Testimony

Challenges and Approaches to Realizing Autonomous Vehicle Safety and Mobility Benefits

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Challenges and Approaches to Realizing Autonomous Vehicle Safety and Mobility Benefits

Testimony of Nidhi Kalra[1]
The RAND Corporation[2]

Before the Committee on Appropriations
Subcommittee on Transportation, Housing and Urban Development, and Related Agencies
United States House of Representatives

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Chairman Diaz-Balart, Ranking Member Price, and distinguished members of the subcommittee, thank you for the opportunity to testify on the important emerging opportunities and risks related to autonomous vehicles. Autonomous vehicles have the potential to change transportation profoundly around the world. Today, I would like to discuss two important questions about the future of autonomous vehicles and how policies can shape that future. First, what can policymakers do to promote the safe deployment of autonomous vehicles? Second, how can autonomous vehicles improve mobility for Americans who currently may have limited mobility? I will focus most of my remarks on fully autonomous vehicles—those that can operate without a human driver some or all of the time—rather than on vehicles that require a human driver behind the wheel.

Autonomous Vehicles Present Benefits and Risks to Safety

As you know, traffic crashes present an enormous public safety crisis in the United States. Autonomous vehicles have the potential to significantly mitigate this crisis by eliminating many of the mistakes that human drivers routinely make.[3] To begin with, autonomous vehicles cannot

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[2] The RAND Corporation is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest.

[3] James M. Anderson, Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and Oluwatobi A. Oluwatola, *Autonomous Vehicle Technology: A Guide for Policymakers*, Santa Monica, Calif.: RAND Corporation, RR-433-2-RC, 2014; and Daniel J. Fagnant and Kara Kockelman, "Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations," *Transportation Research Part A: Policy and Practice*, Vol. 77, July 2015, pp. 167–181.

be drunk, distracted, or tired; these factors are involved in 29 percent, 10 percent, and 2.5 percent, respectively, of all fatal crashes.[4] Autonomous vehicles could also perform better than human drivers because of better perception (e.g., no blind spots), better decisionmaking (e.g., more accurate planning of complex driving maneuvers), and better execution (e.g., faster and more precise control of steering, brakes, and acceleration).

However, autonomous vehicles likely will not eliminate all crashes. For instance, inclement weather and complex driving environments pose challenges for autonomous vehicles, as well as for human drivers, and autonomous vehicles might be worse than human drivers in some cases, particularly at early stages of testing and deployment.[5] Autonomous vehicles also could pose new and serious crash risks—for example, cyber attacks could cause crashes.[6] Clearly, autonomous vehicles present both potential benefits and risks to transportation safety. Several challenges stand in the way of managing those safety risks and maximizing the benefits.

There Is Currently No Proven, Practical Way to Determine Autonomous Vehicle Safety Prior to Widespread Use

A road test at the Department of Motor Vehicles assesses whether a person can perform a specific set of driving skills under regular traffic situations. Passing the test does not prove that the person will be a safe driver, but it is nevertheless viewed as an adequate basis for granting a permit or a license. Such road tests could similarly demonstrate that an autonomous vehicle can perform basic driving skills, but such a test would not be able to assess its safety performance.

A logical alternative is to test-drive autonomous vehicles extensively in real traffic and observe their performance before making them commercially available. Even though the number of crashes, injuries, and fatalities from human drivers is high, the rate of these failures is low *in comparison with the number of miles that people drive*. Americans drive nearly 3 trillion miles every year.[7] The 35,092 fatalities and 2.44 million injuries in 2015 correspond to a failure rate of 1.12 fatalities and 78 injuries per 100 million miles driven. Given that current traffic fatalities and injuries are rare events compared with vehicle miles traveled, fully autonomous vehicles would have to be driven hundreds of millions of miles and sometimes hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries. Even with aggressive testing, this would take tens and sometimes hundreds of years for existing test fleets to drive these miles—an impossible proposition if the aim is to demonstrate autonomous vehicle

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[4] This does not mean that 41.5 percent of all fatal crashes are caused by these factors; a crash may involve, but not be strictly caused by, one of these factors, and more than one of these factors may be involved in a single crash. National Highway Traffic Safety Administration, 2016; and National Highway Traffic Safety Administration, "Drowsy Driving," *Traffic Safety Facts: Crash Stats*, Washington, D.C.: National Center for Statistics and Analysis, U.S. Department of Transportation, DOT HS 812 449, March 2011.

