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Issues in Autonomous Vehicle Testing and Deployment

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SUMMARY

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Autonomous vehicles have the potential to bring major improvements in highway safety. Motor vehicle crashes caused an estimated 36,096 fatalities in 2019; a study by the National Highway Traffic Safety Administration (NHTSA) has shown that 94% of crashes involve human error. For this and other reasons, federal oversight of the testing and deployment of autonomous vehicles has been of considerable interest to Congress. In the 115th Congress, autonomous vehicle legislation passed the House as H.R. 3388, the SELF DRIVE Act, and a separate bill, S. 1885, the AV START Act, was reported from a Senate committee. Neither bill was enacted. Comprehensive legislation concerning autonomous vehicles was not introduced in the 116th Congress, but the America's Transportation Infrastructure Act of 2019, S. 2302, which was reported by the Senate Environment and Public Works Committee, would have encouraged research and development of infrastructure that could accommodate new technologies such as autonomous vehicles. Comprehensive legislation has not been introduced in the 117th Congress as of the date of this report.

In recent years, private and government testing of autonomous vehicles has increased significantly, although it is likely that widespread use of fully autonomous vehicles—with no driver attention needed—lies many years in the future. The pace of autonomous vehicle commercialization was slowed after to the 2018 death in Arizona of a pedestrian struck by an autonomous vehicle, which highlighted the challenges of duplicating human decisionmaking by artificial intelligence. The National Transportation Safety Board determined that the fatality was caused by an "inadequate safety culture" at rideshare company Uber—which was testing the vehicle—and deficiencies in state and federal regulation. Two April 2021 fatalities in a Tesla vehicle that was operating with no one in the driver's seat raised further questions about driverless technologies.

Since 2016, the U.S. Department of Transportation and NHTSA have issued five reports that inform the discussion of federal autonomous vehicle policies. These suggest best practices that states should consider in driver regulation; a set of voluntary, publicly available self-assessments by automakers showing how they are building safety into their vehicles; a proposal to modify the current system of granting exemptions from federal safety standards; and a multimodal strategy to prepare for the integration of more automated vehicles. In February 2020, NHTSA announced its approval of the first autonomous vehicle exemption—from three federal motor vehicle standards—to Nuro, a California-based company that plans to deliver packages with a robotic vehicle smaller than a typical car.

Proponents of autonomous vehicles contend that lengthy revisions to current safety regulations could impede innovation, as the rules could be obsolete by the time they take effect. Congress has not enacted legislation to address gaps in regulation due to disagreements on several key policy issues. These include the following:

- The extent to which Congress should alter the traditional division of vehicle regulation, with the federal government being responsible for vehicle safety and states for driver-related aspects such as licensing and registration, as the roles of driver and vehicle merge.
- The number of autonomous vehicles that NHTSA should permit to be tested on highways by granting exemptions to federal safety standards, and which specific safety standards, such as those requiring steering wheels and brake pedals, can be relaxed to permit thorough testing.
- How much detail legislation should contain related to addressing cybersecurity threats, including whether federal standards should require vehicle technology that could report and stop hacking of critical vehicle software and how much information car buyers should be given about these issues.
- The extent to which vehicle owners, operators, manufacturers, insurers, and other parties have access to data that is generated by autonomous vehicles, and the rights of various parties to sell vehicle-related data to others.

The 117th Congress may address these issues in legislation reauthorizing surface transportation programs. The current surface transportation authorization expires at the end of FY2021. Policy decisions about the allocation of radio spectrum and road maintenance also may affect the rate at which autonomous vehicle technologies come into use.

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Introduction

Fully autonomous vehicles, which would carry out many or all of their functions without the intervention of a driver, may someday bring sweeping social and economic changes and "lead to breakthrough gains in transportation safety."[1] Motor vehicle crashes caused an estimated 36,096 fatalities in 2019 and are estimated to have caused significantly more deaths in 2020.[2] A study by the National Highway Traffic Safety Administration (NHTSA) has shown that 94% of crashes involve human error.[3]

Legislation that would encourage development and testing of autonomous vehicles has faced controversy in Congress. In the 115th Congress, the House of Representatives passed an autonomous vehicle bill, H.R. 3388, by voice vote in September 2017. The Senate Committee on Commerce, Science, and Transportation reported a different bill, S. 1885, in November 2017, but after some Senators raised concerns about the preemption of state laws and the possibility of large numbers of vehicles being exempted from some Federal Motor Vehicle Safety Standards, the bill did not reach the floor. The America's Transportation Infrastructure Act of 2019, S. 2302, which was reported by the Senate Environment and Public Works Committee in the 116th Congress, would have encouraged research and development of infrastructure that could accommodate new technologies such as autonomous vehicles; however, it was not voted on by the Senate. Since then, Congress has taken no further action on the subject. No comprehensive autonomous vehicle legislation has been introduced in the 117th Congress as of the date of this report.

Meanwhile, several fatal accidents involving autonomous vehicles have raised new questions about how federal and state governments should regulate vehicle testing and about the introduction of new technologies into vehicles offered for sale. A pedestrian was killed in Arizona by an autonomous vehicle operated by Uber on March 18, 2018,[4] and, in separate incidents, three Tesla drivers died when they failed to respond to hazards not recognized by the vehicles.[5] In April 2021, two men were killed in Texas after a Tesla they were riding in crashed, with no one reportedly in the driver's seat.[6] These accidents suggest that the challenge of producing fully autonomous vehicles that can operate safely on public roads may be greater than developers had envisioned. Some auto-industry executives have expressed a similar view.[7] With the authorization of federal highway and public transportation programs set to expire at the end of FY2021, there

[1] U.S. Department of Transportation, *Preparing for the Future of Transportation: Automated Vehicles 3.0*, October 2018, p. 1, at https://www.transportation.gov/av/3/preparing-future-transportation-automated-vehicles-3.

[2] Annual highway traffic fatalities generally declined from more than 50,000 in 1973 to 32,675 in 2014, but have moved higher in recent years. See NHTSA, *Preview of Motor Vehicle Traffic Fatalities in 2019*, DOT HS 813 021, October 2020, at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813021. NHTSA has not released data for 2020, but the National Safety Council, a private organization, estimates that traffic fatalities rose 8% in 2020, the largest year-over-year increase since 1924. See National Safety Council, "Preliminary Semiannual Estimates," at https://injuryfacts.nsc.org/motor-vehicle/overview/preliminary-estimates/.

[3] S. Singh, *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey*, National Highway Traffic Safety Administration, DOT HS 812 115, February 2015.

[4] National Transportation Safety Board, *Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian*, HWY18MH010, November 19, 2019, at https://ntsb.gov/investigations/AccidentReports/Pages/HWY18MH010-prelim.aspx.

[5] Neal Boudette, "Despite High Hopes, Self-Driving Cars Are 'Way in the Future,'" *New York Times*, July 17, 2019, at https://www.nytimes.com/2019/07/17/business/self-driving-autonomous-cars.html.

[6] Bryan Pietsch, "2 Killed in Driverless Tesla Car Crash, Officials Say," *New York Times*, April 20, 2021, at https://www.nytimes.com/2021/04/18/business/tesla-fatal-crash-texas.html.

[7] Aarian Marshall, "Ford Taps the Brakes on the Arrival of Self-Driving Cars," *WIRED*, April 9, 2019, at https://www.wired.com/story/ford-taps-brakes-arrival-self-driving-cars/.

may be efforts to include autonomous vehicle provisions in a surface transportation reauthorization bill.

Advances in Vehicle Technology

While fully autonomous vehicles may lie well in the future, a range of new technologies is already improving vehicle performance and safety while bringing automation to vehicular functions once performed only by the driver. The technologies involved are very different from the predominantly mechanical, driver-controlled technology of the 1960s, when the first federal vehicle safety laws were enacted. These new features automate lighting and braking, connect the car and driver to the Global Positioning System (GPS) and smartphones, and keep the vehicle in the correct lane. Three forces are driving these innovations:

- technological advances enabled by new materials and more powerful, compact electronics;
- consumer demand for telecommunications connectivity and new types of vehicle ownership and ridesharing; and
- regulatory mandates pertaining to emissions, fuel efficiency, and safety.

Manufacturers are combining these innovations to produce vehicles with higher levels of automation. Vehicles do not fall neatly into the categories of "automated" or "nonautomated," because all new motor vehicles have some element of automation.

The Society of Automotive Engineers International (SAE), an international standards-setting organization, has developed six categories of vehicle automation—ranging from a human driver doing everything to fully autonomous systems performing all the tasks once performed by a driver. This classification system (**Table 1**) has been adopted by the U.S. Department of Transportation (DOT) to foster standard nomenclature to aid clarity and consistency in discussions about vehicle automation and safety.

Table 1. Levels of Vehicle Automation

SAE Automation Category	Vehicle Function
Level 0	Human driver does everything.
Level 1	An automated system in the vehicle can sometimes assist the human driver conduct some parts of driving.
Level 2	An automated system can conduct some parts of driving, while the human driver continues to monitor the driving environment and performs most of the driving.
Level 3	An automated system can conduct some of the driving and monitor the driving environment in some instances, but the human driver must be ready to take back control if necessary.
Level 4	An automated system conducts the driving and monitors the driving environment, without human interference, but this level operates only in certain environments and conditions.
Level 5	The automated system performs all driving tasks, under all conditions that a human driver could.

