

SEPTEMBER 18, 2014 | NUMBER 758

Policy Implications of Autonomous Vehicles

BY RANDAL O'TOOLE

EXECUTIVE SUMMARY

Partially autonomous vehicles that can take over some driving functions, such as steering and speed control, are on the market today. Highly autonomous vehicles that can drive themselves in most situations should be available for sale in less than a decade. Fully autonomous vehicles that won't even have an option for a human driver will be available within a decade after that.

Such autonomous vehicles will transform the 21st century in the same way that mass-produced automobiles transformed the 20th. Auto travel will become safer. Congestion will decline if not disappear. People who can be productive rather than endure the stress of driving will look at travel in an entirely new way. Eventually, mobility will be available to everyone, not just those who have a driver's license.

Considering the technology available today and what experts think will be available in the near future, Congress and other policymakers should consider the following steps:

- Congress should stop funding expensive and obsolete rail transit projects, which will have no place in a future likely to be characterized by widespread sharing of self-driving cars.
- Congress should end the mandate for states and metro-

politan planning organizations to write long-range transportation plans, as planners cannot predict the effects of autonomous vehicles and are likely to instead impose obsolete systems and designs on their regions.

- The National Highway Safety Traffic Commission should not mandate that vehicle-to-vehicle communications be installed in all new cars, as such devices will rapidly become obsolete, while voluntary devices in the form of smart phones that can use vehicle-to-vehicle applications are already in use by more than half the adult population.
- State and local governments should focus on maintaining existing infrastructure and making cost-effective improvements, such as dynamic traffic signal coordination, to alleviate today's safety and congestion problems. The best thing state and local transportation agencies can do to prepare the way for autonomous vehicles is to cooperate in the development and use of consistent road striping, sign, signal, and similar standards that can be read by autonomous vehicles.
- By reducing congestion, autonomous cars may lead to a revival of inner cities, but by reducing the cost of travel, they may also lead to more rapid exurbanization. Cities and states should not try to restrict either trend.

“If people can work, read, surf the web, or watch movies or television while traveling, they may be willing to spend more time in motion, which in turn could lead to another wave of suburbanization.”

INTRODUCTION

Self-driving cars are coming. Cars that can take over some driving functions, such as steering on highway lanes or controlling speeds to avoid accidents, are already on the market. Google has a prototype car that doesn't even have the option of being operated by humans.

Just as the mass-produced automobile transformed the 20th century, the autonomous car will transform the 21st. Housing, work, shopping, and recreation will all dramatically change as mobility no longer depends on fallible and easily distracted human drivers.

This mobility will contribute to a new birth of freedom in the United States and around the world. As Volvo researcher Anders Tylman-Mikiewicz observes, “The core concept of individual mobility is ultimately about freedom.”¹

One obvious improvement is safety. Highway fatalities have declined by 25 percent since 2005, thanks in part to smart auto technologies such as electronic stability control and antilock brakes.² The decline in fatalities should accelerate as motor vehicles become more autonomous.

Other changes will be more subtle. One is the amount of time people will allot for travel. One study found that, throughout the world and throughout history, people have spent an average of about 1.1 hours per day traveling.³ But if people can work, read, surf the web, or watch movies or television while traveling, they may be willing to spend more time in motion. This could lead to another wave of suburbanization or exurbanization of both people and jobs.

Partly because the U.S. Department of Transportation cancelled its research programs on self-driving cars in 1998, most of the work on autonomous vehicles is being done by private auto manufacturers, engineering, and software companies. This is a good thing, as it has resulted in a variety of competing technologies and innovations.

However, most federal, state, and local policymakers are acting as if this revolution isn't happening. For example, not a single long-range metropolitan transportation plan

has attempted to account for the possibility of self-driving cars. One of the few federal agencies that is getting involved in these new technologies, the National Highway Traffic Safety Administration, is threatening to write rules that could do more harm than good.

Not all of the changes that will result from autonomous vehicles are predictable, but what is predictable is that the changes will be profound. Legislators and policymakers need to be aware of the implications of these changes before they make long-range decisions relating to transportation and land use.

