RESEARCH REPORT

Regulations to Respond to the Potential Benefits and Perils of Self-Driving Cars

Analysis and Recommendations for Advancing Equity and Environmental Sustainability

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Executive Summary

The mobility system in the United States is unsafe, inequitable, and environmentally destructive. Most Americans rely on personally owned, individually occupied, and gas-powered cars—a status quo that leads to tens of thousands of people dying each year in collisions, creates barriers to employment and other opportunities for people of color and people with low incomes, and maintains a resource-intensive transportation system that contributes to climate change and spurs sprawling land uses that destroy ecologies. Autonomous vehicles (AVs)—self-driving cars that can travel along publicly accessible streets some or all of the time without human involvement—could help mitigate these problems, if they are implemented in a thoughtful, well-regulated manner. However, if deployed haphazardly with inadequate oversight and regulation, they could produce even worse inequities than those caused by the current system.

Vehicle manufacturers have deployed various improvements to passenger vehicles using autonomous technology. Adaptive cruise control, one of the earliest stages of this technology, is readily available; however, it requires constant driver supervision, even though car companies sometimes describe it as an "automated" feature. Manufacturers are currently testing fully autonomous vehicles in communities throughout the United States but have yet to deploy them in large-scale commercial operation. These advanced AVs would allow drivers to do other things while moving, or potentially replace drivers altogether. In theory, fully autonomous vehicles would be better than humans at avoiding crashes, reduce operating costs, and help mitigate climate change by running on electricity rather than gas. In fleet operation, they could improve people's access to employment, especially in communities that have faced historic disinvestment. But if deployed in a way that incentivizes individual ownership and fails to include requirements to limit emissions, AVs could increase vehicular miles traveled, increase the pace of climate change, and create urban sprawl, exacerbating segregation and inequity while worsening public health. Moreover, it is still uncertain whether AVs are, or will ever be, safer than human-driven cars and whether AV operators will serve all neighborhoods in an equitable manner.

To evaluate the current landscape for AV deployment and use in the United States, we conducted a study focusing on automobile-sized AVs designed for passenger use as opposed to other types of AVs that could be used for public transit service or freight. Through a scholarship review, a scan of legislation nationwide, and interviews with stakeholders, we examine key potential benefits that AVs could generate, as well as the problems they could exacerbate. Carefully designed regulations could

help ensure that these new technologies improve access to mobility and reduce pollution. We identify the following key priorities in regulating AVs:

- Expanded testing and deployment by the US Department of Transportation and the National Highway Traffic Safety Administration to allow AV technology to develop, while still maintaining safety for all.
- Federal development of vehicle design standards for unconventional vehicles, such as cars without steering wheels, that clearly demonstrate that they reduce the possibility of injury for vulnerable road users such as pedestrians and cyclists.
- Federal requirements to quickly move AVs toward zero-emissions powertrains.
- Federal and state mandates to ensure that manufacturers make AVs as accessible as possible for people with disabilities.
- Federal and state creation of minimum standards for consumers and the public to ensure that they are protected from oversurveillance, are not exposed to inappropriate liability concerns in the case of AV malfunction or poor design, and understand the differences between levels of automation offered by AVs.
- Federal, state, and local support for equitable access principles, with the goal of creating metrics to ensure that people of color and people with low incomes can benefit from increased transportation access through AV service.
- State and local funds, incentives, and fees to associate the rollout of AVs with a reduction in privately owned vehicles, such as through support for shared rides and increased multimodal public transportation options.
- Local initiatives to link AV deployment with the redesign of streets to make them safer for pedestrians, including children.

All levels of government will play a role in making regulatory choices about AV rollout, with the federal government, states, and localities each contributing to the construction of the overall AV ecosystem. Our primary recommendations for regulating AVs in a way that promotes safety, social equity, and environmental sustainability are summarized in table 1.

TABLE 1

Recommended Roles for Federal, State, and Local Governments in AV–Related Policy Domains

Policy Domain	Federal Government	State and Local Governments
Vehicle design	▪ Substantially expand AV testing and deployment ▪ Replace or supplement federal vehicle standards for AVs ▪ Guarantee safety of nonmotorized street users ▪ Require zero-emissions AVs ▪ Develop guidance for access for people with disabilities	▪ Fill regulatory gaps if the federal government is unable to develop rules that prioritize equity and environmental sustainability
Vehicle operation	▪ Maintain and improve the NHTSA general order on federal crashes data collection ▪ Develop plans for data collection and cybersecurity ▪ Create national liability and insurance standards ▪ Provide guidance to state and local governments on equity and the environment	▪ Institute reasonable data-sharing requirements for all AVs ▪ Use data produced by AVs to inform policy and capture their negative equity and environmental externalities ▪ Consider instituting minimum service requirements for people with disabilities and priority neighborhoods
Consumer standards	▪ Provide baseline consumer information to consumers about AVs ▪ Use tax measures to disincentivize personal AV ownership ▪ Develop a path to full compliance with the Americans with Disabilities Act in ride-hailed AVs	▪ Create opportunities for easy AV use, even for people without a smartphone or a bank account ▪ Incentivize shared rides through taxes and fees ▪ Provide transit-linked subsidies for passengers with low incomes ▪ Adjust registration requirements to handle cars without drivers
Street standards	▪ Provide opportunities for state and local governments to develop street standards	▪ Geofence key streets to reopen them for pedestrian use ▪ Incentivize shared rides through curb space rules ▪ Develop safety protocols to minimize overpolicing

Source: Authors' review of scholarship and interviews.

Notes: AVs = autonomous vehicles. NHTSA = National Highway Traffic Safety Administration. Recommendations vary depending on the level of AV rollout; most recommendations relate to level 4–5 AVs.

Autonomous Vehicles and Achieving Transportation Equity

A century of federal and state spending on an automobile-dominated, fossil fuel–powered transportation system and its associated sprawling land uses has encouraged high levels of pollution, underinvestment in cities, racial and economic segregation, and high levels of traffic-related injuries, in addition to depriving people who cannot drive of access to a large share of employment and public services (Freemark and Tregoning 2022). Existing public transit options are often limited, inaccessible for seniors and people with disabilities, or too expensive, leaving many residents without options. Unreliable transit, particularly at off-peak hours, means that people who work irregular schedules often have no safe or affordable way to get to their jobs (Giuliano and Narayan 2005; Rast 2004; Sanchez, Shen, and Peng 2004). Ride-hailing services such as Uber and Lyft are typically too expensive for a large share of the population to use for their regular commutes (Dong 2022). Moreover, limited access to nonmotorized options such as bike-sharing facilities means that low-income people and people of color are often unable to use alternative modes of transport (Ursaki and Aultman-Hall 2015).

Some researchers and vehicle manufacturers have proposed autonomous vehicles (AVs)—self-driving cars that can travel along publicly accessible streets some or all of the time without human involvement—as a potential solution to address these gaps. Because AVs can be deployed without drivers, these vehicles theoretically could expand access to transportation to more people at a lower cost than human-driven ride-hailed services, with potentially fewer accidents than human-driven automobiles. If powered with electricity, they could also help transition the country toward a more environmentally sustainable model than the current primarily gas-powered transportation system (Fagnant and Kockelman 2015). Manufacturers are currently testing AVs in multiple communities across the United States, and they have rolled out early elements of AV technology such as lane detection and adaptive cruise control on production cars (Urbán 2021). Most automakers have also voluntarily agreed to deploy automatic emergency braking in virtually all cars by fall 2022.[1] Although certain autonomous features are present in cars on the road today, these have not profoundly altered the function and effects of the transportation system. On the other hand, fully autonomous vehicles—such as cars without steering wheels or those that do not require a human driver at all—will likely have a more dramatic effect, potentially influencing transportation equity and access.

If AVs reduce costs for households that currently spend a large share of their incomes on transportation—a cohort disproportionately comprising people of color and families with low

incomes[2]—they could reduce transportation inequities. If AVs are deployed in a manner that maximizes roadway space, such as by pooling high-occupancy vehicles or limiting individual AV ownership, they could reduce the political demand for highway expansion and improve roadway reliability. And if the federal government requires all AVs to be electric or otherwise zero emissions, they could, in theory, help reduce vehicle-produced air pollutants that disproportionately harm communities of color (Clark et al. 2017; Jbaily et al. 2022; Tessum et al. 2021) and reduce greenhouse gas emissions if their electricity comes from renewable energy sources (Toba et al. 2019). This effect could be even more pronounced if electricity-powered AVs replace gas-powered personal vehicles, which, on average, are more than 12 years old and much less efficient.[3] If governments incentivize shared rides or multimodal links with transit options, AVs could also build on existing options—including public transportation, biking, and walking—to ultimately reduce vehicular miles traveled (VMT). This could also free up urban streets for other uses, including child's play and greenery, because of better collision avoidance (Duarte and Ratti 2018; Hancock, Nourbakhsh, and Stewart 2019).

The potential reductions in travel costs associated with AV rollout—in terms of both money and time—remain to be demonstrated. However, if achieved, these benefits could also produce a number of downsides including increased VMT, increased traffic, excess pollution, and further suburban sprawl (Wadud, MacKenzie, and Leiby 2016).[4] For example, people who had previously driven their own cars may find themselves willing to spend more time in an AV since they would be able to work, read, watch entertainment, sleep, or do some other task while letting the automated system pilot the car. This could, in turn, encourage more VMT, and thus more traffic and more pollution in the form of tailpipe and upstream emissions, especially if AVs are powered by fossil fuels (Harb et al. 2022). If individuals privately own AVs, they might use their vehicles to "circle the block" rather than pay for parking, leading to more VMT. Each of these trends could encourage increased political support for highway expansion—itself a generator of more roadway use—due to people's willingness to travel longer distances. Together, these outcomes would have a negative impact on environmental sustainability. Additionally, if AVs encourage further outward development of residences and employment, they may exacerbate inequitable access to mobility. People with low incomes may be unable to afford using AVs to travel long distances, and research demonstrates that suburban sprawl is associated with reduced upward mobility for people with low incomes (Ewing et al. 2016).

The degree to which AVs change the transportation system and society overall will be mediated by regulatory choices at the local, state, and federal levels (Freemark, Hudson, and Zhao 2020). If AVs ultimately reinforce inequitable access to transportation, reduce public transit use, increase VMT, increase congestion, and exacerbate the causes of climate change, this technological advancement may

ultimately fall short of its full promise—or even worsen the existing problems endemic to the automobile-dominated US transportation system (Stacy and Meixell 2018). AVs may also have mixed effects, such as potentially reducing traffic deaths even as they increase suburban sprawl. Although the federal government has produced several high-level reports identifying potential issues AV regulations could address, it has not yet developed AV–specific rules on issues such as emissions, nor has Congress passed legislation on the matter. Moreover, the car manufacturing industry's ability to scale deployment of purpose-built AVs without human controls is currently capped at 2,500 vehicles per manufacturer annually—a limit imposed by non-AV-specific federal vehicle design requirements. This figure is a pittance compared with the roughly 15 million vehicles sold annually in the United States.

AVs may offer some improvements for the transportation system, but they are not a panacea and are limited by the regulatory environment and urban forms in which they operate. Investment in public transportation remains essential to guarantee fast, frequent, affordable, and quality service in many neighborhoods. Ensuring that AV–related policies are designed to support equity improvements and environmental sustainability will be key to leveraging this technology for the public good. In this report, we lay out a set of recommendations for how federal, state, and local governments can harness AV technology to increase equity and access to opportunity for people with low incomes, communities of color, and people with disabilities—all while supporting the goal of increasing environmental sustainability. These recommendations also focus on how to maximize the net societal benefits of AVs through reduced traffic fatalities for drivers, pedestrians, and bikers; reduced car-based pollutants with the transition to an electrified and renewable energy–powered fleet; and reduced overall VMT through shared fleet services. Given that AV technology remains in development, decisionmakers should be willing to adjust their approaches over time to meet changing needs. Key recommendations for the federal government include:

- Substantially expanding AV testing and deployment, including through the creation of AV–specific standards that allow alternative vehicle designs, guarantee the safety of nonmotorized street users, support the implementation of an all-electrified fleet, and aim for universal accessibility;
- maintaining AV crash data collection at the national level, with the goal of comparing overall safety levels of AVs with those of human-driven cars, particularly for pedestrians, and creating nationalized liability and insurance standards for highly automated vehicles that protect customers from unfair treatment under the law;

- providing consumer information for AV buyers so that they understand the risks of purchasing and using different types of vehicles, as well as using tax measures to disincentivize personal AV ownership; and
- developing a collaborative "table" with advocates and representatives from the transportation industry and the federal government to identify specific measures and potential regulations around AVs to ensure better access for more people and to reduce transportation inequities.

We recommend that state and local governments collect data on all AV trips (for both fleet- and individually owned vehicles) with the goal of using this information to capture negative equity and environmental externalities and to identify which neighborhoods and individuals need better access. We also recommend that state and local governments develop incentives for shared rides, combined with subsidies for people with low incomes, and explore ways they can use the built environment to incentivize pooling over individually owned cars, such as by reserving curb space for pooled vehicles. Finally, we suggest that governments maximize AV benefits by developing policies to geofence streets for safe interactions with pedestrians and other nonmotorized street users.

What Are Autonomous Vehicles?

AVs are transportation conveyances that can use the public right-of-way on streets and roads with limited or no involvement from human drivers. They differ from automated public transportation systems such as automated metros or people movers because AVs are designed to operate without a fixed guideway and—at least in some cases—amid human-driven vehicles, pedestrians, cyclists, and other street users. AVs can come in all shapes and sizes, from small delivery robots to automobiles to buses to freight-hauling trucks. In this report, we focus on automobile-sized AVs.

In all cases, AVs leverage some form of driver-assistance software that is integrated into the design of the vehicle itself but may not be created or maintained by the same provider (e.g., one company could design the car while another creates and updates the software).[5] Less advanced automated software, called advanced driver assistance systems (ADAS), provide aid to the driver; the most basic versions of ADAS, such as adaptive cruise control, are common features of many new cars sold to customers today. More complicated ADAS systems can take on steering, acceleration, and braking, but these require human supervision.

More advanced automated software, called automated driving systems (ADS), allow vehicles to truly operate without driver supervision in some or all cases. ADS software typically uses vehicle-

mounted cameras and other tools such as Lidar (a form of laser-based imaging), ultrasound, and moisture systems to make choices about navigating vehicles down streets; many ADAS systems also use these technologies, albeit to a more limited degree. This software is usually augmented by mapping data that the ADS retrieves from central servers. The developer typically updates ADS "over the air" as it makes improvements to the software. Some AVs using ADS can only operate without driver supervision for portions of a journey (level 3 AVs); others can operate at all times without driver involvement (levels 4–5), offering the opportunity to create innovative vehicle designs, such as cars without steering wheels or with an unconventional seating arrangement.