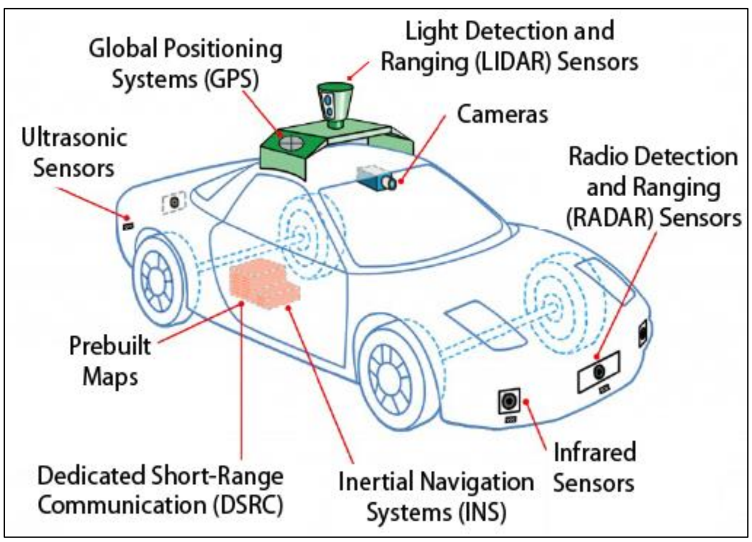
Source: DOT and NHTSA, *Federal Automated Vehicles Policy*, September 2016, p. 9, https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016.

Note: SAE is the Society of Automotive Engineers International, http://www.sae.org.

Vehicles sold today are in levels 1 and 2 of SAE's automation rating system. Although it appears that some autonomous vehicles at level 3 will be available soon,[8] deployment of fully autonomous vehicles in all parts of the country at level 5 appears to be more distant, except perhaps within closed systems that allow fully autonomous vehicles to operate without encountering other types of vehicles. Testing and development of autonomous vehicles continue in many states and cities.[9]

Technologies that could guide an autonomous vehicle (**Figure 1**) include a wide variety of electronic sensors that would determine the distance between the vehicle and obstacles; park the vehicle; use GPS, inertial navigation, and a system of built-in maps to guide the vehicle's direction and location; and employ cameras that provide 360-degree views around the vehicle. To successfully navigate roadways, an autonomous vehicle's computers, sensors and cameras will need to accomplish four tasks that a human driver undertakes instinctively: detect objects in the vehicle's path; classify those objects as to their likely makeup (e.g., plastic bag in the wind, a pedestrian, or a moving bicycle); predict the likely path of the object; and plan an appropriate response. Most autonomous vehicles use dedicated short-range communication (DSRC) to monitor road conditions, congestion, crashes, and possible rerouting. As 5G wireless communications infrastructure is more widely used, vehicle communications are likely to become integrated with it, enabling greater interoperability, reliability, and cybersecurity. Some versions of these autonomous vehicle technologies, such as GPS and rear-facing cameras, are being offered on vehicles currently on the market, while manufacturers are studying how to add others to safely transport passengers without drivers.

Figure 1. Autonomous Vehicle Technologies



Source: CRS, based on "Autonomous Vehicles" fact sheet, Center for Sustainable Systems, University of Michigan.

Manufacturers of conventional vehicles, such as General Motors and Honda, are competing in this space with autonomous vehicle "developers" such as Alphabet's Waymo. In addition,

[8] "Honda wins world-first approval for Level 3 autonomous car," *TechXplore*, November 11, 2020, at https://techxplore.com/news/2020-11-honda-world-first-autonomous-car.html.

[9] Aarian Marshall, "Don't Ask When Self-Driving Cars Will Arrive—Ask Where," *Wired*, January 2, 2019, at https://www.wired.com/story/when-self-driving-cars-will-arrive-where/.

automakers are aligning themselves with new partners that have experience with ride-sharing and artificial intelligence:

- Ford and Volkswagen, which have jointly invested in Argo AI, are testing vehicle technologies in several cities, including Miami, FL, and Pittsburgh, PA;
- General Motors (GM) acquired Cruise Automation, a company that is developing self-driving technology for Level 4 and 5 vehicles, and has also invested $500 million in the Lyft ride-sharing service;
- Honda, after breaking off talks about partnering with Waymo, purchased a stake in GM's Cruise Automation;
- Volvo and Daimler have announced partnerships with ride-sharing service Uber; and
- BMW partnered with the Mobileye division of Intel, a semiconductor manufacturer, to design autonomous vehicle software.

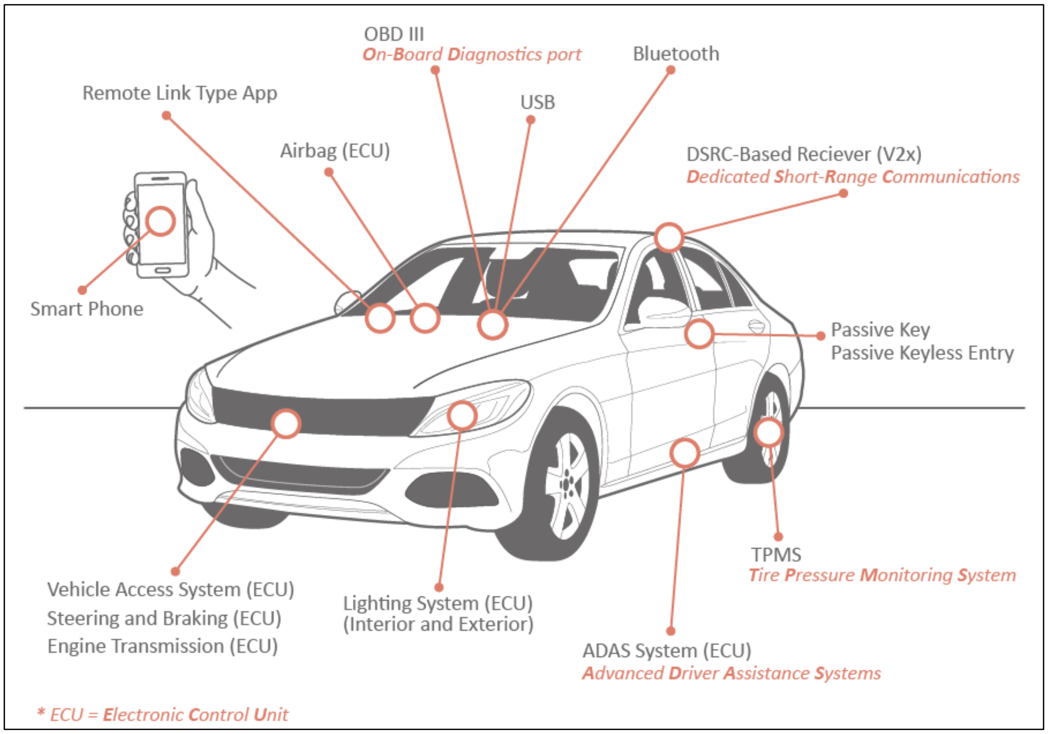
Cybersecurity and Data Privacy

As vehicle technologies advance, the security of data collected by vehicle computers and the protection of on-board systems against intrusion are becoming more prominent concerns. Many of the sensors and automated components providing functions now handled by the driver will generate large amounts of data about the vehicle, its location at precise moments in time, driver behavior, and vehicle performance. The systems that allow vehicles to communicate with each other, with roadside infrastructure, and with manufacturers seeking to update software will also offer portals for possible unauthorized access to vehicle systems and the data generated by them.

Protecting autonomous vehicles from hackers is of paramount concern to federal and state governments, manufacturers, and service providers. Hackers could use more than a dozen portals to enter even a conventional vehicle's electronic systems (**Figure 2**), including seemingly innocuous entry points such as the airbag, the lighting system, and the tire pressure monitoring system (TPMS).[10] Requirements that increasingly automated vehicles accept remote software updates, so that owners do not need to take action each time software is revised, are in part a response to concerns that security weaknesses be rectified as quickly as possible.

[10] TPMS is an electronic system designed to monitor the air pressure inside pneumatic tires.

Figure 2. Potential Entry Points for Vehicle Hacking



Source: CRS.

To address these concerns, motor vehicle manufacturers established the Automotive Information Sharing and Analysis Center (Auto-ISAC),[11] which released a set of cybersecurity principles in 2016. DOT's autonomous vehicle policies designate Auto-ISAC as a central clearinghouse for manufacturers to share reports of cybersecurity incidents, threats, and violations with others in the vehicle industry.

Aside from hackers, many legitimate entities would like to access vehicle data, including vehicle and component manufacturers, the suppliers providing the technology and sensors, the vehicle owner and occupants, urban planners, insurance companies, law enforcement, and first responders (in case of an accident). Issues pertaining to vehicle data collection include vehicle testing crash data (how is it stored and who gets to access it); data ownership (who owns most of the data collected by vehicle software and computers);[12] and consumer privacy (transparency for consumers and owner access to data). At present, no laws preclude manufacturers and software providers from reselling data about individual vehicles and drivers to third parties.[13]

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[11] https://www.automotiveisac.com.

[12] Most new conventional vehicles on the road have an event data recorder (EDR), which captures a limited amount of information about a vehicle, the driver, and passengers in the few seconds before a crash (e.g., speed and use of seat belts). The most recent surface transportation reauthorization (P.L. 114-94) included the Driver Privacy Act of 2015, which established that EDR data is property of the vehicle owner but does not govern the other types of data that will be accumulated by autonomous vehicles.

[13] Two motor vehicle trade associations have developed *Privacy Principles for Vehicle Technologies and Services*, Alliance of Automobile Manufacturers and the Association of Global Automakers, at https://autoalliance.org/ connected-cars/automotive-privacy-2/principles/.