DEFINING AUTONOMOUS VEHICLES

Autonomous vehicles, also known as smart cars or robocars, use a variety of sensors, computer processors, and databases such as maps to take over some or all of the functions of driving from human operators. The National Highway Traffic Safety Administration and Society of Automotive Engineers have each defined several degrees or levels of autonomy; confusingly, one has five levels while the other has six, so level 4 under one system is level 5 under the other. In both systems, a level 0 vehicle has no automation while the top level can operate full time without a human driver.⁴

Three levels of autonomy are important for policymakers:

- Partial autonomy, in which the car can take over some of the functions of driving while still requiring the driver to remain fully alert to driving conditions;
- High autonomy, in which the car can drive itself in most conditions but still may need to call upon a human driver to deal with extraordinary or unanticipated situations; and
- Full autonomy, in which human operation is not needed and may not even be possible.

Partially autonomous vehicles rely on radar, lasers, infrared, and/or optical sensors

to detect road conditions and use computer processors to respond to those conditions. Highly autonomous vehicles also incorporate detailed maps so the car can determine the optimal routes to get to destinations selected by the occupants and know all of the rules of the road over those routes. Fully autonomous vehicles will be capable of dealing with deviations from those maps caused by such things as road construction, weather conditions, and traffic accidents.

Partially autonomous vehicles are already on the market, with some being available for under \$26,000.⁵ Also known as advanced driver assistance systems (ADAS), vehicles equipped with these technologies typically include adaptive cruise control, which allows the car to automatically accelerate and brake to keep a fixed distance from the car in front; lane keeping, which either steers between the stripes on a highway or alerts the driver if the car starts to cross the stripes without signaling; and various sorts of collision avoidance systems that can brake or otherwise control the car to prevent accidents.

None of these systems use or require any kind of centralized computer system to monitor or direct their travel. Instead, all of the electronics and processing power are in the vehicles. When parked in a place where they can get secure access to the Internet, vehicles may download updates of maps or other data. Otherwise, they operate completely independently of any central control.

AUTONOMOUS VEHICLE TIMETABLE

In 2013 Nissan announced that it would market “multiple affordable” highly autonomous vehicles by 2020.⁶ More recently, the company said it would make available more advanced partially autonomous cars that can deal with traffic and change lanes by 2018.⁷

Google, which has operated its highly autonomous vehicles more than 700,000 miles since 2009, is even more ambitious, saying it expects such cars to hit the market as soon as

2017.⁸ Although Google is building 100 prototypes of a fully autonomous car without any driving controls, it doesn’t expect to manufacture cars itself but hopes to supply software to automakers.

A survey of more than 200 experts who attended an automated vehicles symposium near San Francisco in July 2014 found that the median date they expected highly automated vehicles to reach the market was 2020, while most expected fully automated vehicles to be available by 2030.⁹

Of course, reaching the market and dominating the roads are two different things. The average car on the road is more than ten years old.¹⁰ This suggests that, even if all cars made after 2020 were highly autonomous, it could take close to a decade before half the cars on the road were capable of driving themselves.

But not all cars made in 2020 will be highly autonomous. Although the costs of manufacturing the hardware required to make new cars autonomous, including sensors, processors, and other electronics, are expected to rapidly decline, IHS Automotive predicts that highly autonomous cars will initially cost at least \$7,000 to \$10,000 more than cars without this capability.¹¹ Moreover, to maximize profits, auto manufacturers tend to introduce new features on high-end cars first, and slowly work down the price chain. Thus, the first Nissan-made car to be highly autonomous is more likely to be a top-of-the-line Infiniti than an affordable Versa.

Pessimists note that 17 years passed before the introduction of antilock brake systems and their use on just 5 percent of cars on the road. Similarly, 15 years passed before the introduction of adaptive cruise control and 5 percent market penetration. In this view, it will be 2060 or so before enough cars on the road are highly or fully autonomous to make a difference in transportation habits and conditions.

However, highly autonomous vehicles offer far more benefits than antilock brakes. After all, surveys show that the vast majority of American drivers consider themselves to be above-average drivers and probably consider

“Partially autonomous vehicles capable of accelerating, braking, and even steering are already on the market, with some being available for under \$26,000.”

“Competition from aftermarket manufacturers will put pressure on automakers to sell autonomous cars at affordable prices.”

themselves immune enough from auto accidents that antilock brakes were only important for other drivers.¹²

A better comparison is the introduction of the moving assembly line, which allowed Ford to sell cars at far lower prices than ever before. In 1913, when Henry Ford began experimenting with the moving assembly line, less than 5 percent of American families owned an automobile. Fourteen years later, 55 percent owned a car.¹³ “We’d rather do without clothes than give up the car,” a small-town resident told social scientists in the mid-1920s.¹⁴

While the key to growing automobility in the early 20th century was affordability, there are several reasons to think that highly autonomous cars will quickly become affordable. First, software makers such as Google will have an incentive to prod automakers to make highly autonomous cars widely available so they can sell their software, which will likely be sold on a subscription basis due to the need to frequently update maps and other data.

