



The Policy Trajectories of Autonomous Vehicles

John Paul MacDuffie, PhD

ISSUE BRIEF

VOLUME 6

NUMBER 4

MAY 2018

In March, news broke that a self-driving car belonging to Uber accidentally struck and killed a pedestrian in Arizona.

It was the first non-passenger death caused by an autonomous vehicle (AV) in the United States. Two years earlier, in May 2016, Tesla made headlines when one of its cars with automated capabilities collided with a truck on a Florida highway while in “Autopilot” mode, killing the driver who had not responded to the car’s sensors beckoning him to reassume full control of the driving task. That incident will forever be remembered as the first “self-driving” car death.¹ Despite the daily tragedies that unfold across the U.S., which witnessed 37,461 driving-related deaths in 2016, stories like these become breaking news because of their intrigue.² A future with self-driving cars dominating the streets and highways of America could mean far fewer driving-related deaths, and it’s a future sought by government (at all levels), industry, and many of the potential users of these vehicles. But when accidents inevitably occur during these years of technological development, many people reasonably ask, “What risks are we (society) willing to accept to advance this technology?” and “What are policy-makers doing to mitigate these risks?” The American public will need to answer these questions many times over in the coming years, but the federal government has already made its preferences clear, at least for the moment.

SUMMARY

- As automobile crashes are tremendously costly both in terms of human fatalities and economic losses, and typically result from human error, the development of autonomous vehicles (AVs) has become a priority at all levels of government.
- But the development of AVs has not been casualty-free, thus raising a key question: How do we best promote AV innovation while ensuring public safety?
- The current flexibility states enjoy in regulating AV technology and safety, while desirable from the perspective of supporting exploration and experimentation for learning purposes, has created an inefficient patchwork of guidance across the country.
- H.R. 3388, or the SELF-DRIVE Act, would potentially address this problem by enforcing a uniform standard for both technology and safety, while also barring states from blocking the use of AVs without human controls within their borders.
- As a general rule, such a paradigm of regulatory consistency that boosts innovation would enhance safety too, given the iterative nature of software and technology development.
- Beyond H.R. 3388, there are many tools available to government lawmakers and regulators to foster such innovation. This brief looks at several, including new voluntary federal policy guidance, the development of a standardized AV “driver’s license test,” infrastructure investments, and geofencing and other local policy initiatives.



In September 2016, the U.S. Department of Transportation through its National Highway Traffic Safety Administration (NHTSA) published non-binding performance guidance in order to facilitate the development of AVs, offering a consistent regulatory regime to the carmakers and technology companies competing to bring self-driving cars to market.³ This document included a 15-point safety assessment for developers and model state policy. One year later, NHTSA updated its guidance,⁴ and in the same week, the U.S. House passed H.R. 3388—the SELF-DRIVE Act—a standard setting piece of legislation that seeks to further advance the innovation of this technology.⁵ Both the NHTSA guidance and H.R. 3388 have important implications, as we will discuss, but what these measures make immediately clear is that federal lawmakers and regulators are working alongside private industry to boost innovation in ways that, in other policy contexts, they so often do not.

There are concerns from consumer advocates and other parties that these proposed measures put the safety of Americans at undue risk, and we will address these in turn. But there is no disagreement as to why the federal

government is trying to stay ahead of and support this burgeoning technology. The aforementioned 37,461 deaths in 2016 represent a 14% increase from 2014.⁶ According to NHTSA, “94 percent of crashes can be tied to a human choice or error,” so removing human judgment from the driving equation could save many lives.⁷ Not only that, AVs would allow increased mobility to those with disabilities, revolutionize the auto industry, and potentially decrease economic losses from crashes, which may have been as high as \$836 billion in 2010.⁸

How exactly we arrive at a future with fully automated cars is still largely up for debate, and in this Issue Brief we will examine the inflection points in two sequential phases. In the first phase, we will address the benefits and costs of setting uniform standards—for both technology and safety—versus allowing for flexibility at the state or local levels in establishing these standards. As part of that discussion, we will review the current legislation proposed in Congress and the actions undertaken by several states up to this point. In phase two, we assume that public support for developing AVs holds at least until 2021—the year many companies have promised to deliver large scale rollouts

of AVs—and highlight how federal lawmakers and regulators can mitigate near-term safety risks while facilitating innovation.