Pathways to Autonomous Vehicle Deployment Abroad

Autonomous vehicles are being developed and tested in many countries, including those that produce most of the world's motor vehicles. Several analyses have evaluated the factors that are contributing to the advancement of autonomous vehicles in various countries:

- **Innovation.** Benchmarks in this area include the number and engagement of domestic automakers and technology developers working on automation, the partnerships they forge with academic and related businesses, the prevalence of ride-sharing services, and autonomous vehicle patents issued.
- **Vehicle infrastructure.** Autonomous vehicles will need new types of infrastructure support and maintenance, including advanced telecommunications links and near-perfect pavement and signage markings. Planning and implementing these highway improvements may enable autonomous vehicles to be fully functional sooner. In addition, many test vehicles are currently powered by electricity, so the availability of recharging stations could be a factor in their acceptance.
- **Workforce training.** The increased reliance on autonomous vehicle technologies may require different workforce skills. Many traditional mechanical parts may disappear, especially if autonomous vehicles operate entirely on battery power, while the arrangement and function of dashboards and seating may be reinvented. Components suppliers that are already addressing this new product demand and reorienting their workforces will assist in the transition to autonomous vehicles.[14]
- **Government laws and regulations that encourage development and testing.** Fully autonomous vehicles may not have standard features of today's cars, such as steering wheels and brake pedals, as there will not be a driver. By law or regulation, motor vehicles built today are required to have many of these features. Some governments are taking a lead by modifying vehicle requirements for purposes of pilot programs and tests.[15] Permanent changes in standards will most likely be necessary if autonomous vehicle technologies are to be commercialized.
- **Level of consumer acceptance.** Markets are more likely to embrace autonomous vehicles if many residents in cities see autonomous vehicles on the road, a high level of technology is in use (including internet access and mobile broadband), and ride-hailing services are more widely used.

[14] For a discussion of possible U.S. manufacturing employment losses with a shift from internal combustion engine vehicles to electric vehicles, see CRS In Focus IF11101, *Electrification May Disrupt the Automotive Supply Chain*, by Bill Canis.

[15] While the U.S. Congress has not passed legislation addressing autonomous vehicle legislation and DOT considers how it will ensure safety if some current motor vehicle safety standards are relaxed, it is noteworthy that the European Union is moving forward with a framework for regulating autonomous vehicles developed and proposed by a United Nations regulatory forum. The UN's World Forum for Harmonization of Vehicle Regulations (WP.29) is a worldwide regulatory forum within the institutional framework of the UN Economic Commission for Europe's Inland Transport Committee. Its proposed regulations have formed the basis of many countries' vehicle regulations since 1958. United Nations Economic and Social Council, *Revised Framework document on automated/autonomous vehicles*, September 3, 2019, at https://www.unece.org/fileadmin/DAM/trans/doc/2019/wp29/ECE-TRANS-WP29-2019-34-rev.1e.pdf.

Several surveys have been conducted analyzing many of these factors. For example, a 2018 Harvard University report highlights plans in China, South Korea, Japan, and the United States to "seize the benefits" of autonomous vehicles.[16] In a report on innovation policies in four Asian countries (China, Japan, South Korea, and Singapore), the United Nations Economic and Social Commission for Asia and the Pacific ranked Singapore first in autonomous vehicle readiness because of its policies and new laws governing their deployment and its high consumer acceptance. The report also notes that South Korea's K-City facility is "intended to be the world's largest testbed for self-driving cars."[17]

A more detailed comparison of factors affecting autonomous vehicle development and deployment has been conducted by KPMG International, which has developed an index to measure how 25 countries are guiding autonomous vehicles (**Table 2**).

Table 2. Autonomous Vehicles Readiness Index

Rankings of Top Five Countries

Overall Rank	Country	Technology and Innovation	Policy and Legislation	Infrastructure	Consumer Acceptance
1	The Netherlands	10	5	1	2
2	Singapore	15	1	2	1
3	Norway	2	7	7	3
4	United States	3	9	8	6
5	Sweden	6	10	6	4

Source: Richard Threlfall, *Autonomous Vehicles Readiness Index*, KPMG International, 2019, at https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/02/2019-autonomous-vehicles-readiness-index.pdf.

Notes: In developing this index, KPMG used publicly available information, a consumer survey in the 25 countries, and other research. Each of the four categories is given the same weight in devising the overall country ranking. KPMG *Autonomous Vehicles Readiness Index*, p. 42.

The Netherlands ranked first overall in the KPMG report, where it was cited as "an example of how to ready a country for AVs by performing strongly in many areas," as well as first in infrastructure.[18] Singapore came in first on policy and legislation because it has a single government entity overseeing autonomous vehicle regulations, it is funding autonomous vehicle pilots, and it has enacted a national standard to promote safe deployment.[19] Contributing to its rank was a World Economic Forum (WEF) report that ranked it first among 139 countries in having an effective national legislature and efficient resolution of legal disputes.[20] Singapore also

[16] Aida Joaquin Acosta, *What Governments Across the Globe Are Doing to Seize the Benefits of Autonomous Vehicles*, Berkman Klein Center for Internet and Society at Harvard University, Policy Primer on Autonomous Vehicles, July 13, 2018, at https://cyber.harvard.edu/publication/2018/what-governments-across-globe-are-doing-seize-benefits-autonomous-vehicles.

[17] United Nations Economic and Social Commission for Asia and the Pacific, *Evolution of Science, Technology and Innovation Policies for Sustainable Development*, January 14, 2018, p. 65, at https://www.unescap.org/publications/evolution-science-technology-and-innovation-policies-sustainable-development-experience.

[18] The Netherlands work on infrastructure includes deploying truck platooning along major commercial corridors there and in adjoining Belgium and Germany, installing 1,200 "smart" traffic lights, and building out a network of electric vehicle charging stations. KPMG International, *Autonomous Vehicles Readiness Index*, 2019, p. 14.

[19] *Autonomous Vehicles Readiness Index,* 2019, p. 15.

[20] In the WEF ranking of 139 countries on a broad technology measurement of "networked readiness," the United

scored first place on the consumer acceptance metric, primarily because its extensive autonomous testing is being conducted throughout the island nation, thereby familiarizing residents with autonomous passenger vehicles and buses.

Two other major auto-producing countries—Germany and Japan—fall just below the United States on technology and innovation, according to KPMG, while Japan ranks higher on autonomous vehicle infrastructure (**Table 3**).

Table 3. Autonomous Vehicle Readiness Index for Major Auto Producing Countries

Overall Rank	Country	Technology and Innovation	Policy and Legislation	Infrastructure	Consumer Acceptance
8	Germany	4	6	13	13
10	Japan	5	15	3	18
12	Canada	11	8	16	11
13	South Korea	7	16	4	19
20	China	19	20	18	14
23	Mexico	23	24	22	21

Source: Richard Threlfall, *Autonomous Vehicles Readiness Index*, KPMG International, 2019, https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/02/2019-autonomous-vehicles-readiness-index.pdf.

Issues in Federal Safety Regulation

Vehicles operating on public roads are subject to dual regulation by the federal government and the states in which they are registered and driven. Traditionally, NHTSA, within DOT, has regulated auto safety, while states have licensed automobile drivers, established traffic regulations, and regulated automobile insurance. Proponents of autonomous vehicles note that lengthy revisions to current vehicle safety regulations could impede innovation, as the rules could be obsolete by the time they take effect.

In 2016, the Obama Administration issued the first report on federal regulations affecting autonomous vehicles.[21] The Trump Administration issued four additional reports. Separately, the Federal Communications Commission (FCC) has decided to reconfigure the allocation of electromagnetic spectrum currently reserved for motor vehicle communications; that decision in November 2020 may affect how autonomous vehicles evolve.

Obama Administration Policy Direction

DOT's 2016 report proposed federal and state regulatory policies in these areas:

- A set of *guidelines* outlining best practices for autonomous vehicle design, testing, and deployment. DOT identified 15 practices and procedures that it

States ranked 49th on the effectiveness of its lawmaking bodies. World Economic Forum, *Networked Readiness Index,* 2016, at http://reports.weforum.org/global-information-technology-report-2016/economies/#economy=USA.

[21] U.S. Department of Transportation and National Highway Traffic Safety Administration, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*, September 2016, at https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016.

expected manufacturers, suppliers, and service providers (such as ridesharing companies) to follow in testing autonomous vehicles, including data recording, privacy, crashworthiness, and object and event detection and response. These reports, called Safety Assessment Letters, would be voluntary, but the report noted that "they may be made mandatory through a future rulemaking."[22]

- A *model state policy* that identifies where new autonomous vehicle-related issues fit in the current federal and state regulatory structures. The model state policy, developed by NHTSA in concert with the American Association of Motor Vehicle Administrators and private-sector organizations, suggests state roles and procedures,[23] including administrative issues (designating a lead state agency for autonomous vehicle testing), an application process for manufacturers that want to test vehicles on state roads, coordination with local law enforcement agencies, changes to vehicle registration and titling, and regulation of motor vehicle liability and insurance.
- A *streamlined review process* to issue DOT regulatory interpretations on autonomous vehicle questions within 60 days and on regulatory exemptions within six months.[24]
- Identification of *new tools and regulatory structures* for NHTSA that could build its expertise in new vehicle technologies, expand its ability to regulate autonomous vehicle safety, and increase speed of its rulemakings. Two new tools could be expansion of existing exemption authority[25] and premarket testing to assure that autonomous vehicles will be safe. Some of the new regulatory options cited would require new statutory authority, while others could be instituted administratively. The report noted that "DOT does not intend to advocate or oppose any of the tools.… [I]t intends … to solicit input and analysis regarding those potential options from interested parties."[26]

Trump Administration Guidelines and Proposed Safety Rules

The four reports issued by the Trump Administration described a more limited federal regulatory role in overseeing autonomous passenger vehicle deployment, while also broadening the scope of DOT oversight by addressing the impact of autonomous technology on multimodal transportation, including commercial trucks, public transit, rail, and ports and ships.[27] The following policies are described in these reports:

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[22] Ibid., p. 15.

[23] Ibid., p. 37.

[24] Ibid., pp. 48-67.

[25] Current law permits NHTSA to exempt up to 2,500 vehicles per manufacturer from federal motor vehicle safety standards. Expansion to 25,000 or more vehicles would allow more testing of autonomous vehicles on roads; such an expansion would require a statutory change. Ibid., pp. 75-76.

