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Self-Driving Regulation

Pro-Market Policies Key to Automated Vehicle Innovation

*By Marc Scribner**

Leonardo da Vinci first sketched the design for a self-propelled cart with programmable steering in the late 15th century. Fast forward to 2010, when Google announced its fleet of self-driving cars had quietly racked up over 140,000 miles on public roads.[1] Robotic cars found in science fiction, as well as Leonardo's sketch books, will soon be science fact. To ensure innovation is fostered and fleet deployment is rapid, policy makers must prepare for this new reality.

Google's announcement surprised even those who had been tracking vehicle automation developments. As of this writing, Google's self-driving cars have now logged a total of over half a million miles.[2] Autonomous vehicles—also known as driverless cars and self-driving cars—promise to dramatically reduce human error, which is a crash factor in over 90 percent of auto accidents.[3] This has the potential to save tens of thousands of lives annually, significantly reduce traffic congestion and air pollution, and offer greatly improved transportation access to traditionally mobility-impaired populations such as the disabled, elderly, and youth.[4]

Such innovation would result in a massive shift in the role of automobiles in society and the institutions that have been built around automobility. The advent of highly automated vehicles may require modernization of our motor vehicle codes, auto safety regulations, infrastructure investment, products liability law, and local transportation service regulations to best adapt to this future.

But regulatory and legislative intervention also poses great risks to the development of the technology. In particular, laws and regulations that narrow the scope of permissible development, testing, and operational functionality risk locking in inferior technology, delaying adoption, and increasing prices faced by consumers. To reduce these risks, lawmakers and automakers should adopt a liberalized approach toward innovation and a cautious stance on legislation and regulation, particularly at this early stage.

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A Brief History of Vehicle Automation. The concept of automated vehicles is not new. As noted, in the late 15th century, Leonardo da Vinci sketched out plans for a self-propelled cart with programmable steering, which was later compiled in the *Atlantic Codex*.[5]

Engineering interest in vehicle automation stretches back to the 1920s, when auto ownership first came within reach of middle-class households. Inventor Francis P. Houdina demonstrated a radio-controlled car on the streets of Manhattan in 1925.[6] Most of the public saw Houdina's invention mainly as a novelty—although his company's prominence led to an altercation with famed escape artist Harry Houdini, resulting in a disorderly conduct charge against Houdini[7]—but the challenge of developing automated vehicles became recognized in research communities.

At the 1939-1940 New York World's Fair, General Motors' interactive *Futurama* exhibit predicted high-speed automated roadways in 20 years.[8] While GM's prediction of a driverless world proved premature, its Great Depression-era prediction of automobile ownership becoming widespread, rather than a luxury for the wealthy, proved accurate.

The first practical application of vehicle automation took place not on the roadway, but in a warehouse. In 1954, Arthur Barrett, Jr., developed the first automated guided vehicle (AGV), which he described as a "driverless vehicle" called the Guide-O-Matic.[9] The Guide-O-Matic, which followed a wire in the ceiling, helped turn Barrett Electronics into a major provider of advanced logistics and distribution center equipment. Barrett Industrial Trucks was later sold to Nissan.

Robotic vehicles that rely on guide wires or laser sensors have been widely adopted by industry, but technology aimed at consumers has not kept pace. Beginning in the 1960s, interest arose from industry, academia, and government in developing automated highway vehicles. These experiments have continued for decades and have resulted in adaptive cruise control, lane keeping assistance, and other automated features that have found their way into vehicles currently available to consumers.

Serious research into highway vehicle automation began in the late 1950s and 1960s. Joseph Bidwell, the head of General Motors' Research Engineering Mechanics Department, and his team of engineers developed a crude automatically guided Chevrolet in 1958.[10] At the front of the car sat a pair of coils that could detect the alternating current of a wire set in the roadway and adjust the steering wheel to follow the path.[11] In principle, this was little different than Barrett's Guide-O-Matic, but it illustrated automobile manufacturers' seriousness in pursuing highway vehicle automation.

