

**U.S. SENATE COMMITTEE ON COMMERCE, SCIENCE, & TRANSPORTATION
SUBCOMMITTEE ON SURFACE TRANSPORTATION, MARITIME, FREIGHT, AND
PORTS**

**EXAMINING THE ROADWAY SAFETY CRISIS AND HIGHLIGHTING
COMMUNITY SOLUTIONS**

**TESTIMONY OF JEFF FARRAH, CHIEF EXECUTIVE OFFICER, AUTONOMOUS
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I. Introduction

Chairman Peters, Ranking Member Young, members of the Subcommittee, it is my honor to testify before the Subcommittee on this incredibly important topic. The autonomous vehicle industry appreciates the strong engagement of members of this Subcommittee on autonomous vehicle (“AV”) policy and shares your dedication to improving safety on U.S. roads.

The Autonomous Vehicle Industry Association (“AVIA”) is the unified voice of the AV industry, and we represent the world’s leading technology, ridesharing, automotive, trucking, and transportation companies.¹ Our mission is to bring the tremendous safety, mobility, transportation, and economic benefits of AVs—otherwise known as SAE International Levels 4- and 5-capable vehicles—to consumers and businesses in a safe, responsible, and expeditious manner and ensure the U.S. is the global leader on AVs.² Vehicles operated by AVIA members have driven nearly 70

¹ AVIA members include more than 20 leading companies developing autonomous vehicle technologies. *See Our Mission and Members*, AUTONOMOUS VEHICLE INDUS. ASS’N, <https://theavindustry.org/> (last visited May 17, 2024).

² SAE International’s J3016 standard, which has been adopted industry wide, establishes a taxonomy for vehicle automation technologies that includes six levels of driving automation, rising from “No Driving Automation” (Level 0) to “Full Driving Automation” (Level 5). Level 2 systems (often called advanced driver assistance systems or “ADAS”) are available on vehicles today and are capable of “partial driving automation,” require human supervision at all times. Level 3 vehicles have “conditional driving automation,” where the vehicle requires human interaction only in specific situations. Level 4 vehicles are defined as having “High Driving Automation.” Only Level 3, 4, and 5 vehicles are equipped with automated driving systems (“ADS”). *See* SAE INT’L, TAXONOMY AND DEFINITIONS FOR TERMS RELATED TO DRIVING AUTOMATION SYSTEMS FOR ON-ROAD MOTOR VEHICLES, J2016_202104 (2021).

million autonomous miles on U.S. public roads, a distance roughly equivalent to 293 round trips to the Moon or driving across Route 66 over 29,000 times.³

For decades, AVs have been a technological aspiration for our country’s most brilliant innovators. Today, AVs are a reality and are increasingly being deployed on America’s roads and highways, using advanced technology to perform all aspects of the driving task. In states as diverse as Arizona, Arkansas, California, Florida, Michigan, and Texas, AVs provide valuable transportation services, transporting both passengers as part of autonomous ride-hailing fleets and goods as part of trucking fleets and middle- and last-mile delivery operations. The U.S. Department of Defense has also embraced autonomous technology, including technology developed by AVIA member company Kodiak, to keep America’s soldiers safer.⁴

In recent years, the United States has faced unacceptably high levels of roadway crashes and fatalities. We cannot accept these fatalities as the cost of mobility in our country. AVs are poised to significantly improve roadway safety, as they do not speed, they do not text, and they do not drive while impaired by alcohol, drugs, or fatigue. Tragically, human drivers do all those things, leading to an epidemic of deaths on America’s roads, with over 40,000 traffic fatalities recorded each year since 2021, according to National Highway Traffic Safety Administration’s (“NHTSA”) estimates.⁵ In the first half of 2023, the Governors Highway Safety Association estimates 3,373 pedestrians were killed on U.S. roads, a 14% increase over 2019.⁶ When compared

³ *Autonomous Vehicle Industry Association Releases First-Ever “State of AV” Report*, AUTONOMOUS VEHICLE INDUS. ASS’N (Apr. 10, 2024), <https://theavindustry.org/newsroom/press-releases/first-ever-state-of-av-report>.

⁴ See *Accelerating Autonomous Vehicle Technology for the DoD*, DEF. INNOVATION UNIT (Apr. 3, 2024), <https://www.diu.mil/latest/accelerating-autonomous-vehicle-technology-for-the-dod>. AVIA member Kodiak Robotics is currently working with the U.S. Army’s Army Robotic Combat Vehicles program. See *U.S. Army Robotic Combat Vehicle (RCV Program)*, KODIAK ROBOTICS (Nov. 9, 2023), <https://kodiak.ai/news/us-army-robotic-combat-vehicle-program>.

⁵ NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP’T OF TRANSP., DOT HS 813 561, EARLY ESTIMATE OF MOTOR VEHICLE TRAFFIC FATALITIES IN 2023, <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813561>.

⁶ GOVERNORS HIGHWAY SAFETY ASS’N, PEDESTRIAN TRAFFIC FATALITIES BY STATE JANUARY – JUNE 2023 PRELIMINARY DATA, 3 (2023), <https://www.ghsa.org/resources/Pedestrians24>.

to peer countries, road deaths in the U.S. remain much higher, and have risen over the past decade.⁷ By removing human error as a cause of roadway incidents, AVs can help reduce roadway deaths, saving the lives of countless Americans.

When discussing AVs and roadway safety, it is critical to distinguish autonomous vehicles from vehicles from other types of technology. “Driver-assistance technology”—which can be found in tens of millions of cars and trucks on our roads today—is important and helpful, but it is not *autonomous* driving. Rather, the term “autonomous vehicle,” or “AV,” indicates that the vehicle is capable of driving on its own, without relying on or having any expectation that a human will be supervising the vehicle’s actions. With an AV, the vehicle performs *all* aspects of the driving task on a sustained basis. This is the technology that is being developed and deployed by AVIA’s members, and it will transform the way people and goods move in the world.

Today, the United States is the global leader in the AV industry, with a robust ecosystem of American companies developing all aspects and applications of the technology. However, China and other global competitors are pressing forward with the advancement of AVs, with Chinese AV companies beginning wider deployments in major cities.⁸ Continued American leadership will depend on the continued support for the AV industry by stakeholders across government, including this Subcommittee.⁹ The AV industry remains dedicated to improving the safety of our roads, and looks forward to continued cooperation with our partners in government as we work to do so.

⁷ *Road accidents*, OECD DATA, <https://data.oecd.org/transport/road-accidents.htm> (last visited May 17, 2024).