This Issue Brief also serves as a snapshot of the state of AVs in the U.S. at a crucial moment, when the costs (in terms of human lives) of developing self-driving technology are already materializing but before any binding federal legislation establishes firm legal parameters. Regardless of the fate of H.R. 3388, many policy challenges and opportunities lie ahead.

THE CURRENT STATE OF AV TECHNOLOGY

In 2017, Waymo—Google’s self-driving car company—filed a lawsuit against Uber, claiming that the ride-sharing company stole trade secrets when a former Waymo employee left to work for Uber. The case was intriguing, both for some of its odd details, but also because of the trade secrets at the heart of the dispute. Uber allegedly stole Waymo’s Lidar designs. Lidar is a highly specialized sensor that, in conjunction with cameras, radar, and various other sensors, helps a self-driving car “see.”⁹ Lidar estimates distances (from lane markings and road edges) by using illumi-

NOTES

- 1 Less than a week after the recent Uber accident, a Tesla crash—again caused by an Autopilot error—resulted in the death of another driver. Executives from other companies were quick to point out that such incidents are not representative of the AV industry as a whole, with some (e.g., Waymo CEO John Krafcik) going so far as to say that their company’s technology would have prevented these accidents.
- 2 See <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812451>.
- 3 U.S. Department of Transportation (2016), Federal Auto-

- 4 U.S. Department of Transportation (2017), Automated Driving Systems 2.0, available at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.
- 5 H.R. 3388 available at <https://www.congress.gov/115/bills/hr3388/BILLS-115hr3388eh.pdf>.
- 6 The uptick in accident-related deaths, which many attribute to increased instances of distracted driving, occurred

- 7 Singh, S. (2015), Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey. (Traffic Safety Facts Crash Stats. Report No. DOT HS 812 115). Washington, DC: National Highway Traffic Safety Administration.
- 8 See <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPubli>



nated, invisible lasers. Unlike the other hardware upon which self-driving cars rely, Lidar is expensive to mass-produce, although great strides have been made in the last few years to make it more affordable. In February 2018, just five days into the trial, Uber settled out of court, paying Waymo \$245 million and granting its competitor oversight rights for reviewing the future development of Uber’s Lidar technology.¹⁰ Uber initially offered to settle for a larger sum, but Waymo accepted the relatively lower settlement amount in exchange for the ability to monitor the way Uber develops Lidar on its own and integrates that hardware with its software.

In general, AVs are the result of successful hardware-software integration and the melding of digital and automotive components. As Rahul Mangharam of the University of Pennsylvania describes, AVs continuously execute a three-step process.¹¹ First, they must perceive all of their surroundings. Then, using all of the data gathered by the hardware, they must plan their routes and how they will navigate the changing landscape. For this, AVs need advanced processing computers and complex software to guide their decision-making. The final step is the act of driving itself:

they must accelerate, brake, and maneuver on the road without human intervention. All three steps pose problems, technologically and policy-wise. The abruptness with which Waymo settled its case with Uber underscores the fact that hardware alone is not the greatest obstacle facing these companies. It is the algorithms undergirding the software in self-driving cars that will be an especially significant focus of regulation in the coming years.

Since even a brief scan of news articles reveals that terms like “automated,” “autonomous,” and “self-driving” are used interchangeably—despite different people having different interpretations of each term—it is important for there to be a consistent means of describing the many levels of automation.¹² Accordingly, NHTSA has adopted SAE International’s definitions for distinguishing the different levels of automation.¹³ All companies competing to market AVs—whether they are carmakers like Ford, GM, or Daimler, or technology companies like Waymo, Uber, or nuTonomy—have accepted these definitions as their targets, despite there being disagreements about whether Level 3 automation is even marketable (see Figure 1).

