues out of current legislation. However, the reason for the exclusion of this issue in these other national policies is likely slightly different.

Infrastructure issues are also largely ignored in proposed federal and state legislation in the United States. Infrastructure issues are critical: Without appropriate upgrades to allow CATV to be road-compatible, this policy silence may undermine the ability of companies based in the United States to compete on global markets. Providing upgrades to infrastructure in contrast, could create- or at least maintain- a comparative advantage for US Industry. It is also an area with great potential for innovation and technological development in itself. As noted, some foreign governments have made CATV compatibility with their infrastructure a requirement for those who wish to sell cars in their domestic markets and the Indiana bill may also make some stipulations about infrastructure (Burianski & Theissan, 2017; Levine & Kahmann, 2018; Shaub & Zhao, 2017; Soliday et al., 2018).

Although safety is included in the bill, the understanding of safety is narrowly focused on reducing human error. Other dimensions of safety – machine error, questions about which infrastructure design most advances safety, rate and mode of automation failure- are not included. Similarly, questions about cyber security and data privacy are also not covered with any degree of specificity.

The AVSTART bill, in its current draft, does stipulate that committees be formed in order to investigate safety, privacy and cybersecurity. This makes policy development in this area more likely in the future.

The German approach to policy offers possible answers to both privacy questions and ethical issues raised by programming algorithms. The approach to ethics developed in the German bill may be too difficult for legislators in the US to emulate, however, it mandates very demanding ethical standards. For example, it may be difficult to prove that a CATV's programming will always avoid damage to human life, or that the system optimizes the least amount of risk possible, especially with machine learning algorithms where the decision mechanism of the computer is not truly known. It is not yet clear what the ramifications of this approach will be in Germany (*Ethics Commission for Automated and Connected Driving*, 2017).

Legal scholars focusing on connected and autonomous vehicles have been preoccupied with the issue of liability: All seven of the major law review articles focused on automated vehicles reference this issue (Brock et al., 1996-2017). However, state law has developed several straightforward approaches for dealing with legal and insurance questions relating to liability, and it appears to be one of the easier issues to resolve when it comes to outlining the legislative response. If the mandated black box in the vehicle records who is in charge of driving decisions at the time of an accident, liability may be easy to assign.

Where federal law is silent, states may continue to be laboratories for policy innovation. However, if federal legislation- such as the AVSTART bill- is passed, it has the ability to pre-empt state policy in many areas where state law currently holds sway. Industry is broadly supportive of more uniformity in legislative response as it simplifies compliance for businesses operating in multiple states, and for those wishing to sell automated cars and related technology throughout the American market.

Implications

The policy developments discussed above not only reflect the development of new technologies, but they also have shaped, and will continue to shape, research and innovation in the automated technology field. Regulations and other public policy developments can even determine the ease of testing new technologies, making some states more hospitable to innovative industry and research than others. In addition, public support for developing these new technologies in many countries could affect global competitiveness. For example, the ample government support for developing technological innovation in Japan and China is not mirrored in the United States at the national or state level.

In order to realize the benefits of these technologies in terms of safety, mobility, and innovation, long range planning and policy support may be necessary. For example, the benefits of increased mobility may require more than the prohibition of discrimination against the elderly or disabled: It may require infrastructure and regulation to ensure that the potential improvements in mobility are fully realized. A delay in infrastructure developments could significantly impact the safety benefits of CATV, but policymakers in the United States have so far overlooked or elected to

ignore the changes needed to support this technology. Addressing such infrastructural issues would be a significant challenge in many respects, not least because regulation and legislation currently lag well behind the pace of technological innovation and are unlikely to accelerate. A more holistic, forward-looking approach to policymaking will be needed if the potential of these new technological developments is to be realized.

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