⁸ See Edward White, *China challenges the west for driverless car supremacy*, FIN. TIMES (Jan. 30, 2024), <https://www.ft.com/content/3a649978-69df-46eb-94c8-eee23a69e6bb>. China’s progress on AVs is visible. In March 2024, Chinese technology giant Baidu launched China’s first 24/7 AV ride-hailing service in Wuhan. Press Release, Baidu, Inc., Baidu Launches China’s First 24/7 Robotaxi Service (Mar. 8, 2024), <https://www.prnewswire.com/news-releases/baidu-launches-chinas-first-247-robotaxi-service-302084097.html>.

⁹ See *Explainer: US Must Maintain Global Leadership on AVs*, AUTONOMOUS VEHICLE INDUS. ASS’N, <https://theavindustry.org/resources/testimony/explainer> (last visited May 17, 2024).

II. The State of Roadway Safety

The United States continues to face epidemic levels of fatalities on our nation's roads. In 2023, 40,990 people were killed across the country in motor vehicle traffic incidents.¹⁰ 2023 was the third year in a row to see traffic deaths rise above 40,000,¹¹ a number of fatalities that previously had not occurred since 2007.¹² Pedestrian deaths have also risen; 2022 was the deadliest year for American pedestrians since 1981, with 7,508 people killed.¹³ That trend continued into 2023, with an estimated 3,373 pedestrians killed in the first half of the year, a 14% increase over 2019.¹⁴ The increase in roadway fatalities is consistent across vehicle types. In 2022, 5,887 people died in crashes involving large trucks, a 1.8% increase in fatalities from 2021.¹⁵ This increase is part of a decade-long 49% increase in such crashes.¹⁶ Further, 2022 saw large trucks involved in over 120,200 crashes that resulted in an injury, an 18% increase since 2016.¹⁷ The toll of motor vehicle crashes is not measured in fatalities and injuries alone. According to the National Safety Council, "the total motor vehicle injury costs" in 2022 were estimated at \$481.2 billion."¹⁸

Research continues to confirm that human behavior is overwhelmingly the most common factor in fatal accidents on our roads. A recent study by the NHTSA found that over 55% of all people injured or killed in a roadway incident tested positive for one or more drugs (including

¹⁰ NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., *supra* note 5.

¹¹ *Id.*

¹² *Fatality Facts 2021: Yearly Snapshot*, INS. INST. FOR HIGHWAY SAFETY (May 2023), <https://www.iihs.org/topics/fatality-statistics/detail/yearly-snapshot>.

¹³ GOVERNORS HIGHWAY TRAFFIC SAFETY ASS'N, PEDESTRIAN TRAFFIC FATALITIES BY STATE 2022 PRELIMINARY DATA (JAN.-DEC.) (2023), <https://www.ghsa.org/sites/default/files/2023-06/GHSA%20-%20Pedestrian%20Traffic%20Fatalities%20by%20State%2C%202022%20Preliminary%20Data%20%28January-December%29.pdf>.

¹⁴ GOVERNORS HIGHWAY SAFETY ASS'N, *supra* note 6, at 3.

¹⁵ NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP'T OF TRANSP., DOT HS 813 448, EARLY ESTIMATE OF MOTOR VEHICLE TRAFFIC FATALITIES AND FATALITY RATE BY SUB-CATEGORIES IN 2022, 1 (2023), <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813448>.

¹⁶ Nat'l Safety Council, *Large Trucks*, NSC INJURY FACTS, <https://injuryfacts.nsc.org/motor-vehicle/road-users/large-trucks/> (last visited May 15, 2024).

¹⁷ *Id.*

¹⁸ Nat'l Safety Council, *Motor Vehicles: Introduction*, NSC INJURY FACTS, <https://injuryfacts.nsc.org/motor-vehicle/overview/introduction/> (last visited May 15, 2024).

alcohol).¹⁹ Drivers are also frequently distracted by electronics; at any given time, almost 3% of all drivers are looking at or using their handheld device.²⁰ Studies have also found that drivers manipulating cell phones are two to six times more at risk for a crash.²¹ Several categories of behavior-related fatalities have increased in the past few years, including police-reported alcohol-involved crashes and deaths of unrestrained passengers.²²

Roadway safety is an issue that impacts each community differently. Roadway crashes, and the resulting injuries and deaths, are not evenly distributed across socioeconomic, racial, or ethnic groups. An analysis published by the Governors Highway Safety Association highlights the disproportionate number of traffic fatalities experienced by Black, Indigenous, and People of Color (“BIPOC”).²³ In particular, per capita rates of traffic fatalities among American Indian/Alaskan Natives and Black populations were all higher than the national average,²⁴ and pedestrian death rates per capita were higher than the national average for American Indian/Alaska Natives, Black, and Hispanic individuals.²⁵ Estimates published by NHTSA indicate that these discrepancies have become exacerbated in recent years, with traffic fatalities of Black people up 23% in 2020 compared to 2019, while American Indian deaths rose 11%.²⁶

¹⁹ NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP’T OF TRANSP., DOT HS 813 399, ALCOHOL AND DRUG PREVALENCE AMONG SERIOUSLY OR FATALLY INJURED ROAD USERS, 2 (2022), https://rosap.nhtsa.gov/view/dot/65623/dot_65623_DS1.pdf.

²⁰ NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP’T OF TRANSP., DOT HS 813 184C, DRIVER ELECTRONIC DEVICE USE IN 2020, 1 (2021), <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813184.pdf>.

²¹ *Distracted driving*, INS. INST. FOR HIGHWAY SAFETY, <https://www.iihs.org/topics/distracted-driving> (last visited May 17, 2024).

²² NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP’T OF TRANSP., DOT HS 813 298, EARLY ESTIMATES OF MOTOR VEHICLE TRAFFIC FATALITIES AND FATALITY RATE BY SUB-CATEGORIES IN 2021, 1 (2022), <https://www.nhtsa.gov/press-releases/early-estimate-2021-traffic-fatalities>.

²³ GOVERNORS HIGHWAY SAFETY ASS’N, AN ANALYSIS OF TRAFFIC FATALITIES BY RACE AND ETHNICITY 18 (2021), <https://www.ghsa.org/sites/default/files/2021-06/An%20Analysis%20of%20Traffic%20Fatalities%20by%20Race%20and%20Ethnicity.pdf>.

²⁴ *Id.* at 8.

²⁵ *Id.* at 13.

²⁶ *Id.* at 18; NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP’T OF TRANSP., DOT HS 813 118, EARLY ESTIMATES OF MOTOR VEHICLE TRAFFIC FATALITIES AND FATALITY RATE BY SUB-CATEGORIES IN 2020 8 (2021), <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813118>.