[26] Ibid., p. 70.

[27] DOT and NHTSA, *Automated Driving Systems 2.0: A Vision for Safety*, DOT HS 812 442, September 2017, at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf ; DOT and NHTSA, *Preparing for the Future of Transportation: Automated Vehicles 3.0*, October 2018, at https://www.transportation.gov/av/3/preparing-future-transportation-automated-vehicles-3; National Science & Technology Council and DOT, *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0*, January 2020, at.https://www.transportation.gov/sites/dot.gov/files/2020-02/EnsuringAmericanLeadershipAVTech4.pdf and Automated Vehicles Comprehensive Plan, January 11, 2021, at https://www.transportation.gov/av/avcp.

- Encouraged *integration of automation across all transportation modes*, not just passenger vehicles.[28] The October 2018 report *Automated Vehicles 3.0* outlined how each of DOT's agencies, which generally oversee a single mode of transportation, would address autonomous vehicle safety within its purview.
- Established *six automation principles* that have been applied to DOT's role in overseeing passenger cars, trucks, commercial buses, and other types of vehicles. These include giving priority to safety; remaining technology-neutral; modernizing regulations; encouraging a consistent federal and state regulatory environment; providing guidance, research, and best practices to government and industry partners; and protecting consumers' ability to choose conventional as well as autonomous vehicles.[29]
- Reiterated the traditional roles of federal and state governments in regulating motor vehicles and motorists, respectively. The reports cited *best practices that states should consider* implementing, such as minimum requirements for autonomous vehicle test drivers, and discussed how DOT provides states with technical assistance.[30]
- Recommended voluntary action in lieu of regulation. The reports suggested that manufacturers and developers of autonomous driving systems issue and make public voluntary safety self-assessments to demonstrate transparency and increase understanding of the new technologies and that industry groups develop "voluntary technical standards" to "advance the integration of automation technologies into the transportation system."[31] The NHTSA Voluntary Safety Self-Assessment web page lists 27 companies that have filed self-assessment reports with the federal government, including five major automakers.[32] To provide a perspective, 63 companies have been issued autonomous vehicle testing permits by the State of California alone.[33]
- Accelerated NHTSA decisions on requests for exemptions from federal safety standards for autonomous vehicle testing.[34]
- Promoted development of *voluntary technical standards* by other organizations, such as the Society of Automotive Engineers, the government's National Institute of Standards and Technology, and the International Organization for Standardization.[35]

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[28] Transportation agencies mentioned in the 2018 report and their regulatory areas are: National Highway Traffic Safety Administration (passenger vehicles and light trucks); Federal Transit Administration (local transit buses, subways, light and commuter rail, and ferries); Federal Motor Carrier Safety Administration (large trucks and commercial buses); Federal Aviation Administration (aviation); Federal Railroad Administration (railroads); Federal Highway Administration (highways, bridges, and tunnels).

[29] *Preparing for the Future of Transportation: Automated Vehicles 3.0*, pp. iv-v.

[30] Ibid., pp. 19-20.

[31] *Preparing for the Future of Transportation: Automated Vehicles 3.0*, p. viii.

[32] NHTSA VSSA web page, viewed April 5, 2021, https://www.nhtsa.gov/automated-driving-systems/voluntary-safety-self-assessment. BMW, Ford, General Motors, Mercedes-Benz, and Toyota are the five major automakers that have filed VSSA reports; the others are autonomous vehicle developers such as Apple, Waymo, and Uber.

[33] State of California, Department of Motor Vehicles, *Permit Holders (Testing with a Driver, Driverless Testing, and Deployment)*, viewed April 5, 2021, at https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/permit.

[34] *Preparing for the Future of Transportation: Automated Vehicles 3.0*, p. 8.

[35] Ibid., Appendix C, pp. 49-63.

DOT has indicated that it wants to revise regulations pertinent to autonomous vehicles, such as redefining the terms "driver" and "operator" to indicate that a human being does not always have to be in control of a motor vehicle. It also said it plans to require changes in standards for the inspection, repair, and maintenance of federally regulated commercial trucks and buses.[36] Along these lines, NHTSA has initiated several rulemakings, including an Advance Notice of Proposed Rulemaking in May 2019 requesting comments on testing and verifying how autonomous vehicle technologies should comply with existing federal crash avoidance standards,[37]as well as an Advance Notice of Proposed Rulemaking published in December 2020—with public comments due by February 1, 2021—that sought public comment on a framework for automated driving system safety.[38] The latter proposal seeks to identify four objective principles of automated driving systems and vehicle competence that would inform safety regulators about how an autonomous vehicle

- receives information about its environment through sensors,
- detects other road users and conditions,
- analyzes each situation on a road and plans the route of the vehicle, and
- executes that plan.

If NHTSA follows the path envisioned in the proposed December 2020 rulemaking, it could mark a shift in its focus away from amending existing vehicle safety rules to developing a unique safety framework for autonomous vehicles.[39]

The Trump Administration issued its fourth report on autonomous vehicles on January 11, 2021, describing DOT's "multimodal strategy to promote collaboration and transparency, modernize the regulatory environment, and prepare the transportation system for the safe integration of automated vehicles."[40] This report fulfilled a Government Accountability Office (GAO) recommendation[41] and a 2018 congressional requirement that DOT "develop a comprehensive plan to better manage departmental initiatives related to automated vehicles … [and] to specify within this plan goals, priorities, steps to achieve results, milestones, and performance measures to track progress."[42] It also summarizes regulatory steps regarding autonomous vehicles that NHTSA took during the Trump Administration.

[36] *Preparing for the Future of Transportation: Automated Vehicles 3.0*, pp. 40-41.

[37] NHTSA, "Removing Regulatory Barriers for Vehicles with Automated Driving Systems," 84 *Federal Register* 24433, May 29, 2019; status of the rulemaking found at https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202010&RIN=2127-AM00.

[38] NHTSA, "Framework for Automated Driving," 85 *Federal Register* 78058-78075, December 3, 2020.

[39] U.S. Department of Transportation, "U.S. Department of Transportation Seeks Public Comment on Automated Driving System Safety Principles," press release, November 19, 2020, at https://www.nhtsa.gov/press-releases/public-comment-automated-driving-system-safety-principles; status of the rulemaking found at https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202010&RIN=2127-AM15.

[40] Department of Transportation, *Automated Vehicles Comprehensive Plan*, January 11, 2021, at https://www.transportation.gov/sites/dot.gov/files/2021-01/USDOT_AVCP.pdf., introductory letter from then-DOT Secretary Chao, p. i.

[41] U.S. Government Accountability Office, *Automated Vehicles: Comprehensive Plan Could Help DOT Address Challenges*, GAO-18-132, November 2017, at https://www.gao.gov/assets/gao-18-132.pdf.

[42] "Consolidated Appropriations Act of 2018," Joint Explanatory Statement, *Congressional Record*, vol. 164, No. 50-Book III (March 22, 2018), p. H2875. The legislation, H.R. 1625, was enacted on March 23, 2018 (P.L. 115-141).

The Biden Administration

The Biden Administration has not laid out its approach to autonomous vehicles as of the date of this report. Transportation Secretary Pete Buttigieg stated at a March congressional hearing[43] that a priority would be to "establish safety and establish certainty for industry." He also observed that U.S policy had fallen behind technological developments and that he looks to Congress to assist DOT in establishing a framework for regulations that do not now account for fully autonomous vehicles. At the hearing, he said, "we intend to pay a lot of attention [to] that and do everything we can within our authorities."[44]

Federal Safety Standards Exemption Process

NHTSA has a legislative mandate[45] to issue Federal Motor Vehicle Safety Standards (FMVSS) and regulations. Manufacturers of motor vehicles and motor vehicle equipment must comply with these standards to protect against unreasonable risk of crashes occurring as a result of the design, construction, or performance of motor vehicles. The FMVSS regulations cover a wide range of vehicle components, including windshield wipers, brakes, lighting, tires, mirrors, seating, seat belts, airbags, and child restraint systems.

Under current law, NHTSA can exempt up to 2,500 vehicles per manufacturer per year from existing FMVSS. In the past, this exemption authority has been used when a manufacturer has had a unique vehicle, such as an armor-plated security vehicle that has thick windshields not in compliance with federal windshield standards. NHTSA can exempt the automaker from a specific standard after a public comment period.

With the advent of autonomous vehicle systems with no human driver, some vehicles may not need components once thought essential to driving, such as steering wheels or brake pedals. The exemption process has been cited as way to encourage innovation and facilitate field-testing by waiving some of these standards. An application for temporary autonomous driving-related exemptions filed by Nuro Inc., a California robotics company, was approved in 2020 by NHTSA.

Nuro's exemption from federal safety standards—the first granted by NHTSA for autonomous vehicle testing—will allow it to operate low-speed, electric-powered autonomous delivery robots that will carry only cargo; it will not have seating or a passenger cabin or manual controls. Nuro received exemptions for as many as 5,000 vehicles over a two-year testing period, eliminating federal requirements for rearview mirrors, windshields, and backup cameras. Walmart and Domino's Pizza have reportedly announced that they would employ Nuro vehicles for customer deliveries.[46] NHTSA will monitor the test, and Nuro is required to report to NHTSA about its operations.[47] For an image of the Nuro vehicle, see the **Appendix**.

General Motors has indicated that it may apply for an exemption in partnership with its Cruise self-driving car unit, asking NHTSA for approval to deploy electric vehicles without steering wheels and brake and accelerator pedals in pilot cities.[48]

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[43] U.S. Congress, House Committee on Transportation and Infrastructure, *The Administration's Priorities for Transportation Infrastructure*, 117th Cong., 1st sess., March 25, 2021, at https://transportation.house.gov/committee-activity/hearings/the-administrations-priorities-for-transportation-infrastructure, at https://transportation.house.gov/hearings/watch?hearingid=BA512082-A946-A5EB-BC22-B04FC2B36F77.