Carmakers have different beliefs

about how ultimately to attain full autonomy. Toyota, for example, subscribes to the idea of “human in the loop,” which involves human drivers doing most of the driving most of the time, but the automated system (AS) would kick in during a dangerous situation, like fishtailing. Tesla’s approach is essentially the opposite: the AS will handle all routine driving scenarios but will alert the human driver to retake control of the wheel (through a combination of bright lights, auditory alerts, and physical sensors in the seats) whenever unpredictable circumstances develop. Meanwhile, Waymo and Ford believe Level 3 automation is not even feasible due to safety concerns. They argue that forcing a distracted rider to assume control of the driving task and to monitor the road environment in a matter of seconds is too risky, especially at higher speeds. For this reason, Waymo cars will not even have steering wheels or pedals.¹⁴ Most carmakers, however, have been silent on this debate, implying that most believe Level 3 automation is achievable and marketable in increments. In theory, Level 3 cars could reach the market faster, as they have fewer NHTSA regulations with which to contend. The first challenge for either Level, however, is the current

NOTES

cation/812013.

⁹ Cameras are best for object recognition; radar and LIDAR are both good at distance; but only LIDAR (short for light direction and ranging) provides sharp 3-D images, accurate distance, and high ability to recognize objects in all light conditions.

¹⁰ See <https://www.uber.com/newsroom/uber-waymo-settlement/>.

¹¹ Jason Laughlin, “Can driverless cars be safe? Grand Theft Auto helps Penn scientists find out,” *Philly.com*, December 6, 2017.

¹² Today, there are numerous examples of Level 1 and Level 2 automation present in many cars on the market. NHTSA

provides a concise list, which includes the following: automatic emergency braking, adaptive cruise control, adaptive lighting, backup cameras, park assist, forward collision warning, lane keeping assist, lane departure warning, blind spot detection, and automatic crash notification (e.g., OnStar). Automated cars have been available to consumers for a long time. The lab and road tests that companies are conducting now, in fact, involve developing Level 3 and Level 4 capabilities. Audi has claimed to have even created the first car with Level 3 automation, but they assert that they are unable to deploy it anywhere in the world

because of excessive liability and the lack of governmental permission. See Michael Taylor, “The Level 3 Audi A8 Will Almost Be the Most Important Car in the World,” *Forbes*, September 10, 2017.

¹³ U.S. DOT, *supra note 3*.

¹⁴ Will Oremus, “The Big Problem with Self-Driving Cars,” *Slate*, September 8, 2015.

¹⁵ For the source of Figure 2, see Gabriel Weiner and Bryant Walker Smith, *Automated Driving: Legislative and Regulatory Action*, available at cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action.

FIGURE 1 THE FIVE LEVELS OF VEHICLE AUTONOMY

SAE level	Name	Execution of Steering and Acceleration Deceleration	Monitoring of Driving Environment	Failback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment					
0	No Automation	Human Driver	Human Driver	Human Driver	n/a
1	Driver Assistance	Human Driver and system	Human Driver	Human Driver	Some driving modes
2	Partial Automation	System	Human Driver	Human Driver	Some driving modes
Automated driving system ("system") monitors the driving environment					
3	Conditional Automation	System	System	Human Driver	Some driving modes
4	High Automation	System	System	System	Some driving modes
5	Full Automation	System	System	System	All driving modes

lack of legal parameters. Which states or localities will even allow them on their roads?

PHASE 1: THE CHALLENGE OF LEGISLATING A UNIFORM STANDARD

States have differed widely as to their interest in and approaches toward allowing the testing of Level 3 and 4

cars on their roads. The map in Figure 2 shows where legislation has and has not been passed that would authorize AV testing.¹⁵ Arizona (red on the map because state legislation failed) has actually been the preferred testing ground for companies like Waymo and Uber because of active promotion by state and local officials. This is in keeping with the general presumption that experimentation is allowed . . . until it

is not.

