Removing Roadblocks to Intelligent Vehicles and Driverless Cars

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Abstract

This paper addresses some of the early policy concerns about “connected cars” and driverless vehicles and promotes “bottom-up” solutions to ensure that innovation continues to flourish in this space. The authors argue that the generally unabated advancement of intelligent-vehicle technology will produce significant economic and social benefits. Various technical and policy barriers to more widespread adoption remain, however, and misguided regulation could delay or curtail the adoption of this important technology. This paper outlines ways of overcoming those hurdles. The authors also argue that policymakers should keep in mind that individuals have gradually adapted to similar disruptions in the past and, therefore, patience and humility are needed when considering policy for intelligent-vehicle systems.

JEL codes: L9, R00, R40, R41, R48, R58, H4, K23, L5, N7, O1, O3

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In this paper we address some of the early policy concerns about "connected cars" and driverless vehicles and promote "bottom-up" solutions to ensure that, to the maximum extent possible, *permissionless innovation* continues to flourish in this space. We argue that the generally unabated advancement of intelligent-vehicle technology will produce significant economic and social benefits. Where public policy must be adjusted to address concerns about intelligent vehicles, it should be with an eye toward maximizing the potential for permissionless innovation to work the same magic here that it has in so many other sectors of the economy.

Many vehicles already include various computer-operated safety functions, which operate independently of driver action. Even if there is some initial unease, or if the current higher cost of intelligent vehicles limits initial willingness to purchase them, demand for these technologies will likely expand in coming years.[1] As the efficacy of intelligent-vehicle technology improves and costs fall such that these vehicles become more ubiquitously available to a growing market of potential consumers, citizens will become more comfortable with these systems.[2]

This is particularly likely in light of the enormous benefits associated with intelligent-vehicle technology, especially autonomous-vehicle technology. "This new technology has the potential to reduce crashes, ease congestion, improve fuel economy, reduce parking needs, bring mobility to those unable to drive, and over time dramatically change the nature of US travel,"

[1] Susan Thurston, "Bottom Line with Driverless Cars: Will People Buy Them?," *Tampa Times*, February 17, 2014, http://www.tampabay.com/news/business/bottom-line-with-driverless-cars-will-people-buy-them/2166010.
[2] Lou Fancher, "Hard Drive: Self-Driving Cars Are Closer Than They Appear," *SF Weekly*, February 19, 2014, http://www.sfweekly.com/2014-02-19/news/google-self-driving-cars-center-for-automotive-research-darpa/full.

notes an Eno Center for Transportation report on the impact of driverless cars.[3] They will also greatly enhance convenience and productivity for average Americans by freeing up time spent behind the wheel. Thus, while it is true, as a recent Rand Corporation report noted, that "the history of technology in general—and transportation in particular—is littered with promising ideas that never achieved widespread adoption," it seems unlikely that intelligent vehicles will meet a similar end.[4]

Various technical and policy barriers to more widespread adoption remain, however, and misguided regulation could delay or curtail the adoption of this important technology. This paper argues that a general embrace of permissionless innovation can help overcome those hurdles. We also argue that policymakers should keep in mind that individuals have gradually adapted to similar disruptions in the past and that, generally speaking, patience and humility are the wise policy virtues when considering what to do about highly disruptive technologies. Living in fear of hypothetical worst-case scenarios and basing policy on them will mean that the best-case scenarios associated with intelligent vehicles will never come about. Thus, patience and regulatory forbearance is generally the wise policy disposition at this time, bearing in mind that the tort system will continue to evolve to address harms caused by intelligent-vehicle systems.

A Brief History of Intelligent Vehicles

Few technologies have played a more central role in American society over the past century than the automobile. From their inception, cars were a highly disruptive force, upending other modes

[3] Eno Center for Transportation, *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations* (Washington, DC: Eno Center for Transportation, October 2013), 17, https://www.enotrans.org/wp-content/uploads/wpsc/downloadables/AV-paper.pdf.

[4] James M. Anderson, Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, Oluwatobi A. Oluwatola, *Autonomous Vehicle Technology: A Guide for Policymakers* (Santa Monica, CA: Rand Corporation, 2014), 135. (Hereinafter referred to as "Rand, *Autonomous Vehicle Technology*.")

of transportation and radically altering the way countless other existing industries operated.[5] The social impact of the automobile on the daily lives of average Americans was equally dramatic, and they quickly became viewed as an essential part of fulfilling "the American Dream." Moreover, the automotive industry became, and remains, a profoundly important sector of the US economy, affecting jobs and innovation in countless other sectors.

Any major changes in the way automobiles work will, therefore, have serious economic and social ramifications. Such a moment has arrived with the rise of "smart cars" and "autonomous vehicles."[6] "We stand on the precipice of a great advance in quality of life, enabled by the automation of driving,"[7] notes Jack Cutts, senior manager of business intelligence at the Consumer Electronics Association. "It will cause great upheaval in the lives of some while it produces new opportunities and conveniences in the lives of even more."[8] These changes could come about very quickly. "Motor vehicles and drivers' relationships with them are likely to change significantly in the next ten to twenty years, perhaps more than they have changed in the last one hundred years," notes the National Highway Traffic Safety Administration (NHTSA), a federal agency that oversees vehicle-safety issues.[9]

As far back as the 1939 World's Fair, General Motors (GM) was introducing the far-flung notion of parkways that would permit the use of cars driving themselves. In the early days, automakers were likely caught up in the era of *Buck Rogers*–style futurism, but by the mid-late 1950s GM, along with the Radio Corporation of America, "had developed a scale model

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[5] Jean-Pierre Bardou, *The Automobile Revolution: The Impact of an Industry* (Chapel Hill: University of North Carolina Press, 1982).
[6] Charlie White, "Car Tech Outlook: Self-Driving Cars Are Just around the Corner," *Mashable*, June 23, 2013, http://mashable.com/2013/06/23/self-driving-cars-3.
[7] Cutts, "On the Road to Driverless Cars," *Technology Trends to Watch 2014* (Arlington, VA: Consumer Electronics Association, 2014), 12.
[8] Ibid.
[9] National Highway Traffic Safety Administration, "Preliminary Statement of Policy Concerning Automated Vehicles" (May 2013), 1, http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.

automated highway system, which allowed them to begin experimenting with how electronics could be used to steer and maintain proper following distance."[10] The experiments never achieved practical implementation. While the interim decades of the 1950s–70s continued to fill the public consciousness with dreams of flying cars and other unrealized technological promises, revolutions in semiconductors and computer processing silently grew to form the foundation of future developments in autonomous navigation.

Fast-forward to 1989, when engineers at Carnegie Mellon successfully navigated an ALVINN (Autonomous Land Vehicle In a Neural Network) using "images from a camera and a laser range finder" to automatically direct the vehicle along the roadway. Their conclusion suggested "the possibility of a novel adaptive autonomous navigation system capable of tailoring its processing to the conditions at hand."[11] Sensor-based technology driven by microprocessors set the standard for future advances in automated robotics, as evidenced by the fact that all the vehicles that won DARPA's 2004, 2005, and 2007 Grand Challenges were based on this type of technology.[12] Meanwhile, as of April 2014, Google's driverless vehicles had racked up more than 700,000 miles of crash-free driving.[13]

Definitions are evolving rapidly in this space. Smart-car, or "connected vehicle," technology refers to the communications and data devices and functions found in many new automobiles. By contrast, "autonomous vehicles" or "driverless cars" are automotive

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[10] Tom Vanderbilt, "Autonomous Cars through the Ages," *Wired.com*, February 2, 2012, http://www.wired.com/autopia/2012/02/autonomous-vehicle-history.

[11] Dean A. Pomerleau, "ALVINN: An Autonomous Land Vehicle In a Neural Network" (Technical Report AIP-77, Artificial Intelligence and Psychology Project, Carnegie Mellon University, 1989).

[12] *The DARPA Cyber Grand Challenge*, DARPA, http://www.darpa.mil/cybergrandchallenge. (The Grand Challenge was a series of long-distance challenges, sponsored by the Defense Advanced Research Projects Agency, or DARPA, for autonomous vehicles as a means of spurring further development of robotics technologies.)

[13] Marc Scribner, "Google's Self-Driving Cars Approach 700,000 Miles of Crash-Free Driving," *OpenMarket.org*, April 28, 2014, http://www.openmarket.org/2014/04/28/googles-self-driving-cars-approach-700000-miles-of-crash-free-driving.

technologies that permit automobiles to operate without human assistance.[14] There is a constantly growing spectrum of automotive automation, and these definitions, and our understanding of these technologies, will likely change over time.[15] Generally speaking, however, these various technologies can be grouped together under the banner of "intelligent car technology."[16]

Policymakers are already struggling with these distinctions and the policies that should govern these emerging technologies, but federal standards are slowly emerging. NHTSA has identified a range of five different levels of vehicle automation, ranging from a vehicle in which "the driver is in complete and sole control of the primary vehicle controls . . . at all times" (level 0) all the way to a vehicle designed so "the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip" (level 4).[17] Table 1 describes these five NHTSA categories. Today's vehicles already feature many level 1 "function-specific automations," such as electronic stability control and parking assist. Increasingly, manufacturers are offering level 2 "combined function automations" and even some level 3 "limited self-driving automations," although those are currently limited to higher-end luxury models.

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[14] Bryant Walker Smith, "Automated Vehicles Are Probably Legal in the United States" (working paper, Stanford Law School, Center for Internet and Society, Stanford, CA, November 1, 2012), 9, http://cyberlaw.stanford.edu /publications/automated-vehicles-are-probably-legal-united-states.

[15] Bryant Walker Smith, "My Other Car Is a . . . Robot? Defining Vehicle Automation," *Center for Internet and Society Blog*, February 19, 2012, http://cyberlaw.stanford.edu/blog/2012/02/my-other-car-robot-defining-vehicle -automation; SAE International, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*, January 16, 2014, http://standards.sae.org/j3016_201401.

[16] Ruth Dawson, "Interview: Catherine McCullough, Executive Director, Intelligent Car Coalition," *Automotive World*, December 2, 2013, http://www.automotiveworld.com/analysis/interview-catherine-mccullough-executive -director-intelligent-car-coalition.

[17] US Department of Transportation, "U.S. Department of Transportation Releases Policy on Automated Vehicle Development," May 2013, http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+ Transportation+Releases+Policy+on+Automated+Vehicle+Development.

Table 1. NHTSA's Five-Part Continuum of Vehicle Control Automation

Level 0: No Automation. The driver is in complete and sole control of the primary vehicle controls—brake, steering, throttle, and motive power—at all times.
Level 1: Function-Specific Automation. Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than by acting alone.
Level 2: Combined Function Automation. This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a level 2 system is adaptive cruise control in combination with lane centering.
Level 3: Limited Self-Driving Automation. Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
Level 4: Full Self-Driving Automation. The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

In February 2014, the NHTSA announced it would be taking steps to enable vehicle-to-vehicle (V2V) communication technology for light vehicles.[18] The agency noted, "This technology would improve safety by allowing vehicles to 'talk' to each other and ultimately avoid many crashes altogether by exchanging basic safety data, such as speed and position, ten times per second."[19]

State legislative activity affecting intelligent vehicles varies widely.[20] Some scholars have argued that highly automated vehicles are presently legal in most US jurisdictions, meaning that these jurisdictions may only need to recognize or clarify the legality of these

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[18] National Highway Traffic Safety Administration, "U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles," 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.
[19] Ibid.
[20] "Driverless Cars Due Soon, but Rules Lag," *Boston Globe*, September 30, 2013, http://www.bostonglobe.com /business/2013/09/29/self-driving-vehicles-move-ahead-faster-than-rules-road/tU38MARJuzVzwxkJttrajJ/story.html.

technologies.[21] In December 2013, Michigan passed legislation permitting the use of driverless vehicles for research and development purposes, with the caveat that a driver must be present in the vehicle in order to reassert manual control if necessary.[22] Nevada has also crafted a licensing framework for driverless cars, mandating driver's licenses for the operators of such vehicles.[23] As of early 2014, over a dozen states were already studying driverless-car policies or devising licensing requirements, with California and Florida permitting the same type of R&D-testing permits as Michigan.[24]

Most recently, Johnson County, Iowa, became one of the first areas in the United States to explicitly permit driverless cars on public city streets.[25] In terms of regulatory hurdles for testing purposes, Daniel McGehee, director of the Human Factors and Vehicle Safety Research division at the Public Policy Center of the University of Iowa, indicated that Iowa "would present fewer bureaucratic hurdles than other states" to implementing self-driving cars. When asked about the need for investment in infrastructure to accommodate the vehicles, McGehee noted that only high-contrast paint on the roads would be required because "self-driving cars rely on their own sensors . . . to understand what's around them."[26] Whether the implementation process goes smoothly or runs into roadblocks remains to be seen. As with many emerging technologies, legal and regulatory frameworks have yet to catch up with the speed of innovation in this area. The reasons for this will be discussed later.