[5] Lee Gomes, *Hidden Obstacles for Google's Self-Driving Cars: Impressive Progress Hides Major Limitations of Google's Quest for Automated Driving*, Massachusetts Institute of Technology, August 28, 2014.

[6] Anderson et al., 2014.

[7] Bureau of Transportation Statistics, 2015.

performance prior to releasing them on the roads for consumer use.[8] In the meantime, human drivers would continue to cause avoidable crashes and enormous harms to people and property.

Developers of autonomous vehicles and third-party testers need to develop innovative methods of demonstrating safety and reliability. This is a rapidly growing area of research and development. There are promising ideas, but no demonstrated and accepted methods of proving safety.

There Is No Consensus on How Safe Autonomous Vehicles Should Be

There is also no consensus on how safe autonomous vehicles *should* be. Some will insist that anything short of totally eliminating risk is an unacceptable safety compromise; it is acceptable if humans make mistakes, but not if machines do. However, waiting for autonomous vehicles to operate nearly perfectly misses opportunities to save lives, as it means the needless perpetuation of the risks of human drivers. It seems sensible to allow autonomous vehicles on America's roads when they are judged safer than the average human driver, allowing more lives to be saved while still ensuring that autonomous vehicles do not increase risk. It is even possible that some policymakers might choose to allow autonomous vehicles even when they are not as safe as average human drivers if developers use early deployment as a way to rapidly improve vehicle safety. The lack of consensus on this point is not a failure but rather a genuine expression of Americans' different values and beliefs when it comes to humans versus machines, but it complicates the challenge of developing safety benchmarks for the technology.

Real-World Driving Experience Is Needed for Safety but Poses Risks

Resolving the above challenges is urgent because real-world driving experience may be one of the most important tools for improving autonomous vehicle safety and, by extension, road safety. Autonomous vehicle developers use the driving experience of individual vehicles to improve the state of the art in autonomous vehicle safety. The machine learning algorithms that govern autonomous vehicle perception, decisionmaking, and execution rely largely on driving experience to improve. Therefore, the more (and more diverse) miles that autonomous vehicles drive, the more potential there is for improving the state of the art in autonomous vehicle safety performance.

Yet having autonomous vehicles learn from real-world driving experience presents its own problem: Learning in real-world settings implies risks to early adopters or to other road users. This is analogous to the risk of allowing teenage drivers on the road: They may not be good drivers yet, but they need experience to become good drivers. However, until then, they pose risks to themselves and to others. We have policies in place to try to limit risks from inexperienced young drivers, such as a minimum driving age and restrictions on learner's permits. Those policies seek to balance the goal of long-term improvement with the need for near-term experience.

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[8] Nidhi Kalra and Susan M. Paddock, *Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?* Santa Monica, Calif.: RAND Corporation, RR-1478-RC, 2016.

The same will be true for autonomous vehicles. Choices made now about when and how autonomous vehicles are introduced for public use will affect not only safety in the near term but also how quickly the vehicles improve, at what near-term cost, and how safe they ultimately become in the future.

What Can Policymakers Do to Promote Safety?

First, feasible and sound methods of testing safety are urgently needed. These methods can be developed and proposed by industry, researchers and academics, or federal regulators. The methods need to be validated rigorously, objectively, and independently both to assess their statistical soundness, relation to existing safety and performance standards, and engineering and social considerations and to build confidence in the methods among diverse stakeholders.

Second, testing methods should be used to develop a regulatory framework that articulates what safety performance thresholds must be met in order to put autonomous vehicles on the road. Importantly, the framework should balance the need for real-world autonomous vehicle testing with the need to protect the public from undue risk. For example, a lower threshold of safety may be acceptable for early demonstration projects intended to improve autonomous vehicle performance in controlled environments. A higher threshold of safety would be warranted for widespread consumer use in uncontrolled environments. Developing the appropriate thresholds of safety should be informed by research on levels of tolerable risk in automotive and other contexts, historical safety regulation and performance criteria, stakeholder values and preferences, and an assessment of how different safety levels could shape the evolution of transportation safety over the long term. Thus, establishing these thresholds requires a combination of objective evidence and subjective values.