Census tracts have recorded pedestrian fatality rates within low-income metropolitan areas approximately twice that of more affluent neighborhoods.²⁷ These patterns are echoed in a City of Chicago report revealing that Black residents and those living in communities with high levels of economic hardship were more at risk of dying in a traffic crash compared to white residents and those living in communities with low and medium levels of economic hardship, respectively.²⁸ By reducing crashes across the board, AVs can reduce these inequities and improve the quality of life for all communities.

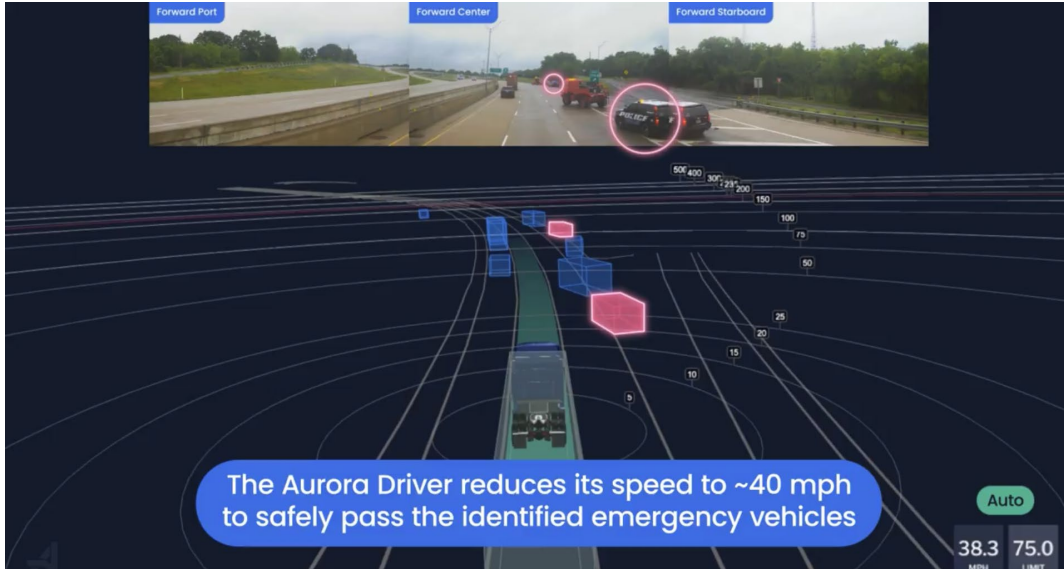
America's roads remain a dangerous place for drivers, passengers, and other road users, in large part due to the deficiencies of human drivers. However, the United States does not need to accept this status quo. By removing human error from the equation, AVs offer a vital tool for improving roadway safety.

III. AV Technology as a Vital Tool for Improving Roadway Safety

Improving road safety is the primary goal of the AV industry. Automated driving systems (“ADS”) are the heart and brain of an AV and are equipped with suites of sensor systems (including lidar, radar, and cameras) with sensitivities, capabilities, and reaction times well beyond those of a human driver. These sensors grant an ADS a 360-degree field of vision which can detect, track, and react to objects and people even when hidden from human perception due to vehicles, buildings, and other obstructions. For example, AVs are developed to specifically detect vulnerable road users—such as motorcycles, pedestrians, and cyclists—and then predict and safely respond to their unique behavior (e.g., motorcycle lane splitting). Included below are examples of what an AV “sees” when it encounters a vulnerable road user:

²⁷ GOVERNING, AMERICA'S POOR NEIGHBORHOODS PLAGUED BY PEDESTRIAN DEATHS 1 (2014), http://media.navigatored.com/documents/Governing_Pedestrian_Fatalities_Report.pdf.

²⁸ VISION ZERO CHICAGO, ACTION PLAN 2017-2019 17, https://visionzerochicago.org/wp-content/uploads/2016/05/17_0612-VZ-Action-Plan_FOR-WEB.pdf.



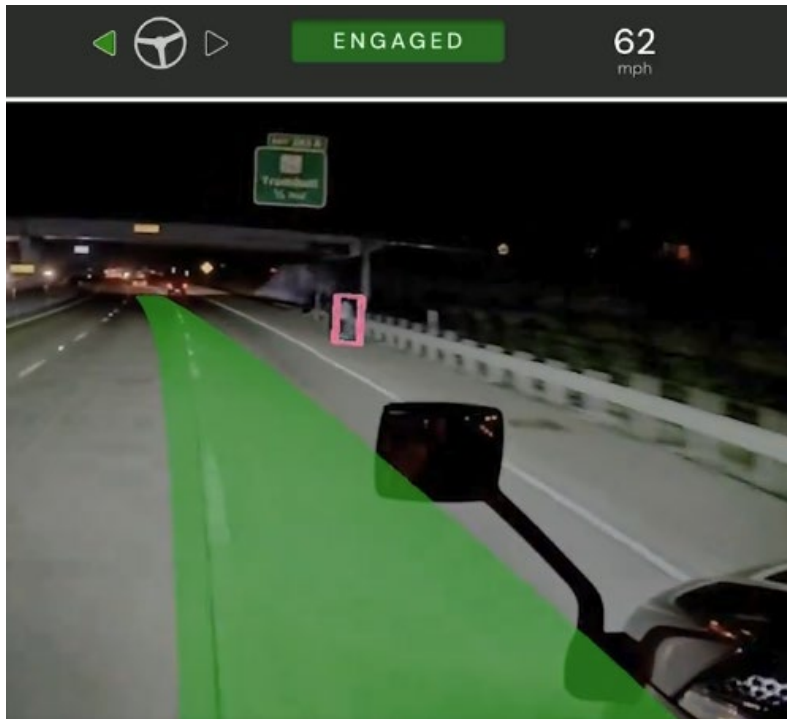
An Aurora autonomous truck safely and accurately detects an emergency vehicle, slows down and changes lanes.²⁹



A Waymo vehicle recognizes and adheres to a police officer directing traffic at a Los Angeles intersection.³⁰

²⁹ Aurora (@aurora_inno), X (Jan. 18, 2024, 5:01 PM), https://twitter.com/aurora_inno/status/1748103257128374548.

³⁰ Dmitri Dolgov (@dmitri_dolgov), X (Jan. 18, 2024, 7:04 PM), https://twitter.com/dmitri_dolgov/status/1748134215265456444.



A Kodiak autonomous truck recognizes a pedestrian on a highway from over 130m away at night, shifting to another lane to give the pedestrian extra space.³¹

AVIA members are committed to building the safest vehicles possible. To that end, AVIA recently debuted a set of TRUST Principles to guide our work with government, communities, and the public at large.³² Among these principles is support for the establishment of safety-first culture and governance for AV developers.³³ By building safety-first cultures, AV developers further enhance the safety benefits of the vehicles they are designing. The AV industry believes that public trust in AVs goes hand-in-hand with their deployment and that we must earn and maintain that trust.