At the federal level, it is currently illegal to operate AVs without human controls on U.S. roads. The states noted in Figure 2, however, have passed a variety of different rules on everything from what can be tested and where, to what data AV companies are required to share with state officials for safety monitoring purposes. And most state laws do include provisions requiring a human driver “in the loop” to help protect against accidents, although the recent Uber incident is evidence of the risks still inherent in road tests. States that have higher emissions standards, such as California and Massachusetts, also obligate AV companies to account for that variable in any new AV test designs.

The current flexibility states enjoy in regulating AV technology and safety, while desirable from the perspective of allowing for exploration and experimentation for learning purposes, has created an inefficient patchwork of guidance across the country. States are free to disregard NHTSA’s model state policy, of course, and many have, but in publishing these documents, NHTSA has reaffirmed its authority to oversee the changing auto industry.¹⁶ The non-binding guid-

NOTES

¹⁶ Specifically, NHTSA has reaffirmed its “authority to identify safety defects, allowing the Agency to recall vehicles or equipment that pose an unreasonable risk to safety even when there is no applicable Federal Motor Vehicle Safety Standard (FMVSS).”
¹⁷ U.S. DOT, *supra* note 3.
¹⁸ After a concerted lobbying effort from labor groups concerned about the economic impacts on their members from automation, self-driving commercial trucks were not included in this legislation.
¹⁹ Bryant Walker Smith, “Congress’s Automated Driving Bills

Are Both More and Less Than They Seem,” The Center for Internet and Society, October 23, 2017.
²⁰ Sarah Light, “Autonomous Vehicle Bill Leaves Safety Gaps,” *The Regulatory Review*, September 25, 2017.
²¹ S. 1885 available at <https://www.congress.gov/bill/115th-congress/senate-bill/1885/text>.
²² Eric Kulisch, “Safety groups say Congress has given self-driving companies too much leeway,” *Automotive News*, March 22, 2018.
²³ Historically, federal law has covered vehicles and state law has covered drivers – hence the confusion about what is ap-

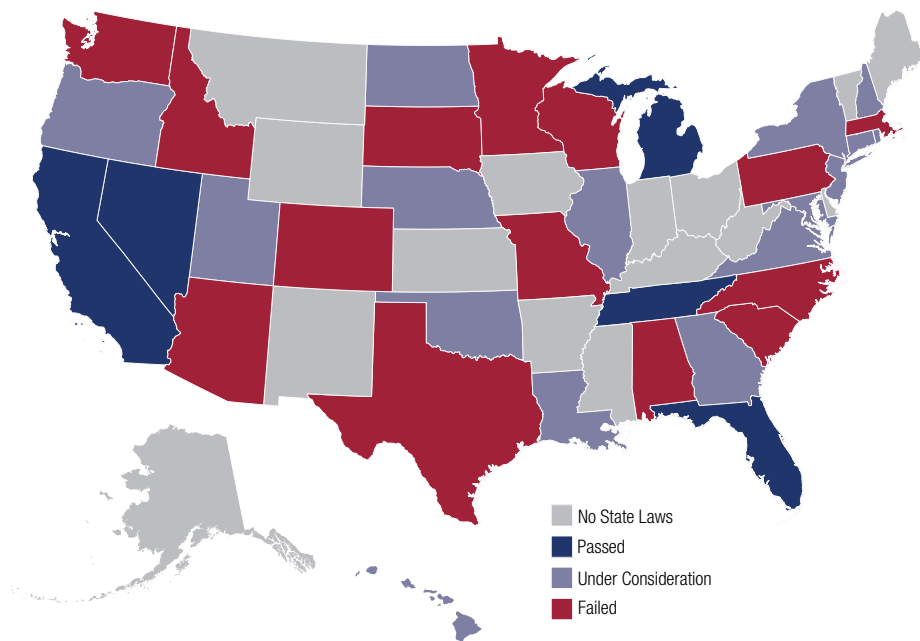
propriate at the state level for a vehicle with no human driver.
²⁴ Laughlin, *supra* note 10.
²⁵ There is more than one pathway to achieving V2V communication capability. Two leading contenders are DSRC (Dedicated Short Range Communications) technology and 5G, the next telecom standard.
²⁶ See <http://archive.darpa.mil/grandchallenge/>.
²⁷ See <http://fortune.com/2018/02/06/volkswagen-vw-emissions-scandal-penalties/>.
²⁸ For a good overview of how AVs will reshape the auto insurance industry, see John Cusano and Michael Costonis,