Engineers, regulators, and others interested in the field have developed a new set of terms to discuss AVs, some of which are defined in box 1. Although these terms feature heavily in state and federal legislation and regulation, they are not necessarily well understood by consumers—including those who are now taking advantage of many ADAS features in new cars. Much AV–related regulation aims to address how AVs operate in different scenarios, such as in dangerous situations where the AV technology cannot respond in a safe manner.

BOX 1

Key AV Terms

Regulators developing rules for AVs in the United States have created a series of specialized terms to help explain AVs and their operation. These terms include:

- **Advanced driver assistance system (ADAS):** technology used as an automated assist to a human driver, such as adaptive cruise control, emergency braking, and lane adherence (implemented in AVs operating in levels 1–2). Human drivers are necessary to supervise vehicular movements.
- **Automated driving system (ADS):** the term often used by regulators to describe the technology used to pilot an AV in cases where human drivers do not have to be engaged (implemented in AVs operating in levels 3–5).
- **Dynamic driving task (DDT):** the operational and tactical functions required to operate a car in traffic, typically including lateral vehicle motion control (steering), longitudinal vehicle motion control (acceleration and braking), and monitoring the environment, including through event response, maneuvering, lighting, and signaling. An AV in levels 3–5 should have full control over these functions when in operation. A DDT fallback occurs when an AV or ADS has a system failure and requires requesting a human to intervene and passing control to a driver (level 3), or automatically switching to a minimal risk condition (levels 4–5).

- **Highly automated vehicle:** an AV capable of performing DDTs, though this does not typically include commercial motor vehicles. Highly automated vehicles correspond to level 3–5 AVs; a dedicated highly automated vehicle is level 4 or 5.
- **Levels of automated driving:** represent the spectrum of AV operations, as defined by SAE International and typically used by regulators. These levels include:
    - **Level 0:** no driving automation. Human controls every aspect of driving.
    - **Level 1:** driver assistance. An automated system controls either the lateral or longitudinal elements of the DDT (such as through adaptive cruise control), with the driver performing the remainder of functions and supervising any automation.
    - **Level 2:** partial driving automation. An automated system controls both the lateral and longitudinal elements of the DDT, with the driver performing the remaining functions and supervising any automation.
    - **Level 3:** conditional driving automation. An automated system performs full DDTs under the relevant operational design domain (ODD), but the user must determine whether and how to achieve a minimal risk condition, if needed, and the user can become the driver if needed.
    - **Level 4:** high driving automation. An automated system performs all DDTs under the relevant ODD and transitions automatically to minimal risk condition if needed.
    - **Level 5:** full driving automation. An automated system performs all DDTs under all conditions.
- **Minimal risk condition:** the stable, stopped condition to which a user or AV may bring a vehicle after a DDT fallback to reduce risks, such as a crash, if a trip should not or cannot be continued.
- **Operational design domain (ODD):** the times, places, and conditions (such as weather) in which an AV, rather than a human driver, is designed to operate. An AV could have an ODD that applies to all roadways and all times, or the ODD could be limited to, for example, only limited-access highways, leaving driving on other types of streets to a human driver.
- **Strategic functions:** trip scheduling and selection of destinations and waypoints. These functions are outside the control of the AV system, but are input either by the human rider or by the trip provider, such as the ride-hailing operator.

These terms can be used together. For example, a highly automated vehicle operating at level 3 uses an ADS to conduct a DDT within a specific ODD. A human defines that AV's strategic functions and may have to take over the AV's operation during a DDT fallback to bring the AV to a minimal risk condition.

Sources: SAE International 2021; H.R. 3388, SELF DRIVE Act, 2017–2018; DOT 2021.

To some degree, AV technology has become ubiquitous. Most automakers offer cars with level 1 forms of driver assistance. Over the past several years, several carmakers have introduced level 2 technology, including Ford's BlueCruise, General Motors's Super Cruise/Ultra Cruise, and Tesla's Autopilot system.[6] Each of these technologies allows a car to steer and navigate itself (including through acceleration and braking) under many conditions, particularly on major highways; that said, drivers are expected to supervise them. Tesla has started scoring driver safety and requiring drivers to hit a specific average safety score before they can use its Autopilot technology.[7] Honda and Mercedes-Benz offer level 3 technology on some vehicles in Japan and Germany, respectively, allowing drivers to not monitor the highway in certain conditions unless the vehicle requests assistance.[8]

More advanced AVs—levels 4 and 5—are at an earlier testing stage and are not yet available for individual consumer purchase. Waymo provides automated ride-hailed services in Phoenix, Arizona, with an "autonomous specialist" who supervises the vehicle and passengers; May Mobility uses modified automobiles to serve public transit routes in Ann Arbor, Michigan, and Arlington, Texas; and Transdev uses very small bus-like vehicles manufactured by Easy Mile to provide select transit services in locations in California, Florida, North Carolina, and Virginia. May Mobility and Transdev both have fleet attendants (similar to autonomous specialists) on board, and Cruise has plans to roll out similar services in San Francisco.[9] Several other car manufacturers are testing fully autonomous vehicles (with ADS and without driver assistance), though without nonemployee passengers inside.[10] These operations typically use heavily modified consumer market vehicles, such as the Chrysler Pacifica for Waymo and the Chevrolet Bolt for Cruise. In their current form, most of the these more advanced AV operations feature a remote human driver—an individual who can drive the car manually from an offsite location if the automated system fails. Whether AVs will continue to need such remote human backup in the future is an open question.

Because of federal limitations on innovative vehicle designs, purpose-built AVs—such as those with no steering wheel or driver's seat— have not been significantly tested on public roads. But both Cruise and Zoox have announced designs for level 5 AVs with no steering wheels or any provisions for drivers whatsoever.[11] Although its vehicle is designed for freight use, Nuro is the only AV company thus far to receive an exemption from vehicle design standards, which we detail below (Caporal et al. 2021). As of summer 2022, both General Motors (working with Cruise, its subsidiary) and Ford have petitioned the US government for exemptions as well, with the goal of serving more passengers. If approved, the exemptions would allow each manufacturer to produce and put into operation up to 2,500 truly driverless vehicles.[12]

Understanding the technical framework of AV operations and their rollout to date helps us consider the different ways these vehicles might operate. These operations are poised to have significant impacts, both on the US ground transportation system as a whole and for equity of access, as we describe later in this report. But those impacts depend on whether AVs are deployed as shared vehicles; whether they are powered by fossil fuels or electricity (and whether the electricity is generated from renewable sources); whether they are accessible for people with disabilities; and whether they are safer than human-driven automobiles.

Key Research Questions

With the advent of more advanced AV technology, the rollout of these vehicles will require a thoughtful regulatory approach to ensure that they contribute to a more equitable, environmentally sustainable transportation system. Orienting policy toward achieving these goals is all the more important because of the possibility that AVs could magnify inequities and pollution levels rather than reducing them, depending on the drivetrains manufacturers select and the cost and travel-time reductions AVs may engender. Our goal for this project, then, was to address the following questions:

1. What is the current AV regulatory environment at the local, state, and federal levels throughout the United States?
2. Which individual regulatory and legislative elements are likely to expand access to historically disenfranchised communities, encourage economic opportunity, and mitigate negative environmental outcomes?

We focus on recommendations for the federal government, which we believe can play an important role in helping lead in the creation of a more equitable and environmentally sustainable transportation system. Nevertheless, our report also evaluates current and potential regulatory approaches at the local and state levels, because any AV service will be subject to policy constraints or opportunities imposed or encouraged by all three.

We limit our analysis to passenger car–sized AVs, meaning those that are currently deployed for ride-hailing services in several US cities and potentially available for individual purchase in the future. We intentionally concentrated our recommendations on this subset of the overall AV field, which has received the most attention by scholars, policymakers, and the media in recent years.

Data and Methods

We began by conducting a broad overview of the current status of AV–related regulations and policies throughout the United States. To our knowledge, this is the first comprehensive analysis of AV–related rules to date. By understanding what policies are currently in place and what policies have been proposed, we can better predict the effectiveness of future policy.

We conducted a review of relevant scholarship, interviewed key stakeholders nationwide, and reviewed legislation and regulations oriented around AV rollout.

Scholarship Review

The findings from our review of recent scholarship related to AV rollout are referenced throughout this report. They contributed to our understanding of the distribution of current regulatory capacities and informed our recommendations for government interventions related to AVs.

Our review identified several dozen particularly relevant articles or book chapters. For each piece, we evaluated its approach and findings. We then coded unique elements in a spreadsheet that contained the key themes highlighted in this report, including vehicle design, vehicle operation, consumer-facing issues, street standards, and other areas. For each of these themes, we developed subthemes (e.g., vehicle crashworthiness under the vehicle design theme or cybersecurity under the vehicle operation theme); in total, we identified 22 subthemes for coding. We used this coding mechanism to organize our findings and recommendations in the following sections.

Interviews

To further our understanding of AV impacts and potential mechanisms to regulate them, we conducted semi-structured interviews with a small cohort of stakeholders to identify what regulatory elements at the federal level could be most effective in building a better mobility system. We interviewed policymakers, staff at AV companies, researchers, and community leaders representing historically excluded residents as part of this work. We identified interviewees through web searches, communication with colleagues, and snowball sampling. The interviewees included:

- An academic who studies AV policy and rollout;
- an entrepreneur who has written and spoken extensively on potential AV impacts;
- four advocates for three national nonprofit organizations representing underserved minority groups;
- two staff members of two national automotive industry organizations;
- a staff member of a company developing AV software technologies;
- two staff members of a company providing AV services;
- and a staff member of a company investing in AV technology.

To ensure that the interviewees were able to speak openly about their experiences and thoughts related to AVs, we maintain their anonymity in this report.

Legislative Review

We conducted a comprehensive review of available regulations and legislative tools, identifying shared characteristics and differences that may impede or support equitable AV rollout. This review included a targeted look at the ways in which each regulation is likely to influence the equity and sustainability of the mobility system. In other words, we examined which individual regulatory and legislative elements are likely to expand access to historically disenfranchised people, encourage economic opportunity, and mitigate climate change, and which are likely to do the opposite.

Using the Autonomous Vehicles State Bill Tracking Database, published by the National Conference of State Legislatures and last updated in May 2022,[13] we identified all AV–related legislation enacted by state legislatures between 2017 and 2022. We then summarized each bill on a spreadsheet (appendix A provides a sample of such laws) and coded their key characteristics to identify how state governments have established their role regarding AVs.

As part of this review, we also explored previous proposals for federal AV regulations. Although these bills did not become law, they provide context for how federal legislators have conceptualized their role. Finally, for a comparative perspective, we examined current European Union policy on AVs.

Limitations

Our research has several limitations. We were unable to examine all AV–related scholarship, and our interviews were limited to a small group of the many people who have views on regulating AVs. It is quite possible that we missed out on important perspectives. Although we took a broad perspective in examining state laws, there are surely many bills under consideration that are piloting innovative, new mechanisms to ensure that AVs improve mobility and access; we believe that additional research is needed to ensure that all aspects of AV policy are appropriately evaluated.

Our focus on passenger-carrying, automobile-sized AVs means we do not provide policy recommendations on larger AVs for public transportation, freight, or other AV uses. Autonomous technology will greatly affect these transportation modes as well, but they likely will require distinct regulatory approaches.

Finally, we do not discuss the potentially significant impacts of AVs on the workforce, such as in ride hailing (Ao, Lai, and Li 2021) or among freight drivers, where AV technology could result in a widespread displacement of human drivers and negatively disrupt the economy. Without programs to ensure upskilling of current transportation workers into new employment, a rapid AV deployment could lead to unemployment for millions of Americans. Black people are overrepresented in occupations such as taxi driving and trucking, indicating that the effects of AVs on job loss could be racially inequitable (Patterson 2021). At the same time, AV deployment could expand employment opportunities for people who currently have inadequate mobility options and improve productivity for people who use vehicles as part of their day-to-day jobs (Beede, Powers, and Ingram 2018). Analyzing these myriad possibilities, however, is beyond the scope of this paper.

How Might AVs Affect Transportation and Land-Use Systems?

AVs in some ways represent a paradigm shift for road use, and their growing use in the coming years could dramatically shape the ground transportation system writ large by improving equitable access to mobility. In this section, we point to several potential implications of AVs, drawing from our review of recent research on the subject and interviewee responses. AVs could increase equity by reducing transportation-related fatalities, which disproportionately affect people of color (Hamann, Peek-Asa, and Butcher 2020); increase access to transportation options for people with low incomes, people of color, and people with disabilities; and reduce carbon emissions through electrification, but these potential benefits depend on regulations that make AVs safer, cheaper to use, and more environmentally sustainable than cars on the road today. We conclude this section by noting the challenges and uncertainties around the future of AVs: fully driverless vehicles remain in development, and AVs will likely remain in mixed operation with human-driven vehicles for decades, raising further questions about their impact on traffic safety.

AVs' Impact on Transportation Systems

Replacing human drivers with automated systems offers several potential upsides, assuming that AVs are better at detecting potential crashes and avoiding pedestrians and cyclists.[14] Widespread adoption of AVs could reduce the incidence of fatalities and other major injuries as well as reduce net societal costs, despite the expense of AV technology (Harper, Hendrickson, and Samaras 2016). Automobile-related fatalities disproportionately affect people of color and take the lives of tens of thousands of US residents each year. If AVs are better drivers than people, they could use road space and fuel or electricity more efficiently through automated speed adjustments and lane maneuvers (Fagnant and Kockelman 2015). They could automatically provide authorities with data on crashes and other roadway incidents and keep everyone on the road safer in the process (Prahl and Teng 2022).

An AV approach that prioritizes or includes mandates for electrification could mitigate the adverse climate impacts of the current US transportation system. Interviewees emphasized that because AVs leverage new technologies, they may be more likely to use electric propulsion. In addition to benefiting

the environment, people with low incomes and people of color would see better health outcomes and quality of life. These populations are more likely than wealthier people and white people to live in neighborhoods near highways and other major thoroughfares, where they face greater exposure to harmful particulate emissions from tailpipes that are known to increase the risk of lung cancer (Boehmer et al. 2013).

Even so, AVs may also produce several potential downsides for the transportation system. The first problem is that there is no evidence that AVs in testing today—or AVs in the future—will deliver the benefits described above. We do not know, for example, whether AVs are or will be better at driving than humans, because there is inadequate evidence or experimentation to determine whether that is the case. It is possible that a world in which AVs are widely used is actually *less* safe for pedestrians and others on the road, either because of poorly conceived software or software that is biased against the needs of people outside of cars. Similarly, we cannot be certain that AVs will reduce greenhouse gas emissions from transportation. Many level 3–5 AVs currently being tested, and many level 2 AVs in consumer operation (apart from those manufactured by Tesla), remain powered by fossil fuels—and even those using electricity could still source that power from fossil fuels rather than renewables (Freemark, Nassir, and Zhao 2022).