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[21] Smith, "Automated Vehicles."
[22] "New Law Allows Driverless Cars on Michigan Roads," *CBS Detroit Local News*, December 28, 2013, http://detroit.cbslocal.com/2013/12/28/new-law-allows-driverless-cars-on-michigan-roads.
[23] State Senate of Nevada, Assembly Bill No. 511—Committee on Transportation, http://www.leg.state.nv.us/Session/76th2011/Bills/AB/AB511_EN.pdf.
[24] "Automated Driving: Legislative and Regulatory Action," Center for Internet and Society, Stanford Law School, last accessed August 20, 2014, https://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action.
[25] Josh Leary and Marco Santana, "Iowa County Says Yes to Driverless Cars," *USA Today*, July 25, 2014, http://www.usatoday.com/story/money/cars/2014/07/25/iowa-driverless-cars/13159845/.
[26] Ibid.

"Permissionless Innovation" and Intelligent Vehicles

As the technology matures, concerns about connected cars and autonomous vehicles will likely intensify from various critics and concerned parties. At this stage, policymakers should focus on clearing away existing roadblocks to the growth of intelligent vehicles and exercise restraint regarding the hypothetical concerns about their use. No doubt, challenges will arise as these technologies take off. There has already been some resistance to early forms of autonomous vehicles and even some concern about "smart car" technologies, especially on privacy grounds, which will be discussed below.[27]

In this paper, we address some of these early policy concerns about driverless cars and promote "bottom-up" solutions to ensure that, to the maximum extent possible, permissionless innovation continues to flourish in this space. "Permissionless innovation" refers to the notion that experimentation with new technologies and business models should generally be permitted by default.[28] Unless a compelling case can be made that a new invention poses a serious immediate threat to public well-being, innovation should be allowed to continue unabated; problems, if they develop at all, can be addressed later.

Permissionless innovation has been the primary driver of entrepreneurialism and economic growth in many sectors of the economy.[29] The most notable modern example of the power of permissionless innovation at work has been the development of the Internet and the

[27] Craig Timberg, "Web-Connected Cars Bring Privacy Concerns," *Washington Post*, March 5, 2013, http://www.washingtonpost.com/business/technology/web-connected-cars-bring-privacy-concerns/2013/03/05/d935d990-80ea-11e2-a350-49866afab584_story.html.

[28] Adam Thierer, *Permissionless Innovation: The Continuing Case for Comprehensive Technological Freedom* (Arlington, VA: Mercatus Center at George Mason University, 2014).

[29] Adam Thierer, "Why Permissionless Innovation Matters," *Medium*, April 24, 2014, https://medium.com/challenging-the-status-quo/257e3d605b63.

enormous economic and social benefits it has generated.[30] As an open and lightly regulated platform, the Internet allows entrepreneurs to try new business models and offer new services without seeking the approval of regulators beforehand. Its very architecture is premised on this style of innovation.

This same open model, as opposed to the policies of a "precautionary principle," should guide policy in the developing space of autonomous vehicles.[31] The "precautionary principle" refers to the belief that new innovations should be curtailed or disallowed until their developers can prove that they will not cause any harm to individuals, groups, specific entities, cultural norms, or various existing laws or traditions.[32] Policymakers often adopt precautionary policy approaches in an attempt to preemptively head off potentially risky scenarios or unfortunate outcomes.

When public policy is based on the precautionary principle, however, it poses a serious threat to technological progress, economic entrepreneurialism, social adaptation, and long-run prosperity. Put simply, living in constant fear of worst-case scenarios—and premising public policy on them—means that best-case scenarios will never come about.[33] In concrete terms, precautionary-principle policymaking results in fewer choices, lower-quality goods and services, diminished economic growth, and a decline in the overall standard of living. Thus, despite being well-intentioned, precautionary-principle-based regulatory constraints can produce unintended consequences that undermine the very goal they were meant to serve.

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[30] Vinton Cerf, "Keep the Internet Open," *New York Times*, May 24, 2012, http://www.nytimes.com/2012/05/25/opinion/keep-the-internet-open.html.
[31] As Eli Dourado puts it, "Advocates of the Internet are right to extol the permissionless innovation model—but they are wrong to believe that it need be unique to the Internet. We can legalize innovation in the physical world, too. All it takes is a recognition that real-world innovators should not have to ask permission either." Dourado, "'Permissionless Innovation' Offline as Well as On," *Umlaut*, February 6, 2013, http://theumlaut.com/2013/02/06/permissionless-innovation-offline-as-well-as-on.
[32] Thierer, *Permissionless Innovation*, 16–18.
[33] Ibid.

Only through trial and error can we discover new, better, and safer ways of doing things. As the late political scientist Aaron Wildavsky showed, wisdom and prosperity are born of experimentation and experience. We learn how to be wealthier and healthier as individuals and as a society only by first being willing to embrace uncertainty and even occasional failure. By contrast, if we adopt a trial *without* error attitude (i.e., a precautionary-principle-based mindset), the results will be disastrous, as Wildavsky noted:

> The direct implication of trial without error is obvious: If you can do nothing without knowing first how it will turn out, you cannot do anything at all. An indirect implication of trial without error is that if trying new things is made more costly, there will be fewer departures from past practice; this very lack of change may itself be dangerous in forgoing chances to reduce existing hazards. . . . Existing hazards will continue to cause harm if we fail to reduce them by taking advantage of the opportunity to benefit from repeated trials.[34]

For similar reasons, we argue that the generally unabated advancement of intelligent-vehicle technology will, on net, benefit everyone individually and society as a whole. Where public policy must be adjusted to accommodate disruptive changes, it should be with an eye toward maximizing the potential for permissionless innovation to work the same magic here that it has in so many other sectors of our economy. Many policy recommendations in this space currently revolve around getting ahead of what might become problematic issues for intelligent vehicles, especially driverless cars. Instead of focusing on what might occur, policy prescriptions should assess what issues currently require resolution and how best to achieve them with minimal disruption of innovation. The most advantageous course, for individuals and society alike, is to keep the door open to new ideas and ongoing experimentation. We can think of this disposition as "dynamism."

[34] Wildavsky, *Searching for Safety* (New Brunswick, CT: Transaction Books, 1988), 38.

In her 1998 book *The Future and Its Enemies*, Virginia Postrel contrasted the conflicting worldviews of "dynamism" and "stasism" and showed how the tensions between these two visions would affect the course of future human progress.[35] Postrel made the case for embracing dynamism—"a world of constant creation, discovery, and competition"—over the "regulated, engineered world" of the stasis mentality. Permissionless innovation is rooted in dynamism; the precautionary principle is based on stasis thinking. Importantly, Postrel argued that we should "see technology as an expression of human creativity and the future as inviting" and reject the idea "that progress requires a central blueprint." Dynamism defines progress as "a decentralized, evolutionary process" in which mistakes are not viewed as permanent disasters but instead as "the correctable by-products of experimentation."[36] In sum, they are learning experiences.

The crucial takeaway from Wildavsky's and Postrel's works is that not every complex economic or social problem requires a convoluted legal regime or heavy-handed regulatory response. We can achieve *reasonably effective* safety, security, and privacy without always layering on more and more law and regulation. "Dynamic systems are not merely turbulent," Postrel noted. "They respond to the desire for security; they just don't do it by stopping experimentation."[37] She adds, "Left free to innovate and to learn, people find ways to create security for themselves. Those creations, too, are part of dynamic systems. They provide personal and social resilience."[38] To the extent that more serious problems develop or persist, public policy can always be adjusted to address those issues after careful evaluation of the costs and benefits of proposed rules.

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[35] Postrel, *The Future and Its Enemies* (New York: The Free Press, 1998), xv.
[36] Ibid., xiv.
[37] Ibid., 199.
[38] Ibid., 202.

All this is applicable to intelligent vehicles. Through ongoing trial-and-error experimentation, both individuals and society as a whole will gradually develop solutions to vexing problems while also acclimating to new technological realities. But attempting to foresee and plan for all these problems will only derail the many potential benefits associated with these technologies. As Rep. Tom Petri (R-WI), chairman of the Subcommittee on Highways and Transit of the House Transportation and Infrastructure Committee, has wisely cautioned, "There are going to be many issues with driverless vehicles, and it's impossible to anticipate all—or even most—of them. Congress should try to maintain a flexible system that deals with real problems rather than a system that tries to anticipate solutions for problems that don't exist yet."[39] That is sound advice for all federal, state, and local policymakers who are considering rules for intelligent vehicles.

Finally, some philosophers claim that autonomous vehicles create ethical issues, including the question of how they should be programmed to respond during life-and-death situations.[40] We discuss some of these issues below and concede that some thorny ethical questions will arise with the advent of more autonomous vehicle systems. But these issues will also be worked out over time according to the same trial-and-error process described above.[41] And importantly, these ethical considerations need to be evaluated against the backdrop of the current state of affairs, in which tens of thousands of people die each year in auto-related accidents due to human error.[42] While auto-related accidents and fatalities have fallen over the past decade, the human toll remains staggering, with almost 100 people dying and more than

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[39] Ambreen Ali, "Government Hitting the Brakes on Driverless Cars," *OZY,* March 20, 2014, http://www.ozy.com/fast-forward/government-hitting-the-brakes-on-driverless-cars/30434.article.

[40] See Tom Chatfield, "Automated Ethics," *Aeon Magazine*, March 31, 2014, http://aeon.co/magazine/world-views/can-we-design-systems-to-automate-ethics; Patrick Lin, "The Ethics of Saving Lives with Autonomous Cars Are far Murkier Than You Think," *Wired*, July 30, 2013, http://www.wired.com/2013/07/the-surprising-ethics-of-robot-cars.

[41] Adam Thierer, "On the Line between Technology Ethics vs. Technology Policy," *Technology Liberation Front*, August 1, 2013, http://techliberation.com/2013/08/01/on-the-line-between-technology-ethics-vs-technology-policy.

[42] Gary Shapiro, "Driverless Cars Can't Come Soon Enough," *Washington Post,* April 23, 2014, http://www.washingtonpost.com/blogs/innovations/wp/2014/04/23/driverless-cars-cant-come-soon-enough.

6,000 being injured in motor vehicle accidents each day in the United States. Table 2 describes this human toll in detail.

Table 2. Facts about Vehicle Safety in the United States, 2012

- 33,561 total traffic fatalities (92 per day).
- 5,615,000 reported crashes.
- 2,362,000 people injured (6,454 per day).
- 169,000 children 14 and younger injured.
- Motor vehicle crashes were the leading cause of death for children age 4 and 11–14.
- An average of 3 children 14 and younger were killed and 462 were injured every day in the United States in motor vehicle crashes during 2012.
- 5,560 people 65 and older killed and 214,000 injured in motor vehicle traffic crashes. These older people made up 17% of all traffic fatalities and 9% of all people injured in traffic crashes during the year.
- 10,322 people killed in alcohol-impaired-driving crashes (28 per day). These alcohol-impaired-driving fatalities accounted for 31% of the total motor vehicle traffic fatalities in the United States.

Source: National Highway Traffic Safety Administration, Traffic Safety Fact Sheets, 2012.

Economic Considerations

Intelligent vehicles will produce many economic and social disruptions, but also many benefits. We first consider some of the economic effects associated with intelligent vehicles before turning to social considerations.

General Economic Effects

Transportation economists Clifford Winston and Fred Mannering argue that "the private sector is developing new technological innovations, especially the driverless car, which will eventually leapfrog the technology that the public highway authorities could and should implement today, thus providing road users with most of the potential benefits from technological advances in highway travel."[43] "These impacts will have real and quantifiable benefits," the Eno Center for

[43] Clifford Winston and Fred Mannering "Implementing Technology to Improve Public Highway Performance: A Leapfrog Technology from the Private Sector Is Going to Be Necessary," *Economics of Transportation* (2014): 2, 6–7, http://www.brookings.edu/research/papers/2014/02/improving-highway-performance-winston.

Transportation notes, because more than 30,000 people die each year in the United States in automobile collisions, and "driver error is believed to be the main reason behind over 90 percent of all crashes."[44] These driver errors include drunk driving, distracted operators, failure to remain in one's lane, and a failure to yield the right of way. The total annual costs of such accidents amount to over $300 billion, or 2 percent of US GDP.[45]

The current generation of intelligent-vehicle technology (lane-departure warnings, pedestrian detection, parking assist, adaptive cruise control, etc.) is already yielding many safety benefits and will offer even more as the technology grows more sophisticated and drivers make the transition to newer vehicles.[46] But completely driverless cars will likely have an even greater impact.[47] On balance, driverless vehicles will save lives by preventing harm from bad drivers, even if a driverless vehicle is not necessarily superior to an alert driver in every situation. For instance, the response time of a computer directing the primary functions of a vehicle, informed by an advanced sensor suite capable of calculating and recalculating changing positions and circumstances in fractions of a second, is bound to respond better than the average driver. While a computer won't be 100 percent perfect 100 percent of the time, it will likely come much closer to achieving a level of control and awareness that no human could claim to possess.