ance offered by NHTSA in each of the past two years has helped to provide some additional assurance to AV companies that the federal government, absent legislation, is eager to boost innovation and is being careful not to set too many boundaries. The language and content of these documents were favorable to companies developing AVs, and most companies will likely operate within the established bounds. Neither document picked winners or losers and both presented uniform standards for algorithms and technology that would be applicable across all states—something manufacturers will ultimately need. But just as important, they upheld currently mandated federal safety standards and confirmed that states should retain their “traditional responsibilities for vehicle licensing and registration, traffic laws and enforcement, and motor vehicle insurance and liability regimes.”¹⁷

Despite the NHTSA guidance, current legislative proposals would restrict the flexibility that states currently enjoy. H.R. 3388, or the SELF-DRIVE Act, now awaiting a vote in the Senate after passing the House with unanimous support in September, would enforce a uniform standard for both technology and safety, and

FIGURE 2 STATUS OF STATE LAWS ON SELF-DRIVING CARS



This map shows the status of all state laws concerning self-driving cars as of April 2018. Additionally, Arizona (2015) and Massachusetts (2016) issued state executive orders facilitating the testing of AVs on public roadways.

Source: Gabriel Weiner and Bryant Walker Smith, Automated Driving: Legislative and Regulatory Action, cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action

it would bar states from being able to block the use of AVs without human controls within their borders. States also would no longer be able to set rules on AV production and testing standards. Under this bill, self-driving carmakers could seek exemptions from existing safety standards in the first year for up to 25,000 cars—a measure meant to accelerate production. This

number rises to 100,000 over the next three years.¹⁸ For their part, manufacturers of self-driving cars would be required to demonstrate that their AVs are at least as safe as traditional cars. They would have to submit “safety evaluation reports” to NHTSA, including data related to crashes and cybersecurity, thereby formalizing the earlier NHTSA guidance. But they

NOTES

“Driverless Cars Will Change Auto Insurance. Here’s How Insurers Can Adapt,” *Harvard Business Review*, December 5, 2017.

²⁹ Corporate Partnership Board (2015), *Automated and Autonomous Driving: Regulation under Uncertainty*, International Transport Forum (OECD).



would not need NHTSA approval of their unique technologies before bringing their cars to market.

There are various perspectives on how H.R. 3388 deals with safety. Bryant Walker Smith of the University of South Carolina School of Law generally supports the bill’s approach to safety, as it follows what he calls the “public safety case.”¹⁹ This is the idea that as long as “an automated driving developer tells the rest of us what they are doing, why they think it is reasonably safe, and why we should believe them,” this paradigm “encourages innovation in safety assurance and regulation, informs regulators, and—if disclosure is meaningful—helps educate the public at large.” He emphasizes that H.R. 3388 increases the obligations of AV companies relative to existing federal law.

Sarah Light of the Wharton School, however, elucidates a serious concern shared by many consumer advocates. Specifically, she notes that in addition to preempting all state safety standards, H.R. 3388 actually mandates none at the federal level, leaving a significant gap in regulation. Acknowledging the benefits to innovation and economies of scale from uniform technology standards, Light states, “[P]reempting state action even in the absence of federal safety standards fails to take into account the significant concerns that states have in protecting their citizens from harm.”²⁰ She proposes that a state exemption for safety-setting authority be added to the final measure.

