THE AUTONOMOUS VEHICLE REVOLUTION

FOSTERING INNOVATION WITH SMART REGULATION

MARCH 2017

CSPC

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INTRODUCTION

A future in which autonomous motor vehicles are capable of picking up passengers, navigating suburban, urban, and rural streets, and automatically reacting to roadway obstacles is not that far away. Already, various models of autonomous vehicles are being tested in research facilities and, increasingly, on public roadways. While automated vehicles were once relegated to the realm of science fiction, aspects of autonomous vehicle technology are already incorporated into a wide range of vehicles—even if many drivers don't yet realize it.

The commercialization of this technology will dramatically alter our nation's transportation network. In the short term, it will impact transportation safety, efficiency, and accessibility. This technology will also create second-and-third-order effects related to jobs, urban planning, economic models, and roadway rules and regulations. Along with the many benefits of this technology, it will raise public concerns about the safety of these vehicles on public roadways, and the potential displacement of jobs related to transportation. For policymakers, the most pressing challenges will involve crafting a regulatory regime that fosters innovation, ensures safety, and balances the equities of stakeholders at the federal, state, and local levels.

To address this challenge, the Center for the Study of the Presidency & Congress (CSPC) convened off-the-record roundtables in Washington, D.C.; San Francisco, California; and Seattle, Washington. Our goal was to begin a dialogue between the government and private sectors about this transformative technology and to identify solutions to potential problems.

During these discussions, project participants discussed the role of the Federal Government—particularly the authorities of the National Highway Traffic Safety Administration (NHTSA) and the "Federal Automated Vehicles Policy" released in September of 2016. Policy options within the NHTSA document, as well as other proposals currently being discussed, have the potential to either broaden the testing opportunities needed to develop this technology, or else unnecessarily stifle innovation through overly complex and restrictive regulatory regimes. Participants also discussed how the development and deployment of autonomous vehicles would be unnecessarily impeded if states fail to harmonize their regulations, resulting in interference in federal safety authority or in a patchwork of incompatible regulations across the 50 states and the District of Columbia.

In addressing these and other policy challenges, the way forward is clear—to fully realize the many benefits of autonomous vehicles, the United States needs to foster a regulatory environment that encourages innovation and places technical solutions—rather than regulatory action—at the forefront of a new transportation paradigm.

REPORT FINDINGS

The development of autonomous vehicles presents a clear challenge for policymakers, given that the rate of technological change is rapidly outpacing a regulatory regime based on more than a century of human operation of motor vehicles. While many of these technologies are in their infancy, they are already being incorporated into vehicles to assist drivers. Players ranging from traditional automakers to major tech companies to small startups are developing prototype vehicles that operate with little-to-no human input.

The advent of this technology and its increased testing in anticipation of deployment on public roadways has raised unresolved issues related to regulation, liability, and insurance. There are also questions surrounding licensing and registration of these vehicles, technical standards, and security and safety requirements. Many of these topics are being addressed at the state and local levels, with the Federal Government continuing its key role of providing national safety standards and requirements. While industry is moving forward, the unsettled regulatory landscape for these technologies requires further dialogue between innovators, industry, and government.

The United States is on the cusp of a global transportation revolution. The continued development and commercial deployment of autonomous vehicles promises to completely reshape the transportation environment through increased transportation accessibility, efficiency, and, most importantly, safety. Innovation in this field will transform how Americans use their time spent in cars, and transform the paradigm of car ownership and utilization. If it remains a leader in autonomous vehicle innovations, the United States can ensure that its vehicle manufacturing and technology industries remain competitive on the world stage.

To fully realize the promise of this exciting technology, however, regulators at the local, state, and federal levels—specifically the Department of Transportation (DOT) and NHTSA—must be creative and supportive. States play the key role in regulating vehicle licensing and registration, traffic laws and enforcement, vehicle insurance and liability, and NHTSA has exclusive authority to set safety performance standards. The long-term success of this exciting technology depends on coordination among federal, state, and local agencies in developing rules of the road based on best practices and reliable data. Maintaining a patchwork of conflicting laws and regulations that differ in varying locales will prove an enemy of innovation. The regulatory environment must be one that encourages innovation, avoids regulatory capture, and empowers innovators and consumers to choose the technologies that will guide future transportation paradigms.

The Promise of Autonomous Vehicles

With the technology—and the vision behind it—advancing at a rapid pace, the autonomous vehicle has the potential to reshape transportation for the better. The autonomous vehicles' safety improvements— which should reduce human error on roadways—are a potential boon to public health and safety. The ability of these vehicles to also improve capacity on our roadways, and more productive utilization of our travel time, also promises significant productivity growth. Finally, autonomous vehicles can increase the mobility of young people, elderly, the disabled, and other communities underserved by traditional personal and public transportation systems. They can thus redefine transportation accessibility, having a positive impact on economic opportunity and productivity in our society.

Safety

A two-year NHTSA survey from 2005 to 2007 estimated that 94% of the accidents on U.S. roadways are due to human error—with 35,092 people dying on U.S. roadways in 2015.[i] From inattention to intoxication, from speeding to sleepiness, the human factor is responsible for most of the current dangers on our roadways. For comparison, if the same number of people were dying each year due to accidents in air travel, it would be the equivalent of just over two commonly-configured Boeing 777-300s crashing each week. Imagine the outcry for government action if that carnage were associated with air travel—yet it is what we have generally accepted for roadway travel.

While many of these technologies are still in a developmental or testing stage, it is already clear that some of the autonomous vehicle's many advantages will include: the ability to constantly scan the road for other vehicles, bicyclists, pedestrians, and potential hazards, and accurately navigate via a combination of onboard sensors and GPS data. These autonomous guidance systems will also work with vehicle communication systems—integrated into autonomous vehicles and traditionally operated vehicles—that will share information about driver actions, traffic patterns, and roadway conditions. As a result, vehicles will perceive the road ahead in far greater detail than a human driver or automated sensors alone. By combining these systems and capabilities with state-of-the-art vehicle construction and physical safety equipment, the autonomous vehicle of the near future may very well represent a quantum leap in safe transportation.

While no system is fully foolproof, the autonomous vehicle will have the potential to provide an unprecedented level of transparency when incidents do occur. Rather than relying on the recollection of a human driver or eyewitnesses, the autonomous vehicle will have a wide range

of data about the conditions before, during, and after an incident that can be used for investigative purposes, as well as to "teach" other autonomous vehicles what went wrong.

One current challenge is the perceptions of autonomous vehicle safety as the technology is still in a developmental stage. As with any technology still undergoing research and development, there will be "stops and starts." In the final analysis, however, no autonomous vehicle manufacturer will want to risk deploying technology that is unsafe or underdeveloped. Safety advocates may well seek to enforce stricter safety standards for these technologies—definitions of standards that do not yet exist. Given the number of fatalities on current roadways, however, the human operated automobile is an insufficient benchmark for safety. Finally, as the technology is developed and more and more autonomous features are incorporated into traditional vehicles—e.g. "self-driving modes" for highway or stop-and-go traffic or advanced collision avoidance technology—the public will gain a greater understanding and familiarity with the safety advantages of this technology.

Efficiency

The autonomous vehicle will transform the efficiency of transportation in terms of roadway capacity, energy usage, and the time spent by riders in automobiles. Even before totally autonomous vehicles are integrated onto roadways, some aspects of the technology are already being developed—such as adaptive cruise control, traffic/hazard avoidance navigation, and traffic signal synchronization—have already demonstrated great potential. Studies indicate a two to four percent improvement in both energy consumption and emissions over ten years from traditionally-operated vehicles with those systems.[ii]

As prototype testing continues, both researchers and policymakers are seeing potential areas of improved efficiency. Operating closer together and at higher speed than is safe for a human driver, for instance, "platooning" of autonomous vehicles may significantly increase roadway capacity. The persistent availability of "on call" autonomous shared vehicles would reduce the need to set aside real estate—both on roadsides and around buildings—for parking. Autonomous vehicles also have the potential to increase the area serviced by commuter rail systems, reducing stress on roadways between suburbs and downtowns across the country.

Finally, as we consider a future with autonomous vehicles, significant amounts of time currently spent behind the wheel will be freed up for other work or leisure. Per the U.S. Census Bureau, the average one-way American commute time is 25.4 minutes—though in further suburbs and exurban areas, that average time can be 45 minutes or more.[iii] Autonomous vehicles could reduce that time due to more efficient use of roadways, and allow the vehicle occupants to direct most, if not all, of their attention to purposes other than driving.