In addition to GM, others such as RCA's Vladimir Zworykin were also developing infrastructure-reliant highway vehicle automation. Zworykin's 1960 model used circuits buried under roadways to detect vehicle speed and location, the data from which were then transmitted to a central control computer that guided the vehicle.[12]

Private sector research into highway vehicle automation largely collapsed following the passage of federal auto safety laws and the promulgation of strict safety regulations beginning in the mid-1960s.[13] This was followed by strict fuel economy regulations in the 1970s. Rather than investing in futuristic research and development projects, automakers redirected resources to building vehicles that met the new political safety and energy requirements.[14]

Industry and government researchers turned their attention back toward highway vehicle automation technologies in the 1980s and 1990s. The Intermodal Surface Transportation Efficiency Act of 1991 tasked the U.S. Department of Transportation (DOT) with creating the Automated Highway System (AHS) program.[15] AHS led to the formation of the National Automated Highway System Consortium (NAHSC), a public-private effort to develop automated highway systems prototypes.[16]

Robert Ferlis, technical director of the Federal Highway Administration's Office of Operations Research and Development, describes the NAHSC effort thus:

> The work of the NAHSC culminated in August 1997 with an AHS proof-of-concept demonstration on I-15 in San Diego, CA, where more than 20 fully automated vehicles operated flawlessly for 4 days on two protected lanes (normally the HOV lanes) that had been blocked off from other traffic. The demonstration provided participants with a "hands-off, feet-off" driving experience and gave the public a tantalizing taste of the future.[17]

Yet with enactment of the Transportation Equity Act for the 21st Century in 1998, the Department of Transportation ceased all funding of NAHSC.[18] Within DOT, several AHS components were continued in less ambitious intelligent transportation systems (ITS) programs, such as the Intelligent Vehicle Initiative, which primarily aimed to provide better data and control to human drivers.[19] However, by the late 1990s, no comprehensive long-term research program dedicated to developing highly automated highway technologies existed at DOT.

In 2000, Congress passed the National Defense Authorization Act (NDAA) for Fiscal Year 2001. Section 220 of NDAA FY 2001 provided the Defense Advanced Research Projects Agency (DARPA) $100 million to develop "unmanned advanced capability combat aircraft and ground combat vehicles."[20] Two years later, in NDAA FY 2003, Congress authorized the development of "a program to award cash prizes in recognition of outstanding achievements that are designed to promote science, mathematics, engineering, or technology education in support of the missions of the U.S. Department of Defense."[21] This was the genesis of the unmanned combat aircraft (drone) programs that have become a source of great controversy in recent years. DARPA also used its NDAA authority to create a series of Grand Challenges—contests open to the public aimed to promote the development of autonomous ground vehicles.

DARPA held its first Grand Challenge at a 142-mile course in the Mojave Desert in 2004.[22] The race ran from Barstow, California, to Primm, Nevada, offering $1 million to the winning team. None of the competitors finished the course. The following year, DARPA held a second, similar Grand Challenge, with the prize money doubling to $2 million. Stanford University's "Stanley" won the event, with four other vehicles also completing the course.[23] In 2007, DARPA held a final Urban Challenge on a 60-mile course in moving traffic, offering a $3.5 million purse to the three fastest teams who safely completed the course in six hours or less.[24]

Since the three DARPA challenges, the private sector has taken the lead in continued development of highly automated vehicles. Google's exploits are now well known, and it appears to have the most advanced prototype to date. In addition, Bosch, Volkswagen, Volvo, Toyota, and others are in various stages of developing their own autonomous vehicle prototypes. It is now within the realm of possibility that highly automated vehicles will be available for consumer purchase by 2020.

Assessing the Current Landscape. Given the proprietary nature of highly automated vehicle technology, it would be premature to discuss with any conviction current developments as they relate to public policy. However, there are two areas for which sufficient public information exists—legality and safety policy.

Legality. To date, Nevada,[25] Florida,[26] California,[27] the District of Columbia,[28] and Michigan[29] have enacted laws that explicitly recognize the legality of autonomous vehicles. Several other states are considering similar legislation.[30]

Despite some commentators' erroneous assumptions,[31] highly automated vehicles are likely legal in most jurisdictions in the United States.[32] State motor vehicle codes are decades old and simply do not consider the possibility of a highway vehicle being directed without real-time human input. Policy makers should keep in mind this distinction between *legalization*, which implies that autonomous vehicles are presently illegal, and *recognizing legality*.