According to the Eno Center for Transportation, the annual economic benefits of 50 percent market penetration of driverless cars (that is, 50 percent of all vehicles on the road being fully autonomous vehicles) are estimated to include 9,600 lives saved, almost 2 million fewer

[44] Eno Center, *Preparing a Nation for Autonomous Vehicles*, 17, 3.
[45] Ibid., 3.
[46] As a 2014 Lloyd's report puts it, "By replacing the fallible human driver with sufficiently capable technology, it is thought that collision rates will substantially decrease, with significant implications for safety." Lloyd's, *Autonomous Vehicles, Handing over Control: Opportunities and Risks for Insurance* (2014), 5, http://www.lloyds.com/the-market/tools-and-resources/research/exposure-management/emerging-risks/emerging-risk-reports/business/autonomous-vehicles.
[47] See "The Road to Self-Driving Cars," *Consumer Reports*, February 2014, http://www.consumerreports.org/cro/magazine/2014/04/the-road-to-self-driving-cars/index.htm.

crashes, close to $160 billion in comprehensive cost savings, a 35 percent reduction in daily freeway congestion, and almost 1,700 travel hours saved.[48] Even at the low-end estimate of 10 percent market penetration (that is, for every nine manual cars on the road there is one driverless vehicle), "this technology has the potential to save over 1,000 lives per year and offer tens of billions of dollars in economic gains, once added vehicle costs and possible road-side hardware and system administration costs are covered."[49]

The costs of congestion are also significant, and alleviating those problems will also generate benefits in terms of potential fuel savings and freed time for drivers.[50] In 2011, according to the Texas A&M Transportation Institute's latest *Urban Mobility Report*, "congestion caused urban Americans to travel 5.5 billion hours more and to purchase an extra 2.9 billion gallons of fuel for a congestion cost of $121 billion."[51] According to the Eno Center, use of semiautonomous technologies like cooperative adaptive cruise control at the "10 percent, 50 percent, and 90 percent market-penetration levels . . . increase lanes' effective capacities by around 1 percent, 21 percent and 80 percent, respectively."[52] Table 3 details these benefits. Essentially, the more computer-operated vehicles deployed on the roads, the less room for human-initiated driving errors, allowing for higher vehicle speeds at closer intervals. It could be the case that total miles traveled would actually *increase* because of the additional persons who would now be able to use their own cars but that congestion would nonetheless fall thanks to smart-car technology.

[48] Eno Center, *Preparing a Nation*, 8.
[49] Ibid., 9.
[50] Ibid., 4.
[51] Texas A&M Transportation Institute, *2012 Annual Urban Mobility Report* (December 2012), 1, http://mobility.tamu.edu.
[52] Eno Center, *Preparing a Nation*, 5.

Table 3. Estimates of Annual Economic Benefits from Autonomous Vehicles (AVs) in the United States

Assumed adoption rate	10%	50%	90%
Crash cost savings from AVs			
Lives saved (per year)	1,100	9,600	21,700
Fewer crashes	211,000	1,880,000	4,220,000
Economic cost savings	$5.5 B	$48.8 B	$109.7 B
Comprehensive cost savings	$17.7 B	$158.1 B	$355.4 B
Economic cost savings per AV	$430	$770	$960
Comprehensive cost savings per AV	$1,390	$2,480	$3,100
Congestion benefits			
Travel time savings (millions of hours)	756	1680	2772
Fuel savings (millions of gallons)	102	224	724
Total savings	$16.8 B	$37.4 B	$63.0 B
Savings per AV	$1,320	$590	$550
Other AV impacts			
Parking savings	$3.20	$15.90	$28.70
Savings per AV	$250	$250	$250
Vehicle miles traveled increase	2.0%	7.5%	9.0%
Change in total # of vehicles	−4.7%	−23.7%	−42.6%
Annual savings: economic costs only	$25.5 B	$102.2 B	$201.4 B
Annual savings: comprehensive costs	$37.7 B	$211.5 B	$447.1B

Source: Eno Center for Transportation.

Other studies have also found that intelligent vehicles will yield significant benefits. A November 2013 report from Morgan Stanley estimated that autonomous cars could contribute $1.3 trillion in annual savings to the US economy, with global savings estimated at more than $5.6 trillion.[53] A decline in costs for fuel and accidents, as well as $507 billion in annual productivity gains, would drive these savings. In 2011, analysts with the Cisco Internet Business Solutions Group forecasted an estimated $810 of the $1,400 in value per connected vehicle per year could be freed up by reducing the cost of crashes and congestion.[54]

[53] Morgan Stanley, "Autonomous Cars: Self-Driving the New Auto Industry Paradigm," *Morgan Stanley Research*, November 6, 2013, http://www.morganstanley.com/public/11152013.html.

[54] Andreas Mai and Dirk Schlesinger, Cisco Internet Business Solutions Group, "A Business Case for Connecting Vehicles: Executive Summary," *Point of View* (April 2011), 5, http://www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Exec_Summary.pdf.

There would be enormous, but hard to quantify, benefits that accrue to elderly and disabled citizens from the deployment of intelligent vehicles. These benefits come in two forms—direct and indirect. The direct benefits would include the increasing ease of mobility for elderly and disabled persons who might otherwise be restricted in their ability to transport themselves in automobiles. In terms of indirect benefits, one important consideration is that, once elderly and disabled individuals have more mobility options, new economic and social opportunities will open up not only for them but for many others. Autonomous vehicles would also have an added indirect benefit in that they are likely to decrease accidents associated with attempts by some elderly and disabled individuals to operate vehicles on their own. These combined direct and indirect benefits will, therefore, improve societal well-being enormously in terms of both convenience and safety.

This is particularly important because of the higher risk factors associated with senior drivers. *Los Angeles Times* reporter Brett Berk notes that "the collision rate for older drivers is among the highest of any age group. Seniors are surpassed only by teenagers and entitled millennials when it comes to per capita insurance damage claims. And older drivers have one of the highest rates of traffic fatalities per mile driven, in part because they lack resilience to recover from injuries sustained."[55] Indeed, NHTSA reports that in 2012, 5,560 people 65 and older were killed and 214,000 injured in motor vehicle traffic crashes. This constituted 17 percent of all traffic fatalities and 9 percent of all people injured in traffic crashes during that year.[56] There is already discussion of future retirement communities being designed to accommodate the integration of self-driving cars, which could speed up use of these

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[55] Berk, "Self-Driving Cars Could Keep Seniors in the Driver's Seat," *Los Angeles Times*, April 6, 2014, http://articles.latimes.com/2014/apr/06/opinion/la-oe-0406-berk-autonomous-autos-aged-20140406.
[56] National Highway Traffic Safety Administration, "Older Population," *Traffic Safety Facts: 2012 Data*, DOT HS 812 005, March 2014, http://www-nrd.nhtsa.dot.gov/Pubs/812005.pdf.

technologies and result in greater benefits in the near term.[57] Moreover, there is great potential for driverless shuttles and carts to revolutionize "non-highway" transportation, such as around shopping centers, private communities, business and university campuses, resorts, or even small city centers.[58]

The disruptive impact of these changes will reverberate throughout other sectors. Frank Diana of TCS Global Consulting predicts that if autonomous vehicles bring about the massive reduction in traffic accidents, commute times, and overall number of cars on the road that some have predicted, it would create a "ripple effect" that would disrupt many established industries. He says, for example,

- 90% of insurance premiums could disappear;
- Car sales could be reduced, impacting a $600 billion annual US business;
- Spending on highway construction could be reduced;
- Gasoline sales could be reduced due to less cars and greater efficiency (e.g., by drafting);
- Hospital and health insurer revenue are effected as car related injuries plummet;
- Governments could lose fines because traffic laws are obeyed;
- Police could need fewer officers on the road;
- Prisons could need less capacity;
- Utilities could lose revenue as traffic lights become unnecessary and street-lighting needs diminish;
- Reduced number of parking lots would free land and reduce property values.[59]

Some of the more significant likely effects of intelligent vehicles are discussed in more detail below.

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[57] Nat Bottigheimer, "Self-Driving Cars Are Coming, and They Could Change Everything We Know about Cities," *Greater Greater Washington*, February 4, 2014, http://greatergreaterwashington.org/post/21491/self-driving-cars-are-coming-and-they-could-change-everything-we-know-about-cities/.
[58] Bryant Walker Smith, "Driverless Carts Are Coming Sooner Than Driverless Cars," *Volokh Conspiracy*, September 30, 2014, http://www.volokh.com/2013/09/30/driverless-golf-carts-coming-sooner-driverless-cars.
[59] Diana, "Autonomous Vehicles: A Disruption Case Study" *Frank Diana's Blog*, February 5, 2014, http://frankdiana.wordpress.com/2014/02/05/autonomous-vehicles-a-disruption-case-study.

Impact on Commercial Service Providers

Much of the concern about the economic effects of intelligent-vehicle technology has to do with the potential loss of jobs among truckers, taxi drivers, and other people whose occupations might lose importance or become obsolete. Here, the development of computers holds an important comparison. As Peter Singer of the Brookings Institution has noted, "For hundreds of years, there was a highly skilled profession of men who did mathematics for hire. They were well paid, many making the equivalent of $200,000 a year. They were called 'calculators.' They have gone the way of so many other professions reshaped by new technology like the blacksmith making horseshoes or the elevator operator."[60] Intelligent-vehicle technologies will likely have similarly disruptive impacts on various sectors and professions, resulting in significant short-term economic perturbations and employment dislocations.

Mechanics and auto repair shops may end up servicing fewer customers due to the diminished likelihood of accidents. On the other hand, just as mechanical vehicles require regular upkeep, so too will autonomous vehicles. So, it may be the case that such establishments will simply need to retrain their workers to accommodate these changes. Instead of hiring and training pure mechanics, businesses might begin fusing fundamental IT skills with traditional automotive repair skills. After a certain amount of time, some mechanics might be skilled enough to move over to higher-paying jobs somewhere in the information sector. We cannot discount the possibility that a new technology will kill off a large sector; nor can we assume away the possibility that all industries will adapt to new advances in technology.[61] For some, the

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[60] Singer, "The Predator Comes Home: A Primer on Domestic Drones, Their Huge Business Opportunities, and Their Deep Political, Moral, and Legal Challenges," Brookings Institution, March 8, 2013, http://www.brookings .edu/research/papers/2013/03/08-drones-singer.
[61] Robert Atkinson, "Why Robots Don't Kill Jobs," *ROS Industrial*, May 9, 2014, http://rosindustrial.org/news/2014 /5/9/why-robots-dont-kill-jobs.

change may come gradually. But it will demand new business models and worker retraining to accommodate the dynamic nature of the modern auto market. New skills will be needed, but it is entirely possible, even likely, that such skills will be developed in on-the-job scenarios (especially considering that older vehicles will still require routine tune-ups and repairs for the foreseeable future).

Other sectors or professions may not be as fortunate. The rise of autonomous vehicles could radically disrupt, and perhaps even drive into extinction, some industries or jobs. This technology could eventually eliminate the jobs of cabbies, bus drivers, and truckers.[62] What then is to become of these workers? Perhaps traditional taxi and bus service will come to an end, but as with any technological change, it will come in incremental steps as market forces slowly shift indicators of profitable, long-term careers away from these industries and toward new and emerging sectors. In fact, for cabbies, some of these first steps are being taken, not by driverless cars, but by fully manual vehicles manned by ordinary drivers. Users of services like Uber, Sidecar, and Lyft can essentially operate as unlicensed taxi operators, and the traditional regulatory scheme of "medallions, inspections, minimum wages, regulated fares, and 'consumer protections'" is turning out to be largely irrelevant for the American public.[63]

Concerns about sectoral disruption or worker displacement should not forestall the advancement of autonomous vehicles.[64] After all, what would have happened if the regulators of the early 20th century had put a swift end to the development of the automobile for the sake of

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62 Brian Fung, "What Will Happen to Truck Drivers When Self-Driving Vehicles Take Over?," *Washington Post*, *The Switch* (blog), November 20, 2013, http://www.washingtonpost.com/blogs/the-switch/wp/2013/11/20/what-will-happen-to-truck-drivers-when-self-driving-vehicles-take-over.

63 Ira Stoll, "Tech Innovation Outstrips Government Obstructionism," *Reason,* January 20, 2014, http://reason.com/archives/2014/01/20/tech-innovation-outstrips-government-obs.

64 Matthew Mitchell, "Share and Share Alike: Regulatory Burdens Threaten to Overwhelm Sharing Services Like Uber and Airbnb," *US News and World Report*, April 15, 2014, http://www.usnews.com/opinion/economic-intelligence/2014/04/15/uber-airbnb-and-letting-the-sharing-economy-thrive?src=usn_tw.

the established industries of carriage drivers and woodworkers whose livelihoods depended on the construction, maintenance, and operation of horse-drawn wagons? When policymakers choose winners and losers in the market, it only serves to benefit those industries with entrenched, static interests—not consumers and certainly not future entrepreneurs.