Such a framework could, for example, be built into the changes that are being considered to exemptions to the Federal Motor Vehicle Safety Standards (FMVSS). Manufacturers can seek exemptions from the FMVSS on the basis that their nonconforming vehicle designs are as safe as or safer than conforming vehicles and must provide evidence of this safety. Currently, no more than 2,500 vehicles can be sold annually per each safety-based exemption,[9] but autonomous vehicle developers are seeking, and policymakers are considering, a potential increase up to 100,000 vehicles per year.[10] However, this is risky given the difficulty of assessing autonomous vehicle safety prior to widespread deployment. A two-phased approach of initially allowing a smaller number of exemptions and then, after safety is demonstrated through deployment, increasing the cap on exemptions could provide a viable path to deploying innovative vehicle designs while managing risk.

In the interim, the industry should be allowed to continue technology development with safeguards in place. A first step is to conduct real-world, lower-risk pilot studies of autonomous

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[9] Exemptions may be granted on other bases, but the safety bases are likely most appropriate for autonomous vehicles. 49 CFR 555.6

[10] Greg Rogers, "Washington Preparing for Action on Automated Vehicles," *Eno Transportation Weekly*, April 27, 2017.

vehicles for limited uses and in constrained environments. A second consideration is sharing driving data across the industry and with policymakers.[11] There are certainly serious concerns about protecting trade secrets, but these concerns could be addressed and must be balanced with the societal need for safe, autonomous vehicle technology. Data-sharing should also involve regular information about the number of miles driven, crashes, failures, and other information that can help provide early evidence of safety and security concerns.

How Can Autonomous Vehicles Improve Mobility for Americans Who Currently May Have Limited Mobility?

Mobility is essential for a rich, productive, and healthy life. Even with the increasing ability to interact online, the ability to get to work, visit friends and family, access health care and other services, participate in civic activities, and generally be connected to the outside world remains vital. Despite mobility's importance, many Americans have limited, sometimes very limited, mobility as a result of advanced age, youth, disabilities, or lack of means. Autonomous vehicles could help these people overcome the obstacles of limited mobility.

The number of Americans 65 and older will increase from 48 million in 2015 (15 percent of the population) to 74 million in 2030 (23 percent). Driving is important to many of these adults' quality of life. Of adults over 65, 90 percent say they intend to age in place—and 80 percent live in car-dependent areas.[12] Eighty-five percent of adults aged 65 to 84 hold licenses, and almost 60 percent of adults over 85 hold licenses.[13]

However, driving is risky for many older Americans. A recent study found that, when compared with drivers aged 55 to 64, drivers over 75 were more than 2.5 times as likely to die in a car crash, and drivers over 85 were almost four times as likely.[14] This increased risk of death is due both to increased likelihood of accidents and greater vulnerability to injuries. But giving up driving has risks as well. Driving cessation almost doubles the risk of increased depressive symptoms and is correlated with (though not strictly a cause of) cognitive, social, and physical declines and higher rates of entry into long-term care.[15]

In addition to older people, people with disabilities, adolescents, and people living in poverty face mobility challenges. In 2010, 56.7 million individuals (18.7 percent of the population)

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[11] The kind of data that are shared must be carefully considered. Different developers have very different autonomous vehicle technology designs, which may limit the lessons that can be learned from data-sharing across fleets.

[12] David Dudley, "The Driverless Car Is (Almost) Here," *AARP The Magazine*, December 2014/January 2015.

[13] Policy and Governmental Affairs Office of Highway Police Information, "Distribution of Licensed Drivers – 2014 By Sex and Percentage in Each Age Group and Relation to Population," web page, U.S. Department of Transportation, September 2014.

[14] AAA Foundation for Traffic Safety, "Drivers Over 65 Almost Twice as Likely as Middle-Aged Drivers to Die in Car Crashes, According to AAA Foundation Study," February 18, 2004.