When Google asked the California State Highway Patrol in 2010 about the legality of allowing a legally blind man to sit in the driver seat of one of its self-driving cars during operation, it was told no law prohibited such operation.[33] Ironically, California's 2012 law recognizing the legality of autonomous vehicles appears to have outlawed operations such as Google's 2010 experiment, as state law now requires that a licensed driver sit in the driver seat during autonomous operation on public roads.[34]

Only New York State appears to legally restrict autonomous vehicle operation due to a provision of its motor vehicle code that requires licensed drivers to have one hand on the steering wheel during operation.[35]

Safety. In the United States, highway vehicle safety is regulated by the National Highway Traffic Safety Administration (NHTSA). In May 2013, NHTSA issued its *Preliminary Statement of Policy Concerning Automated Vehicles*.[36] This document provided guidance to the states on testing highly automated and autonomous vehicles and explained the levels of automation defined by NHTSA, which range from 0 to 4 (See Table 1). To date, no Level 4 vehicles have been developed and tested (Google's current self-driving car, for instance, is considered Level 3).

TABLE 1. NHTSA Levels of Vehicle Automation[37]

Automation Level	Definition
Level 0 – No-Automation	Traditional manually driven vehicles, including those with automated warning systems or automated secondary controls (*e.g.*, headlights, turn signals).
Level 1 – Function-specific Automation	One or more independent automated primary control functions (steering, braking, throttling). These include adaptive cruise control, electronic stability control, and dynamic brake support in emergencies.
Level 2 – Combined Function Automation	Two or more automated primary control functions designed to work in unison to relieve the driver of control over these functions. Driver must be able to retake manual control of the vehicle with no warning.
Level 3 – Limited Self-Driving Automation	Driver can cede full control of the vehicle in some situations. Must have ability to retake manual control following warning and transition period.
Level 4 – Full Self-Driving Automation	Vehicle control functions fully automated for an entire trip. Driver has no expectation (or ability) to retake manual control at any point.

NHTSA is currently working to integrate highly automated vehicles into its safety regulatory framework. However, a draft rule is not expected until at least 2017 and it is still unclear if additional statutory authority will be needed to allow for the future integration of autonomous vehicles into the nation's wider automobile fleet. Furthermore, such a rulemaking would not apply to commercial motor vehicles, which are regulated by the Federal Motor Carrier Safety Administration (FMCSA). FMCSA has yet to issue any policy guidance on highly automated vehicles.

Peripheral issues relate to vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. NHTSA is currently developing a V2V rule that will likely require collision warning technology.[38] A draft rule is expected by 2017 at the earliest and it is unclear if it the V2V rule will contemplate, let alone mandate, the integration of collision avoidance communications with the direction of primary vehicle control systems. Analysts have raised concerns that such a rule risks locking in inferior technology and denying consumers a legitimate choice,[39] and likely will be strongly opposed by automated vehicle developers.

One important challenge, which is expected to be met by late 2014 or early 2015, is providing sufficient evidence that road-tested autonomous vehicles are in fact safer than manually driven vehicles. As Bryant Walker Smith of Stanford Law School has noted, a high degree of statistical confidence must be reached in order for automakers and component developers to begin scaling up technology deployment beyond testing.[40] Google's self-driving cars have logged over 500,000 miles on U.S. public roads to date.[41] To demonstrate their safety over manually driven vehicles with 99 percent confidence, Google will need to log approximately an additional 200,000 miles of crash-free automated driving (see Table 2).