Insurance, Liability, and Tort Law

Winston and Mannering assert that "the major obstacle to motorists and firms adopting [autonomous vehicles] as soon as possible is whether the government will take prudent and expeditious approaches to help resolve important questions about assigning liability in the event of an accident, the availability of insurance, and safety regulations."[65]

"The advent of autonomous cars could revolutionise the world of motor insurance," notes a recent report from insurance-market specialists at Lloyd's of London.[66] Frank Diana says "driverless car innovations mean lower claim volume and an impact to the $200 billion in personal and commercial auto insurance premiums written each year in the U.S. Insurance premiums are a direct function of the frequency and severity of accidents, and both frequency and severity are impacted by this innovative technology. . . . In a world of driverless cars, where accidents are curtailed, most of those premiums go away," he notes.[67] Needless to say, this could upend the way the vehicle-insurance market works.[68] There are already "laws in Florida and D.C. [that] limit auto manufacturers' liability when an outfitted car is in an accident, assigning it

[65] Winston and Mannering, "Leapfrog Technology," 7.
[66] Lloyd's, *Autonomous Vehicles*, 18.
[67] Diana, "Autonomous Vehicles."
[68] Jason Koebler, "Driverless Cars Are Going to Kill Insurance Companies," *Motherboard*, February 27, 2014, http://motherboard.vice.com/read/driverless-cars-are-going-to-kill-insurance-companies.

instead to the party that installed the autonomous technology."[69] Whether this is an ideal solution remains to be seen, but assuming there is enough space for technology to adapt without regulatory roadblocks, state and federal laws will likely adapt to accommodate changes.

Challenging questions about liability remain, however.[70] If a car drives itself, who then is liable in the event of a crash?[71] Is it the auto manufacturer? The software designer? "The answer will be developed over time, as will the impact on insurance liability, and it may depend on the situation," notes *Consumer Reports*.[72] "Ultimately," says Jack Cutts, "the judicial system and the court of public opinion will figure that one out."[73]

Legal standards here could evolve gradually through a body of common-law cases, the same way they have for traditional automobiles and many other technologies. It would be unwise to hinder the deployment of these technologies in an attempt to plan for every hypothetical risk scenario. This is what the tort system is for; it deals with product liability and accident compensation in an evolutionary way through a variety of mechanisms, including strict liability, negligence, design-defects law, failure to warn, breach of warranty, and so on.[74]

Indeed, as Brookings scholar John Villasenor has noted, "when confronted with new, often complex, questions involving products liability, courts have generally gotten things right. . . . Products liability law has been highly adaptive to the many new technologies that have

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[69] John Frank Weaver, "Autonomous Car Legislation Backs Google's Vision of the Future over Ford's . . . for Now," *Slate*, November 22, 2013, http://www.slate.com/blogs/future_tense/2013/11/22/autonomous_car_legislation_backs_google_s_vision_of_the_future_over_ford.html.
[70] Claire Cain Miller, "When Driverless Cars Break the Law," *New York Times*, Upshot, May 13, 2014, http://www.nytimes.com/2014/05/14/upshot/when-driverless-cars-break-the-law.html?_r=0.
[71] Brian Fung, "When Driverless Cars Crash, Who's to Blame?," *Washington Post*, *The Switch* (blog), May 12, 2014, http://www.washingtonpost.com/blogs/the-switch/wp/2014/05/12/when-driverless-cars-crash-whos-to-blame.
[72] "Self-Driving Cars," *Consumer Reports*.
[73] Cutts, "On the Road to Driverless Cars," *Technology Trends to Watch 2014* (Arlington, VA: Consumer Electronics Association, 2014), 12.
[74] John Villasenor, "Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation" (research paper, Brookings Institution, Washington, DC, April 24, 2014), 7–14, http://www.brookings.edu/research/papers/2014/04/products-liability-driverless-cars-villasenor.

emerged in recent decades, and it will be quite capable of adapting to emerging autonomous vehicle technologies as the need arises."[75]

How liability is assigned will likely be affected by the level of knowledge and control that intelligent-vehicle manufactures have over these systems. Liability norms may also shift as driverless technology makes auto ownership less necessary.[76] Cars could become used more as a service than a final good; if so, most of the responsibility for their upkeep and safety would likely transfer to the owner of the fleet of cars and away from the end user, who would no longer own a vehicle but instead just order a ride as necessary.[77]

Furthermore, as Bryant Walker Smith of Stanford Law School notes, in liability law, "a seller who can, does, or should know more about the products it sells may be expected to foresee a wider range of product-related uses, misuses, and harms."[78] Therefore, as manufacturers come to possess a greater volume of data about the operation of vehicles and are in a position to take steps to avoid or correct potential risks, their liability will likely ratchet up over time.[79] They will become what economists refer to as the "least cost avoider," or the party who is in the best position to minimize risk at the lowest cost.[80] "The current stance could also potentially be changed to assign more liability to manufacturers, especially if a point were reached whereby users were no longer expected to even oversee the autonomous driving of their car," notes

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[75] Villasenor, "Who Is at Fault When a Driverless Car Gets in an Accident?," *Atlantic*, April 25, 2014, http://www.theatlantic.com/business/archive/2014/04/who-is-at-fault-when-a-driverless-car-gets-in-an-accident/361250.

[76] Eric Jaffe, "Imagine: A World Where Nobody Owns Their Own Car," *Atlantic Cities*, February 13, 2014, http://www.theatlanticcities.com/commute/2014/02/imagine-world-where-nobody-owns-their-own-car/8387; Emily Badger, "Driverless Vehicles Will Force Us to Rethink Car Ownership," *Washington Post*, *Wonkblog*, April 18, 2014, http://www.washingtonpost.com/blogs/wonkblog/wp/2014/04/18/driverless-vehicles-will-force-us-to-rethink-car-ownership.

[77] Lloyd's, *Autonomous Vehicles*, 6.

[78] Smith, "Proximity-Driven Liability," *Georgetown Law Journal*, 102 (forthcoming), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2336234.

[79] As Smith explains, "Since a product use or misuse that should be known to the seller is likely to be foreseeable, this information can also expand the content of other duties." Ibid.

[80] Steven Shavell, *Foundations of Economic Analysis of Law* (Cambridge, MA: Belknap Press of Harvard University, 2004), 189.

Lloyd's.[81] "If such changes were to occur, motor insurance could change substantially to be something more like product liability insurance. Insurers would need to know less about the users of a car, and more about different models of cars themselves."[82] Some residual liability might be left with the user if they still own their vehicle, however, or if they interfere with the intelligent driving systems in the vehicles they use.

Some, like attorneys John F. O'Rourke and Patrick Soon, fear that "if liability shifts to the manufacturer, auto makers may lose their incentive to produce self-driving automobiles" and that "if liability can be shifted to deep-pocket manufacturers, there is a risk that industry leaders could be sued into bankruptcy."[83] They suggest that lawmakers may need to immunize autonomous vehicle manufacturers from liability to ensure innovation is not derailed. In America's litigation-intensive system—which also lacks a "loser-pays" rule to disincentivize frivolous claims—they may have a valid concern. But preempting the evolution of the tort system in this regard should be the last, not first, resort. Moreover, even if some litigation ensues, insurance markets could evolve to handle liability concerns and claims. For that reason, "insurers should be allowed to experiment with innovative insurance products to manage this evolving risk landscape," notes Marc Scribner of the Competitive Enterprise Institute.[84] As a recent Lloyd's report noted,

> The insurance industry's expertise in risk management will be a factor in the adoption of autonomous and unmanned technology. In an area where regulation and safety standards are yet to be developed, insurers can encourage prudent progress by making their own risk assessments and providing policies for responsible operators. There is an opportunity for insurers to engage in the transfer of new risks, making it possible for continued technological innovation. This technological innovation may give rise to new business opportunities, with corresponding opportunities for insurers.[85]

[81] Lloyd's, *Autonomous Vehicles*, 19.
[82] Ibid.
[83] O'Rourke and Soon, "Driverless Technology and the Issue of Liability: Who's Responsible?," *Inside Counsel*, March 14, 2014, http://www.insidecounsel.com/2014/03/14/driverless-technology-and-the-issue-of-liability-w.
[84] Marc Scribner, "Self-Driving Regulation: Pro-Market Policies Key to Automated Vehicle Innovation," Competitive Enterprise Institute, *OnPoint* 192 (April 23, 2014): 10, http://cei.org/onpoint/self-driving-regulation.
[85] Lloyd's, *Autonomous Vehicles*, 5.

While these liability and insurance issues are complicated and may take some time to play out, it is vital to judge these efforts against our current, real-world baseline where so many accidents happen as a result of human error.[86] As Tom Vanderbilt of *Wired* points out,

> Every scenario you can spin out of computer error—What if the car drives the wrong way—already exists in analog form, in abundance. Yes, computer-guidance systems and the rest will require advances in technology, not to mention redundancy and higher standards of performance, but at least these are all feasible, and capable of quantifiable improvement. On the other hand, we'll always have lousy drivers.[87]

Viewed in this light, autonomous vehicles might be a solution to many of the dangers that plague our roads. Instead of focusing on potential disruptions to existing sectors or to liability norms, perhaps our real concern should be with perpetuating a status quo in which human error plays so significant a role in automobile accidents.[88] Consequently, as Villasenor correctly argues, "preemptively resolving liability issues should not be a precondition to commercial rollout of autonomous vehicles."[89] The cost of delay in terms of human lives, health, property damage, convenience, and more is very real.

Infrastructure Issues

Alterations and improvements to infrastructure may be necessary to facilitate more driverless vehicles.[90] The technology currently being developed focuses on real-time sensors to

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[86] Will Oremus, "Google's Self-Driving Car Already Drives Better Than You Do," *Slate*, April 28, 2014, http://www.slate.com/blogs/future_tense/2014/04/28/google_self_driving_car_safety_first_with_city_streets_bicyclists_pedestrians.html.
[87] Vanderbilt, "Five Reasons the Robo-Haters Are Wrong," *Wired*, February 12, 2009, http://www.wired.com/autopia/2012/02/robo-car-haters-are-wrong.
[88] Rishaad Mody, "An Autonomous Future," *Overdrive*, March 9, 2014, http://overdrive.in/news/an-autonomous-future.
[89] Villasenor, "Products Liability," 15.
[90] Clifford Winston, "How the Private Sector Can Improve Public Transportation Infrastructure" (Working Paper No. 14-16, Mercatus Center at George Mason University, Arlington, VA, June 2014), http://mercatus.org/publication/how-private-sector-can-improve-public-transportation-infrastructure.

automatically adjust speed and direction to compensate for changing conditions. While this may necessitate the development of prohibitively expensive “smarter” roads and highways, it is equally as plausible to imagine that infrastructure investment would be minimal.[91] Unfortunately, the costs of such investments are not yet apparent. However, as suggested by the Rand Report cited earlier, these upgrades might be unnecessary, because “most current efforts are focused on developing [autonomous vehicles] that do not depend on specialized infrastructure.”[92] Indeed, it is possible that the onboard technology in driverless cars may become so sophisticated in coming years that they will be able to adapt to almost any circumstance or road condition.

Before we can assess the costs and benefits of such investments, however, it will be necessary to define what these new environments might look like. As transportation consultant Nat Bottigheimer puts it, those “officials responsible for parking lot and garage building, transit system growth, bike lane construction, intersection expansions, sidewalk improvements, and road widenings need to analyze quantitatively how self-driving cars could affect their plans, and to prepare alternatives in case things change.”[93]

There is one area of established roadways that could benefit immensely from intelligent-vehicle technology: intersections. Computer scientists Joe Palca and Kurt Dresner have been working on developing “smart intersections” that would increase traffic flow to 10 times its current speed by using car-to-intersection communication systems. The idea, according to Palca, is that you would have “a four-way intersection with each road carrying five lanes of traffic. With light traffic, cars just zoom through. But with heavier traffic, even

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[91] Rand, *Autonomous Vehicle Technology*, 68.
[92] Ibid., 111.
[93] Bottigheimer, “Self-Driving Cars.”

though some cars are turning and some are going straight, . . . the cars don't slow down all that much, although they frequently come terrifyingly close." It is for this reason, he posits, that autonomous cars are a necessary component of such a scheme. "Dresner says a human driver just couldn't make the necessary adjustments fast enough or remain on course reliably enough to make the system work."[94] In adjusting roadways to accommodate greater traffic flow, easing congestion, and increasing efficiency, such technologies will serve as complements to the development of intelligent and autonomous vehicles. This means that many existing traffic rules, and current infrastructure necessities like stoplights, could be altered or abandoned entirely as intelligent vehicle technologies make driving closer at higher speeds possible. It remains unclear, however, whether *all* vehicles would need to be fully autonomous for such benefits to arise.