[15] Stanford Chihuri, Thelma J. Mielenz, Charles J. DiMaggio, Marian E. Betz, Carolyn DiGuiseppi, Vanya C. Jones, and Guohua Li, "Driving Cessation and Health Outcomes in Older Adults," *American Geriatric Society*, Vol. 64, 2016, pp. 332–341.

identified as having a disability.[16] Only 65 percent of individuals with disabilities drive, compared with 88 percent of individuals without disabilities.[17] Notwithstanding the Americans with Disabilities Act, which mandates that transit authorities operating a fixed route system provide paratransit or a comparable service to individuals with a disability,[18] individuals with disabilities often have limited mobility because of a lack of availability or access to services.

There are also 25 million Americans between the ages of 12 and 17 who have mobility needs but are not yet old enough to drive or are novice drivers.[19] Increased mobility can improve their educational, employment, and volunteer opportunities.

Americans living in poverty also face mobility challenges. About 43.1 million people (13.3 percent of the population) live in poverty.[20] This includes older adults and many individuals with disabilities. In 2014, 10 percent of older adults and 28.5 percent of individuals with a disability had a yearly income below the poverty line.[21] About 24 percent of households below the poverty line do not own a vehicle, compared with just 2 percent of households with incomes over $100,000. Individuals living in poverty are about three times as likely to take transit and 1.5 times more likely to walk.[22] Walking and transit can take much more time and limit travel to destinations that are accessible by these modes. Autonomous vehicles may provide more efficient transportation, which in turn provides the access to education, training, and work that helps people in poverty achieve upward economic mobility.[23]

Affordability, Availability, and Accessibility Are Keys to Realizing Mobility Benefits

Autonomous vehicles offer a promising solution for these mobility-challenged groups. Fully automated vehicles would allow many older adults, adolescents, and individuals with disabilities to travel by car without having to drive. They could increase their mobility, with all of the associated social and economic benefits, while mitigating much of the safety risk. Such vehicles may also provide access to automobile transportation for those who cannot afford taxis.

Yet simply bringing autonomous vehicles to market might not fully solve the mobility challenges Americans face. Autonomous vehicles, like other transportation options, must also be

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[16] Matthew W. Brault, *Americans with Disabilities: 2010,* U.S. Census Bureau, July 2012.

[17] U.S. Department of Transportation, *Freedom to Travel*, Washington D.C.: Bureau of Transportation Statistics, 2003.

[18] U.S. Department of Justice, Information and Technical Assistance on the Americans with Disabilities Act, 2016.

[19] Federal Interagency Forum on Child and Family Statistics, "POP1 Child Population: Number of Children (in Millions) Ages 0–17 in the United States by Age, 1950–2015 and Projected 2016–2050," 2016.

[20] Bernadette D. Proctor, Jessica L. Semega, and Melissa A. Kollar, *Income and Poverty in the United States: 2015*, Washington, D.C.: U.S. Census Bureau, September 2016.

[21] C. DeNavas-Walt and B. D. Proctor, *Income and Poverty in the United States: 2014*, Washington D.C.: U.S. Census Bureau, 2015.

[22] Federal Highway Administration, "Mobility Challenges for Households in Poverty: 2009 National Household Travel Survey," FHWA NHTS Brief, 2014.

[23] Raj Chetty and Nathaniel Hendren, "The Impacts of Neighborhoods on Intergenerational Mobility: Childhood Exposure Effects and County-Level Estimates," Harvard University, 2015.

affordable, available, and accessible. Fortunately, autonomous vehicles may have advantages over conventional transit, taxi, or vehicle-sharing services that require human drivers.

For many older adults, individuals with disabilities, and people living below the poverty line, the costs of a personally owned vehicle are prohibitive. The costs of a personally owned *autonomous* vehicle are expected to be substantially higher, particularly initially. Shared autonomous vehicles will be the key to affordability. Shared conventional vehicles are available for many people to use, either on demand or through a reservation system, and are typically pay-per-use. Some estimates suggest that the per-mile cost of using a shared *autonomous* vehicle service could be 30 percent to 90 percent less than owning a conventional vehicle or using conventional taxis, depending on the nature of the service.[24] In other words, per-trip costs could be comparable to public transit, but with greater convenience and speed. Such fleets are likely to be privately owned and operated, but it there is potential for them to be integrated into a public transit system, particularly if the vehicles are multi-occupancy (e.g., autonomous vans and small buses).