TABLE 2. Demonstrating Automated Vehicle Safety Benefits[42]

	All Crashes	Fatal Crashes
Vehicle-miles Traveled (VMT)	2.954×10^{12}	2.954×10^{12}
Vehicles Involved in Crashes	18,705,600	45,435
VMT per Crash	160,000	65,000,000
Crash-free VMT Required for Benefit*	**725,000**	**300,000,000**

**Poisson distribution, P-value < 0.01, using 2009 data (Smith, Goodall, Census, NHTSA).*

In addition to reaching this statistical milestone, the critical question for autonomous vehicle crash safety is: *How* do autonomous vehicles crash? That is more difficult to answer than it might first appear. Noah Goodall of the Virginia Department of Transportation has been researching autonomous vehicle crash ethics. He notes that while an autonomous vehicle might be able to *avoid* crashes well, but if escaping a crash is impossible, it may not crash as well as a human driver would. He provides the following hypothetical:

> [A]n automated vehicle is traveling on a two-lane bridge when a bus traveling in the opposite direction suddenly veers into its lane. The automated vehicle must decide how to react using whatever logic has been programmed in advance. There are three alternatives:
>
> A. Veer left and off the bridge, guaranteeing a severe one vehicle crash.
>
> B. Crash head-on into the bus, resulting in a moderate two-vehicle crash.
>
> C. Attempt to squeeze past the bus on the right. If the bus suddenly corrects back towards its own lane—a low-probability event given how far the bus has drifted—a crash is avoided. If the bus does not correct itself—a high-probability event—then a severe two-vehicle crash results. This crash would be a small offset crash, which carries a greater risk of injury than the full frontal collision in alternative B.[43]

An automated vehicle must be able to determine the possible outcomes of a trajectory choice, severity of a specific outcome, and the conditional probability of an outcome occurring given the vehicle's trajectory choice. As Goodall explains, determining possible outcomes and their probabilities are technically demanding, while evaluating the severity of an outcome is morally challenging.[44]

While Goodall concludes there is no obvious way to effectively embed human ethical values in software, he proposes a three-phase strategy to deploy something approaching human morality in automated vehicles:

1. Begin with a rational moral system designed to minimize crash impacts based on broad principles, such as injuries being preferable to fatalities;
2. Introduce machine learning techniques to observe human behavior in actual crashes to determine common values; and
3. Enable the automated vehicle to express its decision logic using natural language to allow humans to understand and correct its ethical processes.[45]

Phases 2 and 3 require a technical knowledge base that is not yet developed, but in principle this approach appears sound. Phase 1, while facing a number of technical challenges, will likely be implemented in some manner in first-generation autonomous vehicles.

Finally, integrating robust driver monitoring and warning systems into NHTSA Level 3 vehicles is critical for future adoption and innovation. The importance of human factors in automated vehicles should not be underestimated, particularly for Level 3 automated vehicles.[46] While removing the human decision element from the direction of vehicles will almost certainly improve safety, developers must be careful not to encourage new unsafe behaviors. If 90 percent of driving in a Level 3 vehicle is automated, 10 percent must still be manually directed by the driver. But if this increased automation leads to excessive fatigue, boredom, or distraction, the driver may not be able to safely retake manual control, leading to increased crash risk.

Recommendations for Policy Makers. The previous sections described past and current autonomous vehicle developments, both technical and political. To date, most of this has occurred in an environment with little regulation—or rather, with little regulation specifically applied to automated vehicles.

One major danger is for policy makers' natural fear of the unknown to translate into policies based on the precautionary principle. Such overcaution would likely delay the consumer availability of autonomous vehicles and increase their prices. Assuming automated vehicles are found to be safer than manually driven ones, every day of delay and significant price increase translates into increased property damage, physical injury, and death—in addition to denying the disabled, elderly, and youth increased personal mobility and consumers greater convenience, productivity, and leisure time.

Policy makers must accept that their good intentions—whether in the form of self-styled consumer protection, distributional concerns, or aesthetic preferences—can have harmful and potentially deadly consequences. Simply put, we should leave the automated vehicle market as unencumbered as possible, to allow for the fastest availability to the most consumers.