Experts we interviewed said that current Lyft and Uber ride-hailing options cost between $2.50–3.50 per mile, but shared AV rides could cost less than $1 per mile—potentially even cheaper than public transit, depending on the number of people using a bus or train and whether the transit is automated. The low potential costs of AVs, however, are based on early assumptions about advancements in technological deployment, which could be proven wrong.[15]

If AVs do make it easier and less expensive to move around, they could encourage additional VMT. These increases could result in more congestion, not less, on highways and urban arterials and decrease overall transportation system performance. However, some of the increase would likely be the product of increased mobility among historically underserved groups, such as people with disabilities and the elderly (Harper et al. 2016). Interviewees noted that AVs could reduce the opportunity cost of time drastically, since riders can work, sleep, read, or watch television while moving—which in turn may encourage more driving. Experts emphasized that people will likely continue to have a personal preference for staying in their own vehicles—in part because of low travel costs—thus reducing the likelihood of shared-ride AVs becoming the norm. Because of these lower costs, AV users may also be more likely to move further from their jobs (assuming ADS technology functions in more remote areas), thus increasing sprawl and all of the negative externalities associated with it, including poorer health

outcomes, higher exposure to traffic crashes, and inequitable regional development, cutting people of color and people with low incomes off from opportunities (Ewing and Hamidi 2017).

Easier access to AVs could also mean a modal shift away from public transportation (Abe 2021), diminishing political and ultimately financial support for bus and rail systems nationwide. Some studies show that existing ride-hailing options reduce ridership in large cities with effective transit (Barajas and Brown 2021). Yet other experts suggest that AVs could increase public transit use if deployed in a shared fashion and through multimodal integration (Liu, Qu, and Ma 2021), and some studies have shown that human-driven ride hailing can complement, rather than substitute, transit use (Hall, Palsson, and Price 2018), especially for commuter rail (Babar and Burtch 2020). One interviewee emphasized the way AVs could expand on this feature: "When you get to autonomous, they can be running 24/7," they said. "They can, you know, be roving networks and fleets of electric vehicles; people can get connected to the transit much more easily." And interviewees emphasized that AVs could increase access to mobility for people who are currently unable to use public transit. Forty-five percent of Americans have no access to bus or rail service, and only 5 percent of workers in the US commute via public transit (Burrows, Burd, and McKenzie 2021).[16] If fleet-based AVs become cost- and time-competitive with personal automobiles, they could increase access to opportunity for many households, filling these gaps.

Because AVs collect and maintain considerable data about their own movements and, in ride-hailing situations, their passengers, AV deployment could raise significant privacy concerns. If AVs do not have adequate precautions to preserve cybersecurity, people's data could be inappropriately shared—and vehicles could be commandeered maliciously (Tan and Taeihagh 2021).

AVs' Impact on Equity of Access across the United States

We introduced this paper by emphasizing the failures of the current transportation system in providing people with adequate access to employment, education, and health care, among other needs. But access to mobility is unevenly distributed.[17] Indeed, in the United States, non-Hispanic white individuals are, on average, wealthier and better able to afford the costs of car ownership than other groups, often giving them easier access to employment (Gautier and Zenou 2010). Moreover, people with low incomes and communities of color are disproportionately affected by other ills of the transportation system, including traffic fatalities, encounters with the police, and pollution.

In this report, we consider whether AVs will make a positive dent in reducing those inequities. The fact that AVs could provide new mobility options for those who are young, old, and disabled could represent a positive change for people who are largely excluded from the current system (Fagnant and Kockelman 2015). Perhaps, if offered affordable access to this mode of transportation, more people would be able to successfully participate in society.

Because they do not require driver supervision, manufacturers can design level 4–5 AVs in innovative ways that leave significantly more room for people with disabilities. Low-floor, open floorplan AVs could allow wheelchair users to maneuver directly onto the vehicles far more easily than onto human-driven vehicles with forward-facing seats. People who are blind often struggle to use public transportation, cannot drive, and often cannot afford the high costs of daily human-driven, ride-hailing use. AVs could include sound features and easy-access doors and require no-stair entry, all of which could aid people with difficulty seeing. One interviewee emphasized:

If we are able to get a fleet of autonomous vehicles that blind and low-vision people are able to access, it will open up an avenue for us not to be so dependent on taxis and even ride sharing [that] get pretty costly and create dynamic opportunities for blind people to engage in employment that they previously could not.
—Advocate for a national nonprofit organization representing the blind

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AVs could also increase access to ride-hailing options in communities that predominantly comprise residents of color or residents with low incomes since they remove the unconscious and conscious biases of human drivers that sometimes hinder equitable service. For instance, studies show that current ride-hailing services such as Lyft and Uber underprovide travel options in less wealthy and less white neighborhoods (Barajas and Brown 2021). Even without drivers, however, fleet AV operating companies could program their cars to focus services in higher-income neighborhoods—and locate their charging stations there—because they assume that these communities will more frequently use their services. Such disproportionate service across neighborhoods could also be a product of algorithmic biases used by AV providers, which rely on data about potential users that may be skewed (Danks and London 2017). That said, lower costs overall for AVs could mean that companies will view more neighborhoods as profitable for service provision (Ao, Lai, and Li 2021). Eliminating the inequitable

distribution of operations may require additional regulations, which could include providing a minimum level of service in communities that are predominantly populated by people with low incomes.

If AVs ultimately reduce traffic crashes—which is not guaranteed—they would, in theory, save lives and prevent major injuries for everyone. But automated detection systems may have biases of their own. Recent research indicates, for example, that pedestrian detection mechanisms currently under development are more likely to miss children or not "see" them, putting this vulnerable population at risk (Brandao 2019). We do not know enough about ADS or ADAS technology to know whether it is liable to disproportionately miss detection of people of color, people in wheelchairs, or other groups—raising ethical concerns about whether these vehicles will address the biggest failures in transportation safety (Lim and Taeihagh 2019).

Finally, by eliminating drivers, AVs could reduce the number of dangerous encounters that occur between motorists and the police—encounters that disproportionately affect people of color and sometimes result in violence (Talbott 2021). Assuming that AVs follow the law and that police enforce the law, passengers would ostensibly no longer face the risk of these interactions. However, at this early stage in the rollout process, we may be underestimating the potential for discriminatory treatment by other means.

There are additional reasons to be skeptical of the most optimistic predictions of AV impacts. First, as a new technology, Nair and Bhat (2021) argue that younger, male, wealthier, and more educated individuals will be most likely to adopt AVs. This gap could mirror the inequitable rollout of other recent technologies, such as broadband internet, which may have reinforced preexisting inequalities. Second, many of the potential benefits of AVs are predicated on the assumption that AV rides will be cheaper than current ride-hailing options. But the cost depends on whether AVs are individually owned and used or fleet-owned and shared; the latter could support less overall VMT but may be difficult to achieve in the context of cheaper transport overall (see box 2 on shared vehicles, below).

Finally, AVs may expose users to concerning liability issues. Without clear regulations from governments, AV technology providers may attempt to shift responsibility for crashes or other problems in the roadways from the AV software or vehicle to the AV user, in the case of private vehicle ownership. In 2022, Los Angeles County filed manslaughter charges against a man who was using Tesla's Autopilot system (which may be classified as a level 2 AV, since it technically requires human supervision at all times—though many users may not realize it). The man's car ran into another vehicle, killing the passengers within it.[18] To make matters more confusing, Tesla has been found to shut down Autopilot one second before crashes, in essence forcing a DDT fallback with no ability for the driver to

actually respond.[19] The California Department of Motor Vehicles recently accused Tesla of making false or misleading claims to consumers about its autonomous systems, noting that Autopilot—despite its name—cannot operate a Tesla as a fully autonomous vehicle.[20]

Level 3 AVs, which do not require human supervision in the ODD, could raise even more concerns. And there is no jurisprudence on who is liable for crashes involving personally owned level 4–5 AVs that have no driver at all. If governments do not rectify these liability concerns, AV passengers may find themselves at risk of being held financially and criminally responsible for situations they arguably did not cause. Such outcomes are far less likely to occur with fleet-owned AVs, since riders would not be liable for vehicular operation; this suggests an additional benefit of a shared ridership model over individual ownership. Moreover, the fact that people residing in majority-Black communities are more likely to pay more for automobile insurance than people living in majority-white communities—even if the former group of people are good drivers—suggests the possibility of racially inequitable outcomes for AV liability in the future (Feltner and Heller 2015).

Challenges in Predicting AV Impacts

One of the key challenges in evaluating the possible impacts of driverless AVs in the short term is that the timing of their rollout remains unknown. Waymo, as of this report's publication, is testing level 4–5 AV operations with passengers in Phoenix. But this technology may have years to go before reaching the point of safe, full-scale operation nationwide, even if the regulatory environment encourages it. Given the unpredictability of technological development, we cannot easily predict AV outcomes and the variations in those outcomes that depend on environmental factors. It is also difficult to estimate how quickly the national vehicular fleet will convert to AV operation, if ever.

To make matters more complicated, the pandemic has put into question the future of certain ride-hailing services. In the mid-2010s, companies like Lyft and Uber began offering shared-ride options in which customers were given reduced fares in exchange for combining their rides with those of strangers along the route. In theory, the companies expected that pooled rides would reduce overall VMT and improve the performance of ride-hailed services. But with the onset of the pandemic in 2020, Lyft and Uber shut down shared rides, only partially restoring the service as of summer 2022.[21] One interviewee noted that women in particular were worried about their safety when riding with strangers, given their experiences with public harassment and other safety threats. One question for AV rollout is whether such pooled rides will be commonplace—an assumption that would contribute to those vehicles' environmental sustainability and efficiency (box 2).

We also asked interviewees when they think the United States will see full vehicular automation or when level 4–5 AVs will be fully deployed. Their answers ranged from beyond our lifetimes to arguing that full autonomy is already in operation, pointing to the level 4 AVs currently in testing. Others suggested that rollout would come in the next decade or two. Experts emphasized that the main barriers to level 5 deployment include high-profile crashes that reduce people's trust and thus slow the rollout, gradual technological advancement, problems with handling weather, and inadequate mapping capability necessary for the reliable functioning of ADS technology. The federal government's limitations on exceptions to current vehicle design standards (see next section) present an additional wrinkle in the path to widespread AV use.

BOX 2

AV Sharing: Potentially Beneficial, but Potentially Impractical

There are two ways of describing "sharing" in the context of AVs. The first is in terms of shared vehicles, meaning that a car is shared by strangers but during different trips, such as through a car rental or short-term car-sharing service (e.g., ZipCar). It could also occur through ride hailing (e.g., taxis, Lyft, and Uber), in which customers request a ride for a specific trip at a specific time through an app or some other means. Companies typically own shared vehicles and operate them as fleets. Although ride-hailed vehicles may provide people with a convenient travel option, Shaller (2021) finds that they double VMT compared with the rides they replaced, suggesting that shared vehicles alone—whether AVs or not—could worsen environmental outcomes. Others have estimated less dramatic changes in VMT.

The second description of "sharing" involves shared trips, meaning people who are strangers sharing part or all of a trip. This can occur through ad hoc carpooling (e.g., "slug lines") and through pooled trips scheduled by ride-hailing companies. Freemark, Nassir, and Zhao (2022) emphasize that AV pooled trips could provide mobility services for trips that do not attract adequate ridership to merit a public transportation option. Although slower than nonshared rides, Schweiterman and Smith (2018) show that shared rides can offer quicker, though more costly, trips than public transit. And Shaheen (2018) emphasizes that shared rides could lower travel costs and improve the environmental efficiency of the transportation system overall.

The first level 4–5 AVs will be fleet-operated, shared vehicles, and that type of service is likely to continue by partly or fully supplanting human-driven ride hailing once companies widely deploy the technology. Given tight current federal restrictions on the number of vehicle design exemptions for manufacturers and the lack of ADS–equipped vehicles for sale to consumers, individual ownership of driverless AVs is unlikely in the near term.[22] This could change with reformed federal regulations, though in any conceivable case, companies would maintain the ADS used to navigate all cars, even those that are individually owned. One potentially interesting use of personally owned level 4–5 AVs could be renting them to others when not in use by the owner. Similar to the Turo model, someone with an AV could reserve it for their own use during the day, but if they hope to make a few extra dollars, they can

set it loose as part of a network to pick up and drop off strangers during the night through a ride-hailing operation.

Whether AVs will provide shared-ride services, however, is another question. California allows shared rides through its AV deployment program, but no company currently offers such services. Providing shared rides is key to improving their cost, traffic, and environmental impacts, since sharing can allow more efficient use of each vehicle and thus lower costs, miles, and emissions per passenger. But human-driven ride sharing has absorbed only a small share of the ride-hailing market (Hou et al. 2020). Some may find the relatively confined environment of a car's backseat uncomfortable to share with strangers. It is also unknown whether passengers will consider it safe to share a ride with no driver to intervene in the case of an emergency, harassment, or even violence between riders.

Recent research (Lavieri and Bhat 2019), however, indicates optimism for passenger willingness to ride-share in AVs. Alternative designs for such vehicles—for example, partitions dividing space between strangers—could open new opportunities for comfort. And while drivers today may be somewhat hostile to shared rides, which they sometimes consider difficult to manage, AVs would have fewer difficulties.[23] However, more evidence is needed to show that people will widely accept such trips.

Sources: Freemark, Nassir, and Zhao 2022; Hou et al. 2020; Lavieri and Bhat 2019; Schaller 2021; Schweiterman and Smith 2018; Shaheen 2018; Young, Farber, and Palm 2020.

Current and Recently Proposed AV–Related Regulations and Legislation

The United States distributes policymaking authority in many domains to the federal, state, and local governments, and the transportation system is no exception. Choices around AV regulation will inform the degree to which these vehicles help us achieve the goals of a more equitable and environmentally sustainable mobility system. But determining which level of government will or should take on different types of regulations is an important first step in this process. States are already taking a wide variety of approaches to testing AVs, with some welcoming new vehicles with open arms and others acting with much more hesitancy (Fagnant and Kockelman 2015).

In table 2, we summarize the components of the automobile system and the roles that different levels of government come to play in regulating it. Where such information is available, we emphasize what areas of regulation particularly relate to AVs. We base the following summary on our review of scholarship, examination of legislation, interviews with stakeholders, and comments from peer reviewers. We focus on four key domains—each representing several relevant policy areas—in which government regulation may influence the ways AVs operate:

- Vehicle design
- Vehicle operation
- Consumer standards
- Street standards

Table 2 emphasizes that the federal government now has virtually complete control over regulations related to vehicle design through Federal Motor Vehicle Safety Standards (FMVSS), developed by the National Highway Traffic Safety Administration (NHTSA). The federal government is also involved in regulating emissions, has partial involvement in vehicle operation and consumer standards, and has little role in developing street regulations. State governments play a major role in vehicle operation and consumer standards and engage in elements of street standards. Finally, localities have the most influence over street standards and transportation infrastructure design. This distribution of powers is not set in stone but illustrates the range of decisions made by different levels of government—many of which are responding to automakers' desire for clear, standardized rules related to automobile design and rollout nationwide.

