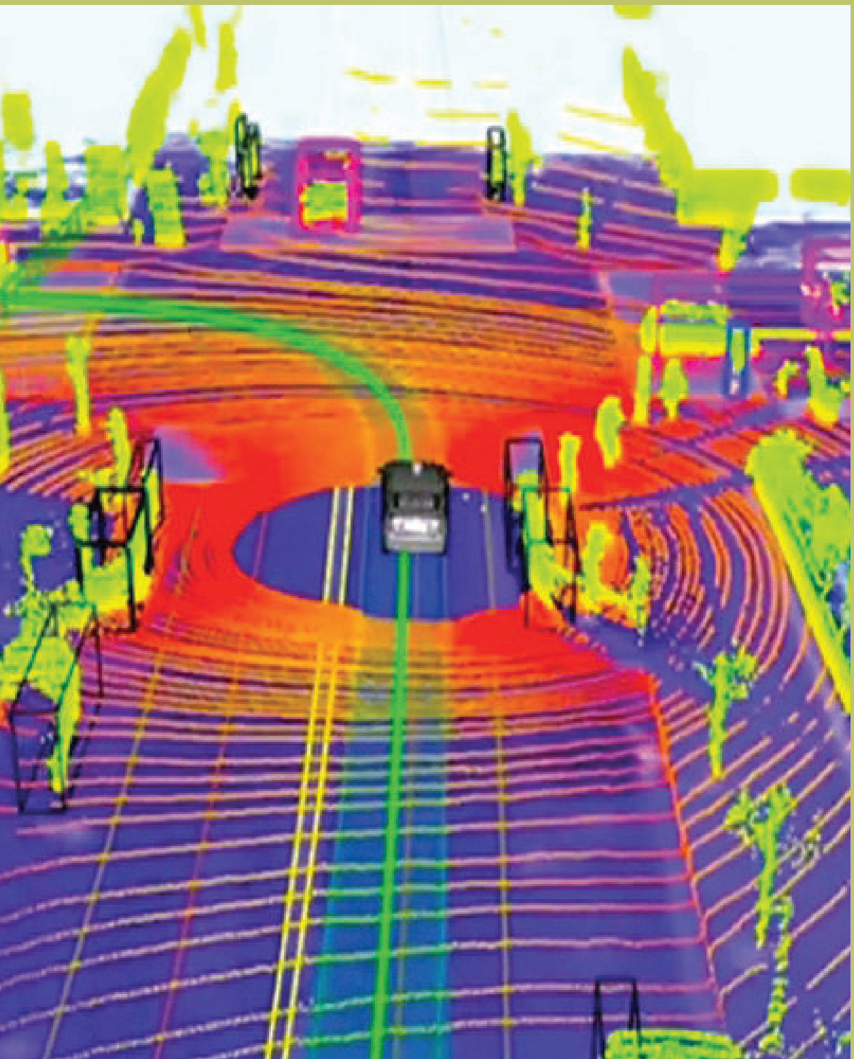
AUTONOMOUS VEHICLE TECHNOLOGY

How to Best Realize Its Social Benefits

The auto industry has been moving toward more autonomous vehicles for years. Americans already drive cars with crash-warning systems, adaptive cruise control, lane-keeping systems, and self-parking technology. Every major commercial automaker is conducting research in this area, and full-scale autonomous vehicles are predicted within 10–15 years—some say much sooner.



Several states have passed laws to regulate use of such vehicles, and other states are considering legislation. A RAND report, *Autonomous Vehicle Technology: A Guide for Policymakers,* by James M. Anderson et al., examines the technological advances in this area, their benefits and risks, and the potential effects of various regulations—as well as the absence of regulation—on the development of this technology. The authors warn against moving too quickly to regulate an industry that is changing so rapidly, but they also identify policies that would create public benefits.

CURRENT STATE OF THE TECHNOLOGY

As of March 2013, Google alone had logged more than 500,000 miles of autonomous driving on public roads without incurring a crash. But driverless vehicles are still an elusive goal. Google vehicles have highly trained operators who can take over in challenging situations.

Top: Google employees have logged more than 500,000 miles testing the company's "self-driving cars," among them this retrofitted Lexus 450h. (Photo: Google)

Left: An image of what Google's self-driving car sees when it makes a left turn. (Photo: Google)

Autonomous vehicles employ a "sense-plan-act" design that is the foundation of many robotic systems. A suite of sensors and cameras on the vehicle gathers data about the outside world and the vehicle's relation to its environment. Software algorithms interpret the data, which is then used to plan the vehicle's actions: its overall trajectory down the road, its speed, and lane changing. These plans are then converted into commands to the vehicle's control system—steering, throttle, and brakes.