[44] David Shepardson and Audrey LaForest, "Biden's transport chief not endorsing gasoline vehicle ban after 2035," *Automotive News*, March 25, 2021, at https://www.autonews.com/regulation-safety/bidens-transport-chief-not-endorsing-gasoline-vehicle-ban-after-2035.

[45] 49 U.S.C. §301.

[46] Nuro's electric-powered R2X robot will be tested initially in Houston, TX. It is smaller, narrower, and lower than a conventional automobile: 3.6 feet wide, 6.1 feet high and 8.9 feet long. It will travel no more than 25 miles per hour; its battery will reportedly enable the vehicle to operate all day without recharging. Its two curbside doors open upward; customers will enter a code texted them to open the doors and retrieve deliveries. Although there will be no human operator on board, the robot will be monitored and can be controlled in an emergency by a remote operator. The R2X is assembled in Michigan in partnership with Roush Enterprises, an engineering and automotive development company.

[47] NHTSA, "Nuro, Inc.; Grant of Temporary Exemption for a Low-Speed Vehicle With an Automated Driving System," 85 *Federal Register* 7826-7842, February 11, 2020.

[48] "Cruise, GM to seek U.S. okay for self-driving vehicle without pedal, steering wheel," *Autonomous Tech News*, November 5, 2020, at https://www.autonomoustechnews.com/2020/11/05/cruise-gm-to-seek-u-s-okay-for-self-driving-vehicle-without-pedal-steering-wheel/.

National Transportation Safety Board Investigation and Recommendations

On November 19, 2019, the National Transportation Safety Board (NTSB)[49] issued its report on the probable cause of a 2018 fatality involving an autonomous vehicle in Tempe, AZ. In that accident, a pedestrian was fatally injured by a test vehicle operated by Uber Technologies with an operator in the driver's seat.[50] The NTSB investigation determined that the probable cause of the crash "was the failure of the vehicle operator to monitor the driving environment and the operation of the ADS [automated driving system] because she was visually distracted throughout the trip by her personal cell phone."[51] Though the vehicle detected the pedestrian 5.6 seconds before the crash, the NTSB reported that "it never accurately classified her as a pedestrian or predicted her path."[52]

Beyond the immediate cause of this accident, NTSB reported that an "inadequate safety culture" at Uber and deficiencies in state and federal regulation contributed to the circumstances that led to the fatal crash.[53] Among the findings were the following:

- Uber's internal safety risk-assessment procedures and oversight of the operator were inadequate, and its disabling of the vehicle's forward collision warning and automatic emergency braking systems increased risks.
- The Arizona Department of Transportation provided insufficient oversight of autonomous vehicle testing in the state.
- NHTSA provides insufficient guidance to developers and manufacturers on how they should achieve safety goals, has not established a process for evaluating developers' safety self-assessment reports, and does not require such reports to be submitted, leaving their filing as voluntary.

NTSB recommended that Uber, the Arizona Department of Transportation, and NHTSA take specific steps to address the issues it identified. It also recommended that the American Association of Motor Vehicle Administrators inform all states about the circumstances of the Tempe crash, encouraging them to require and evaluate applications by developers before granting testing permits.

Connected Vehicles and Spectrum Allocation

Federal regulation of spectrum used in vehicle communications may affect how U.S. automation proceeds. A recent decision by the FCC with regard to spectrum for vehicle use is opposed by DOT.

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[49] NTSB is an independent federal agency that investigates all civil aviation accidents and significant accidents in other transportation modes: highway, rail, marine, and pipeline. Source: https://ntsb.gov/Pages/default.aspx.

[50] NTSB also found that the pedestrian's impairment from drug use and her crossing outside of a crosswalk also contributed to the crash. National Transportation Safety Board, *Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian*, HWY18MH010, November 19, 2019, pp. 2 and 3, at https://www.ntsb.gov/news/events/Documents/2019-HWY18MH010-BMG-abstract.pdf.

[51] Ibid., p. 4.

[52] Ibid., p. 1.

[53] NTSB, "'Inadequate Safety Culture' Contributed to Uber Automated Test Vehicle Crash," press release, November 19, 2019, at https://www.ntsb.gov/news/press-releases/Pages/NR20191119c.aspx.

Autonomous vehicles, whose artificial intelligence and technology are generally self-contained in each vehicle, are part of a larger category of connected vehicles and infrastructure. Federal, state, and industry research and testing of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications has been under way since the 1990s. Together, these two sets of technologies, known as V2X, are expected to reduce the number of accidents by improving detection of oncoming vehicles, providing warnings to drivers, and establishing communications infrastructure along roadways that would prevent many vehicles from leaving the road and striking pedestrians. These technologies fall within the broad category of intelligent transportation systems, which have received strong support from Congress due to their potential to improve traffic flow and safety.[54]

For vehicles to communicate wirelessly, they use radio frequencies, or spectrum. Spectrum use is regulated by the FCC. In 1999, the FCC allocated 75 MHz in the 5.9 gigahertz (GHz) band solely for motor vehicle safety purposes for vehicles using DSRC. Over the past two decades, industry, DOT and other government agencies have collaborated to develop, test, and deploy DSRC technologies. States have invested in DSRC-based improvements, and this technology is operating in pilot tests in dozens of states and cities. Several automakers have installed DSRC in new vehicles; according to the FCC report, 15,506 DSRC-equipped vehicles are in use.[55]

In 2017, a competing vehicle communications technology—C-V2X—emerged. The 5G Automotive Association (5GAA), which includes some automakers, technology companies, telecommunication providers, and standards bodies, asserts that C-V2X performs better than DSRC, offers higher capacity and better congestion control, and may more readily incorporate future technologies made possible by 5G communications. In 2018, 5GAA petitioned the FCC for spectrum in the 5.9 GHz band to develop and deploy C-V2X; testing has so far been limited to a few cities. Standards and test procedures have not been finalized.

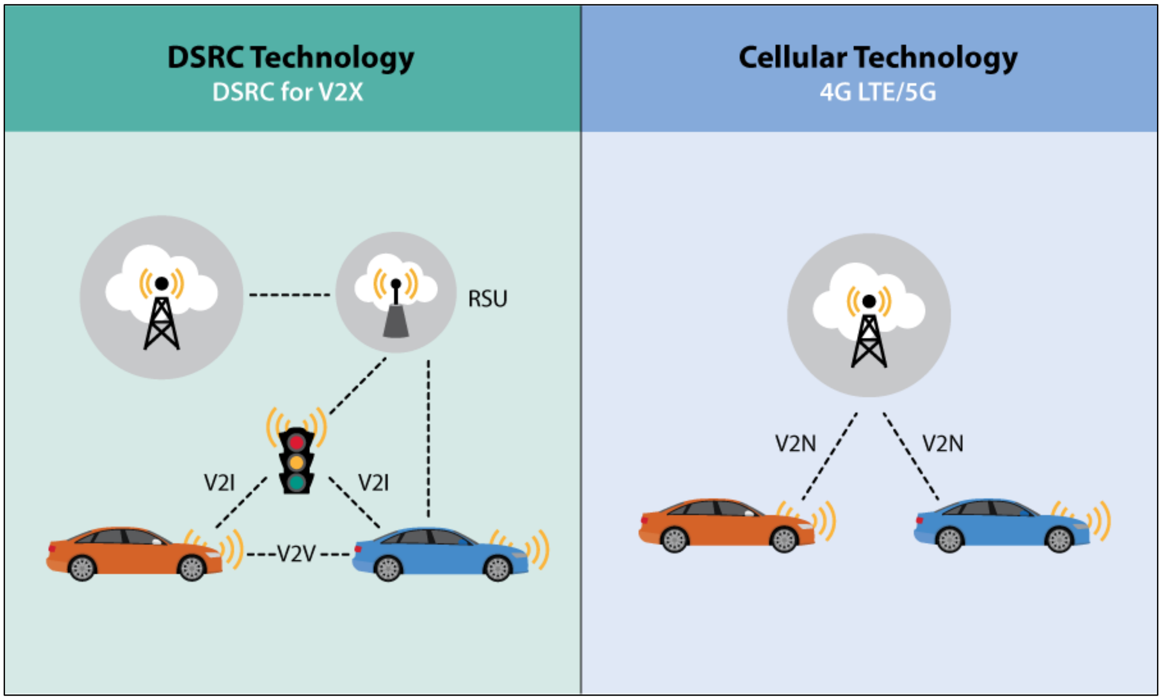
Figure 3 shows that these two technologies facilitate somewhat different types of vehicle and infrastructure communications. In light of their different characteristics, the European Commission has approved DSRC use for direct V2V and V2I communications, while endorsing cellular-based technology for vehicle access to the cloud and remote infrastructure.[56]

[54] P.L. 105-178, Transportation Equity Act for the 21st Century (TEA-21), Subtitle C—Intelligent Transportation Systems.

[55] Federal Communications Commission, "Use of the 5.850-5.925 GHz Band, First Report and order, Further Notice of Proposed Rulemaking, and Order of Proposed Modification, FCC 20-164," *FCC Record 13440*, November 20, 2020, p. 14, at https://docs.fcc.gov/public/attachments/FCC-20-164A1.pdf

[56] Pablo Valerio, "Europe has defined DSRC WiFi as the V2X standard, and now faces 5G vendors revolt," *IoT Times*, May 3, 2019, at https://iot.eetimes.com/europe-has-defined-dsrc-wifi-as-the-v2x-standard-and-now-faces-5g-vendors-revolt/.

Figure 3. Vehicle Communications Systems



Source: CRS.