What follows is a brief discussion of policies that will best promote automated vehicle innovation and consumer availability. These are broken down into five categories: 1) legality, 2) safety, 3) infrastructure, 4) products liability, and 5) transportation services. Discussion related to potential privacy issues is intentionally omitted, as data security and ownership issues are not unique to automated vehicles and are beyond the scope of this paper.[47]

Legality. As noted above, five U.S. jurisdictions have enacted laws recognizing the legality of autonomous vehicles. Several others are considering similar legislation. The primary purpose of these laws is to facilitate road testing. Lawmakers should also avoid laws that unnecessarily restrict certain automated vehicle functions. For instance, a requirement that a licensed driver remain in the driver seat at all times likely will not overly burden most test operations. However, it would restrict experimentation with autonomous rideshare or "driverless" taxi operations, one of the more promising automated transportation service applications.

To this end, states should pass legislation recognizing legality and issue regulations that minimize references to specific technologies and functions. At the very least, states should adopt key legislative and regulatory principles that aim to do as little regulating as possible for the purpose of fostering rapid development and rollout of highly automated vehicles.

The American Legislative Exchange Council, a center-right public-private partnership organization of state legislators and private-sector members, has adopted a model resolution that warns of the potential risks of overregulating autonomous vehicles and provides a good starting point for future legislative activities related to vehicle automation (see Appendix).

Safety. Highway vehicle safety is almost exclusively the domain of the federal government. NHTSA and FMCSA issue safety rules that dictate design elements. Currently, federal regulators do not differentiate between manual and automated vehicles, although this is likely to change in the future.

Automated vehicles should not be subject to more burdensome Federal Motor Vehicle Safety Standards (FMVSS) than manually driven vehicles. However, some existing rules that would apply to automated vehicles by default should be relaxed, as innovation has already made some of these standards obsolete.

A good example of what is likely to come is the joint petition to NHTSA from Tesla and the Alliance of Automobile Manufacturers requesting an update of rear-view and side-view mirror requirements to allow for optional compliance with cameras rather than mirrors.[48] NHTSA recently published a final rule revising its rearview mirror standards that will require automakers to install rearview cameras on all new vehicles by May 2018.[49] As the petitioners note, NHTSA's recent revision does not permit voluntary replacement of side-view mirrors with cameras while bringing the mirror rule into potential conflict with state motor vehicle codes, many of which still require driver- and passenger-side mirrors even if a camera has replaced mirrors' viewing function.

As highly automated vehicles become available to consumers, many federal and state regulations will need to be updated to reflect this new reality. Congress and state legislators should be aware of this arduous task ahead and prepared to staff the relevant regulatory agencies appropriately in order to minimize the regulatory lag on technological innovation.

Finally, safety regulators should avoid promulgating rules that greatly increase costs but provide few benefits. As University of Chicago economist Sam Peltzman noted in his seminal 1975 study of automobile safety regulations, consumer response to safety mandates in the form of risk compensation (*i.e.*, safer cars can lead occupants to take more risks) can cancel out any benefits that come from safety regulation, leaving only the high costs of compliance as the net result.[50]

Infrastructure. Automakers have privately expressed skepticism of automated, or "smart," highway concepts that have been promoted for years by the U.S. Department of Transportation and some outside researchers. Most private companies appear to be proceeding with the development of independent automation technology that does not require vehicle-to-vehicle or especially vehicle-to-infrastructure communications.[51] These V2V and V2I applications are generally proposed to rely upon Dedicated Short-Range Communications (DSRC).

There are four reasons to be concerned about connected vehicle mandates:

1. V2V and V2I proponents have been consistently wrong about the challenges facing DSRC device deployment. The primary current function of DSRC appears to be wasting valuable spectrum.[52]
2. Developers fear a top-down V2V or V2I approach will lock in inferior first-generation technologies.
3. There are legitimate cybersecurity concerns regarding vehicle platooning, where a single "rogue" vehicle has the potential to cause system-wide efficiency reductions.[53]
4. Highway funding, particularly at the federal level, is currently not meeting basic infrastructure needs, which suggests additional requirements, such as roadside V2I equipment, will be too costly and complex for present government transportation agencies to deploy.

The "smart" highway concept should not be pursued at this time. Perhaps in the future, after significant automated vehicle market penetration, dedicated infrastructure using V2I communications for high-speed platooning will be worthwhile and attainable. Until then, however, mandating V2V and V2I automation technology will merely misallocate resources away from more beneficial projects.