The authors describe a number of tough problems that researchers and automakers must resolve before this technology can achieve the ultrareliability that will allow the driver to be fully removed from driving:

Making sense of the world. One of the greatest difficulties is building a vehicle that can make sense of world around it—traffic infrastructure, other vehicles, pedestrians, cyclists, traffic workers, and wildlife. Although the sensor systems can gather much more data about the environment than the human eye can, they are less adept at turning the data into a clear understanding of the environment. (Is that obstruction in the roadway a deer? A cardboard box? A bicycle?) Interpreting sensor data remains a fundamental research challenge.

Environmental challenges. Weather and terrain vary significantly across the United States, as do the road materials and signage practices across jurisdictions. A vehicle that operates easily on flat terrain in Louisiana may have trouble on Colorado's steep (and snowy) roads, or New York City's congested urban canyons.

Detection of sensor failure. Sensors may fail because of electrical failures, physical damage, or age. It will be critical for autonomous vehicles to have internal sensing and algorithms that can detect when internal components are not performing adequately. This is not easy. A sensor that fails to provide any data is easily detected, but a sensor that occasionally sends spurious data may be much harder to detect.

Vehicle communication. Communicating with surrounding vehicles and infrastructure would allow autonomous vehicles to find out about hazardous conditions and traffic congestion. But this technology may require expensive infrastructure investments; for example, every traffic signal may need to be equipped with a radio to permit it to communicate to cars.

Cybersecurity. As vehicles become more computerized and more connected, they also become more vulnerable to computer viruses and cyberattacks. These security risks, although not well understood, apply to all communications paths into the car, from Wi-Fi to cellular communications to dedicated short-range communications. To be reliable, the system must have the ability to detect failures and breaches and act safely—for example, by switching to a tightly controlled and simple safety system, or refusing to engage at all.

Cost. Despite the current interest in autonomous vehicle technology among automakers and others, ultimately it could be too expensive for wide adoption. Without sufficient demand, economies of scale and network effects will not reduce the marginal cost and the technology might wither. This problem has doomed earlier efforts at road vehicle automation.

Because of these challenges, the first commercially available autonomous vehicles may use a "shared driving" concept of operation: that is, vehicles will drive themselves in certain conditions—such as below a particular speed, on certain kinds of roads, and in certain weather conditions—and drivers will take over outside those boundaries. But this operational concept is not without its own risks. The main challenge is how to quickly and safely reengage the human driver, who may be distracted—watching a movie, checking email, or even asleep.

Some of the computer equipment that is used for autonomous operation is seen in a storage area in this Cadillac SRX that was modified by Carnegie Mellon University. (AP Photo/Keith Srakocic)

Automotive supplier Continental was granted a license to test autonomous vehicles on Nevada's roads in late 2012. Continental's test vehicle is fitted with a special red license plate indicating that the vehicle is autonomous in nature. Earning the plate required Continental to demonstrate the vehicle's abilities to the Nevada DMV, as well as providing the agency with safety plans, training documentation, system functions, and a strategy for accident reporting. (Photo: Continental AG)

Benefits of Autonomous Vehicles

Policymakers are becoming engaged in these developments because automated vehicles have the potential to provide substantial public benefits.

Saving Lives

Autonomous vehicles can dramatically reduce the frequency of crashes. According to the Insurance Institute for Highway Safety, nearly a third of crashes and fatalities could be prevented if all vehicles had forward collision and lane-departure warning, side-view (blind spot) assist, and adaptive headlights. (There were 32,000 traffic fatalities in the United States in 2011.) Further automation is expected to save more lives: Automatic braking when the car detects an obstacle will reduce rear-end collisions, and fully driverless cars will dramatically reduce human error, which is responsible for most fatalities and crashes.

Increasing Mobility

Currently, many people do not drive because they are disabled or too young. Autonomous vehicles will increase mobility for these populations, which may increase their social interaction, health, job opportunities, and happiness.

Reducing Cost of Congestion

Autonomous vehicle technology could also substantially reduce the cost of congestion because vehicle occupants could undertake other activities. It is possible that this decreased cost of driving might lead overall vehicle miles traveled to increase, potentially increasing actual congestion. However, the technology can also enable increased throughput on roads because of more efficient vehicle operation and reduced delays from crashes, so the overall effect on congestion is still uncertain.