Pressure will also come from companies offering aftermarket modifications of existing cars to make them highly autonomous. While the cost of converting an older car to a highly autonomous vehicle would be prohibitive, turning a partially autonomous car into a highly autonomous one would require little more than the addition of a few sensors and a software upgrade. One startup company has already promised to convert partially autonomous Audis to highly autonomous cars starting in 2015.¹⁵

This suggests that, when the first highly autonomous vehicle hits the market, millions of cars already on the road will be ready for a low-cost upgrade to highly autonomous capabilities. This will put pressure on automakers to sell highly autonomous cars at affordable prices or lose sales to aftermarket manufacturers.

Furthermore, when fully autonomous vehicles reach the market in, or likely before, 2030, converting highly autonomous vehicles into fully autonomous ones would take nothing more than a software upgrade. This means that America’s auto fleet could rapidly become fully autonomous in just a few years after 2030,

both because of retrofitting and because manufacturers would quickly begin making affordable autonomous cars.

IMPLICATIONS FOR TRANSPORTATION

The introduction and growing use of partially, highly, and fully autonomous vehicles will each have significant effects on transportation. Partially autonomous vehicles will help relieve traffic congestion. Highly autonomous vehicles will change the way people think about driving and the costs of travel. Fully autonomous vehicles will allow people who lack drivers’ licenses to become as mobile as those who can drive. Each level will also progressively improve roadway safety.

Adaptive cruise control, an important component of most advanced driver assistance systems, helps relieve the driver of the irksome task of maintaining a safe distance behind other vehicles in variable speed or stop-and-go traffic. But it also provides a useful social benefit in helping to relieve congestion in the first place. In heavy traffic, much congestion results from slow human reflexes. By substituting computer speeds for human speeds, much of this congestion may go away.

Actual measurements have found that a typical freeway lane can move about 2,000 to 2,400 vehicles per hour when moving about 50 miles per hour. However, at slower speeds, flows can decline to less than half of the full capacity of the road. This means that if one vehicle on a road that is near capacity slows slightly, the entire flow rate on the road can drop, and speeds can remain slow for hours after the initial slowdown.

Traffic engineers call the transmission of these slower speeds through a traffic lane a “pulse.” Due to its faster response time, a car with adaptive cruise control can interrupt this pulse and permit flows to remain near capacity levels. One study has concluded that, if as few as 20 percent of cars on the road use adaptive cruise control, about half of all congestion could be avoided.¹⁶ A study in Germany confirms that “a small amount

of ACC equipped cars . . . leads to a dramatic reduction of traffic congestion.”¹⁷

Many traffic engineers speculate that highly or fully autonomous vehicles will be able to double or triple roadway capacities because the vehicles will be able to safely operate more closely together. Such huge capacity increases won't result from partially autonomous vehicles, but if partially autonomous cars can just keep flows at near-capacity levels, they will go far towards relieving the traffic congestion that plagues American urban areas.

Although highly autonomous vehicles will also help relieve congestion and improve safety, they will have a more profound effect on travel by changing the way people assess the cost of auto travel. While driving is stressful and requires the full attention of the driver, operators of highly or fully autonomous vehicles will experience little stress and will be able to spend most of their time on productive, social, or recreational activities.

Some people believe that it is an oversimplification to say that most people throughout history have been willing to devote an average of just over an hour a day traveling.¹⁸ However, it is clear that people have two different travel budgets: one a dollar budget and one a time budget. Surveys indicate that, for a slight majority of Americans, it is the time budget that most constrains commuting and other travel.¹⁹

In 2012 the American Community Survey found that Americans who drive to work spend an average of about 26 minutes commuting each way, while Americans who take transit to work spend more than 46 minutes each way.²⁰ Some people see this as an example of transit's inefficiency, but it also suggests people are willing to spend more time en route if they don't have the stress of driving and possibly can be entertained or productive by reading or doing other things.

Several studies have shown that increasing commuting speeds increases worker productivity, probably because it gives employers a larger pool of potential workers to select from and allows more people to find a job that best suits their skill set.²¹ If highly and fully autonomous vehicles allow people to significantly increase

their time travel budgets, the nation is likely to see a similar boost in worker productivity.