In addition, it is possible that automated vehicles will have a large impact on land use through shifts in housing and firm location decisions. As commuting, or traveling by automobile more broadly, will be potentially more productive and/or leisurely due to the reduction in required real-time input needed to direct the vehicle, individuals and businesses may be willing to spend more time in their vehicles to locate further away from urban cores as they seek more affordable real estate and more peaceful settings.

On the other hand, autonomous transportation services such as "driverless" taxis may allow more city residents to forgo auto ownership and seek denser, more walkable living in or near urban cores.

Policy makers, particularly those in state and local government, should be prepared to make changes to their transportation planning and metropolitan growth forecasts that take into account the impact of autonomous vehicles.

Products Liability. Products liability is already a complex area of law and will become even more so in an increasingly automated future. However, this does not mean automated vehicles ought to be subject to unnecessary burdens out of a precautionary principle concern.[54] In fact, products liability is an area that may be able to sufficiently evolve through common law without statutory or administrative intervention.

For instance, as Stanford Law's Smith argues, automakers will continue to have increasing amounts of individualized data about their customers and will increasingly have the ability to "push" warnings about or updates to their products to their customers. He refers to this process as "proximity."[55]

Producers will almost certainly be subject to additional liability, as their wealth of data about their products and consumers' use of their products increasingly means courts will be more inclined to conclude they should have foreseen if product failure or misuse. But, as Smith notes, this increased liability would likely drive increased proximity, as producers seek more information about their consumers to appropriately manage foreseeability risk. It remains unclear if legislative tort law reforms are needed to efficiently manage this risk.

Furthermore, products liability is not binary—multiple parties can be liable in multiple ways in a single event. Third-party modification presents additional challenges. As was demonstrated in *Yun et al. v. Ford Motor Company et al.*, products liability can be incredibly complex and determining foreseeability is often a murky question[56]—such as in, for example, a case where a manually driven vehicle is retrofitted for automated operation in the aftermarket. At present, existing state laws recognizing autonomous vehicle legality either restrict third-party modification or hold that automakers are not liable for damages resulting solely from third-party modification.

Insurers should be allowed to experiment with innovative insurance products to manage this evolving risk landscape. Lawmakers should seek to legalize products such as distance-based vehicle insurance. Distance-based insurance not only has the potential for improved risk pricing, it could also make insurance products more affordable for consumers.[57] Traditional vehicle insurance is based on extensive driver history, which can take time to filter its way into risk-based premiums. By contrast, distance-based vehicle insurance relies on more robust and near-term data to make these evaluations, allowing more accurate real-time pricing.

Transportation Services. Vehicle automation will likely have major implications for transportation services and private automobile ownership. With the rise of carsharing services such as Zipcar and Car2Go and ridesharing services such as Uber, Lyft, and Sidecar, demand for auto trips may trend toward personal transportation services rather than auto ownership in the future. Potential services such as autonomous ridesharing or "driverless" taxis could sharply increase this trend.

However, as existing ridesharing service providers have discovered, many municipalities have cartelized personal transportation services, generally through taxicab and livery regulations that greatly restrict market entry and pricing. Throughout the country, ridesharing services have been served with cease and desist letters for daring to compete with the established cartel.[58] Fortunately, ridesharing providers have been able to harness their customer bases to push back against this protectionism, resulting in increasing rideshare service operations.[59]

While many of these decisions are made by local governments, state policy makers could seek to curtail such anticompetitive behavior on the part of the established taxi and livery industries and regulators. This could be done by engaging in extensive deregulation of existing transportation services, which is preferable, or by creating a new class of regulated transportation services, such as the transportation network company category, as the California Public Utilities Commission did in 2013.[60]

Conclusion. Technical hurdles remain before developers can confidently sell their highly automated vehicle technologies to consumers. But many of the largest potential impediments are related to public policy. Politicians and bureaucrats, however well-intended, generally suffer from a variety of biases and rational ignorance. When implemented in statute or regulation, this can have profound negative effects on society. This risk of overregulating—or regulating badly—looms large.