The bill now moves to the Senate, which had been considering S. 1885 (the bipartisan AV START Act) in committee, to decide how to reconcile

their preferences with H.R. 3388.²¹ If the Senate uses S. 1885 as a guide, the next iteration of this legislation could include language that preempts even more state functions, including some of the same things NHTSA recently affirmed in its guidance: vehicle registration and licensing, traffic law enforcement, and regulating insurance. But several lawmakers are using Senate procedures to hold up the AV START Act in committee because of concerns about safety, cybersecurity, and data privacy, demanding explicit testing and access to micro-level data from AV companies.²²

Between the concerns from consumer safety advocates and the trouble faced by S. 1885, it may be that any Senate-passed version of the SELF-DRIVE Act would make concessions on safety authority. In general, however, regulatory consistency across U.S. states that boosts innovation will enhance safety, given the iterative nature of software and technology development.

PHASE 2: NON-LEGISLATIVE POLICY OPPORTUNITIES FOR PROMOTING AV INNOVATION

The SELF-DRIVE Act is most likely not the final word on how regulators will seek to balance the facilitation of innovation with the ensuring of public and consumer safety. Even if it becomes law and preempts state safety-setting authority, states and municipalities will continue working to fill the regulatory gaps, as they still have a responsibility for protecting their citizens.²³ Conflicts may be inevitable, but they will be workable. Yet regardless of whether H.R. 3388,

or a bill like it, becomes law, there are many opportunities for government lawmakers and regulators at all levels to foster innovation in AV technology without singling out automated cars via dedicated federal legislation. State exemptions and executive actions, new voluntary federal policy guidance, state and federal appropriations, and local policy initiatives are all tools still available to do this. We will discuss some of them here.

1. JOINING THE LEVEL 3 VS. LEVEL 4 AUTOMATION DEBATE

In the presence of new information, NHTSA performance and safety guidance could change. Thus far, the U.S. government has shied away from making its own judgment on the debate over Level 3 viability. Car-makers clearly prefer the incremental pathway to market offered by Level 3 automation, but if this proves too risky, the voluntary federal guidance could shift towards directly favoring the Waymo approach of bypassing “human in the loop” and shooting for Level 4 automation as the next milestone. The current guidance is prudent given the information available, because should Level 3 automation prove to be safe and marketable, it would be an overreach for the government to already be picking winners. This debate may end up being one of the most pivotal strategic, technical, and regulatory issues. Then again, from a regulatory perspective at least, it may not. Level-specific evaluation may be possible in the future (see #2, below), and the government may never need to interject itself in this industry debate.



2. ENFORCING A SINGLE STANDARD FOR PERFORMANCE EVALUATION AND ETHICAL DILEMMAS

Rahul Mangharam's team of scientists at the University of Pennsylvania is developing what they call a "driver's license test" for self-driving cars. Using "mathematical diagnostics and simulated reality," Mangharam's test seeks to evaluate the safety of AVs before they ever reach public roads²⁴—a clear distinction from H.R. 3388's reliance on company disclosures of "safety evaluation reports" and its automatic green light to market cars without NHTSA pre-approval. He has argued that independent federal evaluation of technological performance and safety offers the most publicly desirable trajectory, and these evaluations could develop and improve as years go by and more data is gathered and processed. The tests could even be adjusted by automation level.

The logic behind giving cars a "driver's license" is sound, especially as the industry progresses to higher levels of automation. It is anyone's guess whether an independent test or the reliance on company disclosures and data (or both) will ultimately win out. But one scenario will almost inevitably be subject to a uniform standard for evaluation, namely the loss-loss situation. Algorithms have already been (and will continue to be) written to deal with how an AV will respond to a scenario where damage, injury, or even death is unavoidable regardless of the car's actions. These algorithms are plain attempts at solving dilem-

mas, which is clearly the domain of public policy when the decision maker is a piece of software marketed to consumers. How society—and eventually policymakers—judges the ethical soundness of any line of code is, again, still up in the air.