Today, human error, including speeding, unfamiliarity with the roadway, and fatigue, is a major contributor to roadway incidents. AVs are designed to remove that error from the equation,

³¹ Kodiak (@KodiakRobotics), X (Mar. 21, 2024), <https://twitter.com/KodiakRobotics/status/1770870645116833872>.

³² See *Trust Principles*, AUTONOMOUS VEHICLE INDUS. ASS'N, <https://theavindustry.org/trust-principles> (last visited May 17, 2024).

³³ *Id.*

as they do not drive distracted or tired. AVs have built a significant safety record through more than a decade of development, testing, and deployment, and ADS-equipped vehicles have now driven millions of miles autonomously, with vehicles operated by AVIA members driving nearly 70 million autonomous miles on public roads in the U.S. alone.³⁴ Reinsurer Swiss Re recently published an analysis of 3.8 million autonomous miles driven by passenger AVs operated by AVIA member Waymo. The analysis found that when compared to baseline human drivers, Waymo AVs reduced bodily injury claims by 100 percent, and reduced property damage claims by 76 percent.³⁵ These results led Swiss Re to conclude that Waymo’s AVs are “significantly safer towards other road users than human drivers are.”³⁶ Waymo’s own review of over 7 million rider-only autonomous miles found that the company’s AVs demonstrated a 85% reduction in crashes involving any injury, and a 57% reduction in police-reported crashes, when compared to human drivers.³⁷ A recent Chamber of Progress study looking at California alone found that replacing even 1.3% of drivers with an AV could have prevented 411 fatalities between 2020 and 2022, while replacing 13% of drivers could have prevented 1,342 lives in that same three year period.³⁸ Another study by the Virginia Tech Transportation Institute found that the full scale deployment of occupantless AVs for delivery services could reduce roadway deaths by 58.2%.³⁹

Looking deeper into the AV industry, autonomous trucks have already demonstrated a remarkable safety record, without a single fatality in more than seven years of operations and

³⁴ AUTONOMOUS VEHICLE INDUS. ASS’N, *supra* note 3.

³⁵ LUIGI DI LILLO ET AL., COMPARATIVE SAFETY PERFORMANCE OF AUTONOMOUS- AND HUMAN DRIVERS: A REAL-WORLD CASE STUDY OF THE WAYMO ONE SERVICE (2023), <https://arxiv.org/ftp/arxiv/papers/2309/2309.01206.pdf>.

³⁶ *Id.*

³⁷ *Waymo Significantly Outperforms Comparable Human Benchmarks Over 7 Million Miles of Rider-Only Driving*, WAYMO (Dec. 20, 2023), <https://waymo.com/blog/2023/12/waymo-significantly-outperforms-comparable-human-benchmarks-over-7-million/>.

³⁸ KAITLYN HARGER, ANALYSIS: AVS IN CALIFORNIA COULD HAVE SAVED UP TO 1,300 LIVES, PREVENTED UP TO 5,000 MAJOR INJURIES OVER PAST THREE YEARS (2024), <https://progresschamber.org/wp-content/uploads/2024/03/AV-Safety-Research-California-Traffic-Fatality-Analysis-03-24.pdf>.

³⁹ CHRISTINA WITCHER ET AL., ESTIMATING CRASH CONSEQUENCES FOR OCCUPANTLESS AUTOMATED VEHICLES (Feb. 2021), <https://vtechworks.lib.vt.edu/server/api/core/bitstreams/a28aa936-8f89-4302-8859-ee54d34358e2/content>.

millions of miles driven on public roads. This safety record is supported by data collected by NHTSA. For almost three years, NHTSA has required AV companies to report every incident—no matter how minor or who is at fault—that occurs while an ADS is engaged as part of Standing General Order 2021-01 (“SGO”).⁴⁰ During this period, only one reported incident involving an autonomous truck resulted in injuries, and the cause of that incident was a human-driven vehicle that collided with an autonomous truck. Autonomous trucks will help address the spate of fatalities caused by truck crashes. Reacting to newly released crash data from NHTSA, the Institute of Safer Trucking and Road Safe America said:

This data highlights a critical problem within the United States: a 76% increase in truck crash fatalities since 2009, with the total reaching a devastating 5,936 lives lost in 2022 alone. . . All of this occurred against a 15 percent increase in truck vehicle miles traveled, which means that trucking continues to get more dangerous in the United States.⁴¹

As the autonomous trucking industry continues to grow, so will the roadway safety improvements the technology provides.

AV safety is also subject to detailed requirements and multiple layers of regulatory oversight at the federal level. Both passenger AVs and autonomous trucks are regulated by NHTSA, which administers broadly applicable motor vehicle safety standards and collects incident data from AV companies under the SGO. NHTSA also has authority to recall vehicles that present an unreasonable risk to safety, removing such vehicles from the road when necessary. This structure ensures room for innovation in motor vehicle technologies while retaining rigorous oversight over manufacturers.

⁴⁰ See NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., SECOND AMENDED STANDING GENERAL ORDER 2021-01 (2023), https://www.nhtsa.gov/sites/nhtsa.gov/files/2023-04/Second-Amended-SGO-2021-01_2023-04-05_2.pdf.

⁴¹ Institute for Safer Trucking and Road Safe America Call for Collaboration in Response to New Data Showing Truck Crash Fatalities Continue to Rise in 2022, INST. FOR SAFER TRUCKING, <https://www.safertrucking.org/news-blog/ist-statement-on-2022-fars-data-release> (last visited May 17, 2024).

Autonomous trucks are also subject to an additional legal framework established by the Federal Motor Carrier Safety Administration (“FMCSA”), a regulatory structure for which there is no parallel for passenger vehicles. FMCSA administers standards for commercial motor vehicles (“CMV”) related to safety, inspections, hazardous materials, drivers, and enforcement. With respect to interaction with weigh stations and the commercial vehicle inspection system, AVIA members have worked closely with the Commercial Vehicle Safety Alliance (“CVSA”), motor carriers, and law enforcement to develop a robust inspection process applicable to autonomous trucks, which CVSA calls the Enhanced CMV Inspection Program for autonomous trucks.⁴²

AVs are poised to improve roadway safety and help combat the glut of roadway deaths facing the United States today. By removing human error, AVs avoid the risks that come from driver distraction, fatigue, and incapacitation. Through ongoing AV deployments, AVIA members are refining their technologies and generating valuable data supporting the safety benefits of AVs. The wider deployment of AVs will bring these benefits to communities across the country and help bring an end to thousands of unnecessary and tragic roadway deaths.

