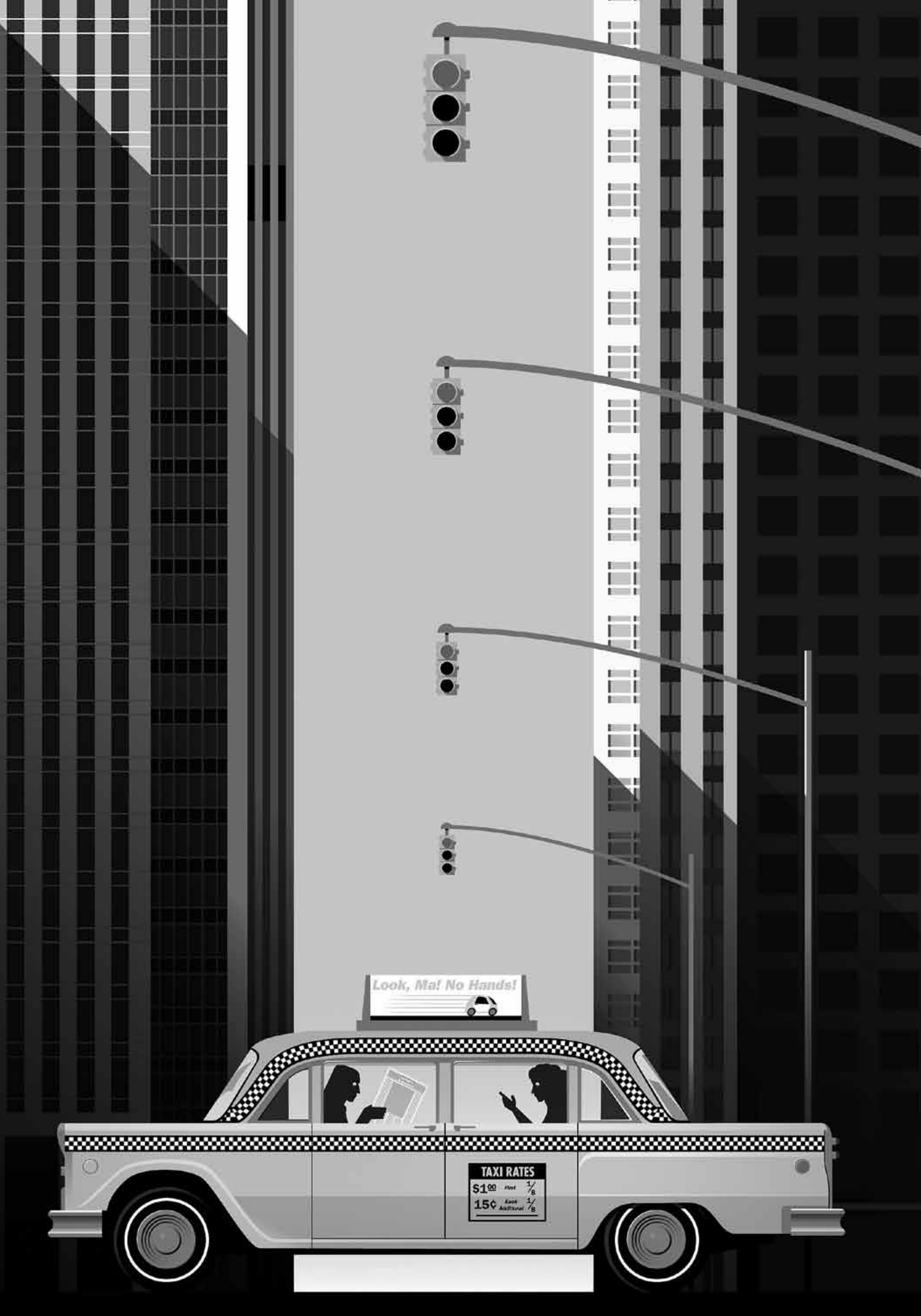
Look, Ma! No Hands!
TAXI RATES
$1.00 First 1/8
15¢ Each Additional 1/8

The Coming Transportation Revolution

BY ROBERT D. ATKINSON

Information and communications technology has already revolutionized industries from publishing and entertainment to education and health care – and now, it's transportation's turn. Two easy examples: Commuters can access real-time traffic information via their mobile phones, while adaptive signal lights can sense that a car is waiting at a red light with no cross-traffic present and switch to green to accommodate it.