TABLE 2

Current Distribution of Jurisdiction over Policy Related to the Automobile System and AVs

Domain	Policy Area	Federal Government	State Governments	Local Governments
Vehicle design	Manufacture and design	▪ NHTSA issues Federal Motor Vehicle Safety Standards (FMVSS), including occupant crash protection standards ▪ No specific rules for AVs, but manufacturers can receive up to 2,500 vehicles per year exempted from standards	▪ Some require AVs to meet FMVSS to operate on public roads, anticipating future regulations	▪ No role
	Crashworthiness	▪ NHTSA conducts New Car Assessment Program for new passenger cars; no specific rules for AVs	▪ No role	▪ No role
	Protections for pedestrians, cyclists, others in the right-of-way (vulnerable road users)	▪ No role, though during its review for exemptions to FMVSS, NHTSA examines protections for vulnerable road users	▪ No role	▪ No role
	Efficiency	▪ NHTSA issues Corporate Average Fuel Economy Standards; no specific rules for AVs	▪ Some states regulate vehicle fuel economy (especially California's rules for light and heavy-duty vehicles)	▪ No role
Vehicle operation	Crash reporting	▪ NHTSA requires manufacturers and operators to report crashes involving level 2–5 AVs under a standing general order	▪ State departments of transportation typically require reporting of all vehicle crashes	▪ No role
	AV operational standards	▪ No role	▪ Some have established basic AV operational standards, including requirements related to developing passenger safety plans and law enforcement interaction plans; in general, states enforce rules related to vehicle moving violations	▪ No role
	Liability and insurance	▪ No role	▪ Impose required insurance coverage and minimum liability limits	▪ No role

	Data	▪ US Department of Transportation guidance recommends that companies have certain procedures in place for recording data and sharing it with NHTSA	▪ Some have required anonymized data to be shared with the government from AVs in testing and ride-hailing capacities	▪ No role
	Inspections	▪ No role	▪ DMVs typically oversee safety and emissions inspections	▪ No role
	Cybersecurity protections	▪ NHTSA has developed a series of cybersecurity measures it recommends manufacturers use	▪ No role	▪ No role
	Equity in operations	▪ No role	▪ California requires ride-hailing providers (AV and not) to provide data on locations of pickups and drop-offs to inform future equity metrics	▪ No role
	Environmental impacts	▪ No role	▪ California is developing emissions standards for fleet-owned, ride-hailing companies, which could eventually apply to AVs; California S.B. 500 requires AVs to be zero emissions by 2030	▪ No role
Consumer standards	Information	▪ Environmental Protection Agency provides data on gas mileage and NHTSA provides data on crashworthiness	▪ States impose sales requirements	▪ No role
	Taxes and fees	▪ No role	▪ Sometimes impose vehicle registration fees. California has taxed AV ride-sharing trips	▪ Sometimes impose vehicle registration fees; some cities have additional fees on ride-hailing services
	Ride-hailing requirements	▪ No role	▪ Sometimes impose rules related to service requirements, costs, and safety for passengers	▪ Sometimes impose rules related to service requirements, costs, and safety for passengers

	Vehicle accessibility (meeting Americans with Disabilities Act standards)	▪ No role	▪ California requires ride-hailing providers (AV and not) to share data on requests for accessible vehicles and successful trips	▪ Some require a minimum share of ride-hailed fleet to be ADA accessible
	Registration and permitting	▪ No role	▪ State DMVs typically regulate registration; some are developing AV permitting programs	▪ No role
	Subsidies	▪ No role	▪ No role	▪ Some provide ride-hailing subsidies for certain users
Street standards	Signage and markings	▪ Federal Highway Administration publishes the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD); no specific rules for AVs	▪ May add specific signage for streets under their jurisdiction	▪ May add specific signage for streets under their jurisdiction
	Pedestrian and cyclist protections	▪ No role outside the MUTCD	▪ Some states have specific requirements, such as for crosswalks	▪ Some cities have developed vision-zero plans designed to reduce pedestrian and cyclist fatalities through street design
	Access and curb use, geofencing	▪ No role	▪ May impose specific rules related to road access; some have preempted local regulation of AV road use	▪ May impose specific rules related to road access on streets they control, enforce nonmoving violations such as double parking, and can designate lanes and curb space for certain uses
	Crash response	▪ No role	▪ On major roads, state sheriffs may become involved; regulate general interactions with law enforcement	▪ Police and sheriff departments typically respond

Source: Authors' review of scholarship and interviews.
Notes: AVs = autonomous vehicles. NHTSA = National Highway Traffic Safety Administration. This table is not meant to be all-encompassing.

In the next several sections, we describe how recent local, state, and federal regulatory and legislative efforts have sought to entrench or, alternatively, transform the distribution of jurisdiction over automobile policy shown in table 2 for the purposes of AV use.

Recent Federal Efforts Related to AV Regulations

The United States has pursued a slow but steady approach to generating AV–related regulations, both through attempts at legislation and proposed rulemaking. These rules could supplement or supersede FMVSS, which apply to all new vehicles—AV or not. Currently, those rules dramatically limit level 4–5 AVs from operating in most places, since they allow automakers to apply for only up to 2,500 exemptions annually to test alternative designs (such as automobiles without a steering wheel or windshield wipers). This restriction has limited the speed of rollout for vehicles that are truly driverless in form and function (Caporal et al. 2021). That said, the federal approach has largely been to underemphasize the government's role in leading the transition to AVs in favor of listening the automobile industry's priorities (Canitez 2021).

Rulemaking for AV Standards

Since 2016, the US Department of Transportation (DOT) has produced a series of AV–related policy documents with the goal of developing voluntary guidance for manufacturers and others involved in AV development (DOT 2016; NHTSA 2017; DOT 2019; NSTC and DOT 2020). Despite these plans and advancement in AV technology over the past few years, the federal government has continued to treat vehicles with autonomous features as conventional vehicles, including by enforcing the same general safety standards it applies to human-driven cars (Yacoub and Briggs 2022). The department's most recent document, the Automated Vehicles Comprehensive Plan, identifies three major goals for future AV policy: promoting collaboration and transparency, modernizing the regulatory environment, and preparing the transportation system for transition (DOT 2021). Although the plan does not regulate any specific actions by AV manufacturers or operators, it emphasizes the need to prioritize safety, cybersecurity, privacy protection, increased accessibility, and US technological innovation. It proposes a DOT–initiated rulemaking process to modernize regulations and promote consistent standards related to AVs, but this process has yet to begin (apart from a stalled commercial vehicles rule[24] that was proposed in 2019 but has not advanced). NHTSA has simultaneously developed optional design guidance for interfaces between drivers and vehicles, cybersecurity, and level 2–3 AVs (NHTSA 2016; Campbell et al. 2016; Campbell et al. 2018).

NHTSA has also developed and solicited comments on three rules. The first, completed in March 2022 (NHTSA 2022a), mandates minimum occupant protection standards for AV users under FMVSS, requiring vehicles to meet the same minimum protection levels as other passenger cars. Although the rule clarifies that AVs may not have a steering wheel, other driver controls, and traditionally positioned seats, the rule itself only applies to passenger vehicles with standard seating configurations. This rule was appended to a 2021 NHTSA mandate that requires all level 2 ADAS and level 3–5 ADS–related incidents to be reported for examination. NHTSA's recent summary of such incidents shows that vehicles using such autonomous features have been involved in 367 crashes between July 2021 and May 2022, resulting in six fatalities (NHTSA 2022b). The agency has not yet calculated whether this crash rate is lower than that of human-driven cars experiencing similar roadway conditions.

NHTSA has two other rules under development at the prerule stage as of summer 2022.[25] The first would alter minimum standards related to crash avoidance in the context of alternative AV designs, such as those with variations in seating positions compared with driver-operated vehicles. The other rule would develop a framework for automated driving regulations that would define standards for innovative AV designs. These rules could result in both voluntary and mandatory mechanisms related to safety and performance, but they remain under development.

For comparison, the EU developed a similar series of strategies for AV deployment, though these strategies thus far do not prescribe specific outcomes (box 3).

BOX 3

The European Union's AV regulations

As a federation of many national governments, the European Union (EU) has declared that individual member states are responsible for encouraging AV testing and deployment, but also acknowledged the importance of cross-border regulation regarding automated driving systems to ensure transportation options across the continent (EU 2016). The European Commission (the EU's executive branch), Council of the EU (a legislative branch comprising member state ministry representatives), and the EU parliament are collectively responsible for coordinating a framework to regulate AV mechanics and software, supporting cross-border initiatives to deploy and test AVs, and investing in AV infrastructure.[26]

Following several years of declarations and resolutions about the appropriate path forward, the EU published a set of comprehensive AV regulations in July 2022 that include performance requirements and a compliance assessment. The performance requirements specify what capabilities an AV must have to receive approval for sale or use in Europe.[27] The requirements identify how level 3–5 AVs must respond in several different scenarios. The performance requirements also implement standards for functional and operational safety, in addition to cybersecurity requirements. And a recent study recommends EU–wide liability requirements for AVs (Evas 2018).

Although the EU has yet to pass legislation specifically regarding AVs, it regulates many features of vehicle operation, vehicle design, liability, and data protection that apply to AVs (Evas 2018). Like the United States, the EU issues type-approval requirements for the general safety of motor vehicles and their components.[28] The EU, unlike the United States, has detailed requirements for protecting the safety of vulnerable road users, such as pedestrians and cyclists, including mandates related to vehicle design and crash testing.[29] Member states have the capacity to provide exemptions to these laws, however, which may be relevant to AVs, depending on their designs. The EU does have an exemption cap by state, which industry stakeholders such as Waymo argue should increase to accommodate AVs.[30]

Source: Authors' examination of legislation and policy on AVs from the EU.

Legislation

In 2017, members of both the US House and Senate introduced legislation to create a framework for federal policy related to AVs. Although no such legislation has become law—despite repeated efforts[31]—we can learn about Congress's general approach by examining bills that have been introduced. The SELF DRIVE Act,[32] which passed the House but was not considered on the floor of the Senate, would have reserved to the federal government regulations over design, construction, and performance of AVs or automated driving systems. It would have preserved state government primacy over registration, licensing, driver education, insurance, law enforcement, crash investigation, safety

inspections, emissions inspections, congestion management, and traffic. The SELF DRIVE Act also would have required the DOT to develop a rule, updated every five years, establishing how manufacturers would receive certification for AV operation; instructed NHTSA to establish performance standards for human-machine interfaces and sensors; required manufacturers to develop cybersecurity and privacy plans; and expanded the current cap on testing AVs, though manufacturers would still need to provide details about crashes to the DOT.

At the same time, the Senate considered (but also did not pass) the AV Start Act.[33] Like the House bill, the AV Start Act would have preempted state government control of AV policy related to vehicle design, construction, or performance, while maintaining state oversight of sale, distribution, and repair of such vehicles. It would have maintained personal liability for motor vehicle safety standards and required state-level AV operational license distribution compliance with the Americans with Disabilities Act (ADA). The bill also commissioned the DOT's Volpe Center to develop a research report describing minimum safety standards for AVs and asked the agency to develop a rulemaking process one year after the bill's passage. Although the legislation would have required safety reports from manufacturers, it prevented the DOT from conditioning AV manufacture or use on these reports.

Both bills suggest that lawmakers were hesitant to be overly prescriptive in regulating AVs directly, in line with Congress's general approach of asking agencies to design informed regulations—though the Supreme Court's recent rulings may diminish this approach to policymaking (Deacon and Litman 2022; Watts 2014). Rather, the proposed legislation focused on reports, future rulemaking by the DOT, or committee discussions (both bills, for example, recommended committees to study AVs). Neither of the bills would have required AVs to meet a minimum standard of protection for responding to other street users or mandated testing to demonstrate that the AV would perform safely at or above a level equivalent to that of a human driver. This leaves in question whether federal government stakeholders will aggressively move to regulate AVs in a way that prioritizes accessibility, equity, or environmental sustainability.

Some advocates publicly raised concerns about the bills' efforts to preempt state and local oversight of AV operations. Others questioned why the proposals—which included minimal safety requirements and no mandate to ensure pedestrian and cyclist safety—would deprive lower-level governments from deciding whether to allow AVs on their streets.[34] Some promoted the idea of requiring a "vision test" to ensure that AVs would be able to adequately "see" other street users.[35] One peer reviewer noted, however, that because AVs use probabilistic decisionmaking to evaluate their environments, "seeing" hardly works in the same way for an AV as a human. This could pose challenges in evaluating the effectiveness of AV or ADS safety systems. In addition, advocates pointed out that

though the AV Start Act discussed accessibility requirements, it was not specific about how manufacturers could meet these standards; for example, such a policy might require all AVs to accommodate people in wheelchairs by a certain date.[36]

Potential Challenges for State and Local Governments Implied by Recent Federal AV Regulatory Approaches

The federal government's forays into AV regulations have been minimal thus far, focusing on developing plans, integrating level 1–3 AVs into the existing FMVSS safety regulations system, and monitoring crashes through data reporting. But the stalled legislation, including the SELF DRIVE Act and AV Start Act, points to how members of Congress conceptualize their function as maintaining the federal government's traditional role of overseeing vehicle design, manufacturing, safety, and performance issues, leaving state and local governments to make choices about other policies.

This approach has the benefit of maintaining a single standard for manufacturers as they design and develop autonomous systems. It keeps in place the simultaneous regulations of vehicles and vehicle operations by several levels of government that we illustrated in table 2. At the same time, it could potentially endanger people using the AV system by preempting certain regulatory mechanisms at lower government levels, depending on the exact writing of legislation or rules. In other words, by mandating certain requirements about AV design, the federal government may allow vehicles that certain states and local governments consider unacceptable; at the same time, states will likely retain the ability to license and permit vehicles, ultimately determining whether a specific AV design is allowed on their streets. The details of federal rules, and the degree to which they mandate preemption, will determine these outcomes.

State Regulatory Policies Related to AVs

As of summer 2022, the legislative bodies of 41 states and the District of Columbia have passed a total of 122 laws related to AVs or ADS.[37] Since no federal legislation thus far has directly addressed AVs and no federal departments have introduced binding regulations on AV design or manufacture, states have generally acted alone. Legislative approaches to AV regulations vary immensely between states. The states with the most comprehensive AV legislation are those that tend to have very active testing regimes, such as Florida and Nevada, or states with ties to the industry, such as California and Michigan. Some states, including Arizona, have introduced a very permissive regulatory environment to

encourage testing and deployment of AV technology. Others, such as Pennsylvania, have legislators who have been more hesitant to permit AV operation in the absence of federal standards on AVs. Appendix A summarizes several example AV–related state laws we identified. In this section, we provide an overview of the state AV legal environment.