Accessibility & Opportunity

Many Americans take the independence that comes with personal transportation for granted. Yet for significant segments of our population, driving is simply not a feasible option. They may be limited by the cost of full-time car ownership, the cost of learning to drive, difficulties with licensing, or factors related to health, disability, or age. For these communities, the difficulty in accessing transportation also leads to socioeconomic disadvantage. Ongoing studies from Harvard University examining social mobility have identified commute time as being the key factor in social mobility—more so even than factors related to crime or education.[iv] Autonomous vehicles have the potential to reshape transportation models that emphasize car ownership as the foundation of full personal transportation freedom and flexibility.

Beyond the potential positive benefits of allowing underserved communities to experience better transportation options and personalized transportation choices, autonomous vehicle technology could also empower those simply unable to drive. For the elderly, those too young to drive, the blind, the disabled, and others, the autonomous vehicle will provide unparalleled, independent access to transportation.

The Political & Regulatory Factors

Political perceptions and regulatory regimes surrounding autonomous vehicles will be significant factors in determining whether this technology reaches its full potential. Difficulties encountered in testing or heavily publicized faults in the technology could present perception problems. Throughout the development of this technology, it will be vital that technology developers, autonomous vehicle advocates, and political and regulatory leaders remain focused on the potential benefits of this technology. Difficulties inherent in the deployment of any new technology are inevitable. The potential of this transformational technology should not be overshadowed by near-term challenges.

As political and regulatory decisions are made regarding autonomous vehicles, it is especially important that policymakers understand the potential benefits of autonomous vehicle technology. Groups that stand to benefit from the development and deployment of this technology—ranging from safety advocates to technology evangelists to underserved communities—will need to build advocacy coalitions. They should advocate for increased testing in virtual, test track, and real life environments; and support market access for a wide range of manufacturers testing, developing, and deploying autonomous vehicles. Public leaders should embrace these coalitions, and avoid the pressure for legislative or regulatory "blowback" that may occur if testing incidents become highly publicized.

An Innovation-Friendly Regulatory Environment

For autonomous vehicles to achieve their potential, it is important that a wide range of innovators have the ability to freely develop and test their technologies. Encompassing traditional automobile and truck manufacturers, ride-sharing companies, Silicon Valley titans, and cutting-edge startups, the autonomous vehicles marketplace is made up of a diverse array of actors. Consumers ultimately stand to benefit the most from a healthy competition between industrial manufacturers and technology innovators, and as this new paradigm in personal and commercial transportation takes shape regulators should focus first and foremost on creating a level playing field.

Foremost in this fluid environment, it is important that regulation remain technology-neutral. Regulators need to understand that the solutions to autonomous vehicle challenges may not necessarily reflect the old way of doing things in a traditional transportation landscape. Where regulations are applied, they are best designed to reflect a desired end state, with developers and manufacturers choosing the best technical solutions to arrive at that performance based end state.

A key to solving challenges with autonomous vehicles is the ability to test a wide range of software and hardware solutions across a broad array of operating environments. Current regulations are designed to accommodate a very limited deployment of vehicles for testing, for instance, but the future of autonomous vehicles will require that an ever-greater number of vehicles are tested on actual roadways. For example, imagine how human drivers' skills would suffer if student drivers were discouraged from gaining roadway experience, rather than encouraged. Beyond the traditional testing of vehicle hardware—which will be largely similar to the testing of traditional vehicles, save for the advanced sensor technology—autonomous vehicle testing will require the constant testing and updating of software that must better "learn" how to drive. Allowing greater numbers of vehicles to test software will expand the sample size for software testing and development.

As software is updated, regulators should avoid overly strict reporting or certification standards for software. With software being constantly updated and tweaked—reflecting both the complexity of the software code, as well as the inputs from the experiences of other autonomous vehicles—requiring each change of software to undergo a regulatory review would slow autonomous vehicle development to a crawl.

With regards to safety, developers and manufacturers should err on the side of caution. No vehicle manufacturer can withstand the perception—either from customers or regulators—that they are deploying dangerous technology. Simply put, no company will succeed if their

vehicles are perceived as a threat to occupants or passersby. For traditional vehicle manufacturers, safety assurances are largely covered by the existing self-certification process in which manufacturers certify to NHTSA that their changes to a vehicle meet safety standards, combined with NHTSA's authority to recall vehicles that have safety deficiencies.

Finally, in order to develop a robust autonomous vehicle marketplace that rewards innovative technologies, regulating agencies should avoid "regulatory capture," through which larger, more established firms are able to influence the crafting of regulations in a way that locks out new entrants to the marketplace. Regulations must not distinguish between or favor any manufacturers, technology firms, or new entrants to the marketplace.

A regulatory environment that meets these standards will foster transportation innovation and ensure that the United States remains a leader in the development and deployment of autonomous vehicle technology. To understand how such an environment might look, it is important to understand the unique roles of federal, state, and local bodies in transportation regulation.

NHTSA's Regulatory Role

In order to ensure a uniform level of safety across the United States, and to prevent a confusing patchwork of safety regulations, the Federal Government sets safety standards for vehicles sold in the United States. Key to the Executive Branch's authority in this area is NHTSA's role within the Department of Transportation. NHTSA sets these standards—known as the Federal Motor Vehicle Safety Standards (FMVSS)—to ensure that vehicles meet a common safety benchmark for operation in the United States. This avoids vehicle standards that vary depending on the state where the car is manufactured, purchased, or licensed. As vehicles are developed, manufacturers self-certify that their vehicles meet these standards, and NHTSA has the authority to demand that manufacturers meet their legal obligation to recall vehicles with safety flaws. This holds manufacturers to safety standards, while also allowing them to quickly bring new models to market each year.

NHTSA leaders have generally embraced the promise of autonomous vehicle technology, particularly the safety benefits that will result from automated operation. While many of the tools that NHTSA has in place are based on the assumption that a human driver is operating the vehicle, NHTSA has displayed a willingness to interpret safety rules and regulations in a way that allows for innovation and flexibility to the extent authorized by the law. For example, in February 2016, NHTSA informed Google that a software guidance system would meet the definition of "driver" within the FMVSS.[v]

With an eye towards a future of autonomous vehicles, NHTSA released the September 2016 findings of its "Federal Automated Vehicle Policy." [vi] This document set forth fifteen factors as guidelines that manufacturers could use to assess and demonstrate the safety of their autonomous vehicles. This allowed for a comprehensive approach to safety, and avoided mandatory standards in a field that is still largely one of research and development. NHTSA also sought to formulate standards and definitions of autonomy by applying the SAE International "Level Zero" to "Level Five" benchmarks for vehicle autonomy.[vii]

In addition to these definitions, NHTSA reiterated the exclusive role of the Federal Government in providing a uniform safety and certification regime across the United States. States remain responsible for the issues that have traditionally been state and local matters—licensing, titling, rules of the road, etc. To avoid interruptions in autonomous vehicle operation when crossing state lines, the NHTSA document urged states to cooperate and to facilitate a level playing field that supports innovation.

Finally, the NHTSA document examined current tools and potential future authorities for addressing autonomous vehicle issues. Of these potential future authorities, two are worth significant attention at this time—but for different reasons. First, the NHTSA report suggested expanding the exemption authority for the testing of vehicles that may not meet the FMVSS. Currently NHTSA's exemption authority is significantly limited in scope and time, making it an ineffective tool for supporting broader deployment of autonomous vehicles. This is an authority that Congress should quickly give NHTSA, so that our nation's automated vehicle fleets have more roadway experience and testing, thus improving the software and hardware systems on these vehicles.

At the same time, the document also suggested that NHTSA may seek pre-market approval authority for autonomous vehicles, similar to the FAA's current approach to aircraft. Such an authority, if applied only to autonomous vehicles, would place their development at a disadvantage compared to traditional vehicles, which can be self-certified by manufacturers. If applied to the vehicle industry writ large, such a measure would stifle development and slow the market for this technology. Such action would also likely encourage vehicle manufacturers to seek other overseas markets for testing and deployment of this technology.