IV. Additional Benefits of American AV Leadership

In addition to increasing safety, the continued expansion of AV deployments will also bring economic, supply chain, and social benefits to American communities. By 2050, the value of public and consumer benefits of AV deployment, including reduced congestion, avoided accidents, and saved time, could add up to \$796 billion annually.⁴³ The wider deployment of AVs can create over three million new jobs by 2035, while driving down the cost of consumer goods, reducing

⁴² See COMMERCIAL VEHICLE SAFETY ALLIANCE, CVSA ANNOUNCES NEW ENHANCED CMV INSPECTION PROGRAM FOR AUTONOMOUS TRUCK MOTOR CARRIERS (Oct. 4, 2022), <https://www.cvsa.org/news/new-enhanced-cmv-inspection-program/>.

⁴³ SECURING AMERICA’S FUTURE ENERGY, AMERICA’S WORKFORCE AND THE SELF-DRIVING FUTURE 9 (2018), https://avworkforce.secureenergy.org/wp-content/uploads/2018/06/SAFE_AV_Policy_Brief.pdf.

delivery costs, and raising annual earnings for all U.S. workers by between \$203 and \$267 per worker per year.⁴⁴ By 2026, AVs could represent not only a potential \$1 trillion market,⁴⁵ but also a key solution to supply chain troubles, all while decreasing transportation costs, creating jobs, and improving safety. For millions of elderly Americans and individuals with travel-limiting disabilities, AVs can provide greater independence compared to mass transit or paratransit systems, opening the door for new employment opportunities, improved access to medical care, and better connection to their communities. AVs are poised to bring economic benefits at both societal and individual levels, and they can help grow the U.S. economy and support the economic competitiveness of American businesses across many industries, in turn supporting the continued growth of the U.S. economy.⁴⁶

A. Connecting People and Protecting Communities

By increasing transportation access and improving safety, AVs can serve American communities of all kinds. Today, millions of Americans have their ability to travel limited by mobility challenges or disabilities. The U.S. Department of Transportation (“USDOT”) has estimated that 25.5 million Americans face travel-limiting disabilities,⁴⁷ and roughly 560,000 people with disabilities never leave their homes due to transportation difficulties.⁴⁸ Over 7.6 million Americans live with significant vision impairment,⁴⁹ conditions which can leave them

⁴⁴ *Id.*

⁴⁵ TECONOMY PARTNERS, FOREFRONT: SECURING PITTSBURGH’S BREAK-OUT POSITION IN AUTONOMOUS MOBILE SYSTEMS ES-1-2 (2021), <https://ridc.org/wp-content/uploads/2021/10/PGH-Autonomy-Report-Executive-Summary.pdf>.

⁴⁶ Jack Caporal, William O’Neil, and Sean Arrieta-Kenna, *Bridging the Divide: Autonomous Vehicles and the Automobile Industry*, CSIS (Apr. 14, 2021), <https://www.csis.org/analysis/bridging-divide-autonomous-vehicles-and-automobile-industry>.

⁴⁷ *ADA at DOT: Accessibility Initiatives*, U.S. DEP’T OF TRANSP. (Feb. 10, 2023) <https://www.transportation.gov/accessibility>.

⁴⁸ BUREAU OF TRANSP. STAT., TRANSPORTATION DIFFICULTIES KEEP OVER HALF A MILLION DISABLED AT HOME (2012), https://www.bts.gov/archive/publications/special_reports_and_issue_briefs/issue_briefs/number_03/entire.

⁴⁹ *Blindness Statistics*, NAT’L FED’N OF THE BLIND, <https://nfb.org/resources/blindness-statistics> (last visited May 17, 2024).

unable to operate a vehicle. This lack of mobility contributes to a lack of economic opportunity, and only 22.5% of people with disabilities are employed, compared to 65.8% of people without a disability.⁵⁰ A study by the National Disability Institute found that the wider deployment of AVs could lead to an increase in 4.4 million jobs for people with disabilities, which could create a 3.8% increase in U.S. GDP (nearly \$867 billion).⁵¹ Whether personally owned, serving as on-demand taxis, or as part of local paratransit services, AVs can provide disabled Americans with greater autonomy, letting them dictate how, where, and when they move through the world.

AVs can also provide vital connections to areas with high demand but low supply of transportation, otherwise known as “transit deserts.” Access to transportation and average length of commute are connected to upward mobility,⁵² and studies have found links between public transit access, income, and unemployment.⁵³ A 2011 study showed that an average person can access only about 30% of all jobs and 25% of low- and middle-skilled jobs in a given metropolitan area via public transit within 90 minutes.⁵⁴ AVs have the potential to reduce or eliminate gaps in transportation access by improving integration with mass transit, whether by providing both first mile and last mile connections to transit, servicing direct trips to workplaces and other endpoints, or by broadly increasing supply that helps free up other conventional and AV transportation

⁵⁰ Economic News Release, U.S. Bureau of Labor Stat., Persons with a Disability: Labor Force Characteristics Summary (Feb. 22, 2024), <https://www.bls.gov/news.release/disabl.nr0.htm>.

⁵¹ DOMINIC MODICAMORE, ET AL, NATIONAL DISABILITY INSTITUTE, ECONOMIC IMPACTS OF REMOVING TRANSPORTATION BARRIERS TO EMPLOYMENT FOR INDIVIDUALS WITH DISABILITIES THROUGH AUTONOMOUS VEHICLE ADOPTION (Dec. 30, 2022), <https://www.nationaldisabilityinstitute.org/wp-content/uploads/2023/02/ndi-economicimpactsofremovingtransportationbarriers.pdf>.

⁵² Mikayla Bouchard, *Transportation Emerges as Crucial to Escaping Poverty*, N.Y. TIMES (May 7, 2015), <https://www.nytimes.com/2015/05/07/upshot/transportation-emerges-as-crucial-to-escaping-poverty.html>.

⁵³ Gillian D. White, *Stranded: How America’s Failing Public Transportation Increases Inequality*, THE ATLANTIC (May 16, 2015), <https://www.theatlantic.com/business/archive/2015/05/stranded-how-americas-failing-public-transportation-increases-inequality/393419/>.