But perhaps the ultimate manifestation of bringing intelligence to transportation is coming in the form of autonomous vehicles – cars and trucks that can literally drive themselves. Major car companies, including Audi, BMW, Ford, General Motors, Mercedes-Benz, Nissan, Toyota and Volvo, as well as some formidable tech giants (notably Google) are vying to field AVs.

I believe the economic impact of autonomous vehicles will be huge, but not for the reasons widely assumed. Direct productivity gains are likely to be modest since drivers still have to be in cars, although

JOHN TOMAC

now only as passengers. The bulk of the gains will come from reducing the costs associated with accidents and traffic congestion. A recent report from Morgan Stanley estimated that autonomous cars could save $1.3 trillion in the United States annually, with global savings totaling more than $5.6 trillion. Cisco Internet Business Solutions Group forecasts savings of $810 to $1,400 per connected vehicle per year from reductions in crashes and congestion.

But for all their potential, autonomous vehicles aren't just around the corner. Even the most optimistic predictions place the date of commercial availability five to ten years in the future. And skeptics, among them, John Leonard, the head of MIT's Marine Robotics Group, told the *New York Times* "there won't be taxis in Manhattan without drivers in my lifetime" because prices for many of the core technologies underlying autonomous vehicles – computer processors, radar, cameras, side-laser scanners, ultrasonic sensors and global positioning systems – just won't come down to levels that are palatable to the mass market any time soon. Moreover, he and others point out that various companies' prototype AVs still encounter difficulty in rain and snow.

This is why Lux Research predicts that a truly autonomous car with the versatility of an experienced driver will not be available before 2030. Note, moreover, that since it takes at least 15 years to turn over most of the U.S. auto fleet, at best – assuming AVs become the standard in 2030 – we are talking about 2045 before they rule the road.

Sooner or later, though, AVs will almost certainly be ubiquitous. So it's worth taking a closer look at the likely economic benefits

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ANNUAL ECONOMIC BENEFITS FROM SWITCHOVER TO AUTONOMOUS VEHICLES

ECONOMIC BENEFITS	U.S. ECONOMIC VALUE-ADDED
Productivity in Transportation Industry	$20 billion
Reduction in Accidents	$900 billion
Reduction in Congestion	$100 billion
More Efficient Fleet Utilization	$12 billion
Reduction in Energy Use	$24 billion
Estimated Total Savings	**$1.05 trillion**

SOURCE: Author's calculations

and the changes likely to be wrought by what promises to be a truly disruptive technology.

LABOR PRODUCTIVITY

MIT's Andrew McAfee and Erik Brynjolfsson point to AVs as a proof for their thesis that technology is advancing so rapidly it will put people out of work faster than it creates jobs [*see an excerpt of their book in the Summer 2014 issue of the* Milken Institute Review– *ed.*]. But promises of higher productivity should be viewed skeptically. AVs are not Scotty's Star Trek transporters; commuting in an AV will still require time en route. An AV would enable people to do things other than drive – e-mail, reading, web surfing or catching up on *Fast & Furious (Sequel 31)*. To the extent this activity involves "real" work, productivity will increase slightly.

If more significant labor-saving gains are to come from AVs, they will come from the automation of trucking. The larger gains are more likely to be reaped in long-haul freight, where a truck is loaded at one warehouse and drives itself hundreds or thousands of miles to another warehouse. Most local commercial trucking would still need a human to load the truck and make deliveries along the route. There are 1.6 million truck drivers in the United States, but many are not long-haul truckers. Equally to the point, trucking adds a relatively modest amount to GDP: If automation eliminated half of truck driver jobs, average labor productivity for the economy as a whole would rise by about half a percentage point.

The story could be quite different for taxis. One could imagine an AV fleet, with individuals hailing them with smartphone apps. These cars could even be owned by individuals who let them be used as taxis when they would otherwise be idle. But the numbers of jobs at stake – and thus the potential for productivity gains – are not large in the greater scheme of things. Even if AVs freed all 240,000 taxi drivers for other work, the one-time productivity increase would be just 0.2 percent.

It's possible that automated buses could be developed, but some degree of on-board supervision would still be needed. If half of bus driving jobs were eliminated, average economy-wide labor productivity would increase by just 0.1 percent. That doesn't entirely exhaust the potential of commercial AVs. The mining company Rio Tinto is already deploying self-driving ore trucks. But again, the numbers suggest evolutionary gains, with roughly $20 billion annually in labor saving.