Interoperability among technical standards and other systems may be another issue. The technology currently being designed and tested by Google "combines information gathered from Google Street View with artificial intelligence software that combines input from video cameras inside the car, a LIDAR [laser imaging, detection and ranging] sensor on top of the vehicle, radar sensors on the front of the vehicle and a position sensor attached to one of the rear wheels that helps locate the car's position on the map."[95] By contrast, BMW and Mercedes are developing technology that relies on real-time sensors to "recognize what is around them."[96] Each variation possesses its own benefits and only time will determine the ideal system of automation. While interoperable standards may be a slight barrier to adoption, this does not mean government-

[94] Palca, "To Make Intersections Smarter, We Need Cars to Be Smarter, Too," *NPR*, December 27, 2013, http://www.npr.org/2013/12/27/257654592/to-make-intersections-smarter-we-need-cars-to-be-smarter-too.
[95] Haydn Shaughnessy, "Why Google Will Lose in Driverless Cars (and Who Will Win)," *Forbes*, February 4, 2013, http://www.forbes.com/sites/haydnshaughnessy/2013/02/04/why-google-will-lose-in-driverless-cars-and-who-will-win/.
[96] Ibid.

mandated standardization would be wise. Experimentation with varying standards can have many benefits, and picking efficient standards ex ante is notoriously difficult.[97]

A different but potentially equally pressing infrastructure issue concerns access to adequate wireless spectrum.[98] Many current intelligent vehicle systems rely on dedicated short-range communications (DSRC) systems to operate properly. Rand reports that DSRC "is intended to enable short-range wireless communications both between vehicles and between vehicles and roadside infrastructure—to support, especially, safety applications such as intersection collision avoidance" but "is also available for non-safety messages, vehicle diagnostics, and even commercial transactions."[99] A 2012 report on autonomous vehicles from the Center for Automotive Research and KPMG argued that "currently, DSRC offers the greatest promise, because it is the only short-range wireless alternative that provides all of the following: fast network acquisition, low latency, high reliability, priority for safety applications, interoperability, [and] security and privacy."[100] Nonetheless, adequate access to wireless spectrum for DSRC—and the technical standards that should govern the use of that spectrum—remain the subject of intense debate between various intelligent-vehicle stakeholders as well as federal and state regulatory agencies.[101] With competing technical standards of both a licensed

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[97] Adam Thierer, "What Is 'Optimal Interoperability'? A Review of Palfrey and Gasser's 'Interop,'" *Technology Liberation Front,* June 11, 2012, http://techliberation.com/2012/06/11/what-is-%E2%80%9Coptimal-interoperability%E2%80%9D-a-review-of-palfrey-gasser%E2%80%99s-%E2%80%9Cinterop%E2%80%9D.

[98] Sean Gallagher, "Potholes Abound on the Road to Car-to-Car Communication," *Ars Technica*, January 30, 2014, http://arstechnica.com/information-technology/2014/01/potholes-abound-on-the-road-to-car-to-car-communication/2/.

[99] Rand, *Autonomous Vehicle Technology*, 79.

[100] Richard Wallace and Gary Silberg, "Self-Driving Cars: The Next Revolution" (Ann Arbor, MI: Center for Automotive Research, August 2012), 12.

[101] See Rand, *Autonomous Vehicle Technology*, 92. Rand notes that "as [autonomous vehicle] technology improves, it will spur further demand for connectivity anyway, because drivers will have more time and attention available for things other than focusing on the road. For mobile communications carriers, this means increasing demand for spectrum to support voice and video applications. The FCC's policymaking in the current proceeding concerning the 5.9 GHz band may have far-reaching implications that will either accelerate or inhibit deployment of DSRC and AVs."

and unlicensed nature, the potential for interference exists within that spectrum range, which worries some intelligent-vehicle companies.

Some believe that major spectrum advancements will be necessary for use by intelligent vehicle innovators if these technologies are to reach their promise. German auto giant BMW has noted that so-called “5G” networks—the next major evolution of high-speed mobile broadband systems—“could be vital in providing the mission-critical reliability as it seeks to deploy self-driving cars onto city streets.”[102] “In order to support a large number of driverless vehicles on highways, you need 5G networks and all the extra capacity they deliver,” notes Dominic Basulto of the *Washington Post*.[103] 5G systems will be significantly faster, have broader coverage, be far more spectrum-efficient, and have lower latency than current systems.[104] But 5G and other advanced licensed and unlicensed wireless systems will require legislators and regulators at the Federal Communications Commission (FCC) to open up more wireless spectrum, which may be challenging in the short term given the many other sectors and innovators also clamoring for more spectrum. As they work to free up more spectrum, it is important that policymakers not attempt to micromanage these spectrum uses in an overly rigid fashion. Unfortunately, Congress and the FCC have traditionally “zoned” spectrum for specific uses, freezing markets and innovation in place according to rapidly outmoded market contours and technological designs.[105]

[102] Matthew Finnegan, “BMW: 5G Is Key to Self-Driving Car Deployment,” *ComputerWorld UK*, February 14, 2014, http://www.computerworlduk.com/news/mobile-wireless/3501253/bmw-5g-could-be-key-self-driving-car-deployment.

[103] Basulto, “Five Reasons to Get Excited about 5G Networks,” *Washington Post*, February 27, 2014, http://www.washingtonpost.com/blogs/innovations/wp/2014/02/27/five-reasons-to-get-excited-about-5g-networks.

[104] See Gary Arlen, “Multiple Cable Options for Broadcom’s 5G Chip,” *Multichannel News*, February 26, 2013, http://www.multichannel.com/blogs/i-was-saying/multiple-cable-options-broadcoms-5g-chip.

[105] See Thomas W. Hazlett, “The Wireless Craze, The Unlimited Bandwidth Myth, The Spectrum Auction Faux Pas, and the Punchline to Ronald Coase’s ‘Big Joke’: An Essay on Airwave Allocation Policy” (Working Paper No. 01-2, AEI-Brookings Joint Center, January 2001), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=286932.

To the maximum extent possible, flexible use of the spectrum should be the guiding principle for future policy in this area.[106]

What should not be lost in this discussion is just how many of these infrastructure-related problems discussed above are of government's own making. This is especially true of transportation infrastructure. As Winston and Mannering observe, it is "hardly surprising that the government has impeded technological advance in public highways and quite possible that the private sector could spur an advance if given an opportunity."[107] They conclude that "the public sector will not make the required investments in the near future to improve highway infrastructure technology; in contrast, the private sector is clearly determined to perfect and implement driverless cars. Thus, driverless car technologies are quite likely to effectively leapfrog most of the existing technologies that the public sector could but has failed to implement to improve highway travel."[108]

A Brief Note on Taxation

Another important consideration for policymakers is the effect of taxation on this developing technology. Taxation of intelligent vehicles should be as limited, noninvasive, and nonstifling as possible in order to ensure development of such technologies is not discouraged. While the ideal solution would be no tax at all, it is unlikely that the onset of autonomous vehicles will come without any tax scheme. States like Oregon, Washington, Colorado, Nevada, and California have

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[106] Harold Furchtgott-Roth, *Granting Licensed Spectrum Flexibility: How to Spur Economic Growth and Innovation in America* (Washington, DC: Hudson Institute, December 2012), http://www.hudson.org/content/research attachments/attachment/1084/hfr--spectrumflexibility--dec12.pdf.
[107] Winston and Mannering, "Leapfrog Technology," 6–7.
[108] Ibid., 7. Also see Mody, "Autonomous Future." ("The reason why autonomous vehicles are in the news isn't just because the various subsystems are slowly coalescing into a functioning self-aware system that can guide a vehicle through the real world. The reason is that everyone seems to believe that there is no viable way to make the road network keep up with the rate of automotive expansion.")

already begun experimenting with the idea of taxing all motorists based on miles traveled.[109] Such approaches to taxation may prove a more efficacious and fair distribution of the costs of road use, personalizing and tailoring taxes based on individual use rather than casting a wide net over all of society.[110] Whether these experiments prove ideal, and scalable, remains to be seen, but the argument in favor of an opt-in "vehicle miles traveled" (VMT) tax is certainly worth consideration.[111]

A prime example of how not to approach taxation is Washington, DC, Council Member Mary Cheh's 2012 proposed legislation that would apply a VMT tax of 1.875 cents per mile to driverless cars. As Scribner astutely pointed out in a *Washington Post* editorial, "no one knows precisely how autonomous vehicle technology will develop or be adopted by consumers. Cheh's bill presumes to predict and understand these future complexities and then imposes a regulatory straitjacket based on those assumptions."[112] Suffice it to say, the more taxes levied specifically on this technology, the less likely we are to see the type of innovation and development that characterized the rise of the Internet and similar technologies.

Social Considerations

Comprehensive change does not come overnight. The roadways will not be quickly and furiously populated by a fleet of wholly driverless vehicles. "Autonomous driving is not going to be a Big

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[109] Jerry Edgerton, "Will You Have to Pay a Tax for Every Mile You Travel?," *CBS News*, November 5, 2013, http://www.cbsnews.com/news/will-you-have-to-pay-a-tax-for-every-mile-you-travel/.

[110] Marc Scribner, "Memo to Road Socialists: There Is Nothing Unlibertarian about Road Pricing," *CEI: Open Market Blog*, November 5, 2013, http://www.openmarket.org/2013/11/05/memo-to-road-socialists-there-is-nothing-unlibertarian-about-road-pricing/.

[111] Tracy C. Miller, "Improving the Efficiency and Equity of Highway Funding and Management: The Role of VMT Charges" (Working Paper 14-04, Mercatus Center at George Mason University, Arlington, VA, February 2014), http://mercatus.org/publication/improving-efficiency-and-equity-highway-funding-and-management-role-vmt-charges.

[112] Marc Scribner, "Driverless Cars Are on the Way. Here's How Not to Regulate Them," *Washington Post*, November 2, 2012, http://www.washingtonpost.com/opinions/driverless-cars-are-on-the-way-heres-how-not-to-regulate-them/2012/11/02/a5337880-21f1-11e2-ac85-e669876c6a24_story.html.

Bang, it's going to be a series of little steps," observes Toscan Bennett, vice president of product planning at Volvo Car Corporation.[113] The change will come incrementally, and market penetration will increase in proportion to the degree of consumer demand for such vehicles, predicated on decreasing costs, a reasonably low burden of taxation, and rising gains in efficiency. Thus, we would expect one of the first actual concerns to involve the existence of autonomous cars driving side by side with manually operated vehicles. "Drivers are likely to become accustomed to semi-autonomous driving, particularly in certain conditions such as stop-start traffic jams or flowing motorway traffic," notes Lloyd's.[114] Can the roadways be shared between the two? As this process unfolds, various social and cultural tensions are likely to develop, especially as they relate to personal security and privacy. This section deals with those and other social considerations.

Cultural Resistance and Social Adaptation

As we give up more and more control over driving, some might lament the loss of the traditional American romance with cars and the open road.[115] The insatiable appetite for the freedom of the road is, for many, a historically significant component of what it means to be an American.[116] From the tinkering hobbyist and the speed demon to the muscle-car magnate and road-tripping 20-something, experiencing the vast expanse of interstate roadways is about on par with mom's apple pie as one of the cultural touchstones of modern America. One might argue that, if we lose direct control of our cars, we lose a little piece of what it means to be American. Perhaps that loss is more than some consumers will be able or willing to stomach at first, but the reality is that

[113] Quoted in Lloyd's, *Autonomous Vehicles*, 9.
[114] Lloyd's, *Autonomous Vehicles,* at 9.
[115] Thurston, "Bottom Line."
[116] Mody, "Autonomous Future."

with time most people will find enough benefit and value in changing their ways to accommodate the new norms.

Indeed, citizen attitudes about these technologies likely will follow a familiar cycle we have seen play out in countless other contexts. That cycle typically witnesses initial *resistance*, gradual *adaptation*, and then eventual *assimilation* of a new technology into society.[117] Many new technologies, including the automobile itself, were initially resisted and even regulated because they disrupted long-standing social norms, traditions, and institutions. Despite these fears, individuals adapted in almost every case and assimilated new technologies into their lives. Technologies that are originally viewed as intrusive or annoying often become not just accepted but even considered essential in fairly short order. Just as that was the case with the first automobile, the telephone,[118] the camera,[119] radio, television, and the Internet,[120] it will likely also be true with intelligent vehicles.