Policy makers must remember that their actions can produce harm. If automated vehicles are demonstrated to be significantly safer than manually driven vehicles, any misstep, convoluted law, or burdensome rule that leads to unnecessary higher costs or delays translates to increased injury and death.

We have come a long way since Leonardo da Vinci's 15th century sketch of a driverless cart. Let's not mess it up.

Notes

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[36] NHTSA, "Preliminary Statement of Policy Concerning Automated Vehicles," May 30, 2013, http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.

[37] Ibid., pp. 4-5.

[38] NHTSA, "U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles," Press Release, February 3, 2014, http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles.

[39] See Randal O'Toole, "VMT Fees Yes—V2V No," Cato at Liberty blog, Cato Institute, February 4, 2014, http://www.cato.org/blog/vmt-fee-yes-v2v-no.

[40] Smith, "Driving at Perfection," The Center for Internet and Society at Stanford Law School, March 11, 2012, http://cyberlaw.stanford.edu/blog/2012/03/driving-perfection. *See also* Noah J. Goodall, "Ethical Decision Making During Automated Vehicle Crashes," forthcoming in *Transportation Research Record: Journal of the Transportation Research Board*, March 6, 2014, pp. 2-3, http://people.virginia.edu/~njg2q/ethics.pdf.

[41] Bilger.

[42] Smith, "Driving at Perfection"; Goodall, pp. 2-3; United States Census Bureau, *Statistical Abstract of the United States*, Publication Table 1107. Vehicles Involved in Crashes by Vehicle Type, Rollover Occurrence, and Crash Severity: 2009, 2012; Federal Highway Administration Office of Freight Management and Operations, *Freight Facts and Figures 2011*, Publication FHWA-HOP-12-002, http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/11factsfigures/pdfs/fff2011_highres.pdf; National Highway Traffic Safety Administration, *Traffic Safety Facts 2009: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, Publication DOT HS 811 402, http://www-nrd.nhtsa.dot.gov/Pubs/811402.pdf.

[43] Goodall, pp. 6-7.

[44] Ibid.

[45] Ibid., pp. 10-12.

[46] A number of papers discussing various human factors issues as they relate to automated vehicles were published in *Human Factors*, Vol. 54, No. 5, October 2012.

[47] Vehicles today already collect a wealth of information on their users via event data recorders and personal mobile devices carried by passengers. Several states have enacted enhanced privacy protections for information collected and stored by event data recorders and Congress is considering federal legislation (U.S. Senate, 113th Congress, "S. 1925, Driver Privacy Act.") to do the same.

[48] Petition for Rulemaking to Update and Upgrade Federal Motor Vehicle Safety Standard No. 111, "Rearview mirrors" to allow Camera-based Systems as a Compliance Option, NHTSA-2010-0162-0254 (March 28, 2014).

[49] Federal Motor Vehicle Safety Standard No. 111, Rearview Mirrors, *Final Rule*, NHTSA-2010-0162, 79 Fed. Reg. 19177 (April 7, 2014).

[50] Sam Peltzman, "The Effects of Automobile Safety Regulation," *Journal of Political Economy*, Vol. 83, No. 4, August 1975, pp. 677-725.

[51] It is important to note that V2V and V2I in this case would not merely transmit audio or visual warnings, as is currently being contemplated by federal regulators for all new highway vehicles, but would link vehicles for the purpose of directing primary and secondary vehicle control functions.

[52] See Comments in Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, *Notice of Proposed Rulemaking,* ET Docket No. 13-49*,* (released February 20, 2013),
http://apps.fcc.gov/ecfs/proceeding/view?z=3i1yb&name=13-49.

[53] Ryan M. Gerdes, Chris Winstead, and Kevin Heaslip, "CPS: An Efficiency-motivated Attack against Autonomous Vehicular Transportation," *Proceedings of the 29th Annual Computer Security Applications Conference*, December 2013, pp. 99-108.