Notes: Symbols used in this image are V2V, vehicle to vehicle communications; V2I, vehicle to infrastructure; V2X, a combination of V2V and V2I; V2N, vehicle to network, connecting vehicles to cellular infrastructure and the cloud so drivers can take advantage of services like traffic updates, and communicate from vehicle to vehicle. In addition, other infrastructure needs include RSUs, roadside units that communicate from vehicles and infrastructure to cell towers; traffic signal controllers that will communicate with the RSUs; a traffic management center that collects and analyzes data from vehicles and infrastructure; and a secure fiber-optic network.

The FCC has monitored the development of these alternative vehicle communications technologies even as it has considered whether the 5.9 GHz band should accommodate some of the burgeoning use of unlicensed consumer devices, such as mobile phones and wireless speakers, rather than being dedicated exclusively to transportation safety. The emergence of C-V2X and the need for new spectrum for wireless devices led the FCC in November 2020 to decide to split the 5.9 gigahertz band, allocating 45 MHz to unlicensed use and 20 MHz to C-V2X, effectively eliminating spectrum for DSRC use. It is seeking comment on whether the remaining 10 MHz should remain dedicated to DSRC or be dedicated to C-V2X.[57]

The Trump and Obama Administrations called for retaining the entire 5.9 GHz band for exclusive transportation use;[58] how the Biden Administration may balance these competing demands remains unclear. The chair of the House Transportation and Infrastructure Committee has expressed his "continued strong opposition" to the FCC decision and requested that the FCC reconsider its action, saying it will "undermine roadway safety."[59]

[57] Federal Communications Commission, "Use of the 5.850-5.925 GHz Band, First Report and order, Further Notice of Proposed Rulemaking, and Order of Proposed Modification, FCC 20-164," *FCC Record 13440*, November 20, 2020.

[58] Diana Furchtgott-Roth, then-Deputy Assistant Secretary, Department of Transportation, Remarks at Transportation Research Board Annual Meeting, Washington, DC, January 13, 2020, pp. 2-3, at https://www.transportation.gov/sites/dot.gov/files/docs/research-and-technology/362901/trb-panel-011320-dfr-remarks.pdf.

[59] Committee on Transportation and Infrastructure, "Chair DeFazio Presses Biden Administration on FCC Decision to

Like the United States, other countries are experiencing conflicting demands for spectrum. There is not a global consensus on a single standard for vehicle safety communications. Many countries that have tested DSRC are now assessing C-V2X. European Union (EU) regulators are encouraging auto and communications companies to decide on a single solution or to find a way to permit interoperability between DSRC and C-V2X. Japan and South Korea, which had previously planned to deploy DSRC, are also undecided on spectrum allocation and types of vehicle communications, while China has opted to make use of C-V2X mandatory on its highways.

For a further discussion of spectrum issues, see CRS In Focus IF11260, *Smart Cars and Trucks: Spectrum Use for Vehicle Safety*, by Bill Canis and Jill C. Gallagher.

Congressional Action

During the 115th Congress, committees in the House of Representatives and the Senate held numerous hearings on the technology of autonomous vehicles and possible federal issues that could result from their deployment. Initially, bipartisan consensus existed on major issues: H.R. 3388, the SELF DRIVE Act, was reported unanimously by the House Committee on Energy and Commerce, and on September 6, 2017, the House of Representatives passed it without amendment by voice vote.[60]

A similar bipartisan initiative began in the Senate. Prior to markup in the Committee on Commerce, Science, and Transportation, the then-chairman and ranking member issued a set of principles they viewed as central to new legislation:[61]

- *prioritize safety*, acknowledging that federal standards will eventually be as important for self-driving vehicles as they are for conventional vehicles;
- *promote innovation* and address the incompatibility of old regulations written before the advent of self-driving vehicles;
- *remain technology-neutral*, not favoring one business model over another;
- *reinforce separate but complementary federal and state regulatory roles*;
- *strengthen cybersecurity* so that manufacturers address potential vulnerabilities before occupant safety is compromised; and
- *educate the public* through government and industry efforts so that the differences between conventional and self-driving vehicles are understood.

Legislation slightly different from the House-passed bill emerged: S. 1885, the AV START Act,[62] was reported by the Committee on Commerce, Science, and Transportation on November 28,

Share 5.9 GHz Spectrum Band for Unlicensed Use," press release, March 19, 2021, at https://transportation.house.gov/news/press-releases/chair-defazio-presses-biden-administration-on-fcc-decision-to-share-59-ghz-spectrum-band-for-unlicensed-use.

[60] The bill was approved under suspension of the rules, a House procedure generally used to quickly pass noncontroversial bills; its title is short for Safely Ensuring Lives Future Deployment and Research In Vehicle Evolution Act.

[61] Bipartisan Principles for Self-Driving Vehicles were announced by Senators John Thune, Bill Nelson, and Gary Peters on June 13, 2017. Senator Gary Peters, "Senators Release Bipartisan Principles for Self-Driving Vehicles Legislation," press release, June 13, 2017, at https://www.commerce.senate.gov/public/index.cfm/2017/6/enators-release-bipartisan-principles-for-self-driving-vehicles-legislation.

[62] American Vision for Safer Transportation through Advancement of Revolutionary Technologies Act.

2017. It was not scheduled for a floor vote prior to adjournment in December 2018 because of unresolved concerns raised by several Senators.[63] To address some of those concerns, a committee staff draft bill that would have revised S. 1885 was circulated in December 2018, but no action was taken.[64]

The House and Senate bills addressed concerns about state action replacing some federal regulation, while also empowering NHTSA to take unique regulatory actions to ensure safety and encouraging innovation in autonomous vehicles. The bills retained the current arrangement of states controlling most driver-related functions and the federal government being responsible for vehicle safety. The House and Senate bills included the following major provisions. Where the December 2018 Commerce Committee staff draft proposed significant changes, they are noted in this analysis.

Preemption of state laws. H.R. 3388 would have barred states from regulating the design, construction, or performance of highly autonomous vehicles, automated driving systems, or their components unless those laws are identical to federal law.[65] The House-passed bill reiterated that vehicle registration, driver licensing, driving education, insurance, law enforcement, and crash investigations should remain under state jurisdiction as long as state laws and regulations do not restrict autonomous-vehicle development. H.R. 3388 provided that nothing in the preemption section should prohibit states from enforcing their laws and regulations on the sale and repair of motor vehicles.

S. 1885 would also have preempted states from adopting laws, regulations, and standards that would regulate many aspects of autonomous vehicles, but would have omitted some of the specific powers reserved to the states under the House-passed bill. States would not have been required to issue drivers licenses for autonomous-vehicle operations, but states that chose to issue such licenses would not have been allowed to discriminate based on a disability. The bill provided that preemption would end when NHTSA establishes standards covering these vehicles.

The Senate staff draft sought to clarify that state and local governments would not lose their traditional authority over traffic laws. It also would have added provisions that state common law and statutory liability would be unaffected by preemption, and would have limited use of arbitration in death or bodily injury cases until new federal safety standards are in effect.

Exemption authority. Both the House and Senate bills would have expanded DOT's ability to issue exemptions from existing safety standards to encourage autonomous-vehicle testing on public roads.[66] To qualify for an autonomous-vehicle exemption, a manufacturer would have had to show that the safety level of the vehicle equaled or exceeded the safety level of each standard for which an exemption was sought. Current law limits exemptions to 2,500 vehicles per manufacturer per year. The House-passed bill would have phased in increases over four years of

[63] Five Senators wrote on March 14, 2018, to the bill's sponsors, Senators Thune and Peters, outlining their concerns about how preemption, exemption authority, and cybersecurity might not adequately advance vehicle safety. Letter from Senators Dianne Feinstein, Kirsten Gillibrand, Richard Blumenthal, Edward Markey, and Tom Udall to Senators John Thune and Gary Peters, March 14, 2018, at https://www.feinstein.senate.gov/public/index.cfm/press-releases?ID=46E4DC09-C5AB-4301-98C1-CBB225AE24F8.

[64] Eno Center for Transportation, *AV START Act—December 3, 2018 Revised Discussion Draft*, December 3, 2018, at https://www.enotrans.org/etl-material/av-start-act-december-3-2018-revised-discussion-draft/.

[65] The bill would permit states and the federal government to prescribe higher standards for autonomous vehicles they purchase for their own use.

[66] For example, Federal Motor Vehicle Safety Standard 111 governs the performance and location of the rearview mirror. Fully autonomous vehicles would not need to be equipped with such mirrors because they rely on rear-facing sensors.

up to 100,000 vehicles per manufacturer per year; the Senate bill would have permitted up to 80,000 in a similar phase-in.[67]

H.R. 3388 provided constraints on the issuance of exemptions from crashworthiness and occupant protection standards; S. 1885 did not address those two issues. DOT would have been directed to establish a publicly available and searchable database of motor vehicles that have been granted an exemption. Crashes of exempted vehicles would have had to be reported to DOT. The Senate bill would not have required the establishment of a database of exempted vehicles, and reporting of exempt vehicle crashes would not have been required.

The Senate staff draft added a provision to ensure that vehicles exempted from federal standards would have been required to nonetheless maintain the same level of overall safety, occupant protection, and crash avoidance as a traditional vehicle. A DOT review of vehicle exemptions would have been required annually. The draft capped exemptions at no more than five years.

New NHTSA safety rules. The House bill would have required NHTSA to issue a new regulation requiring developers and manufacturers to submit a "safety assessment certification" explaining how safety is being addressed in their autonomous vehicles. The Senate bill included a similar provision requiring a "safety evaluation report," and would have delineated nine areas for inclusion in the reports, including system safety, data recording, cybersecurity risks, and methods of informing the operator about whether the vehicle technology is functioning properly. While manufacturers and developers would be required to submit reports, the legislation did not mandate that NHTSA establish an assessment protocol to ensure that minimum risk conditions are met.