3. INVESTING IN INFRASTRUCTURE

There are two camps on the question of whether significant infrastructure investment—in the form of repainted lane markings, repaired and increased safety signage, and newly paved roads—would be a boon or a red herring to the development of self-driving cars. These camps are divided on their answers to the question of how much connectivity is required to make AVs safe.

In one camp are proponents of an older way of thinking about the relationships between different AVs on the road and between an AV and the road itself. They argue that vehicle-to-vehicle (V2V) communication is essential.²⁵ Not only will we need a single mandated closed and controlled communication system for AVs—something akin to air traffic control—but we will need to retrofit all vehicles on the road to have this capacity, according to this position. Furthermore, they argue that AV safety requires good "smart" infrastructure (V2I). In practice, it is highly unlikely there will ever be a single communication system, in large part because there will be too many competing algorithms. Besides that, car companies have never agreed on standards and they certainly do not, in most instances, view this issue the same way most

technology companies do. And it is technology companies and small AV start-ups leading the other camp.

The original breakthrough moment for self-driving cars was when a research team from Carnegie Mellon entered and won DARPA's third and final competition of self-driving cars in 2007 ("Urban Challenge").²⁶ Identifying the inherent software advantages that technology companies had in turning non-automated cars into AVs, Google entered the fray. Their philosophy involved turning an AV into an independent cell that would not be reliant upon direct communication from other cars or upon upgraded or smart infrastructure. This approach has greatly accelerated the development of AVs.

The problem with Google's philosophy, however, is that treating AVs as independent cells can only move the technology most of the way to peak safety. In order to perfect self-driving technology, most experts believe V2V and/or V2I communication is still necessary. Even if the Google approach is 90-95% effective at avoiding collisions, there is a very small chance the American public will accept that outcome, given the public's well-established low tolerance for automobile failures. There seems to be an opportunity here for states to reopen debates over infrastructure investment given the potential benefits to the future of self-driving cars, presupposing they can get the timing right. Put another way, the quality of America's infrastructure is not the red herring it occasionally is made out to be.



4. LINKING AV TESTING TO LOCAL GOVERNMENT PRIORITIES

In the face of all of these competing philosophies, there is one thing nearly every AV engineer agrees on: geo-fencing. That is, the practice of limiting the activity of AVs to specific geographic areas that are mapped in great detail (and perhaps have dedicated lanes for AVs) is the best way to advance driverless technology. The need for geo-fencing is one of the primary differences between Level 4 and Level 5 automation. Beyond certain geo-fenced areas, autonomy will not be assured during the years of testing. Cities naturally are the best-suited environments for geo-fencing, and this presents interesting opportunities for local governments.

Some cities such as Austin and Pittsburgh have had, in some cases, fleets of AVs on their roads for a few years now, despite the fact that their states have passed no explicit AV public testing rules. Cities open up their roads to Level 3 and Level 4 road testing for different reasons and with various expectations, and they likely will continue to be more active than states in setting parameters in the short-term. Because they offer ideal testing conditions for AV companies, they have some leverage to impose demands not necessarily related to autonomous driving.

Here is one hypothetical example. Cities could make AV testing contingent upon self-driving cars meeting certain environmental standards. Ever since “Dieselgate,” there has been a massive uptick in public interest on the topic of fostering electric vehicles.²⁷ Despite the absence of

both federal rules and any explicit technological linkage, cities could demand that a certain percentage of AVs be electric vehicles, at least during the testing phase. In this manner, local governments could push the industry towards self-driving cars that also happen to be greener, should that be a local priority.