NHTSA's key role in the autonomous vehicle future requires continued attention from policymakers and ongoing dialogue with private sector innovators. To its credit, NHTSA has already shown a willingness to take a "light touch" to autonomous vehicle development to encourage innovation, and the leadership of Secretary of Transportation Chao and the incoming NHTSA Administrator—yet to be named at the time of this report's release—will be vital for furthering innovation-friendly policies. Thus far, Secretary Chao's comments have

highlighted both the importance of autonomous vehicle innovation, as well as the Trump Administration's ongoing review of autonomous vehicles policy.[viii] Secretary Chao and other Executive Branch officials should continue to advocate for autonomous vehicle innovation based on their potential safety and accessibility benefits, as well as the importance of continued U.S. leadership in this economically vital field.

Other Federal Agencies

While the majority of regulation and policy in this field will come from the Department of Transportation and NHTSA, it is important to consider the vital roles that other Federal Agencies will play in autonomous vehicles. The two most key responsibilities identified in this project's discussions are the role of the Federal Communications Commission in vehicle-to-vehicle and vehicle-to-infrastructure communications (referred to as "V2X systems" or dedicated short-range communications); and the role of security agencies such as the FBI, the Department of Homeland Security, and the Intelligence Community in protecting against threats to the cybersecurity of autonomous vehicles and other networked transportation infrastructure.

While the FCC has set aside dedicated spectrum for V2X, there are concerns about how opening that spectrum to other uses, such as Wi-Fi, may interfere with V2X and dedicated short-range communications (DSRC) systems. Spectrum has been set aside since 1999 for V2X systems, but major auto manufacturers have only incorporated the technology into a limited number of vehicle models in select markets. At the same time, technology companies have sought to use some of this spectrum for internet communications, as well as demonstrating how prototype vehicles may also use other connections such as cellular or Wi-Fi to communicate with other vehicles and infrastructure. At this time, it is premature for the government to assume that one standard or the other is the correct one for autonomous vehicles, as a mixed approach may ultimately be necessary. As autonomous vehicle technology is further developed, it is better for both vehicle manufacturers and technology companies to find a mutually agreeable solution based on wide-ranging technological solutions, rather than government potentially choosing one solution and thus limiting future technological options.

In terms of autonomous vehicle cybersecurity, it will be vital to build on existing information sharing relationships between government and the private sector to protect autonomous vehicles from bad actors. Autonomous vehicles and networked roadways will present new targets for those who might try and disable or hijack vehicles, or use vehicles and infrastructure to host botnets. Already, discussions on these issues are ongoing between the automotive industry, information technology companies, and government entities such as the FBI, the

Department of Homeland Security, and the Intelligence Community. This dialogue should continue and be expanded to ensure two-way information sharing about potential threats and security vulnerabilities.

The Role of Congress

Given that many of NHTSA's authorities are covered by statute, Congressional action will be necessary to address the need for greater exemption authority, or to prevent the application of overly onerous measures such as pre-market approval. However, it is imperative that Congress not be too prescriptive or restrictive when altering NHTSA authorities. Furthermore, via its oversight role of the Department of Transportation, Congress can continue to foster an innovation-friendly mindset among NHTSA leadership to encourage continued autonomous vehicle innovation.

First and foremost, if Congress is to grant authorities that NHTSA may need to address further autonomous vehicle developments, increasing or eliminating the cap on the number of vehicles exempted from the FMVSS for testing is vital. As previously described, this will allow for a greater amount of testing on roadways to improve the quality and performance of autonomous vehicle hardware and software. To avoid stifling autonomous vehicle innovation, Congress should resist efforts to grant pre-market approval authority to NHTSA, and it should carefully examine additional authorities that regulators may seek. In examining these additional authorities, Congress should err on the side of fostering responsible innovation in autonomous vehicles, and encourage NHTSA to carefully apply existing authorities (similar to traditional vehicles) to address safety concerns.

In terms of the amount of time Congress devotes to autonomous vehicle issues, it is important to remember that Congress's attention follows that of its constituents. For the vast majority of the American public, autonomous vehicles have not yet had an impact on their daily lives. As a result, Congress has been focused on other issues, as reflected in the limited number of hearings that have been held on the topic.

The deployment of autonomous vehicle technology in commercial industry could provoke significant political reaction due to concerns about job losses. Attention is already being paid to how specific industries, geographic areas, and political constituencies may bear disproportionate job losses due to the eventual widespread deployment of autonomous vehicle technology.[ix] At the same time, economists continue to debate the impact of autonomous technology on the American workforce and job market, with some highlighting how specific fields and the broader economy have been positively impacted—both in terms of productivity and job growth—by the marriage of human workers and autonomous technology.[x]

Leaders in the Executive Branch and Congress—as well as at the state and local levels and in the private sector—should continue to highlight the broader societal benefits of autonomous vehicle technology, base policies on sound economic analysis of automation's impact on the American workforce, and, resultantly, provide policies addressing retraining and rehiring opportunities for those displaced by this technology. Even this will not dispel the perceptions of impending job loss and economic displacement among impacted sectors of the public, especially given the modest success of some past job retraining programs—and broader distrust of economists' analyses and politicians' rhetoric.

Despite concerns about economic displacement related to the commercialization of autonomous vehicles, Congress must weigh them against the economic benefits that will surely accrue to U.S. leadership in the global autonomous vehicle marketplace. Regulatory action or protectionism that merely pushes autonomous vehicle development and manufacturing overseas will only cede U.S. leadership in this cutting-edge field.

State-Level Regulation & Policy

Given the aforementioned division between federal and state responsibilities for transportation regulation, states have taken varied approaches to autonomous vehicle testing and development. Some of these decisions have reflected a desire to attract autonomous vehicle manufacturers and startups to the respective states, while others have reflected concerns about the safety and maturity of the technology being tested on public roadways. Given the differences in many of the state approaches to testing, it is important to ensure that these testing-phase regulations do not ossify into regulations that persist during the deployment and commercialization of autonomous vehicles. That would only inhibit easy use of the technology across state lines and could run afoul of the Commerce Clause.

Furthermore, at the state level, there is significant risk of an overly onerous regulatory regime emerging that stifles innovation, as well as the threat of "regulatory capture," where some market participants are favored over others. The two most notable examples of that phenomenon at the state level are California and Michigan, respectively.

This project hosted a discussion with representatives from government, industry, and academia in San Francisco. The effort to establish a regulatory regime for autonomous vehicle testing there came from major manufacturers seeking to establish regulatory certainty for testing within California's borders. However, as the state legislature and DMV put regulations into place, three significant areas of concern quickly arose: data sharing, municipal licensing, and mandatory safety standards based on the NHTSA guidelines.

In terms of data sharing, companies testing in California are concerned about current and proposed requirements that would mandate the sharing of testing data with state regulators. That data, in turn, would be subject to public records requests. Such data would create a competitive disadvantage for companies operating in California, with competitors able to learn about proprietary data and testing information through public records. Data sharing is a valuable tool for improving the operation of autonomous vehicles and the "learning" abilities of software, yet policies that force the sharing of proprietary information or intellectual property will unnecessarily chill dialogue between government and the private sector, as well as between private sector operators. State regulators must continue to emphasize that information sharing is based on identifying problems that autonomous vehicles face—not the proprietary technology that is addressing these problems.

Regarding municipal licensing, the concern is similar to that of a patchwork of rules and requirements across multiple states, but in this case across the various municipalities of California. Finally, while NHTSA emphasized that self-certification of the 15 factors in autonomous vehicle design was optional for vehicles being tested, actions by California's regulators have effectively mandated that tested vehicles meet these once voluntary standards.[xi] Pushback from developers has resulted in additional back-and-forth on the specifics of the policies. These issues have slowed the testing of autonomous vehicles in the state, and encouraged manufacturers and startups to look to other states with a more relaxed regulatory environment.

Finally, in Michigan, an overly strict definition of "manufacturer" has locked all but major automobile manufacturers out of the autonomous vehicle and ride sharing market.[xii] Major companies such as Apple, Google, Lyft, and Uber have all expressed their concerns about the legislation, which requires that companies operating autonomous vehicles in Michigan be an automobile manufacture, defined by selling vehicles that meet FMVSS. Technology or ridesharing companies must partner with an automotive company, for instance, to operate a ride hailing network. Structuring the legislation in such a manner shelters established automakers—which is, admittedly, an important constituency in Michigan—from competition posed by technology companies or startup ventures. Further examination of Michigan's policies is necessary to understand how this "regulatory capture" dynamic could further stifle the development and promise of autonomous vehicle technology. At the same time, there is a broader concern regarding regulatory capture if states create licensing and regulatory regimes that are only accessible to established firms that have vast legal and compliance departments able to interpret complex laws or regulatory regimes regarding autonomous vehicle testing and deployment.