Second, shared autonomous vehicles must be available where people live. Car-sharing vehicles and taxis are not readily available in most small towns and rural communities because there are too few people to support the services. Poor *urban* areas are another underserved segment in today's mobility market. Public transit may not offer complete solutions, and taxis have historically been scarce because of low demand compared to wealthier urban areas.[25] The lower cost of shared autonomous vehicles may increase mobility in these underserved regions, but only if the cars are available there.

Third, shared autonomous vehicles need to be accessible, with vehicle design, websites, and technology interfaces consistent with the Americans with Disabilities Act and other accessibility standards and guidelines. Shared autonomous vehicles will also need diverse payment systems that do not require smart phones or credit cards. Meeting these design goals can be expensive. For example, the National Highway Traffic Safety Administration estimates that the cost of a new vehicle with adaptive equipment (e.g., mechanical hand controls, power transfer seats, and lifts and raps) can be $20,000–$80,000.[26] However, creating an accessible autonomous vehicle may be cheaper than creating an accessible traditional vehicle, as it only needs to be modified for passenger use and not for driving.

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[24] Lawrence D. Burnes, William C. Jordan, and Bonnie A. Scarborough, *Transforming Personal Mobility*, New York: The Earth Institute, Columbia University, January 27, 2013; and Tasha Keeney, "What If Uber Were to Adopt Shared Autonomous Vehicles (SAVs)?" *ARK Invest*, June 22, 2015.

[25] Mark W. Frankena and Paul A. Pautler, *An Economic Analysis of Taxicab Regulation*, Bureau of Economics, No. 1103, May 1984; Nelson\Nygaard, *Boston Taxi Consultant Report*, October 11, 2013; and Hara Associates Inc., *Best Practices Studies of Taxi Regulation: Taxi User Surveys*, prepared for San Francisco Municipal Transportation Agency, 2013. Today's ride share services may be helping provide better service in these underserved populations (see the Uber-funded study by Rosanna Smart, Brad Rowe, Angela Hawken, Mark Kleiman, Nate Mladenovic, Peter Gehred, and Clarissa Manning, *Faster and Cheaper: How Ride-Sourcing Fills a Gap in Low-Income Los Angeles Neighborhoods*, BOTEC Analysis Corporation, July 2015).

[26] National Highway Traffic Safety Administration, *Adapting Motor Vehicles for People with Disabilities*, June 2015.

What Can Policymakers Do To Promote Mobility?

All of this suggests that autonomous vehicles may increase mobility for historically underserved populations in a way that is more affordable, available, and accessible than existing transportation options. However, if policymakers choose to prioritize the realization of these benefits, certain policy options could be considered.

First, policymakers could create incentives for manufacturers and service providers to prioritize these markets and reach them sooner than they might otherwise. Incentives could include cost-sharing programs, subsidies, or other financial levers. They could also include partnerships to integrate both public and private shared autonomous vehicles into existing transit and paratransit services so that they are complementary rather than competing. This might involve making payment seamless across modes, providing easy transfers across modes, and integrating scheduling. Private ride-sourcing services like Uber and Lyft are already working with transit agencies to provide connections to existing transit services, but primarily in urban areas.

Second, policymakers could incentivize technology developers to ensure that accessibility for diverse populations is a priority when designing these vehicles. This could include facilitating collaboration between developers, health care providers, independent living centers and other facilities, and, most importantly, the users themselves. Participatory design would be key.

Third, while the cost of shared autonomous vehicles may be lower than some transportation alternatives, public assistance may still be warranted. In many regions, seniors and individuals with disabilities use public transit at a discounted rate or even for free. Policies might be needed to extend these discounts to shared autonomous vehicle services.

Conflict of Interest Statement: Nidhi Kalra's spouse, David Ferguson, is co-founder and president of Nuro, a machine learning and robotics startup engaged in autonomous vehicle development. He previously served as a principal engineer for Google's driverless car project. This written testimony was carefully reviewed by subject-matter experts within the RAND Corporation; the research quality assurance team for the RAND Justice, Infrastructure, and Environment division; and the RAND Office of Congressional Relations. However, the opinions and conclusions expressed in this testimony are the author's alone and should not be interpreted as representing those of the RAND Corporation or any of the sponsors of its research.