The Senate staff draft would have clarified the process by which federal motor vehicle safety standards would be updated to accommodate new vehicle technologies, providing additional time for new rulemaking. Within six months of enactment, DOT would have been required to develop and publicize a plan for its rulemaking priorities for the safe deployment of autonomous vehicles.

To address concerns that autonomous vehicles might not recognize certain potential hazards—including the presence of bicyclists, pedestrians, and animals—and hence possibly introduce new vulnerabilities to motor vehicle travel, the Senate staff draft would have clarified that manufacturers must describe how they are addressing the ability of their autonomous vehicles to detect, classify, and respond to these and other road users. Manufacturers and developers would include this analysis in their safety evaluation reports.

Cybersecurity. The House-passed bill provided that no highly autonomous vehicle or vehicle with "partial driving automation"[68] could be sold domestically unless a cybersecurity plan had been developed by the automaker. Such plans would have to have been developed within six months of enactment and would have had to include

- a written policy on mitigation of cyberattacks, unauthorized intrusions, and malicious vehicle control commands;
- a point of contact at the automaker with cybersecurity responsibilities;

[67] In H.R. 3388, up to 25,000 vehicles could have been exempted per manufacturer in the first year after enactment, then 50,000 in the second year and 100,000 in each of years three and four. DOT would not have been permitted to raise the cap above 100,000 vehicle exemptions. S. 1885 would have permitted 15,000 exemptions per manufacturer in the first year after enactment, then 40,000 in the second year, and 80,000 in years three and four. A manufacturer could have requested that DOT increase its exemption cap above 80,000. In evaluating the request for an increase in or a renewal of an exemption, DOT would have been required to conduct a safety assessment of the original exemption.

[68] "Partial driving automation" generally refers to Level 3 or 4 autonomous vehicles, in which a driver must remain engaged with the task of driving despite features, such as acceleration and steering, that may operate autonomously.

- a process for limiting access to autonomous driving systems; and
- the manufacturer's plans for employee training and for maintenance of the policies.

The Senate bill would have required written cybersecurity plans to be issued, including a process for identifying and protecting vehicle control systems, detection, and response to cybersecurity incidents, and methods for exchanging cybersecurity information. A cybersecurity point of contact at the manufacturer or vehicle developer would have had to be named. Unlike the House-passed bill, S. 1885 would have directed DOT to create incentives so that vehicle developers would share information about vulnerabilities, and would have specified that all federal research on cybersecurity risks should be coordinated with DOT.

In addition, S. 1885 would have established a Highly Automated Vehicle Data Access Advisory Committee to provide Congress with recommendations on cybersecurity issues. Federal agencies would have been prohibited from issuing regulations pertaining to the access or ownership of data stored in autonomous vehicles until the advisory committee's report was submitted.

The staff draft would have added several cybersecurity provisions, including an additional study by the National Institute of Standards and Technology that would recommend ways vehicles can be protected from cybersecurity incidents.

Privacy. Before selling autonomous vehicles, manufacturers would have been required by the House-passed bill to develop written privacy plans concerning the collection and storage of data generated by the vehicles, as well as a method of conveying that information to vehicle owners and occupants. However, a manufacturer would have been allowed to exclude processes from its privacy policy that encrypt or make anonymous the sources of data. The Federal Trade Commission would have been tasked with developing a report for Congress on a number of vehicle privacy issues.

Although S. 1885 would not have explicitly required privacy plans of developers and manufacturers, it would have required NHTSA to establish an online, searchable database that would include a description of the types of information, including personally identifiable information (PII), that are collected about individuals during operation of a motor vehicle. This database would have covered all types of vehicles—not just autonomous vehicles—and would have included the privacy policies of manufacturers. The database would also have included an explanation about how PII would be collected, retained, and destroyed when no longer relevant.

The Senate staff draft would have added new passenger motor vehicle privacy protections.

Research and advisory panels. Both bills would have established several new advisory bodies to conduct further research on autonomous vehicles and advise DOT on possible new vehicle standards. H.R. 3388 would have established a NHTSA advisory group with a broad cross-section of members to advise on mobility access for senior citizens and the disabled; cybersecurity; labor, employment, environmental, and privacy issues; and testing and information sharing among manufacturers.

S. 1885 would have established other panels, including a Highly Automated Vehicles Technical Committee to advise DOT on rulemaking policy and vehicle safety; a working group comprising industry and consumer groups to identify marketing strategies and educational outreach to consumers; and a committee of transportation and environmental experts to evaluate the impact of autonomous vehicles on transportation infrastructure, mobility, the environment, and fuel consumption. Separately, DOT would have been required to study ways in which autonomous vehicles and parts could be produced domestically, with recommendations on how to incentivize U.S. manufacturing.

The Senate staff draft would have consolidated some of the advisory committees in S. 1885 into a Highly Automated Vehicle Advisory Council with diverse stakeholder representation, and mandated to report on mobility for the disabled, senior citizens and populations underserved by public transportation; cybersecurity; employment and environmental issues; and privacy and data sharing.

No similar comprehensive autonomous vehicle legislation was introduced in the 116th Congress, despite ongoing discussions.[69] However, the Senate Committee on Environment and Public Works reported America's Transportation Infrastructure Act of 2019, S. 2302, which included several provisions in Subtitle D addressing the possible impact of autonomous vehicles on highway infrastructure. It would have established a grant program to modernize the U.S. charging and fueling infrastructure so that it would be responsive to technology advancements, including autonomous vehicles. The legislation would have also required research on ways in which roadway infrastructure should be improved for autonomous vehicles. As of the date of this report, comprehensive autonomous vehicle legislation has not been introduced in the 117th Congress.

Congress has also shown interest in ensuring that the DOT workforce has the skill sets necessary to regulate autonomous vehicles, and requested a GAO assessment, which was completed in December 2020. GAO evaluated a range of skills—such as engineering, data analysis and economics—needed within DOT to ensure that automated technologies used in planes, trains, trucks, buses, and passenger vehicles are safe and working as intended. It found that DOT has generally identified the skills its employees need but has not determined if the current workforce has those skills. In transmitting its report, GAO noted that "While these technologies hold many potentially transformative benefits, accidents involving them—such as Uber and Tesla crashes in 2018 caused in part by the drivers' overreliance on the automated technologies in the vehicles—demonstrate their potential safety challenges."[70]

State Concerns

State and local rules and regulations may affect how autonomous vehicles are tested and deployed. The National Governors Association (NGA) has noted that state governments have a role with respect to vehicle and pedestrian safety, privacy, cybersecurity, and linkage with advanced communications networks. While supporting technology innovations in transportation, a recent NGA report notes that "the existing regulatory structure and related incentives have not kept pace with the new technology"[71] and that "recent accidents have raised concerns about the safety of drivers, pedestrians and other road users in the period during which autonomous and non-autonomous vehicles share the road."[72]

NGA has joined with other state and local government organizations[73] to call for modifications in federal laws relevant to autonomous vehicles, including

[69] Maggie Miller, "Cyber rules for self-driving cars stall in Congress," *The Hill*, September 26, 2019, at https://thehill.com/policy/transportation/463126-cyber-rules-for-self-driving-cars-stall-in-congress.

[70] U.S. Government Accountability Office, *Automated Technologies: DOT Should Take Steps to Ensure Its Workforce Has Skills Needed to Oversee Safety*, GAO-21-197, December 2020, at https://www.gao.gov/products/gao-21-197.

[71] National Governors Association, *Governors Staying Ahead of the Transportation Innovation Curve: A Policy Roadmap for States*, July 17, 2018, p. 1, at https://www.nga.org/wp-content/uploads/2018/07/Transportation-Innovation-Roadmap-Final-Hi-Res-for-Posting-Online.pdf.

[72] Ibid., p. 12.

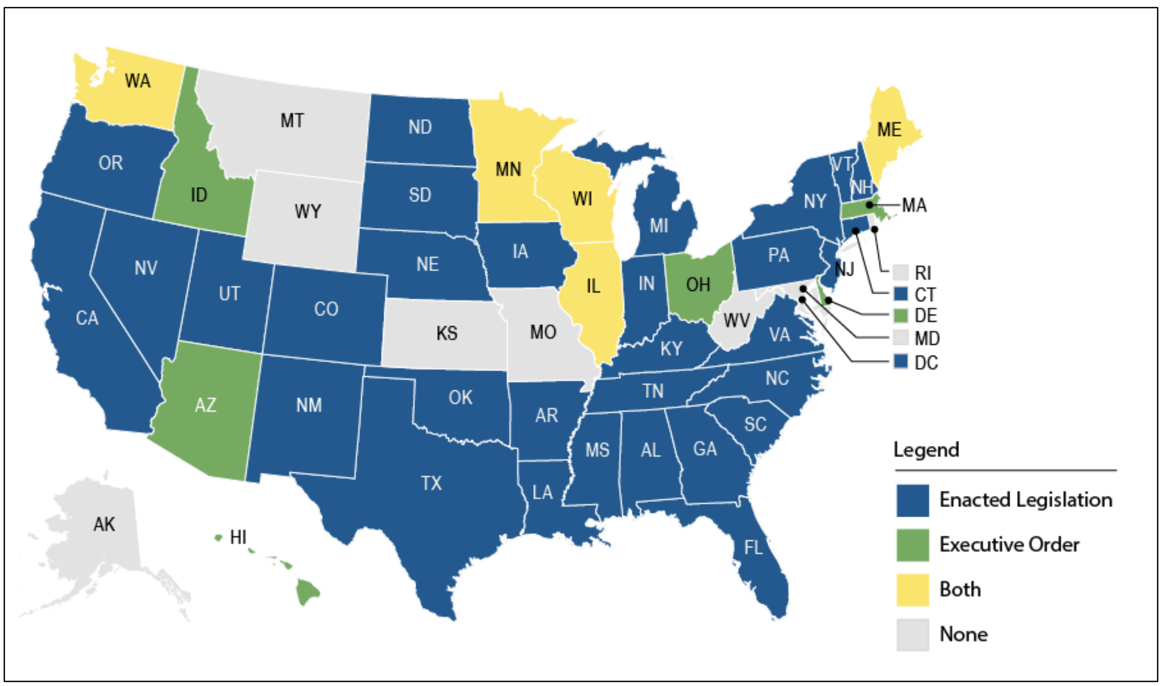
[73] National Governors Association, National Conference of State Legislatures, National League of Cities, U.S.