Conversely, other states have taken a different approach, adopting a light regulatory touch and delaying legislation regarding testing or deployment of autonomous vehicles. For example, our discussions in Seattle, Washington, showed how a flexible approach is allowing policymakers to learn more about the impact of this technology before weighing in with legislation. That has allowed private sector manufacturers to more thoroughly test and improve their technology based on real life experience operating these vehicles. This approach encourages further research and development of these technologies in states with more flexible regulatory regimes. It is also an implicit acknowledgement that much of the technology for autonomous vehicles in still in an early developmental phase, which requires flexibility and robust dialogue between government and the private sector innovators.

In the U.S. system of governance, the states often serve as "laboratories of democracy," where various innovations and solutions are field tested and, if successful, expanded to other states or at a national level. Given the need to encourage a wide range of innovative players in the autonomous vehicle marketplace, the approaches of California or Michigan, if applied in a broader scope, would only impede innovation in this field.

Policymakers should also be aware of attempts by states like California, Texas, New York, and other large states, to use their market power to establish a de facto national standard. California has long led in this area by applying state emissions standards that are more stringent than national levels—based on its exemption to make stricter rules than those mandated by the Clean Air Act—thus forcing automakers and other manufacturers to meet them simply due to the size of California's market. To avoid a legal and regulatory patchwork across the country that might flow from this approach, policymakers should be cautious of the broader application of state level rules or attempts by states to carve out authorities from the federal role in setting national transportation rules and standards.

REPORT RECOMMENDATIONS

Recommendation 1: Advocate for Autonomous Vehicles

From discussing this topic with practitioners at both the state and federal levels, it is clear that an essential enabler of autonomous vehicles will be widespread public support. As more autonomous vehicles are tested on public roadways, the new Administration should take great care to reaffirm its support for this emerging and exciting technology. Secretary of Transportation Elaine Chao and both the acting and incoming NHTSA Administrator should continue the public outreach initiatives that communicate to the public the myriad benefits of autonomous vehicles in terms of safety, transportation accessibility, and U.S. economic and innovation leadership.

Recommendation 2: NHTSA Leadership Will Play a Key Role

To build on existing progress in this sphere, Secretary Chao must coordinate with the yet-to-be-named NHTSA Administrator and Congress in developing and implementing autonomous vehicle regulations. Most importantly, as autonomous vehicles move from testing, and inch closer to commercialization and widespread deployment, NHTSA will need the resources to carefully balance the priorities of harmonizing federal and state regulations, monitoring private sector adherence to safety protocols, and promoting this and other promising technologies.

Recommendation 3: Invest in Infrastructure with an Eye to the Future

When President Eisenhower set in motion the development of interstate highways, he did not build more two-lane highways, but rather the roadways for the future. Future infrastructure investments should aim to foster autonomous vehicle innovation and "future proof" hard infrastructure for the technologies needed by autonomous vehicles. Current drivers and future autonomous vehicles will both benefit from improved roadway surfaces, road markings, and other infrastructure repairs. Government should create an environment that encourages—rather than mandates—private sector innovations that facilitate the testing and integration of autonomous vehicles on roadways, to include: improved tools for gathering and sharing data between government and the private sector about roadway usage, installation of vehicle charging infrastructure, and the integration of some form of dedicated short range communications (DSRC) technology—specifically vehicle-to-infrastructure (V2I) systems. Overall, public-private investment projects that stress the importance of innovation, while accommodating a wide array of potential technological advancements, will go a long way to update our roadway systems.

Recommendation 4: Expand Exemptions for Vehicle Testing

During the roundtable sessions, participants agreed that NHTSA is an essential player in the advancement of autonomous vehicles. Some experts shared concerns, however, that the agency's "exemption authority" for testing new vehicles that do not meet the FMVSS is insufficient or antiquated for needed testing. Currently, the agency's exemption authority—2,500 vehicles per year for a two-year period—makes it difficult to accurately gauge and thoroughly evaluate new vehicle operations. The testing of self-driving vehicles is more similar to "teaching a driver" than it is to simply testing the safety or durability of vehicle hardware. To put it simply, the more opportunities for software to learn from real-road conditions, the better. Congressional action increasing the exemption authority cap beyond 2,500 vehicles—or a process towards eliminating the cap completely—are options that would facilitate the increased testing needed to provide a pathway to commercialization and integration of autonomous vehicles onto public roadways.

Recommendation 5: Continue the Self-Certification Model

For NHTSA, it is important to continue to adapt the self-certification model to autonomous vehicles, rather than relying on a pre-market approval process. To avoid regulatory bottlenecks in vehicle production, the NHTSA's current model focuses on self-certification by manufacturers that vehicles and vehicle components meet safety standards. With the increase in autonomous vehicle technology, some have proposed that NHTSA should have pre-market approval—similar to the FAA—for self-driving vehicle technology. Action by Congress to grant NHTSA authority to apply pre-market approval to autonomous vehicles could create an even worse regulatory bottleneck for this technology, however, and further put autonomous vehicles at a disadvantage. Additionally, given the rapid changes and updates that are to be expected to software systems—in addition to the traditional model-year changes in vehicles—pre-market approval would greatly stifle autonomous vehicle innovation and commercialization.

Recommendation 6: Avoid Regulatory Capture with Broad "Manufacturer" Definitions

NHTSA and state governments must also ensure that their definition of "manufacturer" is not unnecessarily limited in a way that disadvantages new entrants to the autonomous vehicle field such as ridesharing companies, tech companies, and startups. An overly strict definition of manufacturer could provide advantages to traditional vehicle manufacturers, and stifle the growth of new entrants to the market. Allowing more, rather than fewer, entrants to the autonomous vehicle market will foster greater innovation in this field, delivering safer and more reliable technology and promoting U.S. leadership in this increasingly important sector of the economy.

Recommendation 7: Avoid a Regulatory Patchwork

Agencies at the local, state, and federal levels continue to debate how to properly ensure safe testing protocols by the private sector. States differ in terms of regulations governing autonomous vehicle testing, creating a patchwork of sometimes contradictory regulations that could impede the integration of these vehicles onto roadways. At the same time, some local governments are also adopting licensing and testing regulations that create an additional patchwork within specific states. As technology advances, it will be important to ensure that these regulations are harmonized so that autonomous vehicle operators can use their vehicles across state borders, without having to activate or deactivate various systems. Thus far, the recommendations from NHTSA that safety and system certification be handled at the federal level and that states maintain their traditional role in licensing, insurance, and traffic laws—combined with a model set of state regulations—encourage such a harmonization. Therefore, state and local governments should avoid state-specific or municipality-specific policies that create barriers to autonomous vehicle testing and deployment.

Recommendation 8: Continue the Cybersecurity Discussion

Autonomous vehicles are a significant segment of a broader challenge that the nation will face in securing in an increasingly networked society and the so-called "Internet of Things." The computer networks and software that are necessary for autonomous vehicle operation will be an attractive target for a wide range of threat actors. Securing autonomous vehicle systems will be important for both public acceptance of the technology, as well as its successful integration onto roadways. Along with many other important sectors, autonomous vehicle manufacturers should be key players in future dialogues related to cybersecurity information-sharing and new cybersecurity models.

Recommendation 9: Plan Ahead for an Autonomous Vehicle Future

Political leaders should encourage the continued development of this groundbreaking technology, as well as plan for its future impact on the economy and urban planning. The technology presents a significant opportunity to improve access to transportation for disadvantaged communities, as well as to improve the safety of roadways. While there are challenges inherent with any new technology, it is important that politicians and regulators avoid political or regulatory backlash based on public perceptions of current technology, versus how it may evolve in coming years. Beyond transportation, the changes to the transportation market, the jobs currently held by drivers, and the shape of our transit and transportation planning will require ongoing attention from leaders in both government and the private sector.