Fully autonomous vehicles will lead to another profound transformation in travel. While highly autonomous vehicles will still require a licensed driver able to take control in some situations, a fully autonomous vehicle will not. This means more cars on the road will be occupied by disabled people or people who are too young or too old to drive.

Car sharing may become more widespread as people who own cars rent them out rather than park them when they aren't using them themselves. The expansion of car sharing may change the way people view the cost of auto travel. Much of the cost of owning a car is fixed, so once someone owns a car, the marginal cost of taking a trip is low. But people renting shared vehicles will have to pay the average cost, which may depress travel.

On the other hand, the introduction of fully autonomous vehicles will lead to a significant number of cars on the road that have no human occupants at all. People may come to view vehicles as robotic assistants as much as a means of travel, sending them off to pick up groceries, drop off dry cleaning, or do other simple tasks. People may always prefer to browse and select their own fresh produce and meats, but retailing of dry and canned goods may change as people simply order what they want on the Internet and then send their car, a shared car, or a store-owned automated delivery vehicle to bring their purchases from an automated distribution center.

In other words, some aspects of fully autonomous vehicles will reduce per capita vehicle travel, while others will increase it. Will the net effect be more or less driving? No one knows, but most experts suspect that vehicle travel would increase.

IMPLICATIONS FOR INFRASTRUCTURE

Telecommunications engineers refer to infrastructure as being either *smart* or *dumb*. Dumb infrastructure would do little but offer

“The introduction of fully autonomous vehicles will lead to a significant number of zero-occupant vehicles on the road as people use cars as robotic assistants for a variety of tasks.”

“Upgrading traffic signals is the most cost-effective way of relieving congestion, saving energy, and reducing pollution, yet few local governments have made an effort to do so.”

avenues of communication; any intelligence would have to be provided by the end users or their devices. Smart infrastructure would build that intelligence into the infrastructure, so that end users would not need to invest in smart machines to use it.

For example, a smart Internet would have word processors, spreadsheets, graphics tools, and other software online, which users could access from dumb terminals that did little but accept user commands and display the results. This would allow users to spend less on their own computers and software.

The problem is that smart infrastructure requires the owners to maintain and upgrade the infrastructure to meet new user demand and needs. It also requires them to foresee what all those needs might be, an impossible job since millions of users might each have their own ideas about what they want and need.

The French Minitel system was an example of smart infrastructure that preceded the Internet. Introduced throughout France in 1982, Minitel was the most advanced system of its day and gave users access to email, online shopping, train and airline tickets, and other features long before the Internet became available to the general public elsewhere. Telephone owners were given free dumb terminals to access the system. However, Minitel could not keep up with the rapidly evolving Internet, and France Telecom shut the system down in 2012.

In the same way, highways used by autonomous vehicles can be smart or dumb. Dumb highways would simply be pavement with no more signs and signals than those observable by human drivers. Smart highways would have built-in systems to guide and coordinate vehicles.

The General Motors Futurama exhibit at the 1939 New York World's Fair first introduced the idea of autonomous vehicles to the public. As conceived by designer Norman Bel Geddes, highways would have built-in magnets that would be sensed by motor vehicles. The vehicles would drive themselves by following the trail of magnets.²²

Nearly 60 years later, in 1997, the federal government funded a demonstration of this

technology in which magnets were inserted into a new freeway built in San Diego and eight driverless cars tested on the road, operating at 70 mph one car length apart from one another.²³ After the successful demonstration, however, the Department of Transportation cancelled any further funding for self-driving cars.²⁴

Since then, General Motors, Volkswagen, Google, and other organizations developing autonomous vehicles have presumed that smart infrastructure will not be available and instead designed their cars to operate using the existing infrastructure. This means that highly and fully autonomous vehicles must be very adaptable, as traffic signals, signs, and even roadway striping vary greatly from state to state.

Auto manufacturers were probably right to be wary about relying on the government to provide smart highways. The United States has more than 330,000 traffic signals, and the Federal Highway Administration estimates that three-fourths of them use obsolete control systems or software. The latest systems dynamically respond to changing traffic conditions, thus avoiding situations where people have to wait for signals to go through a complete cycle even if there is no opposing traffic. Upgrading these systems is quite possibly the most cost-effective way of relieving congestion, saving energy, and reducing air pollution, yet few local governments have made an effort to do so.²⁵ If city and county street and road agencies can't keep traffic signals up-to-date, how long would it take them to install and upgrade smart road systems?