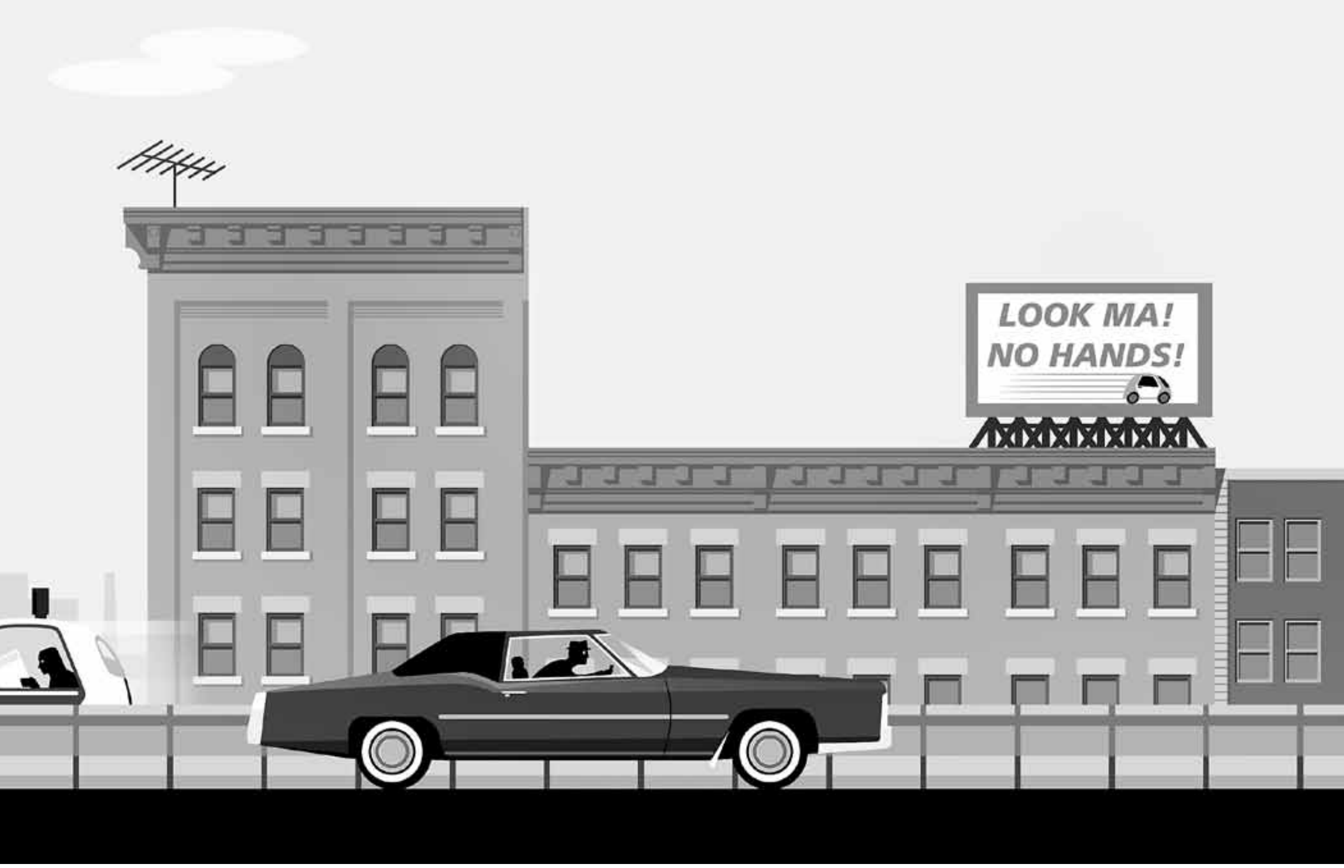

JOHN TOMAC

IMPROVED SAFETY

More significant gains will probably come from collision avoidance. According to the Department of Transportation, the direct cost of traffic accidents in the United States totaled $277 billion in 2010, including $93 billion in lost productivity, $76 billion in property damage, $35 billion in medical expenses and $28 billion in added traffic congestion. Strikingly, this figure was dwarfed by an estimated $594 billion in indirect costs – decreased quality of life due to injuries and death. Human error causes a vast majority of traffic accidents. In fact, one federally funded study from the 1970s estimated that human error probably caused over 90 percent of these accidents. And while that study is dated, one would expect the figure to be even higher in an era in which vehicles are far better equipped for safety.

Autonomous vehicles could drastically reduce accidents. Most obviously, AVs don't drive while distracted, tired, inebriated or impaired by age or inexperience. And, of course, they can be programmed to obey traffic laws. Less obviously, new technologies – including communication among AVs – will add a layer of protection unimaginable a few decades ago.