Recommendation 10: Responsible Innovation by Private Sector Actors

For new entrants into the autonomous vehicle space, it is important that the emphasis continues to focus on delivering safe, reliable transportation technology. Wherever possible, private sector players should emphasize transparency about their technology and plans, interoperability with other systems, and safety for occupants, bicyclists, and pedestrians. Avoiding a political or regulatory backlash against the technology will require responsible innovation by autonomous vehicle manufacturers that emphasizes such tenets and reinforces the effectiveness of existing self-certification models for meeting safety standards. Most importantly, the private sector and Federal Government must continue to stress information and data sharing while continuing an open and frank dialogue with each other and with the American people.

THE FEDERAL ROLE

NHTSA's Findings & Automated Vehicle Policy

To ensure the safety of consumers, it is imperative that NHTSA continue to communicate and work with those in the private sector who are developing and testing autonomous vehicles and other interested stakeholders, such as safety advocacy organizations. The collaboration that has already occurred between these parties has resulted in the clarification of complex issues that would impede the commercialization of this technology.

Since companies have begun to develop and test this technology, there have been questions regarding who or what counts as the driver. For private sector entities looking to develop and sell vehicles at higher levels of automation—Levels 3 to 5—NHTSA has played an important role in beginning the discussion surrounding complex legal and liability aspects related to widespread deployment of this technology. One of these regulatory hurdles was clarified with the February 2016 NHTSA statement regarding the Google vehicle design, which stated that the regulatory body "will interpret 'driver' in the context of Google's described motor vehicle design as referring to the self-driving system, and not to any of the vehicle occupants."[xiii] Not only does this streamline the design and testing process of this technology but allows for companies to innovate without restrictions. Furthermore, this reflected a willingness by NHTSA to acknowledge that FMVSS and other regulations had been written in an era when no one could imagine an alternative to human operation of vehicles, as well as demonstrating how FMVSS could be flexibly interpreted to cover computer guidance systems.

However, even with the NHTSA statement, there are still concerns over the safety of this technology. Unlike traditional vehicles that must undergo a physical safety checklist and must adhere to Federal Motor Vehicle Safety Standards (FMVSS), regulators are unsure of how to develop and enforce FMVSS for vehicle software. In addition, researchers have questioned the ability for vehicle software to "learn" similar to a human, adapting driving style based upon the driving environment. If this regulatory framework is followed, there are questions surrounding the FMVSS applicability vis-à-vis guidance systems and software—as the driver is not traditionally covered by FMVSS that are directly applicable to the physical structure of the car. That said, as NHTSA continues to examine this issue, they seek to identify ways that existing or future authorities can be applied to autonomous vehicle systems.

Building off a 2013 policy statement and in response to the variety of legislation enacted at the state level, NHTSA released the Federal Automated Vehicles Policy in September 2016. This guidance document was released to assist policy makers at the state level when crafting

autonomous vehicle regulation. Issued as agency guidance rather than formal rulemaking to speed an initial framework to manufacturers and state regulators, the document includes a performance guidance section, a model state policy, and details the current NHTSA regulatory tools—as well as proposed new regulatory tools for public comment. For policy makers, the details of the performance guidance section that include "best practices for the safe pre-deployment design, development and testing of HAVs [highly autonomous vehicles] prior to commercial sale or operation on public roads," will be essential as this technology continues to advance.[xiv] In addition, the 15-point safety assessment included within the document aims to ensure that manufacturers are prioritizing safety and security concerns while not stifling innovation or the potential applications of this technology. NHTSA's approach suggests that meeting safety standards across a range of metrics can still allow for the safe testing and integration of a diverse array of test and concept vehicles with different capabilities and designs resulting from private sector research, innovation, and design.

Reflecting the fact that many autonomous vehicle technologies are in the developmental stage, the fifteen factors that NHTSA identified are voluntary guidelines by which manufacturers could provide a self-assessment of how their vehicle addresses these guidelines. By choosing a process that reflects the spirit of the existing FMVSS self-certification model for traditional vehicles, NHTSA ensured that the development and testing process for autonomous vehicles would not differ greatly from that for traditional vehicles, while also allowing for flexibility in how manufacturers would meet the technical challenge of confirming the safety of the vehicle in these factors that may be unique to autonomous vehicles. Acknowledging that this is not a full FMVSS self-certification, while continuing to emphasize manufacturers' voluntary assessments of their autonomous vehicles' features will be vital for continuing to foster innovative approaches to ensure safe and reliable autonomous vehicle technology.

Even though the NHTSA document is described as guidance and not mandatory, it seeks to clarify the roles of policy makers at the federal and state levels. The model state policy included within the document provides a model regulatory framework for states that wish to regulate procedures and conditions for testing, deployment, and operation of highly autonomous vehicles. It also identifies gaps in current regulations under state jurisdiction that should be assessed in removing impediments to innovation, including the licensing and testing of human drivers and the enactment of traffic laws and regulations. Under these recommendations, the Federal Government has "primary control over the actual automation software, as well as being responsible for setting safety standards, carrying out enforcement and handling recalls."[xv] The delineation of responsibilities at the federal versus state level is meant to avoid a patchwork of state laws that could complicate the eventual commercialization of this technology.

In emphasizing its role in vehicle certification and safety, and by creating a model state policy to address areas such as traffic laws, licensing, testing, insurance, and others, NHTSA has used its role as a federal body to discourage a hodgepodge of state regulation that would hamper the eventual deployment and widespread use of autonomous vehicles. This was a useful first step in seeking to harmonize state rules, but it will warrant future attention from Congress, the Department of Transportation, and NHTSA to ensure that various actions being undertaken by states do not start on a pathway towards vastly different state-by-state rules regarding automation.

The automated vehicles policy also highlighted NHTSA's existing authorities to interpret the FMVSS, to exempt vehicles from the FMVSS for testing, to amend or make new rules regarding the FMVSS, and to recall vehicles that are unsafe. Already, NHTSA has demonstrated a willingness to be flexible and innovative in interpreting the FMVSS with regards to autonomous vehicle development. This mindset should be continued as the technology progresses, and it can be fostered with ongoing dialogue between regulators and all of the players in the autonomous vehicle market place. Furthermore, NHTSA is already using its exemption authority to allow autonomous vehicle testing, and expanding this authority will be key for testing and deploying further generations of autonomous vehicles.

The "Federal Automated Vehicles Policy" details five proposed new tools and authorities—additional safety assurances, pre-market approval authority, hybrid certification/approval process, cease-and-desist authority, and expanded exemption authority—that could strengthen NHTSA ability to ensure vehicle safety.[xvi] However, many of these authorities do not take into account the current status of autonomous vehicle technology. Additional safety assurances, a hybrid certification/approval process, and cease-and-desist authority require further examination to determine exactly how such authorities would be implemented, and how they would be integrated with existing tools used by NHTSA. That said it is currently clearer that pre-market approval would unnecessarily slow the development of autonomous vehicles, while expansion of the exemption authority or elimination of the cap on exempt vehicles for testing purposes would help provide the additional testing and data needed for autonomous vehicle research and development.

Considering that automobile technology evolves at a fast pace and manufacturers release new vehicle models each year, it would not be feasible to ask the private sector to abide by a pre-market approval process. Unlike the current self-certification process that is currently used by NHTSA, a potential pre-market approval process may not take into account the ability for companies to update software on a weekly or even daily basis. If that were the case, it would

hinder the dissemination of critical software updates aimed at helping autonomous vehicles "learn" and adapt to their surroundings.

Beyond software, a potential pre-market approval process would operate in a manner similar to how the FAA certifies aircraft. However, traditional automobiles have always operated on a self-certification model, reflecting the greater number of automobiles on the road and the yearly model updates used by manufacturers—compared to the decade or more involved in aircraft design, development, and commercialization. If autonomous vehicles or vehicles with autonomous systems were required to undergo pre-market approval, they would be placed at a disadvantage compared to traditional vehicle self-certification timelines. This would stifle an innovative process for automobile innovation that has worked well in the past, and can continue to thrive with self-certification by manufacturers that meet safety standards and guidelines.

With a need to gather more data about autonomous vehicle operation, it will benefit the private sector and regulators to alter NHTSA's exemption authority. The current authority permits the agency to exempt 2,500 vehicles per year for a two-year period for the purposes of testing. Yet, many within the private sector have questioned the scope of this policy, as it does not take into account the need for a broader sample size to "teach" automated guidance systems, as well as the pace of technological evolution. Unlike traditional vehicles where manufacturers focused much of their testing upon physical functions, autonomous vehicles rely upon complex software that should be periodically updated based upon the functioning of the vehicle. Thus, an expanded exemption authority would allow for companies to develop more comprehensive testing initiatives. During the project, expanded exemption authority was repeatedly cited by project participants, regulators, and private sector innovators as an important tool for improving autonomous vehicles' performance by allowing a greater number of vehicles to experience true roadway conditions.