⁵⁴ Adie Tomer Et Al., *Missed Opportunity: Transit and Jobs in Metropolitan America*, BROOKINGS (May 11, 2011), <https://www.brookings.edu/research/missed-opportunity-transit-and-jobs-in-metropolitan-america/>.

options to build those linkages. Projections indicate that the transportation connections facilitated by the adoption of AVs would increase access to jobs within a metropolitan area by 45% by 2040.⁵⁵

Access to food is another area of inequality that AVs can help alleviate. Transit deserts often overlap with food deserts, which are defined as areas with high poverty (20% or greater) and low access to food (at least 33% of people living more than one mile from a grocery store or supermarket).⁵⁶ A 2017 report by the U.S. Department of Agriculture’s Economic Research Service (“ERS”) estimates that 54 million individuals, or 17.1 percent of the total U.S. population, had limited access to a supermarket or grocery store between 0.5 and 10 miles from their home.⁵⁷ Further, a 2009 ERS report found that, at the time, 2.3 million people lived more than one mile from a supermarket and did not have access to a vehicle.⁵⁸

AVs can prove particularly useful for improving access to food, both by transporting people to previously inaccessible or difficult to access supermarkets and grocery stores, and by bringing food directly to their doors. With greater widespread deployment, AVs could improve access to fresh food for 14 million low-income households, roughly 70% of the total low-income population, living in food deserts.⁵⁹ The addition of safe and affordable options in the transportation ecosystem will expand the capacity to execute on these trips.

⁵⁵ RICHARD EZIKE ET. AL., UNION OF CONCERNED SCIENTISTS, WHERE ARE SELF-DRIVING CARS TAKING US?, 6 (2019), <https://ucsusa.org/sites/default/files/attach/2019/02/Where-Are-Self-Driving-Cars-Taking-Us-web.pdf>.

⁵⁶ Michele Ver Ploeg, Et. Al., *Mapping Food Deserts in the United States*, U.S. DEP’T OF AGRIC.: ECON. RSCH SERV., (Dec. 1, 2011), <https://www.ers.usda.gov/amber-waves/2011/december/data-feature-mapping-food-deserts-in-the-us/>.

⁵⁷ ECONOMIC RESEARCH SERVICE, EIB-165, U.S. DEP’T OF AGRIC. LOW-INCOME AND LOW-SUPERMARKET-ACCESS CENSUS TRACTS, 2010-2015 12 (2017), <https://www.ers.usda.gov/webdocs/publications/82101/eib-165.pdf?v=3395.3>.

⁵⁸ ECONOMIC RESEARCH SERVICE, ACCESS TO AFFORDABLE AND NUTRITIOUS FOOD: MEASURING AND UNDERSTANDING FOOD DESERTS AND THEIR CONSEQUENCES iii (2009) https://www.ers.usda.gov/webdocs/publications/42711/12716_ap036_1_.pdf?v=8423.6.

⁵⁹ Sola Lawal, *Serving America’s Food Deserts*, MEDIUM (July 15, 2020), <https://medium.com/nuro/serving-americas-food-deserts-a7442e922053>.

B. Moving Goods and Growing the American Economy

The integration of AVs into America's commercial fleets will help optimize the transportation of freight nationwide, bringing goods directly to consumers faster and strengthening at-risk supply chains. At present, the United States is not hauling all the freight it could, holding back our nation's farmers, ranchers, and manufacturers. Autonomous trucking offers a means to address supply chain inefficiencies by filling workforce gaps, enhancing fleet flexibility, and reducing travel times.

The growth in autonomous trucking is poised to run in parallel with an ever-growing market for freight trucking, with the Bureau of Transportation Statistics estimating that freight activity in the United States alone will grow fifty percent from 2020 to 2050, reaching a projected value of \$36.2 trillion.⁶⁰ With trucking representing roughly 72% of all freight transportation tonnage,⁶¹ the number of trucks on the road, autonomous and human driven, will need to grow as well. As demand for freight hauling continues to grow, AVs can help shippers keep up with that demand, supplementing and augmenting human driven fleets. With AVs hauling more long-haul freight, more opportunities will be created for truck drivers in their communities. This will also allow companies to strategically place their drivers where they are needed most and ensure America's truck drivers can remain in and near their communities and sleep in their own beds.

For consumers, AVs are positioned to reduce general transportation costs and the cost of goods, and ensure goods are made more readily available and closer to home. Sixty-five percent of U.S. consumable goods are brought to market by trucks, and the implementation of autonomy

⁶⁰ *Freight Activity in the U.S. Expected to Grow Fifty Percent by 2050*, BUREAU OF TRANSP. STAT. (Nov. 22, 2021), [https://www.bts.gov/newsroom/freight-activity-us-expected-grow-fifty-percent-2050#:~:text=New%20long%2Dterm%20projections%20released,trillion%20\(in%202017%20dollars\).](https://www.bts.gov/newsroom/freight-activity-us-expected-grow-fifty-percent-2050#:~:text=New%20long%2Dterm%20projections%20released,trillion%20(in%202017%20dollars).)

⁶¹ *ATA Truck Tonnage Index Increased 2.4% in May*, AM. TRUCKING ASS'N (July 20, 2023), <https://www.trucking.org/news-insights/ata-truck-tonnage-index-increased-24-may>.

in the trucking sector stands to decrease operating costs by about 45%—resulting in savings between \$85 billion and \$125 billion, which can be passed on to consumers and transportation workers.⁶² In California alone, the knock on effects of the introduction of autonomous trucking could increase that state’s real GDP and welfare by at least \$6 billion a year.⁶³ Finally, through the introduction of shared AV fleets, transportation costs—which amount to the second-largest expense for most households—could be reduced by as much as \$5,600 per year.⁶⁴

C. Providing New Jobs

American workers also stand to benefit from the greater adoption of AV technologies. A USDOT-funded study found that autonomous trucking will increase U.S. employment by up to 35,000 jobs per year on average.⁶⁵ AVs will coexist with America’s truck drivers, and the goal of the industry is to create more opportunities for all in our country. A growing AV industry will continue to create new job opportunities for workers with a range of educational backgrounds and experiences, including local drivers, technicians, operations center workers, and more. Indeed, a USDOT study has found that most autonomous trucking adoption scenarios would not lead to layoffs for existing truckers.⁶⁶

The AV industry has already created new jobs and brought new investment, tax revenue, resources, and human capital to states across the country, including Arkansas, California,

⁶² Aisha Chottani, Greg Hastings, John Murnane, and Florian Neuhaus, *Distraction or Disruption? Autonomous Trucks Gain Ground in US Logistics*, MCKINSEY & Co., (Dec. 10, 2018), <https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/distraction-or-disruption-autonomous-trucks-gain-ground-in-us-logistics>.

⁶³ *Autonomous Long-Haul Trucking Stands to Grow the Golden State’s Economy While Creating Jobs and Raising Wages Without Mass Driver Layoffs*, SILICON VALLEY LEADERSHIP GROUP (Apr. 13, 2022), <https://www.svlg.org/study-shows-autonomous-trucking-will-grow-californias-economy/>.

⁶⁴ SECURING AMERICA’S FUTURE ENERGY, *FOSTERING ECONOMIC OPPORTUNITY THROUGH AUTONOMOUS VEHICLE TECHNOLOGY* (July 2020), <https://safe2020.wpenginepowered.com/wp-content/uploads/2020/07/Fostering-Economic-Opportunity-through-Autonomous-Vehicle-Technology.pdf>.