While it would be unreasonable to imagine a future in which an autonomous vehicle is never involved in an auto accident – among other issues, AVs will have to share the road with human drivers for a very long time – Google notes that its driverless cars have already logged more than a half million miles without causing an accident. Moreover, even before truly autonomous vehicles roam the roads, a range of IT-enabled automated driver assistance technologies – including blind spot detection, lane departure warnings, dangerous



Because AVs need less headway to operate safely, highways carrying only autonomous vehicles could accommodate two to three times as many automobiles.

proximity (precollision) indicators, rearview cameras and parking assistance – are already having a significant impact in reducing accidents and injuries.

For example, since 2010, Volvos equipped with a collision avoidance system that can automatically brake to avoid obstacles have experienced one-quarter fewer property-damage claims than Volvos without the system. According to the insurer-supported Insurance Institute for Highway Safety, forward collision warning systems lead to a 7 percent reduction in vehicle-to-vehicle collisions. That number increases to 15 percent with automatic braking systems.

A recent study by engineers at Virginia Tech University examined some 2,500 collisions resulting from unintended lane departures from 2007 to 2011. They found that if the vehicles had been equipped with lane departure warning systems, 30 percent of the crashes could have been avoided. The science journalist Philip Ross notes that parallel simulation examining the effects of forward collision warning systems "found far greater differences, preventing as many as 53 percent of rear-end collisions."

INFRASTRUCTURE PERFORMANCE

A third source of savings will come from improved system performance – that is, increased road capacity and reduced congestion. In 2011, Americans lost 5.5 billion hours (and 2.9 billion gallons of fuel) waiting in

JOHN TOMAC

traffic, which translates into 38 hours per year for the average commuter. The Texas Transportation Institute's *Urban Mobility Report* estimates that this "congestion penalty" – the value of commuters' lost time and extra payments at the pump – conservatively cost Americans over $400 per person in 2011.

One study estimated that even a highway running at peak capacity has only 4.5 percent of its surface area occupied. But because AVs need less headway to operate safely, highways carrying only autonomous vehicles could accommodate two to three times as many automobiles. Moreover, because one-fourth of congestion is attributable to traffic incidents that would largely be avoidable, AVs would increase throughput this way as well. Note, too, that the more efficiently existing transportation infrastructure is utilized, the less need there will be to invest in new roadways. Assuming that AVs reduce congestion by half, the economywide savings could run to $100 billion per year.

AVs would also enable more efficient parking since they could drop off passengers, park themselves at considerable distance and return when called. Note the synergies here: A substantial portion of urban congestion consists of inefficient searches for parking – much of which could be eliminated by automated parking systems.

INCREASED FLEET UTILIZATION

AVs are well positioned to increase use of vehicles as well as road and parking infrastructure. Today, the average American vehicle sits idle 95 percent of the time. But autonomous vehicles could be shared, much the way private aircraft are shared today, with computer systems routing and positioning vehicles for minimum wait time. They will also present a compelling mobility option for those who don't wish to own vehicles. Instead of turning to taxis, Uber or Zipcar when one needs temporary transportation, one can imagine just hitting a button on a smartphone app and an autonomous vehicle that your neighbor owns shows up to take you to your destination.

A recent study calculated that a fleet of autonomous vehicles acting as a personalized public transportation system would be cheaper and more efficient than taxis, using half the fuel and a fifth the road space of ordinary cars. Another study showed that a single shared AV could replace between 9 and 13 privately owned vehicles without impeding travel behavior.

Reducing the number of cars would not reduce costs proportionately because cars depreciate from use as well as age. If increased car sharing allowed a reduction of just 15 percent of passenger vehicles in the fleet, I estimate the savings would exceed $70 billion per year. Assuming that the remaining cars are driven 15 percent more to make up the difference, the economic benefits (netting out faster fleet depreciation) would be approximately $12 billion per year.

ENERGY SAVINGS

With all other things equal, AVs would also reduce energy consumption for travel. As noted earlier, less congestion means higher mileage.

But AVs would also be able to save by "platooning," in which a line of trucks would ride only a few feet apart in order to reduce wind resistance the way stock car drivers "draft" to conserve fuel. A Stanford University technology spinoff, Pelaton, estimates that in a two-truck platoon the rear truck could save approximately 10 percent in fuel costs. If platooning increased average fleet mileage by 5 percent, the savings would come to $24 billion annually.