The State of State AV Regulation

Most states lack comprehensive AV regulation and are still in an exploratory legislative phase. Most AV legislation focuses on testing, requests for study, and recommendations for further regulatory action (with almost all legislation focusing on automobile-sized AVs). Most states have adopted definitions for AVs and ADS technology and incorporated them into their legislative codes in anticipation of further regulation. Preempting local regulation is also common, especially for states that have prioritized rapid AV rollout and thus have acted to prevent cities from prohibiting AV access. Table 3 summarizes the frequency with which states have passed legislation across several thematic areas.

TABLE 3

Frequency of State Legislation Related to AVs, by Theme

Themes	Description	Share of All States with Laws in this Thematic Area
Appropriations	▪ General funding to research or test AVs	▪ 4%
Crash reporting	▪ Imposes or adjusts requirements for crash reporting	▪ 8%
Establishment of committee	▪ Law establishes a committee to study, make recommendations, and oversee AVs	▪ 27%
Liability	▪ Describes liability in crash scenarios, liability related to the manufacturer, and liability for vehicle repair	▪ 22%
Registration and permitting	▪ Licensing requirements for the operation of an AV	▪ 20%
Ride hailing	▪ Regulates ride-hailing agencies and services that provide AVs	▪ 14%
Study	▪ Law includes a provision for further study on AVs, with the goal of producing a report	▪ 24%
Taxes and fees	▪ Includes any regulation on AV–related taxation	▪ 8%
Testing	▪ Regulates permits and requirements for AV testing on public roads	▪ 31%

Source: Authors' review of 122 laws passed by states throughout the country, documented by the National Conference of State Legislatures, "Autonomous Vehicles State Bill Tracking Database," updated July 20, 2022, https://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx.

Notes: This table may not be fully comprehensive; we did not examine Puerto Rico or other territories for this analysis. Our review shows that no state has passed a law related to AV vehicle design; cybersecurity; road access, curb use, or geofencing; equity and accessibility; or specific protections for pedestrians, cyclists, and others in the right-of-way. The table should be read as meaning, e.g., 8 percent of all states plus the District of Columbia (four states or state equivalents) have passed laws implementing requirements related to AV crash reporting.

Based on our review, states have made no effort to legislate on issues related to vehicle design, cybersecurity, road access, equity in operations, or specific protections for pedestrians and others in the right-of-way. Part of this hesitation may result from the federal government historically taking on the role in developing vehicle design standards (Smith, Webster, and Stumpf 2021), or it may be reluctance to engage in issues that are potentially more relevant to local jurisdictions, such as street access. On the other hand, a third of states have passed laws encouraging testing, and many have developed rules relating to registration and permitting, continuing the role they have established in relation to vehicles with a human driver.

States with more comprehensive AV legislation have developed rules to issue permits to AV owners to test and deploy them on public roads. They have also established AV operational standards, such as

requiring an operator or safety driver in level 3–5 vehicles at all times, even in the ODD of the ADS (other levels require drivers to monitor all autonomous actions by the car); prohibiting children from riding alone; and requiring the operator to have a valid driver's license. Some states permit operation without a passenger if the vehicle meets federal performance standards, anticipating the establishment of these standards.

One common AV regulation implemented by 47 percent of states establishes a minimum follow distance for vehicles in a connected driving system, such as trucks in a vehicle "platoon." Since AV technology may allow for coordinated braking, vehicles could theoretically travel more closely together at a low risk of crashing, and laws typically reduce the required following distance between platooning vehicles compared with requirements for human-driven cars. Some states have also extended their regulatory jurisdiction over liability and insurance. In most states with AV–related legislation, such as Iowa, the AV's individual or corporate owner is liable in the event of a crash. For testing and operation purposes, the comprehensively regulated states often set minimum dollar requirements for insurance coverage. Finally, seven states have established AV–specific procedures for crash conditions. Each state mandates that AVs stay at crash scenes and wait for law enforcement to arrive.

The states with the most active AV regulatory regimes have taken steps to regulate services using AV technology, such as ride hailing or passenger-less delivery services. California and Nevada, for example, both implemented a tax on AV ride-hailing services. Eight states explicitly permit the operation of AV ride-hailing services, so long as they meet state operational standards. Most states have not yet developed detailed approaches to regulating AVs through state departments—meaning regulations adopted by state agencies, going beyond the law itself—with the exception of California (box 4). California's regulations related to data collection for AV services are, to our knowledge, the most detailed in the country.

BOX 4

California's AV Regulations

California is a hotbed for AV testing, in part because of its concentration of tech companies. Although municipal governments have some role to play in making choices about street use, the California Public Utilities Commission (CPUC) develops regulations related to ride hailing, including for AVs. In 2020, the agency released an extensive set of requirements for all AV operators, regardless of whether the service is designed for passengers or if the vehicle is owned by a company or an individual. All carriers must hold permits from the Department of Motor Vehicles before applying to the CPUC for permits. These requirements apply both to testing and to full-scale deployment as AV technology evolves.

Before the CPUC issues an operations permit for carriers planning to serve passengers with driverless vehicles, operators must develop a passenger safety plan. The plan should show how the operator plans to minimize harassment and assault without a driver; guarantee safe use for all passengers, including those with disabilities; ensure safe vehicular entry and exit; and provide the ability to contact the operator if needed. That said, the commission explicitly does not prescribe targets and instead focuses on developing reporting standards for operators. For operators applying for the CPUC's "deployment" program, designed for operators beyond the testing phase, the agency will be able to collect required data on pickup and drop-off locations (by census tract and ZIP code), availability of accessible rides, service levels to disadvantaged communities, vehicle fuel type, vehicle miles traveled, waiting times and dwell times, vehicle occupancy, and passenger incidents.[38]

The CPUC continues to refine its requirements in response to changing perspectives about AV regulation. But the requirements in their current form are unlikely to increase accessibility for multiple reasons. First, they set no standard for achieving accessibility for all customers, meaning many vehicles are unlikely to be able to provide access for people in wheelchairs or people with other types of disabilities. In a recent series of public comments related to Cruise's application to provide AV service, Disability Rights California protested the plans as inadequately accessible, even as other organizations, such as the California Council of the Blind, argued that the service would provide essential new benefits.[39] Second, as with existing ride-hailing services, the CPUC bans unaccompanied minors from using them, limiting their ability to take advantage of AVs to get around. Third, although the agency officially adopted the equity goal of "improv[ing] transportation options for all, particularly for disadvantaged and low-income communities," its regulations do not include equity targets because the CPUC argues it is too early to do so. Nor will the requirements increase environmental sustainability since the agency does not set goals related to pollution or city planning issues. That said, through the state's Clean Miles standard, the CPUC is pursuing zero-emissions service by all ride-hailing providers by 2030—five years ahead of the state's 2035 requirement that all new light-duty vehicles sold by manufacturers are zero emissions.

Source: Authors' analysis of California Public Utilities Commission, "Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online-Enabled Transportation Services" (San Francisco, CA: 2020).

Limits to Current State AV Regulatory Policies

Since AV legislation in most states largely focuses on developing a framework—rather than instituting complex AV–specific regulations—there are many gaps that states have yet to address. States have, for example, broadly avoided taking action to update traffic laws and regulations to accommodate driverless vehicles. This could include exempting AVs from certain laws pertaining to human drivers and revising definitions of operators and drivers. So far, only five state laws have sought to update their regulatory codes to accommodate AVs.

Just as importantly, only a few states have updated street signage and infrastructure for AVs, and no state has mandated specific right-of-way protections for pedestrians and cyclists. And states have done very little to ensure accessibility and equity in AV services within their borders. No state legislation includes provisions guaranteeing AV service to disabled people or underserved communities, such as those living in public housing. Across the board, equity remains unaddressed by AV legislation. While some tout the potential environmental benefits of AVs, few states have passed laws that ensure these benefits. California's S.B. 500 mandates that all AVs must be zero emissions by 2030 (and the Clean Miles standard will require zero emissions for all ride-hailing services; see box 4), but this is the sole example of such a requirement. Finally, the internet connections and inter-car communication that are likely to feature prominently in all ADS technologies present a potential cybersecurity and data-sharing challenge. As noted above, California has mandated certain data-sharing standards, but no state has passed legislation specifically addressing cybersecurity.

Challenges for Local Governments Imposed by State Regulations

As with any federal regulation, state-imposed rules may sometimes preempt the specific needs of localities. Among the laws we studied in our review of state legislation, 13 specifically defined the purview of local governments over AV regulations. The California Public Utilities Commission (CPUC) regulation related to AVs prevents local governments from banning testing on their streets, with the CPUC arguing that such preemption is necessary to avoid a patchwork of policies that hand municipalities veto power over operations within their boundaries (2020). Yet localities may consider such limitations as inhibiting their ability to ensure safety and guarantee equity of access—concerns raised by local agencies such as the Los Angeles and San Francisco departments of transportation in response to the proposed CPUC regulations.

Metropolitan areas across the United States have increasingly integrated AV planning into their regional plans, suggesting interest in the technology (Guerra 2016). And staff in local planning offices

have expressed optimism about planning for AVs (Freemark, Hudson, and Zhao 2020). Nevertheless, most local governments have failed to integrate AVs into their policy, and most communities suffer from a lack of local bureaucratic capacity to develop local regulations (Freemark, Hudson, and Zhao 2019). These circumstances may indicate that AV policy will largely remain in the domains of state and federal policymakers unless circumstances change in the coming years.

In our review of current governmental AV policies, we were unable to identify AV–specific regulations emanating from municipal or county governments, which, as we noted above, have a major role to play in regulating several aspects of the automobile system overall, particularly with regards to street and curb design and use. Local governments will have plenty of creative ways to intervene on such policies in the coming years. Even so, the lack of clarity about the federal government's future role—and the wide variety of approaches that individual state governments are currently developing—may help explain why towns, cities, and counties have thus far made few efforts to regulate AVs directly. While some policymakers in both the federal government and many states believe that AVs should help generate more equitable access to opportunity and a more environmentally sustainable transportation system, none of the regulatory approaches we reviewed at any level of government will take a significant step forward in that direction. Leaving AV manufacturers and operators to act on these issues alone, too, is unlikely to be effective. In other words, to achieve those goals, new regulatory approaches that are specific to AVs are necessary at all levels of government.

Challenges to AV Rollout under the Current Regulatory Regime

Interviewees pointed to several challenges to deploying AVs in an equitable manner, including concerns about accessibility, safety, affordability, and a patchwork of regulations. Their thoughts paralleled many of the concerns raised in the scholarship. Experts noted that most groups involved in AV regulation focus on either bringing the technology to market (AV manufacturers and operators) or making technology equitable and safe (advocates for safer and more equitable streets)—but rarely on both. This section summarizes the gaps in current regulatory approaches.

Achieving Equity in Service Provision

Interviewees described inequities in AV testing as a product of the locations of tech companies and variations in state and local policy. As one expert argued, they are piloting AVs "in Arizona, where almost everyone has a car, and they're doing it in San Francisco where there's lots of good transit. Where they should be doing it is places like Trenton, Stockton, or Fresno, where there is a much greater need for affordable mobility and accessibility." Even so, one reviewer pointed out that those generalities fail to address the reality that some people in Arizona do not have car access and some parts of San Francisco are isolated from effective public transportation options.

Another question interviewees raised was related to cost, namely, whether the current regulatory regime would make AVs affordable to people with low incomes. They pointed out that, while AVs could become less expensive than human-driven ride hailing—assuming the technology advances —they are unlikely to be truly affordable to all unless they emphasize shared trips. One expert noted:

No one has been able to solve the shared-ride issue, so there's no real reason to believe that AVs will be able to magically do that on its own. To get the benefits of shared rides for AVs, this will have to be incentivized through carrots and sticks. Regulations should be focused on pushing the whole industry towards sharing and disincentivizing individually owned AVs. —Academic who studies AV policy and rollout

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But no US governing body has introduced policies designed to promote shared rides, meaning AV ride-hailing providers may have no incentive to develop a market that serves people at low price points. Moreover, experts emphasized that there is a strong personal preference among Americans for riding in their own vehicles—indicating that the propensity for ride sharing with strangers is unlikely to change and lead to lower VMT. "Getting rid of a security blanket of a person there is not going to encourage people to hop in a vehicle with a stranger," one person told us. "We still haven't gotten to a point where it's like, 'I'm going to feel safe in a vehicle with a stranger, particularly as a woman.'"

And, while advocates noted the need to make AVs accessible, other experts noted the difficulty of trying to compete and be profitable while also maintaining accessibility. One interviewee said many AV operators are unlikely to want to provide accessible vehicles in the near term, and they raised concerns about whether such vehicles were economically feasible in the early, low-volume phase. "No one's ever heard of this idea before," they noted. "And now advocates and governments are saying, you don't have cars for handicapped people. But if I had to worry about handicapped-accessible cars out of the gate and with low-volume demand, this will never ever become a service, period." Another said that the cost may not "pencil out" for fully accessible vehicles.

Not having AVs at all reduces options for people who are blind or who are unable to drive, so difficult tradeoffs exist when it comes to requirements for different types of disabilities. Without accessibility requirements, however, companies may not provide vehicles that work for people with disabilities. Some interviewees argued that companies providing a passenger-carrying service have a legal obligation under the ADA to make them accessible. (The government has not enforced this requirement on ride-hailing companies such as Lyft and Uber, which claim to be tech companies rather than transport companies; that said, some of their services are wheelchair accessible.) By failing to offer accessibility, companies open themselves up to legal action. One advocate noted:

If profit is the only dictating factor with an industry leader and that's going to be their motivation, the bottom line, then we—people with disabilities—are not going to be even considered because there are not gonna be a lot of blind people, or a sufficient amount of blind people...that's when government has to step in.
—Advocate for a national nonprofit organization representing the blind

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Interviewees also questioned whether AV companies and the media were accurately portraying the vehicles' promised accessibility improvements. Some noted that the current regulatory environment does not allow for minors to ride in AVs alone, raising questions about whether they would experience significant mobility benefits from the vehicles.

Impacts on the Environment

In terms of AVs' impacts on climate change and the environment more broadly, expert interviewees noted that electrification could be a benefit and that electrification would be more feasible if regulations encourage or require it. Electrification could immediately reduce point-source emissions, meaning less cancer-causing tailpipe pollution affecting neighborhoods around roadways. But if the electricity used to power AVs relies on fossil fuels, the vehicles ultimately will offer limited climate benefits. Several interviewees emphasized that clear regulations promoting the use of renewable power sources could be an important element of overall AV policy.