The other potential tools—additional safety assurances, hybrid certification/approval processes, review of aftermarket software updates, and cease-and-desist authority—have their merits, their drawbacks, and many outstanding questions as to how they might be structured or applied. For example, cease-and-desist authority could be applicable in a circumstance where a severe cybersecurity flaw is discovered in an autonomous guidance system requiring faster action than a traditional recall process—though technical solutions such as cloud-based software updating may eventually negate the need for such regulatory solutions. Therefore, expanded testing of autonomous vehicles and dialogue between government and the private sector is necessary for determining what tools NHTSA needs to ensure its mission of roadway safety, while not being so onerous as to stifle innovation in this field.

FCC & V2X Technology

In addition to the NHTSA, the FCC has become an increasingly important player in the development of automated vehicles. An ongoing policy issue is the future of dedicated short-range communications (DSRC), as manufacturers want to commercialize vehicles with more advanced autonomous systems. DSRC can allow for limited, short range communication—often less than one kilometer—via wireless links that provide for vehicle-to-vehicle (V2V), vehicle-to-roadside (V2R), and vehicle-to-infrastructure (V2I) communications. DSRC, combined with the full "V2X" array of applications, can allow for safety-related capabilities such as collision avoidance and information about operating conditions, as well as convenience-related capabilities such as traffic rerouting, vehicle dispatch, and commercial transactions. For fully autonomous vehicles, DSRC is essential as it can be integrated with radar and LIDAR sensors, GPS navigation, and other onboard capabilities to network with other vehicles to create a holistic image of traffic patterns, weather, road conditions, obstructions, and other pertinent information.

The FCC approved DSRC in 1999 as the wireless link for V2V and V2I communications and licenses to use this dedicated spectrum became available in 2004. However, since then, the use of this spectrum has been limited to experimental and demonstrative projects. Yet as manufacturers have expressed their interest in deploying vehicles with DSRC capabilities—General Motors has stated it wants to install this technology in its 2017 Cadillacs—this introduces a new host of privacy, security, and regulatory issues.[xvii] Given the value of spectrum and the needs of other industries for wireless communications bandwidth, there have been concerns that the FCC could release the dedicated spectrum needed for V2X applications.

The Cybersecurity Discussion

As this technology continues to evolve and more networked and autonomous vehicles hit public roads for testing, private sector companies have grappled with securing their vehicles from cyber attacks. "One of the central challenges in vehicle cybersecurity is that the various electrical components in a car (known as electronic control units, or ECUs) are connected via an internal network. Thus, if hackers manage to gain access to vulnerable, peripheral ECUs—for instance, a car's Bluetooth or infotainment system—from there they may be able to take control of safety critical ECUs like its brakes or engine and wreak havoc."[xviii] However, this security concern does not just apply to autonomous vehicles, but to connected vehicles as well. According to researchers, more than half of the vehicles sold in the country in 2014 were connected, and as a result, vulnerable to cyberattacks.

Due to the complexity of this issue, NHTSA took a proactive approach by releasing a set of proposed cybersecurity guidelines for companies developing autonomous vehicles. According to NHTSA, the guidelines focus on a layered and comprehensive approach to ensuring vehicle safety and "recommends risk-based prioritized identification and protection of crucial vehicle controls and consumers' personal data."[xix] Considering that cybersecurity is a constantly evolving concern, NHTSA suggests that companies implement best practices—from NIST, SAE, and the Auto-ISAC—when researching, developing, testing, and validating software platforms.

Working in tandem with NHTSA is the DHS Science and Technology Directorate (S&T). The Cyber Physical Systems Security (CPSSEC) project within the S&T's Cyber Security Division (CSD) focused on collaboration with auto manufactures and researchers to ensure the security of autonomous vehicle software. The division launched a joint project between leading universities, research institutes, and 40 automotive related companies—ranging from startups to tier one suppliers to major automotive manufactures—to develop guidance on how to properly secure this technology.[xx]

In addition to the work conducted by Federal Agencies, private sector entities have begun to implement their own initiatives to secure sensitive systems. Companies such as Tesla, General Motors, Chrysler, and Fiat have established "bug bounty" programs that reward individuals who find and report security flaws in vehicle software. Overall, in order to fully secure these vehicles, it is important for the sector to continue to share information and data with Federal Agencies—DOT, DHS, NHTSA—and with each other, utilizing the Auto-ISAC structure.

Congressional Attention

Due to the complex nature of autonomous vehicles and the current state of vehicle testing, Congress must tread carefully on this issue. The varied levels of interest from constituents, combined with the regulations developed at the state level and by NHTSA, may be sufficient to promote innovation while keeping consumers safe. However, those within Congress who may feel compelled to act and develop legislation related to this sector may feel political pressure to do so based upon the impact autonomous vehicles could have on jobs and concerns about roadway safety and cybersecurity.

Currently, as the technology continues to be tested and further iterations of these vehicles are developed by industry, Congress's role may be better served by maintaining awareness of the advances in this technology, managing the balance of safety concerns with the innovative opportunity of this technology, and working with a wide range of stakeholders to understand the ramifications of the increased use of these technologies.

The primary role of Congress in addressing autonomous vehicle policy will be through its statutory powers related to Title 49 of the U.S. Code. Through these legislative powers related to the Department of Transportation and NHTSA, Congress can move to expand the exemption authority, and can ensure that pre-market approval is avoided. Through other legislative tools, Congress can also continue to look at legislation that allows for information sharing between the government and private sector regarding cybersecurity matters; use the power of the purse to continue research programs; and ensure that future infrastructure planning has the flexibility to incorporate a wide range of potential technological innovation.

Congress may face the temptation to be prescriptive in addressing autonomous vehicle policy as a greater range of advocacy groups and industries—and their lobbyists—pay greater attention to this field. Congress should be judicious and avoid being overly prescriptive in ways that could unnecessarily limit NHTSA's flexibility in addressing innovations that move at a pace far faster than legislative processes. Doing so could impede innovation by forcing the hand of NHTSA and other regulators who are already exercising their flexibility to foster innovation-friendly policies.

In addition, Congress's oversight authority can be used for hearings about the progression of this technology and promote dialogue with manufacturers and technology companies. The first of these hearings was in March, 2016, when the Senate Commerce Committee held a hearing on this topic with representatives from Google, Lyft, General Motors, Duke University and Delphi Automotive.[xxi] The increase in communication between industry leaders and Congress will be essential moving forward as Members must first believe in and trust technology before developing legislation to regulate it.

Traditionally, Congressional action regarding the future of transportation has largely been focused on infrastructure—repairing and improving existing infrastructure and making some investments in future technologies via grants or research funding. This has also been highlighted as a priority by the Trump Administration. In terms of infrastructure, it is important that Congress emphasize investment in future technologies, while avoiding actions that may choose which technologies are applied to transportation systems. Either actively or inadvertently "picking" which technology is part of a transportation or infrastructure investment can stifle future innovations in autonomous vehicles and other transportation solutions.

As autonomous vehicles become a greater and greater part of our nation's transportation portfolio, Congress will likely be forced to pay greater attention to this topic. One area that can already be identified as an area of likely concern is the economic impact of how autonomous vehicles may displace commercial driving jobs in taxi and livery services, ride-hailing apps, public transportation, long-haul bus service, and trucking. According to the 2014 data from the

Census Bureau, in 29 states, "truck, delivery, or tractor driver" is the most commonly held job.[xxii] Congress and economic researchers should address the job displacements caused by automation with new retraining paradigms and tools that avoid further dependence on government assistance.

Beyond the economic impact in terms of job loss, Congress must also understand the economic benefit that the United States will enjoy if it remains a leader in the development and manufacturing of autonomous vehicles. Too onerous of a regulatory environment in the United States will encourage regulatory arbitrage that will encourage manufacturers, innovators, and startups to look elsewhere to expand their companies and build their brands. Combining a favorable regulatory environment with continued support for research and the needed high-tech career paths that will be key to ensuring that the United States remains a leader in the global marketplace for autonomous vehicles.