JOHN TOMAC

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OTHER ECONOMIC BENEFITS

Just some of the possibilities: With AVs, travelers will probably substitute driving for airline travel in medium-distance trips because AVs would be faster than ordinary cars and would allow them to work or play en route… Driving classes and schools are likely to go the way of the manual transmission, once AVs dominate… Much safer roads would allow government to reduce traffic police… Roads would not need to be as well lighted since AV guidance would be electronic… Autonomous vehicles could significantly enhance personal mobility and convenience, particularly for the elderly, disabled and, of course, children… Quantifying this last benefit would not be easy, but it does suggest just how disruptive AV technology could be to a society that is rapidly aging.

GETTING TO THE AV FUTURE

For all their promise, making the transition to AVs will pose challenges. The major one is cost. Innovation and scale economies can be expected to bring down these costs eventually, but for now they are a key barrier. Steven

Enthusiastic acceptance would be critical to market viability because much of the benefit to society depends on wide adoption.

Dellenbeck of the Southwest Research Institute in San Antonio estimates that the cost premium will not fall below $10,000 for at least a decade. On reflection, $10,000 isn't a lot of money in light of the product's advantages in safety and efficiency. But the public will have to be educated about AVs before they're willing to switch; a JD Power survey in 2012 found that only 20 percent of consumers would buy an AV if the price premium was more than $3,000.

More to the point, the public will have to be convinced that driverless cars are very safe; the JD Power study also found that only 37 percent of consumers would definitely or probably buy an AV if it were available, regardless of the price. It is not all that surprising that ceding control of vehicles to computers is daunting to most people. But enthusiastic acceptance would be critical to market viability because much of the benefit to society depends on wide adoption.

To see why, consider the research of Steven Shladover, an engineer at the University of California, and colleagues. They estimate that adaptive cruise control in which AVs communicate with one another could increase lane capacities by 80 percent if 90 percent of cars

JOHN TOMAC

had it. But if only 50 percent of vehicles have the technology, lane capacity grows by only 21 percent.

In other words, this is a classic case in which much of the benefit is "external" to the owner of the vehicle. In cases like this, the economically rationale way to correct what amounts to market failure is to tax the external costs and subsidize the external benefits. Hence, the logic of speeding the transition to AVs by subsidizing them, at least temporarily (as the federal government has done for parallel reasons with hybrid and electric vehicles).

Governments will also have to make AVs legal. Four U.S. states – California, Florida, Michigan and Nevada – along with the District of Columbia have passed laws permitting open road testing of autonomous vehicles. Europe is also beginning to look at adjusting its laws with regard to legalization of AVs. But as a BMW representative recently noted, "The legislation is just not in place for us to be able to put these [autonomous] vehicles on the [European] market."

Still, an important step toward this end was taken in April 2014 when an amendment to the Vienna Convention on Road Traffic (an international treaty designed to facilitate international road transit that covers 72 nations with the major exceptions of the United States, China and Japan) was adopted that will permit AV use on public roads, so long as the vehicle can "be overridden or switched off by the driver."

Europe also has a potential advantage over the United States if it can make autonomous vehicles legal for sale and operation across the entire European Union, while in the United States the legal status of autonomous vehicles is determined on a state-by-state basis. In May 2013, the U.S. National Highway Transportation Safety Administration issued a preliminary policy statement intended to guide states in permitting testing of the emerging vehicle technology. But NHTSA can only advise the states, which will make their own decisions. Arguably, the best reason for optimism here is that states will be competing to attract AV manufacturers, which will presumably be leery of jurisdictions that are unwilling to give them leeway in use on the roads.

A particularly thorny issue will pertain to legal liability – specifically, who is liable if an autonomous vehicle is involved in an accident. Is it the passenger (who is no longer the driver), the manufacturer or the company that wrote the software for the AV's computers? One option would be to create a no-fault fund that compensated victims in AV accidents, possibly modeled after the federal government's Vaccine Injury Compensation Program. Vaccine makers pay a 75-cent tax for every dose purchased (which is presumably passed through in the price of the vaccine) and are thereafter exempt from suits. Note that the rationale would be quite similar: As with vaccines against communicable diseases, much of the benefit of AVs would be reaped by third parties.

* * *

The journalist Tom Vanderbilt reminds us in a recent issue of *Wired* magazine that Karl Benz, a founder of Mercedes-Benz, once lamented that the market for automobiles would be limited by the lack of qualified chauffeurs. Today, Bill Krenik, chief technologist for the semiconductor manufacturer Texas Instruments, argues that the advent of autonomous vehicles will be as transformative as the shift from the horse to the internal combustion engine was in a prior era. And just as it once seemed unimaginable that we could drive vehicles ourselves, today it seems unimaginable that machines could drive them for us.