⁶⁵ ROBERT WASCHIK ET AL., JOHN A. VOLPE NAT’L TRANSP. SYS. CTR., FHWA-JPO-21-847, *MACROECONOMIC IMPACTS OF AUTOMATED DRIVING SYSTEMS IN LONG-HAUL TRUCKING*, 1 (2021), <https://rosap.ntl.bts.gov/view/dot/54596>.

⁶⁶ *Id.*

Alabama, Arizona, Arkansas, Kansas, Nevada, New Mexico, Oklahoma, Pennsylvania, Michigan, Florida, Washington, Colorado, and Texas. In communities throughout those states, the AV industry is providing opportunities for workers with a wide array of expertise and educational backgrounds, including many jobs that do not require a college degree. These jobs include auto technicians, fleet managers, safety operations specialists, sensor calibrators, transportation planners, and many others to serve the growing needs of AV fleets and AV manufacturers. As the industry continues to expand, delivery workers and grocery store employees will be involved in selecting, packing, and delivering goods to consumers, among other jobs and roles. The wider deployment of AVs can create over three million new jobs by 2035, all while expanding access to affordable delivery services, according to a study conducted by Steer.⁶⁷

The AV industry is also investing in partnerships to create the jobs of tomorrow. These investments not only move AV technology forward, but also prepare the American workforce to compete globally. For example, AVIA member Aurora has partnered with Pittsburgh Technical College to create and launch a new associate degree program that trains autonomous service engineer technicians.⁶⁸ Similarly, AVIA member Nuro has developed programs with De Anza Community College in California and San Jacinto Community College in Texas that offer a new career pathway to prepare the next generation of autonomous fleet technicians.⁶⁹ These initiatives include a free tuition option, access to paid internships and part time work, and preference for full time jobs with and benefits upon graduation.

⁶⁷ STEER, ECONOMIC IMPACTS OF AUTONOMOUS DELIVERY SERVICES IN THE U.S., XI (2020), https://www.steergroup.com/sites/default/files/2020-09/200910_%20Nuro_Final_Report_Public.pdf.

⁶⁸ *Pittsburgh Technical College Launches Robotics and Autonomous Engineering Technology Program*, Pittsburgh Technical College (Aug. 29, 2022), https://www.pghtech.org/news-and-publications/PTC_Robotics.

⁶⁹ *Autonomous and Electric Vehicle Technician Pathway*, DE ANZA COLLEGE, <https://www.deanza.edu/autotech/av> (last visited May 9, 2024); Press Release, San Jacinto College and Nuro, San Jacinto College and Nuro Announce First AV Technician Certificate Program in Texas (Feb. 24, 2023), <https://www.newsfilecorp.com/release/156026/San-Jacinto-College-and-Nuro-Announce-First-AV-Technician-Certificate-Program-in-Texas>.

D. Environmental Benefits of Autonomous Vehicles

The wider deployment of AVs stands to bring important environmental benefits as well, including by reducing emissions through greater fuel efficiency and reduced congestion, among other improvements. Many AV developers rely on battery electric vehicles (“EVs”) or gasoline-electric hybrids for their AV fleets, and further adoption of EVs is increasing. A study by Steer found that autonomous, electric local delivery vehicles could avoid more than 400 million tons of CO₂ from 2025-2035.⁷⁰

Autonomous trucking specifically is poised to provide immense environmental benefits. 29% of U.S. total greenhouse gas emissions are attributed to transportation, with medium- and heavy-duty trucks accounting for 23% of all transportation-related emissions.⁷¹ In states such as California, that figure is even higher, with transportation representing approximately 50% of all greenhouse gas emissions.⁷² ADS-equipped heavy trucks can reduce fuel consumption by at least 10% as a result of more efficient driving, resulting in a significant reduction of CO₂ emissions.⁷³ Additionally, AVIA member Aurora recently released a white paper demonstrating that autonomous trucking has the potential for a 13-32% net energy efficiency improvement per loaded miles relative to human-driven trucks.⁷⁴ These benefits emanate from limiting peak speeds,

⁷⁰ STEER, *supra* note 67, at XV.

⁷¹ *Fast Facts on Transportation Greenhouse Gas Emissions*, ENV’T PROT. AGENCY (Oct. 31, 2023), <https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions>.

⁷² *Transforming Transportation*, CA ENERGY COMM’N, <https://www.energy.ca.gov/about/core-responsibility-fact-sheets/transforming-transportation> (last visited May 17, 2024).

⁷³ Ryan Gehm, *Self-driving trucks cut fuel consumption by 10%*, SAE INT’L (Dec. 19, 2019), <https://www.sae.org/news/2019/12/tusimple-autonomous-trucks-cut-fuel>.

⁷⁴ DR. GARRETT BRAY, AURORA, *THE SUSTAINABILITY OPPORTUNITY OF AUTONOMOUS TRUCKING 3* (2024), https://downloads.ctfassets.net/8byw6jksp7h2/4W2yp42p921nrZXjWGKQRt/278c2eaa0f474a3ae6d75802d0d92a63/The_Sustainability_Opportunity_of_Autonomous_Trucking.pdf; *See also* Research & Discoveries (R&D): Autonomous Trucks Can Reduce Emissions, AUTONOMOUS VEHICLE INDUS. ASS’N, <https://theavindustry.org/resources/blog/research-discoveries-rd-autonomous-trucks-can-reduce-emissions> (last visited May 17, 2024).

reducing “dead-head” miles, increasing vehicle utilization and off-peak driving, reducing idling, and programmed eco-driving behavior.⁷⁵

In addition, AVs can serve an important role in achieving environmental goals that advance public health.⁷⁶ Emissions from motorized vehicles are a major source of air pollution, which is a leading risk factor for mortality and morbidity.⁷⁷ Although the American Lung Association has found that 39% of Americans are living in places with unhealthy air, the effects of poor air quality are disproportionately experienced by BIPOC.⁷⁸ Specifically, the American Lung Association’s most recent “State of the Air” report demonstrates that BIPOC were 61% more likely to live in a county with unhealthy air than white peers.⁷⁹

The wider deployment of AVs will bring myriad benefits to communities and individuals across the country. From connecting underserved communities and people with disabilities to new opportunities for employment and independence, to important reductions in transportation sector emissions, to boosting the economy by lowering transportation costs, AVs can help address a diverse set of problems. To ensure these benefits are received, what is needed now more than ever is a supportive federal policy framework that unlocks further pathways to widespread AV deployments nationwide.