[54] "Although a widely accepted definition of the '[precautionary] principle' does not exist, its thrust is that regulatory measures should prevent or restrict actions that raise even conjectural threats of harm to human health or the environment, although there may be incomplete scientific evidence as to their potential significance." Henry I. Miller and Gregory Conko, "Precaution without Principle," *Nature Biotechnology*, Vol. 19, April 1, 2001, pp. 302–303.

[55] Smith, "Proximity-Driven Liability," forthcoming in 102 *Georgetown Law Journal* 2014, November 1, 2013, https://www.law.stanford.edu/sites/default/files/publication/478805/doc/slspublic/SSRN-id2336234.pdf.

[56] In addition, the question of federal preemption of state tort law remains murky. In *Williamson v. Mazda*, 529 U.S. 861 (2011), the U.S. Supreme Court unanimously held that, "FMVSS 208 does not pre-empt state tort suits claiming that manufacturers should have installed lap-and-shoulder belts, instead of lap belts, on rear inner seats." The question was on whether NHTSA's regulation, which allows manufacturers to install either lap-only or lap-shoulder seat belts on rear inner seats, preempts a state tort claim that Mazda should have installed only lap-shoulder seat belts.

[57] See "How's my driving? Gizmos that track driving habits are changing the face of car insurance," *The Economist*, February 23, 2013, http://www.economist.com/news/finance-and-economics/21572237-gizmos-track-driving-habits-are-changing-face-car-insurance-hows-my.

[58] See Brad Tuttle, "Rideshare Battle Shifts to L.A.: City Tells Uber, Lyft, SideCar to Stop Picking Up Riders," *Time*, June 27, 2013, http://business.time.com/2013/06/27/rideshare-battle-shifts-to-l-a-city-tells-uber-lyft-sidecar-to-stop-picking-up-riders/.

[59] See Benjamin R. Freed, "Livery Lobby: Uber's Rapid Response on Proposed Amendment Overwhelmed the D.C. Council," DCist.com, June 20, 2012,
http://dcist.com/2012/07/3768_emails_we_were_getting.php.

[60] Decision Adopting Rules and Regulations to Protect Public Safety while Allowing New Entrants to the Transportation Industry, California Public Utilities Commission, Rulemaking 12-12-011, September 19, 2013,
http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M076/K998/76998666.PDF.

Appendix: Model Resolution on Autonomous Vehicle Legislation and Regulation (American Legislative Exchange Council)

Summary

This resolution holds that autonomous vehicle research, development, testing, and operational functionality should not be impaired by unnecessary legislative or regulatory intervention.

Model Resolution

WHEREAS, autonomous vehicles are motor vehicles equipped with technology that has the capability to direct a vehicle without real-time input or monitoring by a human operator.

WHEREAS, autonomous vehicles greatly reduce human interaction with the direction of motor vehicles.

WHEREAS, human error is a factor in approximately 90 percent of motor vehicle accidents.

WHEREAS, human error is responsible for a significant portion of traffic congestion.

WHEREAS, autonomous vehicles can greatly enhance transportation access for mobility-impaired populations such as the disabled, elderly, and youth.

WHEREAS, the states regulate the licensing and operations of motor vehicles while the federal government regulates highway vehicle safety.

WHEREAS, several states have enacted laws recognizing the legality of autonomous vehicles.

WHEREAS, the federal government is considering safety mandates regarding vehicle-to-vehicle communications.

WHEREAS, autonomous vehicle communications systems, whether vehicle-to-vehicle or vehicle-to-infrastructure, remain in the early stages of development.

WHEREAS, requiring specific and unnecessary components or functions of nascent technologies will likely retard innovation and consumer availability.

WHEREAS, unduly discriminatory statutes or regulations with respect to the nature of insurance that shall be furnished for an autonomous vehicle should be avoided.

WHEREAS, lawmakers and regulators should avoid crafting statutes or regulations regarding autonomous vehicles which fail to distinguish between highway and non-highway vehicles.

NOW THEREFORE BE IT RESOLVED, that [insert state here] opposes the enactment of laws or promulgation of regulations that would restrict autonomous vehicle innovation.

Approved by the American Legislative Exchange Council Board of Directors January 9, 2014.