At the same time, some interviewees emphasized that AVs could generate significantly higher VMT. Several argued that governments should impose a tax or fee on AV owners (fleet or individual) for "empty miles"—trips traveled with no passengers on board—which could contribute to congestion; this would require operators to share data about AV trips with the government. Interviewees noted that current regulations do not enforce such rules for human-driven ride hailing, despite research indicating that such services have significant dead-heading VMT; but these problems could worsen if AVs drive extra miles.

Without full information about AV use, interviewees pointed out that it is unclear whether the problem of empty miles is more likely to be caused by ride-hailing services (as is currently the case), or individual owners. Fleet owners have a financial incentive to keep their vehicles occupied, but with inadequate demand, they may have to travel great distances to pick up passengers for the next trip. Individual owners may find that the marginal cost of keeping a car moving is less than that of parking in dense urban areas; this, too, could encourage empty miles. Interviewees therefore emphasized the need to address both possibilities through regulation.

Provisions for Ensuring Safety

Several experts raised concerns about perceptions of AV safety. Most believed that AVs will eventually be safer than human-driven cars in terms of collisions but noted that people's risk tolerance may delay mass adoption, especially if high-profile crashes occur early on in AV rollout. One interviewee stated, "We can know that statistically an accident will happen...depending on whether that happens in the first 100 or the last 100 trips will change how the public views safety. This is an extreme and statistically irrational fear as a barrier to policymakers who don't want to be caught on the wrong side." Another noted, "Companies can develop the best technology ever," but people may not "want to get in the cars." One of the fundamental challenges at play is confusion about what autonomous technology is and lack of consumer understanding between level 2 driver assistance and level 5 full autonomy.

To address this issue, one interviewee argued, "It's a responsibility...for policymakers and for the media to not propagate misconceptions and myths...about the technology." As such, "We have to clear up the confusion between...[different sorts of] driver-assist technology," between true autonomous service (levels 3–5) and the lane-assist and adaptive cruise control technology (levels 1–2) that "let you zone out for a few minutes." But this requires public trust. Another interviewee said, "You can't move a legislative or policy agenda unless enough people believe in the efficacy of the technology." They argued for more education and information about what AVs are and how they work.

Safety issues extend beyond the safety of people within vehicles. Some argued for explicit rules on handling situations when law enforcement officers pull over AVs. They raised concerns about racialized police violence and uncertainties about how AVs might affect those interactions. "Say you get pulled over, what happens?," an interviewee asked. "In terms of regulations, what and how will that be navigated…particularly to protect folks of color who are in AVs?" Several current AV–related regulations establish protocols for AV interactions with the police, such as requiring them to pull over when a police vehicle signals them. But as far as we identified, no existing policies have specifically recommended approaches to minimize racialized differences in outcomes related to police interactions.[40]

Other interviewees emphasized the need to guarantee the safety of others on the road. One noted that the technology to implement a "sensing suite on the vehicle [that works] in all operating environments, whether weird light conditions, road dust, things like that" has not yet been achieved. This makes it more difficult to guarantee safe operations. To some degree, this requires ADS systems to improve collision avoidance. "If you get that working," one interviewee said, "you've got 90 percent of the benefits." Others stated that AV technology should evolve to the point where the vehicles can see

and respond to all types of pedestrians. One expert, for example, emphasized that regulators need to ensure that all people are protected:

> *Ensure that AVs will be required to 'see' every type of person outside the vehicle, including people of all skin tones and genders, and people with disabilities, including wheelchair users. Regulators need to hold themselves accountable to making this the world that we want to be in with these vehicles.*
> *—Advocate for a national nonprofit organization representing people with disabilities*

Finally, experts raised concerns about AVs' impacts on privacy, which could present a key barrier to deployment and pose tradeoffs with safety. AVs need external cameras for navigation and within vehicles to ensure safety for the people riding in shared AVs, but there are few current protections around street surveillance or rider privacy. US law generally allows people in the public right-of-way to be photographed, but the omnipresence of AV cameras and availability of facial recognition could turn such records into a potentially problematic constant surveillance tool. Although one representative of an AV provider told us that there was a "reasonable expectation of privacy" within vehicles, there are no existing requirements, as far as we could find, for operators to minimize sound or video recording of their passengers or rules around storage of those recordings. Questions for regulators, an interviewee noted, include "blurring or not blurring the images of people walking around the street. When does the in-car camera streaming get turned on, [and] when does it get turned off?" This could pose a particular concern in terms of data sharing with the police, who could use video produced by AVs to target people of color.

Another noted, "How data [related to rides] is going to be used is also a question." While keeping video and audio records of passengers and the surrounding environment could pose consumer privacy concerns, failing to share data on trip origins, destinations, and vehicle use could make evaluating the impacts of AVs more difficult. "There should be regulatory carrots and sticks to incentivize and penalize [misuse of private information], with the objective of attaining some level of data sharing," one person said. The government could use such data to track traffic conditions, identify changes in VMT, and assess equity of operations, among other objectives. But others emphasized the need to ensure that

government officials, companies engaged in malicious data use, or other actors cannot track trips made by individual riders.

Developing Reasonable and Realistic Regulations

Some interviewees raised the concern that technology usually outpaces regulation, presenting roadblocks to rapid deployment. To inform future AV safety standards, NHTSA needs data from vehicles on the roads. But companies are unlikely to be willing to share data freely—and NHTSA currently does not impose such requirements other than for information related to crashes. They noted that reworking FMVSS for AVs will likely require up to a decade of drafting. Further, an AV rollout should involve consistent guidance from the federal government on ensuring equitable service across communities and people—which is itself a process that will take time.

Even so, experts largely agreed that for AVs to have positive impacts on the transportation system in terms of equity and the environment, the government needs to allow more AVs on the road. In referencing the current 2,500 vehicles per manufacturer limit on exemptions to standard FMVSS rules, an interviewee said, "2,500 not only isn't a lot, but it doesn't sustain manufacturing in the United States. It doesn't sustain the manufacturing plant, even. And there's no prospect of scaled deployment, which is necessary to unlock the benefits of AVs." Another noted, "Volume is an important consideration for these new business models," so the federal government should be clear about its regulatory intentions when the service is at scale, as well as allowing for increased exceptions for learning at low volumes. An increase in the number of operating AVs could also provide more accurate information more quickly about the benefits or problems caused by the vehicles—and allow the quicker development of long-term AV–related federal regulations.

Lower levels of government will also play a role in developing AV regulations. But as we showed in our review of existing policies, states have developed an emerging patchwork of regulations. Experts suggested that federal standards are necessary to ensure that different cities and states have complementary requirements and argued that a single federal safety mandate is necessary.

One of the key drivers of success of the US automotive industry has been a national framework, but you didn't have states being able to impose design requirements or certain kinds of performance requirements for motor vehicles in different ways. Because as a matter of manufacturing, that never would have worked—no company could scale in such a way as to make different cars for different states...that's fundamental to being able to scale any kind of technology [in the] automotive context.
—Legal and policy expert on automated transportation

Although many of the experts we interviewed expressed support for the development of new regulations, others were concerned about overregulation in the period before the technology is fully ready. They pointed to the potential need to coordinate between housing and transportation and questions about the location of electric AV charging stations, for example, but raised red flags about moving too quickly on related requirements. Some specifically countered the claim that a federal requirement should come first, arguing instead that the government should allow variation at the state and local levels. In any case, most agreed that a diversity of stakeholders—from disability advocates to members of marginalized communities to representatives of manufacturers—should be involved in any regulatory decisionmaking. Said one interviewee, "I think it is incredibly important and essential to have stakeholders outside of the industry at the table, at every level...those folks [need to be] at the table to weigh in...and have authority and power in those discussions."

Recommendations for AV–Related Policy Approaches

If federal policymakers want to harness AV technology to increase equity and access to opportunity for people with low incomes and communities of color while improving environmental sustainability, there are several key steps they could take to get there. Through regulations and legislation, the federal government could help lead a mobility revolution that maximizes the net societal benefits of AVs through reduced traffic fatalities for drivers, pedestrians, and bikers; reduced car-sourced tailpipe pollutants with the transition to an electrified fleet; and lower overall VMT through shared-fleet services. Because people with low incomes and communities of color are disproportionately harmed by traffic fatalities, pollution, and a single-occupant, automobile-based society, a large rollout of expanded, shared AV services could increase equity—especially if those services were cheap enough to allow people to expand their mobility and access employment and services that are currently too costly or otherwise out of reach.

Achieving these goals, however, will not be easy, even with proactive, targeted regulations. AV operators have yet to demonstrate that their cars operate more safely than human-driven ones, particularly when it comes to detecting and responding to other road users such as pedestrians and cyclists. Convincing a large percentage of riders to share trips has already been difficult with human-driven ride hailing; it may become even tougher to encourage ride sharing without a driver to supervise the trips. And giving people the ability to do other things while in the car, such as reading or watching television, may encourage even more private car ownership and, in that context, lead to much higher VMT and worsen climate impacts. Most importantly, the potential advantages of AVs are inadequate in and of themselves to improve mobility and minimize the harmful impacts of driving on the environment; other necessary approaches include investments in improved public transportation, vouchers for universal access to travel options, and integrated land-use and transportation planning. But there remains hope to associate the AV rollout with positive outcomes.

In the following section, we identify common-sense approaches for the federal government to leverage the introduction of AV technology to improve societal outcomes around equity and environmental sustainability. We frame each of our recommendations as a response to a threat or potential concern about AVs raised in the scholarship or by our interviewees. We then point to possible levers of intervention remaining for state and local governments, which could also play an essential role. We believe that policymakers can undertake these approaches while also encouraging technological

innovation; if done right, AV adoption can play a significant role in developing a better mobility system for all.

Common-Sense Federal Regulatory Approaches to Ensure that AVs Expand Transportation Equity and Increase Environmental Sustainability

The federal government's current approach to regulating AVs is unnecessarily constraining and will limit the speed of vehicle deployment. By limiting the use of nontraditional vehicle designs to 2,500 exemptions to FMVSS standards per manufacturer each year, the government is standing in the way of realizing the potential positive benefits of level 4–5 AVs. The federal government can open up testing and the use of fully driverless AVs in various ways, but in order to ensure that AVs align with equity and environmental sustainability goals, it should endeavor to develop nationally standardized rules about AV use that reduce uncertainty, guarantee equity of access for all, reduce pollution, create incentives that encourage shared rides and disincentive individually owned vehicles, and leave room for state and local innovation to advance these goals.

We lay out recommendations below for the policy domains we described in table 2, including vehicle design, vehicle operations, consumer standards, and street standards. Our recommendations are just a first step and need to be translated into legislation and/or agency rulemaking, which could occur through advisory councils integrating feedback from industry representatives, advocates for historically underrepresented groups, and environmental groups. We acknowledge the potential for conflict between the goals of deploying AV–related policies quickly and spurring technological change. Yet we also believe that today's regulatory environment is so underdeveloped that uncertainty may be slowing progress. And failing to intervene now—when AV deployment remains nascent—could reinforce the negative outcomes of today's automobile system.

Vehicle Design

Federal regulations for vehicle design currently impair the rollout of AVs using innovative designs; we recommend a major expansion in exemption allowances and speeding up the development of new design guidelines for these vehicles. In parallel with these guidelines, we recommend that the federal government emphasize pedestrian safety, zero-emissions technology, and regulations concerning access for people with disabilities in the process of increasing exemptions. Our regulations in this

domain, again with the goals of supporting a more equitable and environmentally friendly transportation system, follow.

- ***Allow significant expansion in testing and deployment***. AVs cannot achieve their equity-building potential unless they are deployed. Current limits on nonstandard vehicle designs departing from FMVSS standards constrain the ability of companies designing level 4–5 AVs to invest in manufacturing and supply chain mechanisms to support them. To address this problem, the federal government could consider substantially increasing the cap on exemptions, such as to 100,000 vehicles per manufacturer per year; developing a new large-scale AV pilot program overseen by the DOT; or working with state governments to create a special driver's license for AV owners that allows them to use vehicles without steering wheels and similar features. Each of these approaches could fill the gap in the testing period as NHTSA develops new AV–specific standards. To address the fact that AV rollout is currently concentrated in just a few states, NHTSA could provide incentives for deployment in regions nationwide.
- ***Introduce new vehicle standards that supplement or replace FMVSS for AVs***. Current FMVSS prevent the deployment of alternative vehicle designs; a future with considerable AV availability must treat these as mainstream vehicles. Over the long term, NHTSA must supplement or replace FMVSS for fully non-human-operated vehicles and corresponding ADS (levels 4–5) that responds to alternative vehicle designs, such as different locations for riders, the lack of a human driver, and design characteristics such as the lack of side mirrors or a steering wheel. One option for such regulations is requiring manufacturers to show how their AV systems can holistically and successfully handle various challenging situations, similar to the EU regulations we described above. Many states have approved AV–related legislation premised on the federal government developing regulations of this sort. We recommend that NHTSA endeavor to continuously revise these AV–specific guidelines to respond to new data and proposals from manufacturers and advocacy groups. Any new guidelines should also consider equity and environmental impacts.
- ***Specifically ensure safety for pedestrians, cyclists, and other nonmotorized street users through tests that guarantee the safety of these vulnerable groups***. While AVs, in theory, could substantially reduce the rate and severity of collisions, the technology has not yet demonstrated its ability to do so, especially in a nondiscriminatory manner. To guarantee protections for the most vulnerable street users—pedestrians, cyclists, people riding scooters, people in wheelchairs, and others—future AV requirements should ensure that NHTSA–approved ADS under the aforementioned supplemented or replaced FMVSS can demonstrate that they can evaluate real

road conditions (such as inclement weather scenarios) more effectively than human drivers and respond in a holistic manner that minimizes threats to human life. Some advocates suggest a "vision test" that could include the use of both camera and noncamera technology, such as Lidar, to evaluate road conditions and avoid running into pedestrians. Given that people of color and people with low incomes comprise a disproportionate share of pedestrian fatalities, ensuring that AVs can achieve this goal is a key equity need. Relatedly, this evaluation process should clearly show that vehicles can detect people of varying races, ages, and abilities equally.