- clarity that states and local governments not only can enforce existing laws governing operation of motor vehicles on public roads, but also originate new statutes and regulations;
- requiring submission of more detailed automaker and developer reports to DOT on the safety of their technologies, so that states and cities can be assured that autonomous vehicle testing is being conducted in a safe manner;
- differentiation between limited vehicle testing and the commercial deployment of large numbers of autonomous vehicles through an expanded exemptions process; and
- expansion of plans for consumer education about "safe use and interaction" with respect to autonomous vehicles.

According to the National Conference of State Legislatures (NCSL), between 2013 and 2020, 31 states and the District of Columbia enacted legislation related to autonomous vehicles, governors in 11 states issued executive orders, and 5 states both issued an executive order and enacted legislation (**Figure 4**).

Figure 4. State Actions on Autonomous Vehicles

Enacted Legislation and Executive Orders, 2013 through 2020



Source: CRS map based on data from National Conference of State Legislatures, *Autonomous Vehicles/Self-Driving Vehicles Enacted Legislation*, viewed April 9, 2021, at http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx, and Autonomous Vehicles State Bill Tracking Database, at https://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx.

Conference of Mayors, National Association of Counties, American Association of State Highway and Transportation Officials, Governors Highway Safety Association, and American Association of Motor Vehicle Administrators, letter to the chairmen of the Senate Committee on Commerce, Science, and Transportation and House Committee on Energy and Commerce, September 12, 2019, at https://www.nga.org/letters-nga/coalition-comments-on-potential-federal-legislation-on-autonomous-vehicles/.

Of the states that enacted laws between 2017 and 2020 pertaining to autonomous vehicles, NCSL reports that the largest number have passed laws that clarify certain types of commercial activity, such as how closely autonomous vehicles can follow each other when they are coordinated, as in truck platooning. According to NCSL, no recent state laws have been enacted dealing with cybersecurity or vehicle inspection reports (**Table 4**).

Table 4. Types of Autonomous Vehicle Laws Enacted by the States

2017-2020

Topic	Number of States That Enacted Legislation
Commercial	24
Cybersecurity	0
Definitions	21
Infrastructure and connected vehicles	5
Insurance and liability	9
Licensing and registration	3
Operation on public roads	14
Operator requirements	11
Privacy of collected vehicle data	1
Request for study	4
Vehicle inspection requirements	0
Vehicle testing	13
Other	8

Source: National Conference of State Legislatures, *Autonomous Vehicles State Bill Tracking Database*, viewed April 12, 2021, at http://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx.

Notes: Includes the 50 states and the District of Columbia; laws enacted; does not include executive orders.

Implications for Highway Infrastructure

Deployment of fully autonomous vehicles will require not only a suite of new technologies, but also changes to the highway infrastructure on which those vehicles will operate. Autonomous vehicles being tested today rely on clear pavement markings and legible signage to stay in their lanes and navigate through traffic. Major highways as well as side roads in urban and rural settings will need to accommodate autonomous vehicles in addition to a large fleet of conventional vehicles with human drivers.[74]

[74] DOT has estimated that 20% of intersections may be V2I-capable in 2025 and 80% will be V2I capable by 2040. Center for Automotive Research and Public Sector Consultants, *Planning for Connected and Automated Vehicles*, March 2017, p. 17.

In this transition period to more autonomous vehicles—which will likely last several decades[75]—the Federal Highway Administration (FHWA) is expected to play a significant role through its administration of the Manual on Uniform Traffic Control Devices (MUTCD), which sets standards for all traffic control devices, including signs, intersection signals, and road markings. For example, overhead signage on Interstate Highways contains white lettering on a green background in all 50 states—easily recognizable to any U.S. driver—due to MUTCD standards. FHWA is in the process of updating the 2009 MUTCD to address issues specific to autonomous vehicle technologies and is seeking public input.[76] However, state compliance with MUTCD is voluntary, and not all states uniformly apply all standards. Audi reportedly announced in 2018 that it would not make its new Level 3 autonomous vehicle technology, called Traffic Jam Pilot, available in the United States because of "laws that change from one state to the next, insurance requirements, and things like lane lines and road signs that look different in different regions."[77] Other automakers have made similar complaints about U.S. roads.[78]

In the near term, improvement and better maintenance of pavement markings, signage and intersection design may be the most helpful steps that federal and state transportation officials can take. Despite national standards based on MUTCD, not all states maintain their highway markings at a level that would be sufficient to guide autonomous vehicles. Inadequate road maintenance may affect the pace of autonomous vehicle deployment. Some 21% of major U.S. roads are in poor condition, and a road with many potholes or temporary pavement repairs may also lack continuous lane markings.[79] Many minor roads, which are generally the responsibility of county or municipal governments, may lack road edge lines as well as center lines, potentially making it difficult for autonomous vehicles to position themselves correctly. Dirt and gravel roads may pose particular challenges for autonomous vehicles, as they generally have no pavement markings and cameras may be unable to detect potholes or edges in low-visibility conditions.

Closely tied to the need for clearer road markings and signage will be ways in which federal and state transportation agencies develop a standardized method to communicate information to vehicles and motorists about construction, road accidents, detours, and other changes to road environments. Many of the perceived benefits of autonomous vehicles—reduced vehicle fatalities, congestion mitigation, and pollution reduction—may depend on the ability of vehicles to exchange information with surrounding infrastructure.[80] The Transportation Research Board (TRB) has evaluated how states should begin now to plan and develop the types of connected

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[75] The average age of light vehicles on U.S. roads was 11.9 years in 2020 (12.4 years for cars and 11.6 for light trucks); most new vehicles on the road today will likely still be driven in 2030. Of the 280 million light vehicles on U.S. roads in 2020, most of them are conventional, with internal combustion engines. Eric D. Lawrence, "Vehicles on the road keep getting older, and COVID could push the age higher," *Detroit Free Press*, July 28, 2020, at https://www.freep.com/story/money/cars/2020/07/28/covid-average-vehicle-age-12-years/5519557002/.

[76] U.S. Department of Transportation, *Automated Vehicles: Comprehensive Plan*, January 2021, p. 15.

[77] Alex Davies, "Americans Can't Have Audi's Super Capable Self-Driving System," *WIRED*, May 15, 2018, at https://www.wired.com/story/audi-self-driving-traffic-jam-pilot-a8-2019-availablility/.

[78] Angelo Young, "Self-driving cars vs. American roads: will infrastructure speed bumps slow down the future of transportation?," *Salon*, April 20, 2017, at https://www.salon.com/2017/04/20/self-driving-cars-vs-crummy-american-roads-will-infrastructure-speed-bumps-slow-down-the-future-of-transportation/.

[79] CRS calculations based on Federal Highway Administration data for federal-aid highways only. See Appendix A in CRS Report R45250, *Rural Highways*, by Robert S. Kirk, p. 21. Federal-aid highways account for about one-quarter of all the roads in the United States and are generally the best maintained. It is likely that many of the other three-quarters of U.S. roads, including rural dirt roads and suburban cul-de-sacs, are also of a poor quality.

[80] Fast internet connections will be necessary for most V2X communications; state and local governments may be called on to make broadband investments to accommodate autonomous vehicle connectivity, raising questions about how those investments will be funded and steps to ensure compatibility across state lines.

vehicle infrastructure that will be necessary for full autonomous vehicle deployment. TRB's research is also focused on how cash-strapped transportation agencies can identify the large investments that will in turn be necessary to implement connectivity on top of regular maintenance of highways, bridges, and other traditional infrastructure.[81]

Other options to facilitate autonomous vehicle travel may include designation of special highway corridors that would include all V2X systems necessary for safe autonomous vehicle operation; three European countries have agreed to build such a corridor.[82]

Over a longer time line, the importance of highway markings may fade as automakers and developers find new ways for autonomous vehicles to navigate, including greater use of guardrails and roadside barriers, sensors, and three-dimensional maps.[83] If highly detailed mapping is deemed to be one replacement for visual cues such as lane markings, then transportation agencies and automakers may need to develop an open standard so that all vehicles will understand the mapping technology. V2X communications may evolve to provide a mechanism for new types of vehicle guidance.

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[81] TRB, part of the National Academies of Sciences, Engineering, and Medicine, completed its report in July 2020. "Business Models to Facilitate Deployment of CV [Connected Vehicle] Infrastructure to Support AV Operations," at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4256.

[82] The Netherlands, Germany, and Austria are undertaking a joint corridor development from Rotterdam through Frankfurt to Vienna. "Tri-national cooperation on the C-ITS Corridor," *ITS International*, viewed October 8, 2019, at https://www.itsinternational.com/categories/networking-communication-systems/features/tri-nation-cooperation-on-c-its-corridor/.

[83] Center for Automotive Research and Public Sector Consultants, *Planning for Connected and Automated Vehicles*, March 2017, p. 12.

Appendix. Image of Nuro Robot, R2X

Figure A-1. Nuro Robot, R2X

First autonomous vehicle approval by NHTSA

Source: Photo courtesy of and with permission of Nuro Inc.

Note: NHTSA announced its approval of the Nuro application for an exemption from three Federal Motor Vehicle Safety Standards on February 6, 2020.

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