5. EXPANDING PUBLIC INSURANCE AND SUPPORTING PRIVATE INSURANCE

Today, private automotive insurance provides a third-party check on the safety of individual drivers. But how does insurance work when there are no drivers? Assuming that, as cars become fully automated, liability gradually will shift from drivers to AV manufacturers, some early-stage ideas include insuring trips or routes instead of humans, insuring against cyber attacks, and insuring against product liability like “software bugs, memory overflow, and algorithm defects.”²⁸ Precisely how this shift in liability will unfold is unknown, but it likely will involve some degree of public insurance, at least during a period of transition. As a report from the Corporate Partnership Board states, “Expanding public insurance and facilitating greater private insurance could provide sufficient compensation to those injured by an automated vehicle while relieving some of the pressure on the tort system to provide such a remedy.”²⁹

Automotive insurance companies worry about the potential lack of access to data. If they are compelled to purchase AV performance data directly from manufacturers via

private business transactions, that process could become exceedingly expensive. Private automotive insurance is desirable from the government’s perspective, so regulators may encounter a scenario in which they must mandate access to AV performance data for insurance companies.

CONCLUSION

As this Issue Brief makes clear, there are ample technological, safety, and ethical problems for carmakers, technology companies, legislators, and regulators to address before 2021—and beyond. Whether or not the U.S. Congress passes legislation mandating some uniform AV performance and safety standards in the short-term, there are plenty of other policy opportunities available at all levels of government for boosting innovation and ensuring public and consumer safety. Self-driving cars may come to dominate the auto market in the next two decades and completely reshape the way Americans think about and use transportation, especially if (as many predict) AV companies introduce their vehicles through their own ride-hailing platforms. There may be a dramatic reduction in car-related crashes, fatalities, and economic losses as automation improves. And the economic impacts of AVs on jobs and the economy as a whole are unclear. All of these questions are the subjects of ongoing research that will need to inform how policymakers approach regulating the future of AV testing and development.



ABOUT THE AUTHOR

JOHN PAUL MACDUFFIE, PhD

Professor of Management, The Wharton School

MacDuffie, in addition to being Professor of Management, serves as Director of the Program on Vehicle Mobility Innovation, which is part of Wharton’s Mack Institute for Innovation Management. His research examines the diffusion of lean or flexible production as an alternative to mass production; the impact of human resource systems and work organization on economic performance; collaborative problem-solving within and across firms; the impact of distance on managing human and social capital; the relationship between product and organizational architecture; and how the interaction of strategic choices with industry structure affects competitive dynamics and industry evolution.

Prof. MacDuffie’s global research on the determinants of high-performance manufacturing is featured centrally in the books *The Machine That Changed the World* and *After Lean Production: Evolving Employment Practices in the World Auto Industry*. His commentaries on the global automotive industry and trends in employment systems have been featured in the *New York Times*, *Wall Street Journal*, *Washington Post*, *Bloomberg Business Week*, *Fortune*, and on *National Public Radio* and *Knowledge@Wharton*. He is a founding board member of the *Industry Studies Association* and a member of the *Automotive Experts Group* at the *Federal Reserve Bank*.

**ABOUT THE PENN WHARTON
PUBLIC POLICY INITIATIVE**

The Penn Wharton Public Policy Initiative (PPI) is a hub for research and education, engaging faculty and students across the University of Pennsylvania and reaching government decision-makers through independent, practical, timely, and nonpartisan policy briefs. With offices both at Penn and in Washington, DC, the Initiative provides comprehensive research, coverage, and analysis, anticipating key policy issues on the horizon.

**ABOUT PENN WHARTON PUBLIC
POLICY INITIATIVE ISSUE BRIEFS**

Penn Wharton PPI publishes issue briefs at least once a month, tackling issues that are varied but share one common thread: they are central to the economic health of the nation and the American people. These Issue Briefs are nonpartisan, knowledge-driven documents written by Wharton and Penn faculty in their specific areas of expertise.

**CONTACT THE PENN WHARTON
PUBLIC POLICY INITIATIVE**

At Penn

Steinberg Hall-Dietrich Hall, Room 201
Philadelphia, PA 19104-6302
+1.215.898.1197

In Washington, DC

300 New Jersey Avenue, Suite 900
Washington, DC 20001
1+202-870-2655

For additional copies, please visit the Penn Wharton PPI website at publicpolicy.wharton.upenn.edu.

Follow us on Twitter: [@PennWhartonPPI](https://twitter.com/PennWhartonPPI)