- ***Limit carbon emissions by requiring zero-emissions AVs as quickly as possible, potentially by 2030.*** The federal government designed Corporate Average Fuel Economy Standards to gradually reduce vehicular emissions, but the planned improvement rate is incommensurate with the goal of radically reducing US transportation emissions. California—the nation's largest automobile market—will require all AVs and ride-hailing providers to be zero emissions by 2030; the federal government could impose a similar requirement nationwide given the current availability of battery-electric propulsion technology. This approach would be especially effective if paired with a mandate showing that the electricity originates from renewable sources. Such a requirement would ensure not only that AVs minimize their contributions to climate change but also that their use limits particulate pollution, which disproportionately affects minority and low-income communities. The federal government could combine such a requirement with careful funding of well-placed new charging stations for AVs as part of the 2021 Infrastructure Investment and Jobs Act's electric vehicle charging infrastructure grants.
- ***Develop guidance for achieving high levels of access for people with disabilities.*** AVs offer considerable potential to improve access for people with limited mobility or other disabilities. But unlike public transit operators, which must offer accessible services, new AVs are not subject to any federally imposed accessibility requirements, regardless of whether they are privately owned; this could raise barriers to equitable access to new technology. To ensure compliance with the ADA, the federal government could define AV service as a transportation service—rather than tech—and require that AVs operated in fleet, ride-hailed services provide accessibility for people in wheelchairs and people with other disabilities by a certain year, such as 2030 (companies could meet this requirement by making a certain share of the fleet accessible, not necessarily the entire fleet). The federal government could also embed such a requirement in AV fleet operational standards (see below). In either case, regulation—developed cooperatively between advocates, policymakers, and representatives of the AV industry—could encourage more creative vehicle designs and help ensure that AVs offer mobility for all.

Vehicle Operations

Once AVs have been approved to hit the road through design regulations, the federal government must then monitor them to ensure continued safety. Given the national scope of AV deployment, the government could play an important role in maintaining a national database of crash data and creating a standard for liability protections. States are likely to play an important role here as well, and we recommend that the federal government aid them in developing their own plans to ensure a more equitable and environmentally sustainable transportation system.

- ***Maintain NHTSA's general order to report crashes while continuously analyzing data***. Since June 2021, NHTSA has mandated that companies operating ADAS level 2 or ADS systems must report collisions. This mandate has allowed the federal agency to supervise AV rollout and identify potential causes for concern. These data can also allow NHTSA to monitor the comparative safety performance of AVs against human-driven vehicles in terms of crash and other safety metrics—essential concerns if one goal for AVs is to ensure they are safer than human-driven cars. NHTSA could keep this order in place, ensure that it produces adequate information to assess relative AV safety,[41] and continuously update its analysis of AV performance. Whether the agency should collect more detailed data about customer rides and other performance indicators from AV operators, as California has done, is an open question. In some ways, such national collection could preempt state-by-state differences that can make operating across state lines difficult. But it could also reduce states' ability to impose their own rules designed to address local needs. The agency should continue to evaluate this question over the coming years.
- ***Develop data collection and cybersecurity plans that ensure rider privacy and prevent inappropriate commandeering of AVs***. Interviewees emphasized that because AVs collect huge amounts of data on their surroundings—and because ride-hailing AVs will collect data on vehicle interiors—passengers, especially people of color, could face the risk of inappropriate surveillance and potential targeting. To avoid perpetuating these outcomes, we recommend that the federal government convene an expert panel to recommend appropriate privacy requirements related to AV ride hailing–generated information, whether about customers or about the surrounding areas. These regulations should include limits on the ability of AV companies (or government agencies that have collected data from them) to track individuals in and out of vehicles or to use facial recognition to identify people outside of vehicles. The panel should also work to develop rules aimed at minimizing cybersecurity threats, building on NHTSA's already developed

cybersecurity recommendations. The federal government may have a specific interest in funding new research on this front to support national security goals.

- ***Create a national standard for minimum insurance and liability than ensures that the ADS operator for level 4–5 AVs, whether owned as part of a fleet or by an individual, is held responsible for financial and criminal damages when automated service is in use.*** Interviewees emphasized that many users of services such as Tesla's Autopilot do not fully understand the limitations of automation in AVs—for both fully self-driving vehicles and less advanced driver-assist tools—or demonstrate adequate insurance literacy. Given the full responsibility of the ADS in the DDT for level 4–5 AVs, the provider of the ADS software should be held financially and criminally liable for damages caused by the AVs, assuming the vehicle's owner maintained the vehicle in acceptable condition, maintained vehicle registration and emissions standards, and did not require the AV to perform a task outside its ODD. The federal government should also require the ADS provider to meet a minimum insurance standard for such eventualities. It should also establish a national standard for liability and insurance in the context of travel that frequently crosses state lines. Assessing liability for AVs operating in levels 1–3 is less straightforward, since a human driver is expected to supervise (levels 1–2) and would be expected to take on part of the driving task in DDT fallback scenarios (level 3); we recommend continued study about the appropriate way to handle such technology. We recommend that the federal government work with states to require minimum levels of insurance coverage for all AVs. We also recommend that the federal government improve consumer information programs (see below) and ensure that penalties for crashes address the joint responsibility in operations between the ADS and human drivers.
- ***Provide guidance to state and local officials to minimize the environmental impacts of AV operations and encourage the highest possible access to underserved communities.*** Even if electrified, AVs could operate in a way that reinforces poor environmental consequences. Interviewees also raised concerns that AVs operating through ride-hailing services may not adequately serve all communities. Because of the historically limited role of the federal government in regulating vehicle operations, we recommend leaving most decisions in this area to local and state authorities. Even so, the federal government could play an important advisory role in aiding lower-level governments to reduce VMT. We expect that states will lead in collecting data on AV operations (as California is piloting) and that this information will lay the groundwork for using regulatory and taxation-based carrots and sticks to discourage empty miles. In addition, the federal government could provide guidance and technical assistance on how to use local and state levers to provide adequate AV–based ride-hailing options to

historically underserved communities, such as neighborhoods that have higher proportions of people with low incomes or people of color.

Consumer Standards

The federal government has historically played an important role in setting standards for consumer information related to new vehicle purchasing, such as fuel economy and crashworthiness. We recommend that the federal government continue playing that role as individual consumers consider purchasing AVs, as well as use its taxation power to discourage individual AV ownership. We recommend that the federal government take the lead in advancing accessibility as a key component of AV ride-hailing operations, building on regulations related to AV design.

- ***Provide adequate information to consumers about AV technology***. Over the past several years, US consumers have bought vehicles with increasingly advanced ADAS technologies. This has led to potential concerns about liability when vehicles operate in a semi-automated fashion and confusion about whether and when vehicles are considered autonomous. We recommend that NHTSA develop new consumer-facing information that includes public ratings of all AVs and the associated ADAS's or ADS's level of autonomy for each new car on the market. It should also provide this information for any AV–operated ride-hailing service. The federal government should task NHTSA with helping consumers understand the tradeoffs between different levels of autonomy, including potential liability concerns.
- ***Disincentivize personal AV ownership through tax measures***. Interviewees repeatedly raised concerns about the negative attributes of a future in which AVs are individually owned. Recent research on the subject suggests that individually owned AVs could result in large increases in VMT, undermining the goal of providing alternatives to the United States' current car-focused mobility system. The federal government can support the goal of reducing car dependency among Americans who live in areas where public transportation and ride-hailed AVs are reasonable options. In future legislation, Congressmembers should consider using taxation measures such as tax credits to reward car-free families and people who use shared mobility options, as well as tax penalties to penalize those who own cars.
- ***Develop a path to full accessibility in ride hailing***. Interviewees emphasized that AVs without full accessibility for all would undermine the goal of using the new technology to ensure more equitable access. Ride-hailing services using AVs should endeavor to provide full accessibility as soon as possible. In addition to instituting design requirements, we recommend that the federal

government prohibit discrimination by providers based on people's health or disability status. These mandates could require each operator to provide a fully accessible fleet; another option would be requiring operators to work with local and state governments to show that they can provide accessible options in their service areas within a reasonable time compared with regular services. In either case, the federal government should work with state and local governments to advance accessibility goals.

Street Standards

We recommend that states and local governments play the major role in making choices related to street design, what vehicles get access to curb space, and crash response, consistent with the historically limited jurisdiction of the federal government in this domain. As such, we recommend that future federal regulations and legislation leave considerable opportunities for experimentation and variation among local governments in this area.

Leaving Key Roles for State and Local Governments

State and local governments have played an essential role in regulating the US ground transportation system across a variety of domains. Although interviewees indicated considerable interest in federal AV–related standards, lower-level governments can also contribute to this important discussion, especially in areas such as ride-hailing operations and street design. Their role could be particularly influential if conducted in concert with historically underserved communities, such as through early engagement in the development of regulation design. Our recommendations for state and local governments across the four domains of interest follow.

Vehicle Design

Establishing national standards for vehicle design, such as through modified or supplanted FMVSS, is necessary to generate the stable regulatory environment for deployment of AV technology. Even so, if the federal government fails to establish standards that ensure safe AV operation, protect the environment, and move toward universal accessibility, we recommend that states step in to develop their own regulations to fill the gap (as California has started to do) before widescale AV operations begin. Responding to the rollout of AVs with proactive measures, at any level of government, is essential to accomplishing these goals.

Vehicle Operations

We recommend that states and localities play the principal role in identifying requirements for both individually owned and fleet-operated ride-hailing AVs. These governments can establish minimum data-sharing requirements, use the data collected to identify negative externalities from such vehicles, and establish rules for ride-hailing providers that support equity.

- ***Create reasonable data-sharing requirements for AVs***. Interviewees pointed out that, without adequate data on AV trips and operations, we will be unable to monitor their relative benefits in terms of safety, increased mobility equity, and reduced environmental impacts. California currently requires that companies providing AV services for ride hailing collect and provide the state with a set of data on ride pickups and drop-offs (by neighborhood, not by exact location), trip lengths, and other information (box 4). This requirement may be difficult for some states to manage due to inadequate capacity. Even so, we recommend that states establish minimum data collection rules. States could share some of these data publicly, but anonymously, for research. To ensure that everyone operating vehicles is treated fairly, however, we recommend that some or all of these rules *also* apply to individually owned AVs, again through a system that ensures confidentiality and prevents the ability to track individuals; governments could place the requirement on whatever company is providing the ADAS or ADS software in use. This practice is necessary to identify additional approaches to reduce automobile dependency.
- ***Develop measures to capture negative externalities produced by AVs***. Given the ease of use and cheaper costs promised by AVs, states and localities need to develop approaches to counter their potentially negative environmental and congestion impacts. First, states could consider offering AV owners (individuals or fleet owners) credits for demonstrating that they are powering their electric vehicles with renewable electricity. Second, states and local governments could use the data collected on AV use to tax empty vehicle miles, or time spent driving without passengers; they could apply such a tax to *all* vehicles, not just those operated as part of ride-hailing fleets. Third, states and local governments could adjust fees on ride hailing to encourage more shared rides and fewer rides taken individually (see more details on the latter ideas below).
- ***Introduce measures to support equity in ride-hailing service provision***. Interviewees emphasized the need to ensure that AVs are welcome to all and serve all communities. Local and state governments should reinforce the federal government's role in acting against discrimination based on disability status. They could work with the federal government to enforce rules requiring minimum performance standards for people with disabilities for each ride-hailing

operator; this could encompass, for example, maximum wait times for people in wheelchairs as a percentage of overall wait times for people using ride-hailing services. In addition, state or local governments could mandate that, in exchange for the right to operate in their jurisdictions, ride-hailing providers offer a minimum level of service to all sections of the community to avoid service deserts.

- ***Work with transit agencies to encourage multimodal options.*** Local governments could work with transit agencies to encourage the development of joint fares and complementary scheduling that encourages customers to use AV ride-hailing services in association with fixed-route bus and rail options.

Consumer Standards

To achieve more equitable access to mobility options, state and local governments can develop improved opportunities for people to access AV options while developing incentives to support shared rides and subsidize the trips of people who are least able to afford such transportation. These could be associated with new registration standards that acknowledge that AV users do not need to hold driver's licenses to use cars safely.

- ***Ensure that information about and access to ride-hailed AVs are widely available—even to people without a smartphone or bank account.*** Although ride-hailed AVs could provide a valuable mobility boost for individuals who live in communities with inadequate public transportation options, they could prove inaccessible for people living without smartphones, bank accounts, or credit cards, limiting mobility options for people with low incomes or people with inadequate knowledge of technology, such as older residents. Local governments could work with AV operators to establish an automated ride-hailing phone line that allows people to request service by telephone; they could also establish fully ADA–accessible kiosks in certain communities with a high share of people in poverty to allow people to "hail" an AV without a smartphone, and they could allow people to pay using a mechanism that does not require having a bank account. These kiosks could also serve as charging depots for AVs to reduce the travel needed to get to these neighborhoods.
- ***Use incentives and taxes or fees to encourage shared rides.*** Local and state governments can encourage shared AV rides instead of individual trips, which are likely to increase overall VMT. Entities managing highways could convert more lanes to high-occupancy vehicle use, giving people riding in shared AVs faster trips than those riding alone; they could enforce similar rules

where congestion pricing or other road-charging initiatives are put into place. They could also link these rules with a data-based tax or fee on empty rides that local governments could enforce to limit VMT.

- ***Institute transit-linked subsidies for riders with low incomes and other key groups to use AV ride-hailed services.*** Although AVs are likely to be cheaper to operate than human-driven ride hailing because of the ability to reduce labor costs, interviewees emphasized that they could still prove too expensive for frequent use by many people with low incomes and may never be cheaper than the marginal cost of operating one's own human-driven car. At the same time, AVs that are priced so cheaply as to undercut the benefit of using public transportation are not in the public interest, especially as transit operators adopt electrification and autonomous technologies themselves. As such, local and state governments may consider instituting subsidies for people with low incomes—such as those who qualify for Supplemental Nutrition Assistance Program benefits—to use shared-ride AVs that connect them with transit options, when such multimodal trips are beneficial. Local governments may also consider working with local business district organizations to fund free, shared-ride AV services in busy areas to replace all car trips within that area; this option could be particularly appealing if linked with a geofencing approach that limits car use and provides more space for active transportation options such as walking and biking (see below).
- ***Adjust state registration requirements to acknowledge the lack of drivers.*** Current state regulations require vehicle operators to hold driver's licenses. This makes it difficult for many people with disabilities, young people, and older people to move around, but level 4–5 AVs will remove this barrier. States could act quickly to alter these requirements in line with changes to FMVSS rules. States could also pilot allowing children to use AVs alone, since doing so could save considerable time for parents and reduce overall VMT if AVs are used as part of a fleet (reduced VMT with child use is less likely if the AVs are privately owned). Taking this step would require considerable supervision and experimentation to avoid dangerous situations, but it could open more mobility options to a group of people often left out of the transportation system.

Street Standards

Local governments will need to take on the primary role of accommodating AVs through street standards, including through the development of new roadway designs. If AVs achieve the promised safety improvements over human-driven automobiles, people could "retake" the street and roam freely

without the fear of being hit and killed. Such improvements may require local governments to experiment with "safe streets" that only allow level 4–5 AVs. Localities could also use their control over local streets to encourage shared rides, such as by accommodating such trips in more convenient locations than for solo rides. At the same time, local and state governments will need to collaborate to develop appropriate protocols to ensure riders' and other transportation users' safety in the context of crashes and other incidents.