President Obama has endorsed a National Highway Traffic Safety Administration proposal to mandate that all new cars be sold with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications systems.²⁶ These systems could alert drivers of congestions or safety hazards on the road ahead. While not directly related to autonomous vehicle technology, some engineers believe that such vehicle-to-vehicle communications will be essential for the success of autonomous vehicles, especially in their ability to greatly increase the capacity of the roads to move autonomous vehicles.

Vehicle-to-infrastructure communications would be a form of smart infrastructure that could allow roadway owners to communicate speed limits, traffic signals, and other information, allowing designers of autonomous vehicles to rely on such radio signals rather than having to program their vehicles to read and interpret signs and signals of various shapes and designs. For this to work, however, all state and local road departments would have to install and maintain such radio systems, something for which there is currently no funding. Rather than rely on state and local roadway owners to install such systems, autonomous vehicle designers say they will use vehicle-to-infrastructure systems if they are available but won't design their vehicles to depend on them.

The need for mandatory V2V communications in increasing road capacities is questionable. Although freeway lanes have been measured moving 2,200 vehicles per hour or more, this much traffic is prone to breakdown if someone slows down slightly and slow human reflexes force an entire column of traffic to slow to stop-and-go speeds. For this reason, managers of variable-priced toll lanes try to keep traffic below 1,800 vehicles per hour, or one vehicle every two seconds.

Today's adaptive cruise control can reduce the gaps between vehicles to 1 second, effectively doubling roadway capacities.²⁷ Advocates of vehicle-to-vehicle communications say that capacities can be increased further through V2V communications, known as cooperative adaptive cruise control, which will allow vehicles to operate in lock-step with one another in long platoons.

However, mandatory V2V communications systems are not needed for this to happen. First of all, radar-based adaptive cruise control can respond nearly as fast as cooperative systems. Second, people who wish to join platoons of close-formation vehicles can do so by installing optional vehicle-to-vehicle communication systems. Such systems could be installed simply by downloading an app to a smart phone and plugging the smart phone into the vehicle.

Indeed, smart phones today already use vehicle-to-vehicle communications systems. When Google Maps, Apple Maps, or other navigation systems report traffic conditions, they make those reports based on reports from other motor vehicles using similar navigation systems. Future smart-phone apps could enable platooning, collision avoidance, or other benefits of vehicle-to-vehicle communications. Some engineers worry that the cell phone network would not respond quickly enough for close-formation platooning to work, but smart phones wouldn't have to use the cell phone network; they could just form a Wi-Fi connection with other cars in the platoon.

Compared with voluntary V2V systems using smart phones, there are several major drawbacks to mandating that V2V communications be added to all new cars. First, it will take around a decade for enough new cars to be sold so that half the U.S. auto fleet has such systems, whereas smart phones are already in the hands of more than half of the adult population.²⁸ Second, smart phone technology is constantly being updated, whereas a new car with a mandatory V2V system will be stuck with that technology for an average of two decades.

Third, a single V2V standard will be more vulnerable to hackers than multiple smart-phone apps from a variety of software makers. One of the benefits touted for V2V communications is that a V2V-equipped car that broke down or got into an accident could send a notice to other cars in the area to avoid that route. This though would make it easy for someone to shut down an entire city by broadcasting such signals from a thousand different points within it.

"Think of the opportunities for chaos," says University of South Florida transportation professor Steven Polzin of V2V and V2I communications.²⁹ The use of multiple standards would make such hacking more difficult, and private entrepreneurs selling traffic software would have more of an incentive to prevent and fix such hacks than public agencies.

Mandatory V2I communications also introduce the possibility that the nanny state could

“If V2V communications are required in new cars, a decade will pass before half the auto fleet has such systems, whereas half of adults already have voluntary V2V systems in the form of smart phones.”