SELECTED STATE-LEVEL POLICIES

In state-level legislation, state governments have responded in different ways to the proliferation of autonomous vehicles. However, the scope of states rules and regulations ranges from defining autonomous technology to codifying specific language regarding manufacturer liability and vehicle testing. This initial phase of examination for this report covered very different approaches from two west coast states—California and Washington. California has demonstrated how states may choose stricter regulatory regime, substituting suggestions of voluntary benchmarks for mandatory standards, granting local municipalities a significant role in autonomous vehicle licensing, and, thus, causing concerns from private sector innovators about the testing and deployment environment in that state. On the other hand, Washington's example reflects a certain level of regulatory and legislative humility—acknowledging that the nascent technology requires further testing as well as the economic potential of attracting autonomous vehicle development and testing to Washington.

California

For proponents of autonomous vehicles, California represents an important case study in the intersection between regulation, innovation, and commercialization. The influence of Silicon Valley—on public policy and on early adapter culture—has shaped the development of autonomous vehicle regulation in a unique way. Yet this case study reflects the delicate balance between implementing regulation to ensure the safety of consumers and allowing for the private sector to innovate.

Typically regarded as a leader in developing and implementing regulation, California has passed a series of regulations regarding autonomous vehicle technology. The state legislature passed two laws—SB 1298 (2012) and AB 1592 (2016)—authorizing the testing of autonomous vehicles by an individual with a proper license[xxiii] and authorizing the Contra Costa Transportation Authority (CCTA) to test a fully autonomous vehicle on a California public road.[xxiv]

In response to the widespread interest in testing autonomous vehicles, the California Department of Motor Vehicles diligently worked to release guidelines clarifying legislation and developing actionable steps companies can take to advance their products. In 2014, the state DMV released guidelines governing the testing of autonomous vehicles on public roads and established the Autonomous Vehicle Tester Program.[xxv] As of January 2017, 21 companies including Honda, Ford, Google, Baidu USA LLC, Tesla Motors, and Delphi Automotive hold permits to test vehicles within the state.[xxvi]

However, when examining California as part of the overall regulatory environment, multiple themes emerge: collaboration, harmonization, and redefining roles and responsibilities. Considering that the state is home to one of the country's leading technology hubs, the private sector's influence on public policy is unmatched. For Silicon Valley, less regulation is preferred, as the slow-moving processes of government have hindered the private sectors ability to innovate, develop, and test new technology. At the beginning of the regulatory process in California, private sector companies collaborated with regulators to craft legislation that would facilitate the advancement of this sector.

Yet, good intentions can result in unintended consequences and tensions between the private sector and state regulators emerged after the California DMV released guidelines in December, 2015 and were revised in September, 2016 that govern the deployment of autonomous vehicles on public roads.[xxvii] Many private sector leaders have called these guidelines too restrictive, as they do not account for the wide breadth of autonomous vehicles and could hinder development and innovation. It is also important to note that overly prescriptive regulations do not just hinder the ability for major manufacturers to operate, but startups and other companies not traditionally in the automotive sector will face regulatory challenges that will restrict their ability to test new types of autonomous vehicles. Overall, representatives from the private sector have expressed frustration over data-sharing policies, acquiring municipal permits or special ordinances for testing, and meeting the DOT's voluntary 15-point checklist.[xxviii]

For state regulators and private sector leaders, continuing to communicate on the development of future regulation and the implementation of current regulation is key. Due to the state's market size and role as a leader in developing regulation for other sectors—specifically environmental standards—interested parties must avoid setting a negative precedent when it comes to private sector/local government collaboration. The progression and resolution to this regulatory debate will be closely monitored by other states who are interested in entering into this sector.

Equally as important as the actual laws themselves, is how local and federal agencies have defined their role and responsibilities regulating the emerging technology. Representatives from NHTSA have commented how the perils of creating a patchwork of state laws would impede the widespread deployment of this technology, as conflicting regulation could force operators to "switch the modes" of autonomous systems in different ways in different states. The harmonization of state and federal regulations has become imperative, and the example of California state regulators is an essential case study as manufacturers and regulators seek to conduct testing and look towards commercialization.

Washington

Even as the technology sector within the State of Washington has evolved and changed, it has remained at the forefront of innovation. The strength of that sector, combined with Washington's transportation industry, has laid the foundation for the deployment of autonomous vehicles within the state. "The Puget Sound area's century-long dominance in transportation technology and decades of wireless communication expertise means the right people are already here working on the future of transportation."[xxix] Even if the physical cars are not being built in the area, the area's technology sector has played a crucial role in developing software platforms which control critical functions of autonomous vehicles.

This welcoming environment—built upon the state's technology sector and experience with electric vehicles—has made Washington State an attractive location to test autonomous vehicles. Unlike other states who immediately reacted to autonomous vehicle technology through regulation, government officials did not want to take action—legislative or otherwise—that would prematurely manage or control this emerging sector. In addition to these factors, the unique weather patterns of Washington State give engineers the opportunity to test vehicle software and sensors to in varied terrain and conditions.[xxx]

However, in order to harness these innovations in transportation models and transportation technology, the City of Seattle and the State of Washington have also pursued innovation-friendly regulations that allow for the use of car-sharing and ride-sharing services, as well as the testing of autonomous vehicles.

The State of Washington has sought to make itself an attractive destination for the testing of self-driving vehicles by avoiding the regulatory frameworks that other states have developed to "frame" the testing and deployment of self-driving vehicles on public roadways. By avoiding strict regulation and keeping an ongoing dialogue with both traditional transportation players as well as startups, the State of Washington has been an attractive destination for the testing of vehicles. Combined with a tech-savvy populace and the geographic and meteorological diversity that allows for testing in multiple environments, the State of Washington's regulatory framework has balanced existing tools for ensuring vehicle and roadway safety, while also maximizing the opportunity to test nascent technologies.

For Google, which has a large campus located in Kirkland, testing autonomous vehicles in Washington State was a natural progression of their program. Google began testing these vehicles in Silicon Valley in 2009, and then expanded to Austin, Texas. Google has deployed their autonomous fleet of Lexus RX 450h SUV's equipped with a steering wheel and a variety of cameras, lasers, and sensors to map out city streets.[xxxi] As companies begin to transition their

autonomous vehicles from private testing facilities to public roads, the State of Washington will continue to be a popular testing destination.

In terms of ride-sharing and car-sharing regulations, Seattle has sought to balance the concerns of traditional industries with the need to accommodate traditional taxi and livery providers with the rise of app-based ride-sharing firms such as Uber and Lyft, as well as car-sharing companies. However, the fact that many regulations regarding transportation such as registration fees, parking permits, etc. are handled at the municipal, sub-county level creates additional layers of bureaucracy for firms seeking to provide car-sharing services that allow their clients to travel and park where they wish without regard to municipal boundaries. At the same time, these registration fees and parking fees are a significant source of revenue for the cities that are applied to both transportation and general budgets.

For car-sharing—and eventually shared self-driving vehicles for personal use—it will be necessary to harmonize various registration and regulatory regimes for road use and parking rules to allow for customers to easily transit between the multiple jurisdictions that make up many of America's great urban areas. It will be important to ensure that these new technologies are made convenient for users, while also allowing for predictability in terms of the transportation and budgetary planning of municipalities.

The introduction of advanced technology, specifically autonomous vehicles, could greatly benefit international commerce with Canadian cities such as Vancouver. The foundation of this economic relationship is the technology sector, which has benefitted from a skilled workforce and geographic location to two of the largest ports in North America. In addition to the billions invested in both cities through venture capital firms, many American companies have begun to open offices in Vancouver, specifically Amazon and Microsoft.

PLANNING FOR THE FUTURE

The autonomous vehicle has the potential to reshape not just our transportation models, but also our economy and urban planning. While the majority of this project was focused on the political and regulatory environment for autonomous vehicles, these future ramifications were also discussed. Just as policymakers must consider how the current political and regulatory environment can foster autonomous vehicle innovation, they must also consider how to plan for future outcomes.

Considering that the majority of autonomous vehicles are still being tested, researchers are unsure of the possible impacts—positive or negative—that this technology could have. Not only can this technology decrease the number of vehicle crashes per year and lead to the development of new insurance models, but there are intangible costs that the introduction of this technology could alter including noise, mobility, supply chains, workforce productivity, land use/urbanization, alternative fuel, congestion, and air pollution. While the ultimate shape of the impact of autonomous vehicles is hard to define, it is important to remember President Eisenhower's maxim, "plans are nothing; planning is everything."