- ***Allow for, and identify, streets and whole neighborhoods where AVs can replace human-driven cars entirely***. If AVs provide significant benefits in terms of reducing traffic crashes and avoiding hitting pedestrians and other nonmotorized road users, interviewees emphasized prioritizing their operation. Localities could install geofencing devices on individual streets or entire neighborhoods that would keep human-driven vehicles out of such areas. This type of geofencing should occur when the vast majority of individuals in residential areas have transitioned to AV use to avoid compromising the mobility of people with low incomes, who may take longer to make the move. But localities could more rapidly implement geofencing in downtown, low car-ownership neighborhoods, shopping centers, and other employment areas with fewer equity concerns, especially if they simultaneously improve public transportation services. This approach has the potential to transform often dangerous streets into multi-use places that preserve the ability for vehicle movement but also allow for child's play and other public use. Localities could also use geofencing to establish pedestrian zones, which would prevent any vehicles—including AVs—from entering sensitive areas.
- ***Provide incentives for shared rides through use of popular curb spaces***. Interviewees noted that local governments can play an essential role in orienting AV rollout toward shared vehicles by leveraging their control over the street and parking areas. Localities could develop curb use requirements that limit the ability of personally owned AVs to drop off passengers in certain high-density neighborhoods. Governments could design such limits to prioritize people traveling in shared-use modes, such as public transportation and shared-ride AVs. In other words, these measures would encourage people hoping to access the most in-demand spots to take shared rides, as people riding by themselves would have to walk further to leave their vehicles. However, localities should make exceptions for people with disabilities.
- ***Develop safety protocols for responding to crashes or other potentially dangerous incidents involving AVs***. People of color have been disproportionately affected by overpolicing, putting them in harm's way at traffic stops, which sometimes result in death. They are also disproportionately victims of traffic collisions. The deployment of AVs could present an

opportunity to develop new approaches to responding to crashes and other dangerous incidents involving AVs, such as conflicts between passengers in shared-ride vehicles. We recommend that local and state governments work with advocates to develop new protocols that reduce the likelihood of violent outcomes.

A Fair Distribution of AV Policy Jurisdiction

The US federal system spreads policymaking across several levels of government. This distribution offers the opportunity for experimentation and variety across the country but also raises questions about ease of technological rollout. Above, we identify recommended policy interventions for the federal government and state and local governments. We believe that specifying which level of government should take on which role represents an evolution of the distribution of current regulatory authority (as seen in table 2) and sets the stage for a promising regulatory environment for technological innovation.

In table 4, we summarize our proposed recommendations for AV regulations across the report's policy domains and between federal and lower-level governments.

TABLE 4

Recommended Roles for Federal, State, and Local Governments in AV–Related Policy Domains

Policy Domain	Federal Government	State and Local Governments
Vehicle design	▪ Substantially expand AV testing and deployment ▪ Replace or supplement Federal Motor Vehicle Safety Standards for AVs ▪ Guarantee the safety of nonmotorized street users ▪ Require zero-emissions AVs ▪ Develop accessibility guidance in line with the Americans with Disabilities Act	▪ Fill regulatory gaps if the federal government is unable to develop rules that prioritize equity and environmental sustainability
Vehicle operation	▪ Maintain and improve the NHTSA general order on federal crashes data collection ▪ Develop plans for data collection and cybersecurity ▪ Create national liability and insurance standards for advanced driver assistance systems and automated driving systems ▪ Provide guidance to state and local governments on equity and environment	▪ Institute reasonable data-sharing requirements for all AVs ▪ Use data produced by AVs to inform policy and capture their negative equity and environmental externalities ▪ Consider instituting minimum service requirements for people with disabilities and priority neighborhoods
Consumer standards	▪ Provide baseline consumer information to consumers about AVs ▪ Use tax measures to disincentivize personal AV ownership ▪ Develop a pathway to full compliance with the Americans with Disabilities Act in ride-hailed AVs	▪ Create opportunities for easy AV use, even for people who do not have a smartphone or a bank account ▪ Incentivize shared rides through taxes and fees ▪ Provide transit-linked subsidies for passengers with low incomes ▪ Adjust registration requirements to handle cars without drivers
Street standards	▪ Provide opportunities for state and local governments to develop street standards	▪ Geofence key streets to reopen them for pedestrian use ▪ Incentive shared rides through curb space rules ▪ Develop safety protocols to minimize overpolicing

Source: Authors' review of scholarship and interviews.

Notes: AVs = autonomous vehicles. NHTSA = National Highway Traffic Safety Administration. Recommendations vary depending on the level of AV rollout; most recommendations relate to level 4–5 AVs.

As noted in the introduction, we limited our analysis to passenger-carrying, automobile-sized AVs. Additional research is needed to develop policies related to autonomous public transportation and freight services, each of which is also likely to have significant impacts on the ground transportation system.

Conclusion

Given the global deployment of AVs, now is the time to identify how these vehicles can improve our society rather than reinforce its worst pathologies. In this report, we reviewed recent scholarship, examined existing policy and legislation, and conducted interviews with stakeholders to develop a series of recommendations for policymakers at the federal, state, and local levels. If implemented, we believe these policies and regulatory approaches could help produce a more equitable, environmentally sustainable transportation system across the country. AV technology offers exciting possibilities, but policymakers must also pursue regulations that allow them to effectively respond to AVs' potential downsides.

We are aware that the policies we describe in this report only represent a portion of potential future regulations. Autonomous technology is likely to have a major impact not only on passenger services provided through automobile-sized vehicles but also on public transportation and the movement of freight. Each of these areas deserves considerable investigation as well. Our report also did not touch on several other issues pertinent to the rollout of this technology, such as its impact on employment. Without adequate preparation and skills-building opportunities for workers, autonomous vehicles could result in hundreds of thousands or even millions of people losing their jobs. Policymakers need to develop new strategies—such as better educational systems or universal basic incomes—to ensure that the technological transition does not contribute to poverty and rising inequality. The government must also pursue other critical mobility improvements, such as support for public transit options and improved cycling and pedestrian facilities, alongside the rollout of AVs.

As one interviewee put it, "This technology cannot undo generations of impacts of things like redlining and access to good schools…[it's] just not fair to expect AVs to fix that." Due to racialized planning policies, communities in the United States suffer from extreme concentrations of wealth and poverty that make it more difficult for people of color and people with low incomes to achieve good health, wealth, and overall life satisfaction. AV technology could help remedy—or exacerbate—those longstanding injustices by affecting access to mobility, economic opportunity, and social connections. But either way, this new technology will operate within the context of an inequitable American society.

These problems require substantial investments and thoughtful solutions. Companies operating ride-hailing services or building AVs themselves are unlikely to subsidize the travel needs of those who most need access to opportunity. AVs will not be a silver bullet, but if regulated appropriately and rolled out thoughtfully, they could be part of the solution. Companies working on every part of the AV

ecosystem, from design and manufacturing to operations, should prioritize equity and environmental sustainability as much as is necessary to combat the legacy of a century of unfair transportation policy.

More research is needed to ensure the equitable and environmentally sustainable deployment of AVs. One important topic for future research is exploring the degree to which AVs operating at a lower price point than existing ride-hailing services could increase access to opportunity for people with low incomes or people of color in certain regions. Another area of potential research is investigating the potential impacts of accessible, low-price services on residential and employment locations, which could worsen or reduce problems related to urban sprawl and segregation. Using data from such analyses would allow us to better set goals and metrics designed to promote equitable service.

Appendix A. Example State AV–Related Legislation

State	Year, Bill Title, and Bill Name	Description
Arizona	2021, H. 2813, Autonomous Vehicles	▪ Defines AVs and terms associated with AVs. Requires AVs in a crash to stop at the scene of the accident and report to law enforcement. Allocates liability in case of a crash to the owner of the AV. Restricts children from riding alone in an AV. Carves out vehicle design exemptions for AVs. Regulates a network for AVs such as in a ride-sharing service. Permits a fully autonomous vehicle to operate on public roads if the vehicle is equipped with software that meets federal standards and can comply with traffic laws.
California	2018, A.B. 87, An Act to Amend Section 22651 of the Vehicle Code, Relating to Vehicles	▪ Authorizes law enforcement or public employees who are engaged in directing traffic or enforcing parking laws and regulations to remove a vehicle that uses autonomous technology without a valid permit (required to operate the vehicle on public roads). The bill authorizes the release of the vehicle after the registered owner or person in control of the AV furnishes the storing law enforcement agency with proof of current registration and a valid driver's license, as well as either a valid permit (required to operate the AV using autonomous technology on public roads) or a declaration or sworn statement to the Department of Motor Vehicles stating that the owner will not operate the AV using autonomous technology, as specified.
California	2018, A.B. 1184, An Act to Add Section 5446 to the Public Utilities Code, Relating to Transportation	▪ Authorizes the City of San Francisco to, if approved by voters, levy a tax on trips taken in AVs that originate within the city and county of San Francisco provided by a transportation network company, such as TNC. Such taxes may be up to 3.25 percent of the fare for each trip. The bill includes some limiting and optional conditions to such fees, including that a discounted fee shall be charged to any shared trip (i.e., greater than one passenger), not to exceed 1.5 percent of the total fare; the city may charge a lower rate for trips taken in zero-emissions vehicles; revenues collected from such a fee would be required to fund transportation operations or infrastructure, and the authority is sunset in 2045.
Florida	2012, H.B. 1207, An Act Relating to Vehicles with Autonomous Technology	▪ Defines "autonomous vehicle" and "autonomous technology." Declares legislative intent to encourage the safe development, testing and operation of motor vehicles with autonomous technology on public roads of the state and finds that the state does not prohibit or specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads. Authorizes a person who possesses a valid driver's license to operate an AV, specifying that the operator is the person who causes the vehicle's autonomous technology to engage. Authorizes the operation of AVs by certain persons for testing purposes under certain conditions and requires an instrument of insurance, surety bond, or self-insurance before testing of a vehicle. Directs the Department of Highway Safety and Motor Vehicles to prepare a report, to be submitted no later than February 12, 2014, recommending additional legislative or regulatory actions that may be required for the safe testing and operation of vehicles equipped with autonomous technology.
Nevada	2017, A.B. 69, An Act Relating to Transportation	▪ Defines terms including "driver-assistive platooning technology," "fully autonomous vehicle," and "automated driving system." Allows the use of driver-assistive platooning technology on highways in the state. Preempts local

State	Year, Bill Title, and Bill Name	Description
		regulation. Requires the reporting of any crashes to the Department of Motor Vehicles within 10 days if the crash results in personal injury or property damage greater than $750. Allows the imposition of a fine up to $2,500 for violations of laws and regulations relating to AVs. Permits the operation of fully autonomous vehicles in the state without a human operator in the vehicle. Specifies that the original manufacturer is not liable for damages if a vehicle has been modified by an unauthorized third party. Allows the DMV to adopt certain regulations relating to AVs. Defines "driver," for purposes of an AV, as the person who causes the automated driving system to engage. Specifies that the following distance requirement does not apply to a vehicle using platooning technology. Imposes an excise tax on the connection of a passenger to a fully autonomous vehicle for the purpose of providing transportation services. Specifies requirements for AV network companies, including a permitting requirement, prohibitions on discrimination, and addressing accessibility. Permits the use of AVs by motor carriers and taxi companies if they meet certain requirements.
Oklahoma	2019, S.B. 189, An Act Relating to Motor Vehicles; Amending 47 O.S. 2011, Section 11-310	▪ Defines "platoon" as a "group of individual motor vehicles traveling in a unified manner at electronically coordinated speeds at following distances that are closer than would be reasonable and prudent without such coordination." Exempts nonlead vehicles in a platoon of not more than two motor vehicles and operators of nonlead vehicles from provisions related to certain mandatory distances that need to be observed by trucks and motor vehicles in general.
Oregon	2018, H.B. 4063, Relating to Autonomous Vehicles	▪ This bill establishes a task force on AVs and clarifies that the state Department of Transportation is the lead agency responsible for the coordination of AV programs and policies. ▪ The task force shall develop recommendations for legislation to be introduced during the next odd-numbered year regular session of the Legislative Assembly regarding the deployment of AVs on highways. The proposed legislation shall be consistent with federal law and guidelines and shall address (1) licensing and registration; (2) law enforcement and accident reporting; (3) cybersecurity; and (4) insurance and liability. ▪ The task force may study and consider the potential long-term effects of AV deployment to be addressed in future legislation, including the following topics: (1) land use; (2) road and infrastructure design; (3) public transit; (4) workforce changes; and (5) state responsibilities relating to cybersecurity and privacy. ▪ The task force must submit a report with recommendations for legislation to the appropriate interim committee of the Legislature related to transportation no later than September 15, 2018.
Vermont	2019, S.B. 149, An Act Relating to Miscellaneous Changes to Laws Related to Vehicles and the Department of Motor Vehicles	▪ Adds a new chapter to codified law establishing an AV testing program and defines key terms. Grants authority to the state Agency of Transportation to adopt rules to implement this new chapter. ▪ Prohibits the testing of AVs on public state or town highways until the Traffic Committee approves a permit application for AV testers who need to comply with certain criteria. For example, during a test, an operator is required to sit in the driver's seat of the AV to monitor the operation of the vehicle and take immediate control if necessary. The legislation also requires that the AV being tested is clearly identifiable by the public. ▪ The Traffic Committee has sole authority to approve test permit applications and is directed to hold a public hearing before approving a permit application. All modifications to the operational design domain or permit conditions require a renewed approval by the committee. The committee may approve AV tests on state highways and certain town highways. For other town highways, the

State	Year, Bill Title, and Bill Name	Description
		committee may approve AV tests only if municipalities have preapproved such tests. Directs the state Agency of Transportation to publish an AV testing guide by January 1, 2021, that includes a list of municipalities that have preapproved testing of AVs on certain highways within their geographic boundaries and to maintain that list. ▪ Requires AV testers to submit an annual report to the committee while tests are conducted. Testers are also required to register each AV with the commissioner and submit proof of insurance of at least $5,000,000. The committee must establish and enforce a zero-tolerance policy for drug and alcohol use by operators and conduct background checks for all operators. Operators and testers must comply with NHTSA standards relating to the testing of AVs and report any motor vehicle crash to the state Agency of Transportation within 72 hours. A law enforcement officer may invalidate AV testing permits for the trip if there is a violation of any condition of the test permit or if the officer determines that the test would be unsafe. The committee may also suspend or revoke a testing permit after providing an opportunity for a hearing. Imposes a penalty of not more than $1,000,000 for operating or testing an AV in violation of a suspension or revocation. ▪ Sets the blood alcohol concentration limit to .02 for operating an AV during a test.

Source: Authors' review of 122 laws passed by states throughout the country, documented by the National Conference of State Legislatures, "Autonomous Vehicles State Bill Tracking Database," updated July 20, 2022, https://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx.

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