V. Policy Recommendations for Promoting AV Deployments

Preserving American leadership in the AV industry is key to ensuring that the safety and benefits of AV deployment reach drivers, companies, and consumers in communities across the

⁷⁵ *Id.*

⁷⁶ See David Rojas-Rueda, et al., *Autonomous Vehicles and Public Health*, 41 ANN. REV. OF PUB. HEALTH 329 (2020), <https://www.annualreviews.org/doi/10.1146/annurev-publhealth-040119-094035>.

⁷⁷ *Id.* at 333 (citing HEALTH EFFECTS INST., STATE OF GLOBAL AIR 2018 1 (2018), <https://www.stateofglobalair.org/sites/default/files/soga-2018-report.pdf>).

⁷⁸ *State of the Air: Key Findings*, AM. LUNG ASS’N, <https://www.lung.org/research/sota/key-findings> (last visited May 17, 2024).

⁷⁹ Press Release, Am. Lung Ass’n, More Than 4 in 10 Americans Breathe Unhealthy Air, People of Color 3 Times as Likely to Live in Most Polluted Places (Apr. 21, 2021), <https://www.lung.org/media/press-releases/sota-2021>.

country. Despite holding the lead in AV development at the moment, the United States is at risk of falling behind the rest of the world on AV public policy, which would deny Americans the technology's lifesaving mobility and efficiency benefits and harm the United States' global economic competitiveness. The American AV industry is at an inflection point, as the technology is now being commercialized and the benefits of AVs are beginning to accrue. Now is the time for policymakers to establish a national AV policy framework that prioritizes American leadership and has Congress, the USDOT, and the private sector acting in partnership. While federal efforts to establish such a framework have stalled in the last several years, a majority of states have recognized the benefits of AVs by expressly approving AV operations on their roads.

Make no mistake: the United States can continue to lead the way on AVs if policymakers support the safe commercialization of AVs and do so with urgency. The United States must commit itself to AV leadership to ensure that the safety, economic, mobility, and efficiency benefits of AVs can be realized not only in the states where AVs are already on the road, but nationwide. Key steps to create an AV federal policy framework include:

- Congressional action on federal legislation, like the AV START Act previously introduced by Sens. Peters and Thune.⁸⁰ Such a bill should encompass all vehicle types and include statutory and regulatory changes to support the wider deployment of AVs across the U.S. AVIA's own federal policy framework, published last year, details a number of components such a law should include.⁸¹ AVIA was pleased to see the Bipartisan Senate AI Working Group - led by Senators Schumer, Rounds, Heinrich, and Young—encourage continued “work on developing a federal framework for testing and deployment of

⁸⁰ See American Vision for Safer Transportation through Advancement of Revolutionary Technologies Act, S. 1885, 115th Cong. (2017), <https://www.congress.gov/bill/115th-congress/senate-bill/1885>.

⁸¹ AUTONOMOUS VEHICLE INDUS. ASS'N, FEDERAL POLICY FRAMEWORK FOR OUR AV FUTURE (MARCH 2023), <https://theavindustry.org/resources/AVIA-Federal-Policy-Framework-for-Our-AV-Future.pdf>.

autonomous vehicles across all modes of transportation to remain at the forefront of this critical space. This effort is particularly critical as our strategic competitors, like the Chinese Communist Party (CCP), continue to race ahead and attempt to share the vision of this technology.”⁸²

- FMCSA granting the still-pending industry exemption request that will allow ADS-equipped vehicles to use alternative warning devices to signal when an ADS-equipped CMV is stopped on the roadside.⁸³ This common-sense and data-backed application, filed in January 2023, has been pending for 16 months when we have seen several equipment and lighting-related petitions over the past several years be acted on, on average, within 8 months.⁸⁴ FMCSA should act expeditiously to ensure autonomous trucking companies can help ease supply chain challenges and support America’s economy.
- Move forward with a proposed rule on AV STEP. First announced in July 2023, under AV STEP NHTSA “would consider applications for deploying noncompliant ADS vehicles subject to review processes, terms and conditions that the agency would require to ensure public safety and transparency.”⁸⁵ According to then Acting Administrator Ann Carlson, “By allowing the deployment of exempt ADS vehicles under conditions that include requirements to demonstrate safety and provide information about vehicle operation and

⁸² BIPARTISAN SENATE AI WORKING GROUP, DRIVING U.S. INNOVATION IN ARTIFICIAL INTELLIGENCE 12-13 (May 2024), <https://www.politico.com/f/?id=0000018f-79a9-d62d-ab9f-f9af975d0000>.

⁸³ See AURORA & WAYMO, FMCSA-2023-0071-0011, JOINT WAYMO-AURORA APPLICATION FOR EXEMPTION (Jan. 10, 2023), <https://www.regulations.gov/document/FMCSA-2023-0071-0011>.

⁸⁴ FMCSA’s own regulations state that the agency will attempt to issue a final decision on any exemption application within 180 days of receipt. 49 C.F.R. § 381.320.

⁸⁵ Ann Carlson, Acting Adm’r, Nat’l Highway Traffic Safety Admin., Keynote Address at the Automated Road Transportation Symposium (ARTS2023) (July 12, 2023), <https://www.nhtsa.gov/speeches-presentations/automated-road-transportation-symposium-arts23-keynote-address>.

deployment, we believe AV STEP would open up a wealth of data [and] hasten NHTSA's progress toward establishing an effective governance structure for ADS performance."⁸⁶

- FMCSA completing the rulemaking process on the "Safe Integration of Automated Driving Systems (ADS)-Equipped Commercial Motor Vehicles (CMVs)."⁸⁷ This includes enacting regulations that codify FMCSA's interpretation that the Federal Motor Carrier Safety Regulations do not require a human driver to operate or be present in a commercial motor vehicle operated by a SAE Level 4 or Level 5 ADS.⁸⁸

VI. Conclusion

The further deployment of AV technologies will vastly increase safety on our roadways and generate economic benefits across the country. However, to ensure those benefits are realized here in the United States, we must preserve American leadership in the AV industry. I thank the Subcommittee for its leadership on these important issues. AVIA looks forward to serving as a resource for technical and policy questions on this subject, and to working with you to make safe autonomous vehicles a reality for Americans nationwide.

⁸⁶ *Id.*

⁸⁷ Safe Integration of Automated Driving Systems (ADS)-Equipped Commercial Motor Vehicles (CMVs), 88 Fed. Reg. 6691 (Feb. 1, 2023).

⁸⁸ U.S. DEP'T OF TRANSP., PREPARING FOR THE FUTURE OF TRANSPORTATION: AUTOMATED VEHICLES 3.0 (AV 3.0) 9 (Oct. 2018), <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>; Safe Integration of Automated Driving Systems-Equipped Commercial Motor Vehicles, 84 Fed. Reg. 24449, 24453 (May 28, 2019).