How quickly will people come to adapt to a technology as potentially life-altering as cars that are so smart they drive themselves? According to a July 2013 CEA Survey, when asked what activity people would prefer to engage in while operating a driverless vehicle, 81 percent indicated they would watch the road (see figure 1). This is understandable, given the unsettling nature of computers operating a motor vehicle. Given enough time, however, users will

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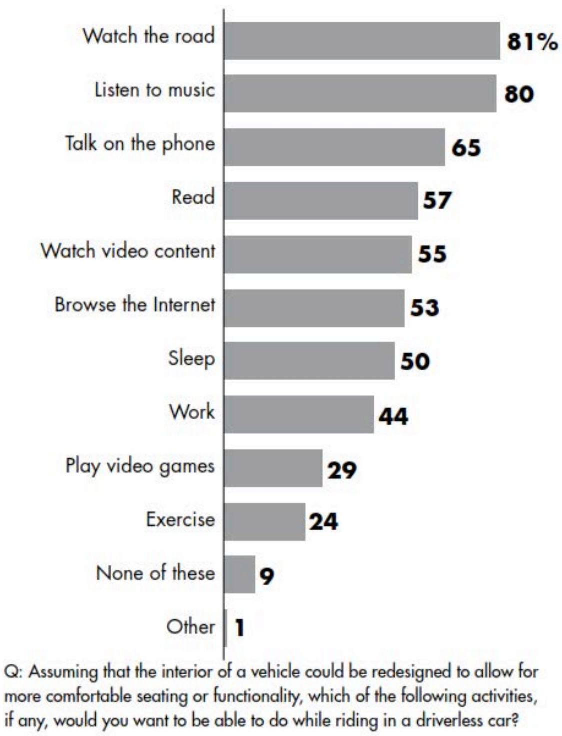
[117] Adam Thierer, "Technopanics, Threat Inflation, and the Danger of an Information Technology Precautionary Principle," *Minnesota Journal of Law, Science, and Technology* 14, no. 1 (2013): 312–50.
[118] See Keith Collins, "OK, Glass, Don't Make Me Look Stupid," *Slate*, May 14, 2013, http://www.slate.com/articles/technology/future_tense/2013/05/google_glass_social_norms_will_it_be_too_awkward_to_use_in_public.html.
[119] Adam Thierer, "A Framework for Benefit-Cost Analysis in Digital Privacy Debates," *George Mason University Law Review* 20, no. 4 (Summer 2013): 1102. (I note that the initial hostile reaction to the camera was gradually overcome as "personal norms and cultural attitudes toward cameras and public photography evolved quite rapidly. Eventually, cameras became a widely embraced part of the human experience and social norms evolved to both accommodate their place in society but also scold those who would use them in inappropriate, privacy-invasive ways.")
[120] See Adam Thierer, "Lessons from the Gmail Privacy Scare of 2004," *Technology Liberation Front*, March 25, 2011, http://techliberation.com/2011/03/25/lessons-from-the-gmail-privacy-scare-of-2004.

invariably adapt to the new "driving" experience, assuming they find enough value in it to justify getting past the hurdle of the initial unease. *Wall Street Journal* automotive journalist Dan Neil notes that some drivers "won't give up easily. They'll cling to their steering wheels. There will be friction. But it will all be over pretty quickly."[121] What Neil recognizes is that gradual acclimation to new innovations inevitably spurs acceptance, and the social norms and cultural trends of the past quickly give way to new norms.

Figure 1. Preferred Passenger Activities in Driverless Vehicles



Source: CEA Survey, July 2013.

Complex machines and robots, for example, have already been integrated into countless factories, and they now work alongside humans without major friction. In this regard, human

[121] Neil, "Why Driverless Cars Are Inevitable—and a Good Thing," *Wall Street Journal*, September 24, 2012, http://online.wsj.com/news/articles/SB10000872396390443524904577651552635911824.

adaptation on the roadways is not significantly different from other aspects of our daily lives. There are currently numerous cars that are already commercially available and include intelligent safety technologies. Whether it's the Volvo S60's Pedestrian Detection system, Mercedes S-Class PRE SAFE and DISTRONIC collision-detection radar, or the Lexus LS Advanced Pre-Collision System, intelligent driving and safety technology is already being incorporated into many cars.[122]

A recent study by engineers at Virginia Tech University examined a sample of 2,848 collisions resulting from unintended lane departures between 2007 and 2011. They find that by incorporating lane departure warning systems into the vehicles involved in these accidents, 30.3 percent of the crashes could have been avoided. The associated reduction of injuries resulting from lane departure accidents was estimated at 25.8 percent.[123] Another study examining the effects of forward collision warning systems finds "far greater differences, preventing as few as 9 percent and as many as 53 percent of rear-end collisions."[124]

As the integration of semi- and fully autonomous systems becomes more ubiquitous, and as their efficacy increases and produces substantial benefits, the sense of unease that may exist among some today will dissipate. Eventually, we will likely come to view these systems as ideal features of modern transportation. Again, change comes gradually in a fashion that permits us to grow accustomed to the inclusion of the new technology in our lives.

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[122] Nick Jaynes, "Smarter, Safer, Self-Driving: 4 (Almost) Autonomous Cars You Can Own Today," *Digital Trends*, January 31, 2013, http://www.digitaltrends.com/cars/autonomy-today-fewer-crashes-tomorrow-five-current-cars-with-autonomous-tech.

[123] Philip E. Ross, "How Many Lives Will Robocar Technologies Save?," *IEEE Spectrum,* May 7, 2014, http://spectrum.ieee.org/cars-that-think/transportation/advanced-cars/how-many-lives-will-robocar-technologies-save?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+IeeeSpectrum+%28IEEE+Spectrum%29.

[124] Ibid.

Safety and Security Concerns

Security concerns could also slow adoption of autonomous vehicles and are already leading to calls for regulation.[125] To the NHTSA's credit, its 2013 "Preliminary Statement of Policy Concerning Automated Vehicles" "does not recommend that states attempt to establish safety standards for self-driving vehicle technologies, which are in the early stages of development.[126] In addition, while the report fully concedes there are numerous technical and human performance issues that must be addressed, they "do not believe that detailed regulation of these technologies is feasible at this time at the federal or state level."[127] Rather, they provide a general framework of principles for testing such technologies, including

- Ensuring a safe, simple, and timely process for transitioning from self-driving mode to driver control;
- Promoting systems that have the capability to detect, record, and inform drivers in the event that automated systems have malfunctioned;
- Ensuring the installation and operation of autonomous technologies do not disable or otherwise interfere with federally mandated safety features; and,
- Ensuring that, in the event of a crash or loss of vehicular control, appropriate information is recorded about the status of automated control systems.

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[125] Jaclyn Trop, "The Next Data Privacy Battle May Be Waged Inside Your Car," *New York Times*, January 10, 2014, http://www.nytimes.com/2014/01/11/business/the-next-privacy-battle-may-be-waged-inside-your-car.html.
[126] NHTSA "Preliminary Statement of Policy," 12–13. It is worth noting here that despite the NHTSA's forward-looking avoidance of preemptive regulations on this particular point, the agency is nonetheless dealing with an archaic and soon-to-be obsolete framework of regulations. Marc Scribner has pointed out that manufacturers, like AAM and Tesla, are currently petitioning the NHTSA to revise their mandate on vehicular mirrors. After all, many sensor suites on current automobiles make mirror appendages redundant and obsolete. This is a prime example of how government regulatory agencies are, going forward, less and less likely to have an effective regulatory scheme; simply put, intelligent-systems technology is advancing too quickly for bureaucratic organizations to adapt.
[127] Ibid.

Such principles constitute a reasonable assessment of what makes for best practices in testing such technology, and are likely the guidelines framing companies' approaches to researching these technologies. As with any new technology, there are legitimate concerns over proper standards of safety, not least of which includes the potential for car hacking—a concern that, while a dominant feature of the current discourse in this space, is likely overblown in terms of its severity.

Despite valid apprehensions over third parties gaining access to and taking control of autonomous vehicles, current car systems are already prone to being hacked, given the level of automobiles' reliance on computer systems regulating certain vital functions. Indeed, car hacking is already possible for the vast majority of cars on the roads today. "Automobiles have already become sophisticated networks controlled by dozens of computers—called electronic control units (ECUs)—that manage critical, real-time systems," observes *Scientific American* reporter Larry Greenemeier.[128]

Ryan M. Gerdes, Charles Winstead, and Kevin Heaslip, have suggested that there is another problem with automated transportation system technologies: the potential for what they call efficiency-motivated attacks.[129] Such attacks focus on causing a target vehicle to expend excessive energy during travel, potentially "over four times as much energy as it would otherwise, with an average increase in energy expenditure of 42%," with the intent of decreasing the efficiency gains of other autonomous vehicles driving with it. The incentive for such an attack could come, for example, from a trucking firm looking to reduce its competitor's profit margins by increasing its fleet's fuel costs or damage its reputation by slowing down delivery times.

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[128] Larry Greenemeier, "Fact or Fiction?: Your Car Is Hackable," *Scientific American*, April 2, 2014, http://www.scientificamerican.com/article/fact-or-fiction-your-car-is-hackable1.

[129] Gerdes, Winstead, and Heaslip, "CPS: An Efficiency-Motivated Attack Against Autonomous Vehicular Transportation" (Logan, UT: Utah State University, December 13, 2013), 99–108.

However, this concern, as analyzed by Gerdes, Winstead, and Heaslip, applies only in the context of a *platoon* framework. A platoon in this sense is "defined as a group of vehicles cooperating to act as one unit by closely following one another at fixed speeds."[130] Although some scholars believe the platoon system is the most ideal means of achieving the massive economic impacts discussed earlier in the paper, there is no guarantee such a system will end up being the most effective long-term solution to networking autonomous and intelligent systems, especially as sensor-suite technologies and telematics develop in the coming years. The problems described by Gerdes and his colleagues, therefore, depend on a very narrow conception of how autonomous vehicles might operate and, in particular, on a very specialized form of attack that is unlikely to be an issue in all but the rarest of cases. Furthermore, while such attacks are potentially problematic, it is already "probable that a malicious actor could effect the attack against present-day vehicles equipped with automatic cruise control." Thus, like other attempts at car hacking, it is not a concern limited to future developments in intelligent-vehicle technology.[131]

Manufacturers have powerful reputational incentives at stake here, which will encourage them to continuously improve the security of their systems.[132] Companies like Chrysler and Ford are already looking into improving their telematics systems to better compartmentalize the ability of hackers to gain access to a car's controller-area-network bus. Engineers are also working to solve security vulnerabilities by utilizing two-way data-verification schemes (the same systems

[130] Ibid.
[131] Ibid, 107.
[132] "Because the failure of an autonomous car has serious implications for human safety, there could be serious reputational risk for the manufacturer of a car or component if it is involved in an accident. This is also the case for the manufacturing of traditional cars—even the suggestion of a fault can affect reputation—but as technology comes to have a larger responsibility for driving, the risk will also increase. The emotional implications of handing over personal safety and responsibility to a machine could lead to volatile public responses to a fault. People are more likely to take issue with a car and its manufacturer if it crashes itself, than if they had crashed it themselves." Lloyd's, *Autonomous Vehicles*, 16.

at work when purchasing items online with a credit card), routing software installs and updates through remote servers to check and double-check for malware, adopting of routine security protocols like encrypting files with digital signatures, and other experimental treatments.[133]

As experimentation and development continue, it is likely we will see beefed-up security measures, ensuring that routine vulnerabilities in a car's security matrix will be weeded out and dealt with accordingly. And despite a lack of legislation demanding a minimum standard of IT security to prevent hacker attacks on vehicles, automakers are presently "beginning to take steps to secure networks the same way the information-technology sector now locks down corporate servers."[134] Security consultant Javier Vazquez Vidal, who has done research on automobile security vulnerabilities, notes that the public "should not panic but know that the security in vehicles is being taken into consideration in order to improve it. Companies are really working on it, and it is improving at incredible speed."[135] In addition, NHTSA "has initiated research on vehicle cybersecurity, with the goal of developing an initial baseline set of requirements," but noted that "the first phase of this work, as funds permit, will take three to four years."[136] Because government research and standard-setting move so slowly and are subject to such budget constraints, private-sector research and experimentation will likely become the de facto baseline for security settings.

While it is prudent for developers and manufacturers to remain abreast of security issues, no amount of anticipatory legislation or preemptive regulatory planning can provide total assurance that hacking will not occur. All we can do is continuously improve our response

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[133] Keith Barry, "Can Your Car Be Hacked?," *Car and Driver*, August 2011, http://www.caranddriver.com/features/can-your-car-be-hacked-feature.
[134] Ibid.
[135] Quoted in Larry Greenemeier, "Fact or Fiction?"
[136] NHTSA "Preliminary Statement of Policy," 7–8.

mechanisms in an attempt to better detect and address these problems. Postrel's lesson about dynamic systems is worth reiterating: "They respond to the desire for security; they just don't do it by stopping experimentation."[137]

The question of *who* is doing the hacking is also worth asking. While some individuals might be permissive of private corporations having access to data about their driving activities, many will likely be more wary about the government's ability to intrude into their travel data. If, for example, the government begins toying with regulatory schemata for intelligent cars, who is to say it won't demand the inclusion of backdoor protocols that permit national intelligence services, local police, or other agencies to not only tap into a car's onboard communication system, but remotely shut down the vehicle at any given moment?[138] The security of vehicles will likely necessitate securitizing our information flows, but the underlying issue surrounding data collection, by the private sector or government, is one of privacy, which is discussed at greater length below.