Reducing Energy Use and Fuel Emissions

Automobiles have become heavier over the past 20 years, partly to meet more rigorous crash-test standards. If crashes become exceedingly rare, it may be possible to make lighter automobiles and reduce fuel use. Other efficiencies could bring further reductions. A lighter, more efficient car that potentially drives itself to refueling areas could also enable other types of alternative powertrains, such as electric cars and fuel cell vehicles that are fueled by hydrogen and have no tailpipe emissions.

Improving Land Use

Fully autonomous vehicles could simply drop off passengers in urban centers and drive away to satellite parking areas. Further, vehicle-sharing programs could decrease the rate of car ownership. In either event, fewer parking spaces would be necessary (by one estimate, about 31 percent of the space in the central business districts of 41 major cities was devoted to parking) and more space would be available for improving the built environment.

U.S. Rep. Bill Shuster, the chairman of the House Transportation and Infrastructure Committee, gets into a self-driven car in Cranberry, Pa., Butler County, in September 2013. The Cadillac SRX that was modified by Carnegie Mellon University went along local roads and highways operated by a computer that uses inputs from radars, laser rangefinders, and infrared cameras as it made a 33-mile trip to the Pittsburgh International Airport. A Carnegie Mellon engineer was in the driver's seat as a safety precaution. (AP Photo/Keith Srakocic)

GUIDANCE FOR POLICYMAKERS

A critical challenge to realizing these benefits is that a number of them accrue to the public, rather than the purchaser: Avoiding 10,000 deaths a year would be a vast improvement in social welfare, but it may not motivate individuals to pay the added cost of the vehicle. Similarly, some of the costs associated with these vehicles (such as the possibility of increased congestion or the decline in public transit) are imposed on others. To address this problem, policymakers may wish to consider a system of subsidies and taxes to help equalize the public and private benefits. But such steps will require more precise estimates of the costs and benefits of the technology than are available at this stage of development.

In fact, one of the key messages of the study is to avoid moving too quickly to regulate this technology without better information about its benefits and costs. That information will come with more research, more technology development, and policies designed to generate information.

Avoid Premature Regulation

As already mentioned, subsidies and taxes may be needed to promote a technology that has such public benefits. Relying strictly on the free market may not maximize social welfare and could even lead to market failure. But the technology is not mature enough to consider such policies.

At this point, aggressive policymaking would probably do more harm than good. If more states develop regulations to guide technology development, they may create a crazy quilt of different, and perhaps incompatible, requirements that could increase costs and make the technology uneconomical. The authors encourage legislators to collaborate closely with insurers, manufacturers, and consumer groups to develop standards and regulations over time, as the technology matures.

At the federal level, a hotly debated issue is the future of dedicated short-range communications. Since these licenses became available in 2004, they have been used only in experimental and demonstration projects. However, the FCC announced that they were considering reallocating the bandwidth to enhance Internet access, a move many stakeholders believe could cause harmful interference with communications among autonomous vehicles. The authors recommend that the FCC defer taking this step until further testing proves that it will not interfere with the development of communications among autonomous vehicles.

Another issue that could call for policy intervention in the future is the allocation of liability. For drivers and auto insurance companies, the decrease in the number of crashes and the associated lower insurance costs will encourage adoption. But as vehicles take on more of the functions that used to be the responsibility of the driver, automakers are concerned that they will become liable for crashes, a concern that could threaten technology development. In the short term, it is not clear that any change in the current liability regime is necessary. However, if concerns about increasing product liability constrain the introduction of these technologies, even if they are socially desirable, there are a number of policy options Congress could consider, from a federal statute limiting tort to a no-fault approach or a regulation that establishes the operator as ultimately in control of the vehicle.

Update Distracted Driving Laws

State lawmakers should to begin to consider updating distracted driving laws to accommodate autonomous vehicle technologies. Distracted driving laws vary widely from state to state, and could prevent the development of standard systems used for automating driver functions and providing infotainment. In other words, driver distraction needs to be permitted with this technology, at least under certain circumstances.

Clarify Data Ownership and Address Privacy Issues

Autonomous vehicles will generate and almost certainly share large quantities of data about location, automobile function, and use. This will raise considerable privacy issues. Could automakers, for example, sell such data to marketers or auto insurers? Should the data be discoverable in legal proceedings? As this technology develops, state and federal policymakers will have to address this important policy gap.

Compare Autonomous Vehicles to Performance of Average Human Drivers

Ultimately, regulations and liability rules should be designed by comparing the performance of autonomous vehicles to that of average human drivers. Instead of taking the position that autonomous vehicles need to achieve near-perfection before introduction, the guiding principle for policymakers should be that autonomous vehicle technology should be permitted if and when it is superior to average human drivers.

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