Highlighted here are two of the many potential ramifications that have been discussed by experts during this project for the attention of policymakers as we move towards an autonomous vehicle future. Many other areas will require attention, and continued dialogue with policymakers, private sector leaders, and academics will help craft better understanding of future scenarios. The scenarios can serve as a useful exercise for understanding the potential impact of technology, but we must also acknowledge the fallibility of our own "crystal ball" and avoid taking regulatory measures based on hypothetical concerns.

Approached in the broadest of strokes, these are areas where we can begin the discussion surrounding the potential of autonomous vehicles to upend models that have been built, layer by layer, over a century of human-operated transportation.

The Economic Impact

If the United States remains a leader in autonomous vehicle innovation and manufacturing, it stands to benefit from being a leader in a rapidly growing global marketplace. The Boston Consulting Group estimates that the global market for partially and fully autonomous vehicles will reach $42 billion by 2025, expanding to $77 billion by 2035. Of this marketplace, the share of fully autonomous vehicles will grow to almost half of the autonomous vehicle market by 2035. To remain a leader in this field is key for the future of manufacturing in the United States.

Furthermore, as described in the report's findings regarding the potential of autonomous vehicles, the increased efficiency and freed use of transit time for other activities presents an opportunity for productivity growth, as well as increased time for working, entrepreneurial activity, hobbies, or much-deserved leisure time. Ancillary fields such as telecommunications and entertainment may also see new markets grow to serve viewers during freed-up travel time.

The economic impact of job displacement was also discussed, given the importance of trucking as a job around the country. However, trucking industry experts have projected a shortage of trucking jobs in the future, and many experts believe that there would still be a human operator on trucks making final deliveries, as fully autonomous operation would only occur during long distance trucking on interstate highways. Still, across a wide range of other driving-related careers, there will be a major impact on employment prospects.

It will also be important to ponder the breadth of economic effects that this technology will have on a various industries that have developed to support widespread car ownership and transportation services. At the same time, it is worth noting the economic benefit that will result from fewer injuries and deaths on roadways, and the impact that will have in terms of lost earning power and insurance costs.

Finally, the entire concept of car ownership could be changed as fleets of autonomous vehicles prompt a greater emphasis on ride sharing—particularly in urban cores and denser suburban areas. Outstanding questions about insurance and liability must be considered within a framework where the occupants of a vehicle are not responsible for the decisions made during operation—as well as how insurance and liability concepts are affected by roadways that are increasingly accident free.

Urban Planning

Some approaches to urban planning have been to either accommodate the automobile by devoting land and space for parking and extra lanes to accommodate increased traffic, while others have sought to reduce reliance on automobiles by encouraging mass transit, bicycling, carpooling, and pedestrian access. It will be important for current and future urban planners to understand the impact of autonomous vehicles on these various approaches, as it will reshape decisions made about transportation.

One potential outcome is that autonomous vehicles will encourage a greater use of personal or shared vehicles as the time spent in traffic is freed up for other uses while within a vehicle. At the same time, it is possible that autonomous vehicles will increase the catchment area for

other forms of public transportation, thus encouraging a greater emphasis on autonomous vehicles combined with high-capacity rail or bus service—and greater pedestrian activity in dense urban cores. Evaluating these scenarios will require policymakers and private sector leaders to evaluate the decision-making of commuters and transportation users to better understand behavioral and comfort preferences in addition to the data of roadway usage and ridership on mass transit systems.

Many cities have enjoyed a renaissance as younger people and retirees have sought to move back into downtowns for reasons of physical accessibility, easy access to business and services, and the network effects of denser populations. Will autonomous vehicles increase the attractiveness of urban cores given that they provide an additional transportation tool in cities, or will living further from the city be an option as autonomous vehicles will reduce the opportunity cost—measured in time—of commuting from further afield? Could far-flung suburbs and satellite towns experience a renaissance based on this new transportation model?

Finally, for municipalities that have long budgeted assuming a revenue stream from parking meters, parking taxes, vehicle stickers, and other revenue tools based on road usage and drivers' needs, this revenue is likely to dry up if shared, autonomous vehicle usage becomes the norm in most major areas. This will present new challenges in funding a wide range of local government activities and transportation needs, while also freeing up land that was used for parking and vehicle storage for new endeavors.

Rural Transportation

Much of the focus concerning the testing and commercialization of autonomous vehicles has focused upon their impact in urban areas. Yet some of the greatest benefits in mobility, accessibility, and connectivity to consumers may occur within rural America. The automation of farming equipment has already introduced many of these communities to the functions and benefits of advanced technology. Policymakers and manufacturers should continue to examine the impacts—societal and economic—of the deployment of autonomous vehicles to rural areas alongside the attention paid to more developed areas.

Considering and planning for these outcomes—as well as the other second and third order effects that will result from an autonomous vehicles future—is a tall task for policymakers, academics, and private sector leaders. A wide range of innovative technologies could make many of these outcomes a reality, yet consumer choice will be the guiding principle as the American people become more and more comfortable with these new vehicles.

CONCLUSION

Even as the development of autonomous vehicles faces technological and regulatory challenges, the benefits it offers to reshape our nation's transportation paradigm cannot be ignored. While it is necessary to apply regulatory powers to ensure the safety of our nation's roadways, they must be balanced with the need for innovative technologies that can solve the greatest safety challenge—human error. Regulatory assumptions about the safety of autonomous vehicles must understand two fundamental facts: the current transportation model is not safe and that a wide-ranging approach to innovation can solve this challenge.

For this technology to reach its potential, its development and testing requires real-world experience. Just as we tolerate a certain level of risk with new human drivers entering the roadways—with caveats such as curfews, occupancy restrictions, and other limitations—we must also carefully judge the risks and benefits of testing self-driving vehicles and integrating them onto public roadways. To ensure that we one day have the best "trained" autonomous vehicles on our roadways, we must now allow for greater and greater learning by the software and guidance systems that will guide these vehicles. To this end, it is important that we encourage, rather than limit the testing of these vehicles.

Additionally, autonomous vehicles must not be disadvantaged compared to traditionally operated vehicles. Doing so will stifle equally their adoption and the benefits of the technology. Applying pre-market approval to autonomous vehicles would be one such disadvantage. Another disadvantage would be a patchwork of state regulations in which a driver operating a vehicle in one state is forced to change the vehicle's operating parameters because it is crossing a state line.

In preparing for an autonomous vehicle future, policymakers in government and the private sector must also plan for changes in the economic and urban planning models that are the foundation for our transportation system and its relationship with everyday life. As these vehicles are integrated into the nation's transportation portfolio, it is important that the transition be as smooth as possible and that the benefits be widely shared across all segments of society. Combined with a public that will be increasingly familiar with automated vehicles and automated vehicle technology, the adoption of this technology can be a smooth process.

Within the regulatory frameworks applied at both the federal and state level, it is also vital that the safety or "manufacturing experience" does not become an excuse for regulatory capture. Transportation is a field that is ripe for commercial disruption, and established players must also match the innovative pace of the marketplace that can be driven by tech companies and

startups. At the same time, those startups and tech companies that have continually operated at the cutting-edge of technology must also understand the example set by the established players—who have long understood the importance of a corporate culture that places safety at the forefront. With companies bringing their various strengths to the marketplace, the consumer can choose from a wide range of options—while investors and the marketplace can also decide how firms are acquired, consolidated, or, ultimately, fold.

Throughout the evolution of this technology, our political and private sector leaders must continue to be advocates for this technology and its potential. While there may be challenges along the way—challenges inherent with any technological evolution—this cannot be the cause of a regulatory or political blowback that stifles the various avenues by which this technology can meet its potential.

At the same time, there must be a willingness among policymakers, regulators, and other public leaders to admit that there is much that we still do not know about the autonomous vehicle landscape, and that applying regulatory measures to what remain hypothetical concerns is premature and likely to stifle needed innovation. Instead, we must approach the autonomous vehicle future with an open mind, aware of its benefits and ready to ensure that technology, innovation, and enterprise also drive advances in safety and reliability.

The autonomous vehicle future is a bright one, and smart political and regulatory leadership—working with the private sector—can ensure that this technology reaches its potential.

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