Ethical Concerns

Although security and safety issues are at the fore of the discussion surrounding autonomous and intelligent vehicles, there are more subtle issues for consideration. Among these is the nature of the algorithms that make automated transportation possible. Writing in *Wired*, philosopher Patrick Lin discusses the ethical implications of algorithms making decisions in no-win situations that must inevitably end in a crash. He argues that "to optimize crashes, programmers

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137 Postrel, *Future and Its Enemies*, 199.

138 "Secret Documents Reveal N.S.A. Campaign against Encryption," *New York Times*, September 5, 2013, http://www.nytimes.com/interactive/2013/09/05/us/documents-reveal-nsa-campaign-against-encryption.html?_r=1&. The NSA has previously been revealed to be involved in operations targeting commercial service providers such as McAfee and Endpoint Encryption. To wit, the Sigint Enabling Project has specific resources set aside to "insert vulnerabilities into commercial encryption systems, IT systems, networks, and endpoint communications devices used by targets."

would need to design cost-functions—algorithms that assign and calculate the expected costs of various possible options, selecting the one with the lowest cost—that potentially determine who gets to live and who gets to die. And this is fundamentally an ethics problem, one that demands care and transparency in reasoning."[139]

Algorithmic functions making benefit-cost decisions that inevitably result in a crash are potentially worrisome, but an analysis of the larger picture is conspicuously absent from Lin's article. Lin is correct insofar as it is indeed difficult to program software "for the hard cases," but cases where such a response mechanism would need to be applied are, as Lin himself admits, "very rare, if realistic at all."[140] Autonomous vehicles are unlikely to create 100 percent safe, crash-free roadways, but if they significantly decrease the number of people killed or injured as a result of human error, then we can comfortably suggest that the implications of the technology, as a whole, are a boon to society. The ethical underpinnings of what makes for good software design and computer-generated responses are a difficult and philosophically robust space for discussion. Given the abstract nature of the intersection of ethics and robotics, a more detailed consideration and analysis of this space must be left for future research. Important work is currently being done on this subject.[141] But those ethical considerations must not derail ongoing experimentation with intelligent-vehicle technology, which could save many lives and have many other benefits, as already noted.[142] Only through ongoing experimentation and feedback mechanisms can we expect to see constant improvement in how

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[139] Lin, "The Robot Car of Tomorrow May Just Be Programmed to Hit You," *Wired*, May 6, 2014, http://www.wired.com/2014/05/the-robot-car-of-tomorrow-might-just-be-programmed-to-hit-you.
[140] Ibid.
[141] Noah J. Goodall, "Ethical Decision Making During Automated Vehicle Crashes," *Transportation Research Record: Journal of the Transportation Research Board* (forthcoming 2014), http://people.virginia.edu/~njg2q/ethics.pdf; Thierry Fraichard and Hajime Asama, "Inevitable Collision States—A Step Towards Safer Robots?," *Advanced Robotics* 18, no. 10 (2004): 1001–24.
[142] Ross, "Robocar Technologies."

autonomous vehicles respond in these situations to further minimize the potential for accidents and harms.

Privacy Considerations

Concerns over privacy and data collection are among the leading tech-policy issues of the day, and they have already begun bleeding into the debate over intelligent-car systems.[143] Some federal lawmakers have already raised concerns about the privacy and security implications of intelligent vehicles.[144] Privacy advocates have also sounded the alarm and called for new rules governing intelligent vehicles.[145] And a group of 18 US senators led by Sen. John Hoeven (R-ND) has introduced legislation called the "Driver Privacy Act," which proposes a preemptive framework to govern access to data gathered by vehicle event-data recorders (EDRs).[146]

In late 2013, the US Government Accountability Office (GAO) surveyed 10 companies that produce cars, portable navigation devices, and map and navigation applications for mobile devices. The GAO found that "All 10 selected companies have taken steps consistent with some, but not all, industry-recommended privacy practices," but "the companies' privacy practices were, in certain instances, unclear, which could make it difficult for consumers to understand the

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[143] "Connected Cars Roll into Privacy Concerns," *InfoSecurity Magazine*, January 18, 2014, http://www.infosecurity-magazine.com/view/36480/connected-cars-roll-into-privacy-concerns; Paul A. Eisenstein, "Spying, Glitches Spark Concern over Driverless Cars," *CNBC*, February 8, 2014, http://www.cnbc.com/id/101386129.

[144] Jaikumar Vijayan, "Sen. Markey Wants to Know: Can Your Car Be Hacked?," *Computerworld*, December 5, 2013, http://www.computerworld.com/s/article/9244562/Sen._Markey_wants_to_know_Can_your_car_be_hacked_?taxonomyId=128&pageNumber=1; Associated Press, "Sen. Schumer Calls on Feds to Regulate 'Smart Car' Technology," *CBS New York*, February 23, 2014, http://newyork.cbslocal.com/2014/02/23/sen-schumer-calls-on-feds-to-regulate-smart-car-technology; Jaikumar Vijayan, "Franken Presses Ford on Location Data Collection Practices," *Computerworld*, January 15, 2014, http://www.computerworld.com/s/article/9245409/Franken_presses_Ford_on_location_data_collection_practices.

[145] Jay Stanley, "Cars That Talk to Each Other: What Are the Privacy Implications?," *Free Future*, February 4, 2014, https://www.aclu.org/blog/technology-and-liberty/cars-talk-each-other-what-are-privacy-implications.

[146] Bill to Limit the Retrieval of Data from Vehicle Event Data Recorders, S. 1925, 113th Cong., 2nd sess. (2014), http://www.gpo.gov/fdsys/pkg/BILLS-113s1925is/html/BILLS-113s1925is.htm.

privacy risks that may exist."[147] Overall, however, the GAO report suggested that these privacy practices seemed to be constantly evolving and improving. "The good news is that issues of data privacy and security are being taken seriously by industry," notes Josh Harris, policy director for the Future of Privacy Forum, a think tank that seeks to advance responsible data practices. "Consumers—and those acting in their interests—can look forward to continued progress in ensuring privacy and security for connected cars," he argues.[148]

Auto manufacturers and intelligent-vehicle service vendors are still figuring out how to strike a sensible balance in this regard. This market and these technologies are evolving rapidly. We should not be surprised that many consumers will initially express skepticism—perhaps even revulsion—at the idea of vehicle data being collected and retained. But those expectations will likely evolve over time as the benefits become more evident. For example, vehicle EDRs and integrated diagnostic tools raise some privacy concerns, because they retain data about the user's vehicle and their driving patterns. But those systems have already been in place for many years in newer-model cars and help ensure that those vehicles operate safely and efficiently. As users gain greater peace of mind about the operation of the machines in which they are driving, they are likely to be more willing to allow those data to be collected and even shared, despite some privacy concerns.

Again, it is important to realize that social norms evolve over time and that privacy concerns tend to be highly subjective, amorphous, and ever-changing.[149] Privacy concerns

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[147] US General Accountability Office, "In-Car Location-Based Services: Companies Are Taking Steps to Protect Privacy, but Some Risks May Not Be Clear to Consumers," GAO-14-81, December 2013, http://www.gao.gov /assets/660/659509.pdf.
[148] Harris, "Connected Cars Are Here. The Good News Is That Privacy Is Being Taken Seriously," *Privacy Perspectives*, February 3, 2014, https://www.privacyassociation.org/privacy_perspectives/post/connected_cars_are _here._the_good_news_is_that_privacy_is_being_taken_serio.
[149] See Adam Thierer, "The Pursuit of Privacy in a World Where Information Control Is Failing," *Harvard Journal of Law and Public Policy* 36 (2013): 409–55.

related to the "intrusiveness" of many past technologies drove some of the early resistance to them.[150] Despite these fears, individuals grew to recognize the benefits of those technologies and gradually adapted their privacy expectations to accommodate them. Indeed, many technologies that were originally viewed as intrusive or annoying have become not just accepted but even considered *essential* in fairly short order.[151] This is likely to also be true for intelligent vehicles as individuals grow more accustomed to them.

Nonetheless, some legitimate privacy concerns will remain and could hold up progress and adoption of these technologies. Better transparency about intelligent-vehicle data-collection and -use practices will be essential if the auto industry and application developers hope to avoid alienating their customers. Jim Farley, a Ford executive responding to questions about data collection, recently remarked, "We know everyone who breaks the law, we know when you're doing it. We have GPS in your car, so we know what you're doing," and, almost as an afterthought, appended, "By the way, we don't supply that data to anyone."[152] Ford later clarified that Farley was referencing a hypothetical future scenario, in which such data *could*, in theory, be collected, and that the company was not currently doing so.[153] Nonetheless, these potential data-collection capabilities have raised obvious privacy concerns.[154] Perhaps the most pressing concern about such data collection is not what Ford might do with it, but what governments

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[150] Larry Downes, "A Rational Response to the Privacy 'Crisis,'" Cato Institute, *Policy Analysis* 716 (January 7, 2013): 10, http://object.cato.org/sites/cato.org/files/pubs/pdf/pa716.pdf. Downes has observed that "after the initial panic, we almost always embrace the service that once violated our visceral sense of privacy."
[151] Ibid.
[152] Eugene Volokh, "Ford 'Know[s] Everyone Who Breaks the Law' Using Cars They Made—Why Aren't They Doing Something about It?," *Volokh Conspiracy*, January 10, 2014, http://www.volokh.com/2014/01/10/ford-knows-everyone-breaks-law-using-cars-made-arent-something.
[153] Jim Edwards, "Ford Exec Retracts Statements about Tracking Drivers with the GPS in Their Cars," *Business Insider*, January 9, 2014, http://www.businessinsider.com/ford-jim-farley-retracts-statements-tracking-drivers-gps-2014-1.
[154] Kyle Stock, "Your Car Is Spying on You and Congress Isn't Sure What to Do about It," *Bloomberg Business Week*, February 17, 2014, http://www.businessweek.com/articles/2014-02-17/your-car-is-spying-on-you-and-congress-isnt-sure-what-to-do-about-it.

might be able to demand of Ford, knowing it possesses such data. Eugene Volokh writes that "as the NSA PRISM story vividly illustrates, surveillance data collected by private entities can easily be subpoenaed or otherwise obtained by law enforcement agencies, without a warrant or probable cause. What the private sector gathers, the government can easily demand."[155]

Concerns over privacy, though warranted, are not unique to the ongoing development of intelligent vehicles. Much like fears over the ability of car hackers to coopt vehicular control,[156] these are issues that will require redress whether autonomous vehicles develop further or not. They should not, therefore, be an argument for forestalling continued innovation in this arena.

The focus should instead be on what precisely is being done with these data. Services like OnStar and GPS systems collect location data as a means of providing drivers with the ability to locate services and map routes to their destinations on the fly, leading some to portend that "the days of a driver being alerted to a deal at a retailer as he drives nearby are rapidly approaching."[157] And while the question of how long such data should be retained is worth asking, we should not presume that providing tracking data to private service providers is automatically a bad idea. Rather, we should be asking to whom such data might be transmitted (e.g., law-enforcement agencies, the NSA, insurance companies, marketers), and under what circumstances. It is also important to distinguish between personally identifiable information (PII) and non-PII data. The sharing of PII by companies raises more legitimate privacy concerns, while the sharing of non-PII raises fewer concerns and still offers many benefits (such as real-time traffic updates).

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155 Volokh, "Tort Law vs. Privacy," *Volokh Conspiracy*, November 25, 2013, http://www.volokh.com/2013/11/25/tort-law-vs-privacy.
156 "Can Your Car Be Hacked?," *Mission Critical* 4, no. 1 (February 2014): 15, http://issuu.com/auvsi/docs/mc/17?e=0/6564626.
157 Trop, "The Next Data Privacy Battle."

Privacy concerns such as these, however, can be remedied by a combination of private self-regulation, tort law, Federal Trade Commission oversight, consumer watchdog pressure and press attention, and various private entities focused on keeping industry best practices in the limelight. For example, the Future of Privacy Forum has launched a Connected Cars Project "to promote best practices in privacy and data security that recognize the benefits of new connected car technologies."[158] This effort aims to translate traditional fair information practice principles (FIPP) into a workable set of industry best practices. Under the heading of FIPP, Obama administration privacy reports have generally listed the following principles: Individual Control (i.e., "notice and consent"), Transparency, Respect for Context, Security, Access, Accuracy, Focused Collection, and Accountability.[159] The administration has advocated that such principles govern private-sector data collection and use and that they be formally enshrined in a congressionally implemented "Consumer Privacy Bill of Rights."[160] Congress has not yet acted on the administration's request, however. That may be because lawmakers understand the challenge of applying FIPP in a strict, legalistic fashion, considering how rapidly technology, business practices, and consumer demands are evolving in the modern economy.[161] Multistakeholder processes, which focus on building consensus among diverse constituencies through ongoing meetings and agreements, would be preferable to top-down, one-size-fits-all administrative regulation.

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[158] Future of Privacy Forum, "Connected Cars Project," accessed February 5, 2014, http://www.futureofprivacy.org/connectedcars. See also Future of Privacy Forum, "Comments of the Future of Privacy Forum on Connected Smart Technologies in Advance of the FTC 'Internet of Things' Workshop," May 31, 2013, http://www.futureofprivacy.org/wp-content/uploads/FPF-Comments-Regarding-Internet-of-Things.pdf.
[159] Federal Trade Commission, *Protecting Consumer Privacy in an Era of Rapid Change: Recommendations for Businesses and Policymakers* (2012), 3, http://ftc.gov/os/2012/03/.120326privacyreport.pdf; White House, *Consumer Data Privacy in a Networked World: A Framework for Protecting Privacy and Promoting Innovation in the Global Digital Economy* (February 2012), 25–27, http://www.whitehouse.gov/sites/default/files/privacy-final.pdf.
[160] Ibid.
[161] See Thierer, "Pursuit of Privacy," 424–35.

Regulation, no matter how well-intentioned, creates complex and sometimes quite costly trade-offs.[162] Advertising and data collection are the fuel that have powered the information economy, meaning that privacy-related mandates that curtail the use of data to better target ads or services could have several deleterious effects.[163] Those effects could include higher costs for consumers; a decrease in the content and services supported by that data collection and advertising; increased costs for smaller operators and new start-ups, meaning less competition overall; and perhaps even the diminishment of America's global competitive advantage.[164] These factors might be weighing on the minds of policymakers and encouraging them to resist enacting new privacy-related regulatory decrees. All these considerations and trade-offs are applicable to the privacy considerations surrounding intelligent vehicles. Instead of imposing the FIPP principles in a rigid regulatory fashion, these privacy and security best practices will need to adapt gradually to new realities and be applied in a more organic and flexible fashion.

For example, providing consumers with adequate notice and consent for data collection remains a sensible best practice. Likewise, automobile manufacturers and application developers would be wise to be highly transparent about their data-use policies and also limit the amount of overall data collection, keeping it limited to core functions as much as possible. Finally, they should limit retention of those data, limit sharing with too many third parties, and safeguard those data against unauthorized interception. By handling data collection and use in this way, automakers can balance legitimate uses and avoid privacy headaches or data breaches.

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[162] See Thierer, "Framework for Benefit-Cost Analysis," 1055–105.

[163] See Adam Thierer and Berin Szoka, "The Hidden Benefactor: How Advertising Informs, Educates and Benefits Consumers," Progress and Freedom Foundation, *Progress Snapshot* 6, no. 5 (February 2010); Berin Szoka and Adam Thierer, *Online Advertising and User Privacy: Principles to Guide the Debate*, Progress and Freedom Foundation, *Progress Snapshot* 4, no. 19 (September 2008).

[164] See Adam Thierer, "A Status Update on the Development of Voluntary Do-Not-Track Standards," Testimony before the Senate Committee on Commerce, Science and Transportation, April 24, 2013, 2, http://mercatus.org /publication/status-update-development-voluntary-do-not-track-standards.

But these policies should not be converted into a regulatory straitjacket that uniformly mandates data collection and use practices according to a centralized blueprint. In the future, some automakers or app developers might craft creative data-sharing policies that provide consumers with myriad unanticipated benefits. Serendipitous discoveries can materialize only in a policy environment that embraces trial-and-error experimentation. That is why flexible and evolving best practices for data collection and use will ultimately serve consumers better than one-size-fits-all, top-down regulatory edicts.

The debate over the ownership of data collected by intelligent-vehicle technologies will continue. How much control will consumers have over these systems and the data they collect? Who owns the data collected by the onboard event-data recorders? If a consumer evades or defeats the data-collection system on his vehicle, will that be strictly a contractual matter that voids his warranty with the manufacturer? Or will government mandates requiring EDRs in intelligent vehicles result in some other form of liability for the owner?

As with the other security and liability questions discussed in this paper, these issues will play out over time through the common law. Policymakers need not respond to all of them preemptively and ought to be mindful that it is unlikely they have all the right answers at this time. Alas, that has not stopped some federal and state lawmakers from already suggesting a regulatory framework, including the Driver Privacy Act mentioned earlier.

Further complicating matters is the patchwork of state laws already developing on this front. As of December 2013, 14 states had also introduced measures governing access to EDR data.[165] As states continue to grapple with intelligent-vehicle issues, privacy considerations will

[165] National Conference of State Legislatures, "Privacy of Data from Event Data Recorders: State Statutes," accessed April 30, 2014, http://www.ncsl.org/research/telecommunications-and-information-technology/privacy-of-data-from-event-data-recorders.aspx.

continue to creep into many of those discussions and a patchwork of conflicting data-use policies may develop.[166] At some point, perhaps sooner rather than later, Congress may need to preempt some of these laws in order to make more uniform the policies governing the sale, use, and regulation of intelligent vehicles.[167]

Embracing Change: General Recommendations to Promote Intelligent Vehicles

We can see that the development of intelligent vehicles has the potential to be a boon to quality of life, to promote economic gains, and to advance social progress. As with many other new technologies, however, autonomous vehicles will be highly disruptive to the economy and society, as well as to legal and cultural norms. There will be a sense of unease at first, but at a certain point, we will come to accept the enormous potential this technology has to benefit society. What was true for Henry Ford's Model T will be equally true for the intelligent vehicles and driverless cars that will soon be on the roads around us. Rather than narrow our gaze toward what is lost in this transition, we should focus on how technological progress improves human welfare in the long run—even for those displaced or inconvenienced by such innovations in the near term.

After all, industries in which individuals have previously been displaced as a result of automation are examples of less-skilled jobs being replaced by more technically skilled and economically advantageous positions. Many of those who once toiled in fields and factories, for example, eventually migrated to service-oriented professions that also provided safer working conditions. None of this is to minimize the plight of those who might suffer in the short term as a

[166] Matthew Heller, "California Regulators Consider 'Big Brother' Hazards Of Driverless Cars," *Mint Press News,* March 19, 2014, http://www.mintpressnews.com/california-regulators-consider-big-brother-hazards-driverless-cars/186951.

[167] Ali, "Government Hitting the Brakes."

result of this disruption, but were we to forestall such technological progress for the sake of preserving those jobs currently in existence, our economy and society would become a static dystopia of contentment, eschewing progress for stability and sacrificing a future of possibilities for the preservation of the status quo. Although worker-retraining programs are certainly one option for minimizing disruptions in the lives of affected individuals, there are many other alternatives that might be worth examining before defaulting to such programs, which typically do not achieve the results their sponsors desire.[168]

Considering the significant benefits that could come from fully intelligent vehicles, the primary role for government in this space should be rooted in humility and patience. It is still unclear what shape innovation will take in the coming years and, therefore, *forbearance* is the wise policy disposition at this time.[169] That is especially the case in light of how rapidly these technologies continue to develop and how challenging it will be to preemptively craft rules that can keep pace. In their *Autonomous Vehicle Technology* report, Rand researchers have explained the challenge of setting regulatory standards that remain relevant:

> First, regulatory promulgation is fundamentally an iterative and slow process, given the cycles of proposals, requests for comments, reviews, and lobbying that precede rulemaking. Second, with [autonomous vehicle] technologies in particular, their newness and rapid evolution create uncertainty in both rulemaking effects and of the

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[168] This is especially true of the Trade Adjustment Assistance program that, despite a robust half-century of funding, has never achieved its expected outcomes for domestic workers (especially in the manufacturing sector) displaced by foreign trade. To wit, a December 2012 *Mathematica* report commissioned by the US Department of Labor's Employment and Training Administration found that the program's net benefit to society was negative $53,802 per participant and the net benefit to participants was negative $26,837. See Sarah Dolfin and Peter Z. Schochet, "The Benefits and Costs of the Trade Adjustment Assistance (TAA) Program Under the 2002 Amendments," *Mathematica Policy Research* (December 2012). Similar program evaluations in peer-reviewed academic journals have almost unanimously concluded the same. For more information relating to how federal employment and training programs are limited in their efficacy and the unintended harms from such investments, see Chris Edwards and Daniel J. Murphy, *Employment and Training Programs: Ineffective and Unneeded* (Washington, DC: Cato Institute, June 2011), http://www.downsizinggovernment.org/labor/employment-training-programs.

[169] Rand, *Autonomous Vehicle Technology*, 139. ("Given the lack of demonstrated problems with autonomous or self-driving vehicle use, we think state lawmakers would be wise to refrain from passing laws or developing regulations in this area. As NHTSA noted, evolution is occurring too rapidly and there are too many uncertainties for productive regulation at this time.")

> technology itself. Moreover, with rapid technology changes, it can be challenging to prescribe rules that will remain relevant and appropriate through the development process. A government transportation official we interviewed stated that, when it came to issuing standards, he thought it was extremely difficult to stay relevant, given the swift pace of technological change.[170]

Importantly, many of the imagined security and privacy problems mentioned above may never materialize, because individuals and organizations could quickly adapt to the new realities of a world filled with intelligent vehicles. On the other hand, unanticipated challenges could develop that require flexible, creative solutions we cannot possibly design a priori. Creative solutions will have to be pursued as those issues develop, because it is impossible to anticipate every possible use or harm scenario in advance.

There are, however, a few general prescriptions that ought to guide lawmakers' decision-making processes in this space. Legislators should first look to sunset laws that inhibit innovation and experimentation. Some issues that may require more serious political attention include infrastructure and network operations as well as obvious licensing issues. States already have various motor vehicle licensing procedures in place that will need to adapt rapidly to accommodate the rise of driverless cars in coming years. As mentioned earlier, some states have already taken action to do so.

Developers of intelligent vehicles should continue to work together, and with policymakers, to overcome both political and technical hurdles to widespread adoption of intelligent-vehicle technologies. The development of clear and fully transparent guidelines and best practices for safety, security, and privacy concerns will be of paramount importance in furthering that goal. But the presence of such concerns need not limit our willingness to allow for continued innovation and trial-and-error experimentation. The solutions to many of these issues

[170] Rand, *Autonomous Vehicle Technology*, 103–4 (internal citations omitted).

lie with the people developing and testing the operational systems; they do not lie in endless bureaucratic proceedings and labyrinthine layers of regulatory red tape. The tort system will simultaneously evolve to help remedy harms that develop. Lawmakers should not interfere with that evolutionary process.

One class of privacy and security-related concerns deserves special consideration, however—law enforcement access to driver data. Governments possess powers that private entities do not—the power to fine, tax, or even imprison.[171] Therefore, when law-enforcement officials seek access to privately held data collected from connected vehicles, strong constitutional and statutory protections should apply. Toward that end, bolstered Fourth Amendment constraints on governmental attempts to access data from connected cars are essential.[172] This should include reform of the Electronic Communications Privacy Act of 1986 (the primary federal statute that governs when law-enforcement agencies may compel private entities to divulge information held on behalf of third-party subscribers) to require the government to obtain a warrant issued upon a showing of probable cause before accessing privately held data and communications.[173] In short, government collection of data ought to be constrained to the fullest extent possible, while granting consumers the right to engage in clearly defined, consensual arrangements to trade data with producers—arrangements that, unlike nonconsensual government collection, often translate to practical benefits, cheaper systems, and a more robust marketplace for citizens.

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[171] Adam Thierer, "Do We Need a Constitutional Amendment Restricting Private-Sector Data Collection?," *Privacy Perspectives*, January 23, 2014, https://www.privacyassociation.org/privacy_perspectives/post/do_we_need_a_constitutional_amendment_restricting_private_sector_data_colle.

[172] James X. Dempsey, "Keynote Address: The Path to ECPA Reform and the Implications of *United States v. Jones*," *University of San Francisco Law Review* 47 (Fall 2012): 479, https://cdt.org/files/pdfs/Keynote_%20Usv Jones.pdf.

[173] Charles H. Kennedy, "An ECPA for the 21st Century: The Present Reform Efforts and Beyond," *CommLaw Conspectus*, 20 (2011): 129.

Conclusion

The issue at stake with potential regulation of this burgeoning industry is not merely the potential abatement of one particular new technological innovation; it is the larger question of what principle will guide the future of technological progress. Will "permissionless innovation" be our lodestar, allowing individuals to pursue a world of which they can, as of now, only dream? Or will reasoning based on the "precautionary principle" prevail instead, driven by a desire to preserve the world in which we find ourselves now?

To the maximum extent possible, we should embrace permissionless innovation for intelligent vehicles. Creative minds—especially those most vociferously opposed to technological change—will always be able to concoct horrific-sounding scenarios about the future. But again, the best-case scenarios will never develop if we are gripped by fear of the worst-case scenarios and try to preemptively plan for them with policy interventions.

Although there are many issues to overcome with respect to safety, privacy, liability, and more, we mustn't be cowed into fear because of the disruptive impact of these new technologies. As Philip Ross notes, "eventually it will be positively hard to use a car to hurt yourself or others."[174] The sooner that day arrives, the better.

[174] Ross, "Robocar Technologies."