“When shared use of autonomous vehicles becomes popular, many people who take transit today will find that car sharing makes more sense.”

try to control how, when, and where people travel. For example, one tech writer observes that V2I is “so accurate a revenue-hungry town could write tickets for doing 57 in a 55 zone.”³⁰

Worse, suppose a state decides to arbitrarily reduce per capita driving. With V2I communications, the government could decide someone has driven enough and simply shut off their car. This isn’t far fetched considering that in 2008 the Washington legislature passed a law mandating such a reduction by 2050, and Immigration and Customs has been known to confiscate and destroy people’s cars for failing to meet federal safety and air pollution standards.³¹

While Obama touts the benefits of V2V for improving safety, the National Highway Traffic Safety Administration doesn’t plan to have a proposed rule before 2017, which means a final rule probably won’t go into effect before 2019. Since experts agree that highly autonomous cars are likely to be introduced at about the same time, the safety benefits of V2V will be rendered obsolete before half the cars on the road even have V2V.

Thus, the disadvantages of mandatory V2V communications greatly outweigh the advantages. The federal government should not add to the cost of car ownership by mandating that systems be added to new cars that will be obsolete before many of the cars are even paid for. To the extent that government plays a role in autonomous vehicles, it should be to maintain existing infrastructure and perhaps develop consistent sign and striping standards to be used across all states.

IMPLICATIONS FOR TRANSIT

Despite steadily growing subsidies, America’s transit industry is one of the most unproductive sectors in the economy. In 1970 taxpayers spent \$357 million (about \$1.6 billion in 2012 dollars) subsidizing transit operations; the average urban resident rode transit 49 times a year, and 8.9 percent of employees took transit to work. By 2012, transit-operating subsidies had grown to \$24 billion, yet the average urban resident rode transit just 44

times a year, and just 5 percent of employees took transit to work.³²

One reason transit is so unproductive is that auto ownership is almost ubiquitous. Nationally, less than 4.5 percent of commuters live in households with no vehicles, and, surprisingly, 21 percent of those nevertheless drive alone to work (presumably in borrowed or employer-supplied cars). In nearly three out of four urban areas, more people who live in vehicle-free households drive alone to work than take transit to work, indicating that transit doesn’t even work very well for people who don’t have cars.³³

Nor is transit particularly needed by low-income people. In fact, people who earn more than \$75,000 a year are more likely to take transit to work than people who earn less than \$25,000; just 5.9 percent who earn under \$25,000 take transit while 6.2 percent who earn over \$75,000 take transit.³⁴ Considering that the average life of an automobile today is around 20 years, auto ownership is so inexpensive that most households that decide not to own one do so for reasons other than personal finance.

Transit is so unviable today that it requires \$3 in subsidies for every dollar paid in fares. What will happen when shared use of autonomous vehicles becomes popular? Many people who today choose to take transit over driving are likely to find that car sharing makes more sense, especially if more than one person in the household is traveling. Transit fares in 2012 averaged 25 cents per passenger mile, while the cost of driving averaged about 38 cents per vehicle mile. Even accounting for the profit earned by the owners of shared vehicles, car sharing could be less expensive than taking transit for two or more people.

As with automobiles in general, the advantage of car sharing is that it allows people to go from where they are to where they are going. Transit, by comparison, requires that people go first to a transit stop and then go from another transit stop to their destination, often transferring from one transit vehicle to another in the process.

An urban area of a million people will have hundreds of thousands of different origins and hundreds of thousands of different destinations, and with an average of around five vehicle trips per person per day this represents millions of different combinations. As University of California planning professor Melvin Webber pointed out in 1994, one way to tailor transit to modern life is to offer “small-box” transit: jitneys and other small vehicles going from many origins to many destinations.³⁵

Instead of following Webber’s advice, transit agencies have become enamored with “big-box” transit: light-rail and other trains going from a few origins to a few destinations. Rail transit is a form of smart infrastructure: the rails do the steering, and in many cases centralized signaling systems also control speeds and where the railcars stop at each station. Unlike roads, which can be used by pedestrians, bicycles, motorcycles, cars, trucks, and buses, rails can only be used by extremely specialized vehicles and in most cases are open only to vehicles owned by the owners of the rails.

Rails are also limited in extent and, due to their high construction cost, are likely to remain so. Just as France Telecom could not predict everything that people might want to do with the Minitel system, transit agencies have difficulties predicting where people want to go, especially over the 30-year life of a rail line. This leads to concerns about how people are going to get the “last mile” (or, in too many cases, the last several miles) from rail stations to their actual destinations.

Many transit advocates hope that fully autonomous cars will provide the solution to the last-mile problem. But once someone is in an autonomous car, why would they get out to transfer to a train that is often slow and unreliable, especially if autonomous vehicles are an effective answer to congestion?

Autonomous vehicles are probably not going to get the 2 million people who work in Midtown and Lower Manhattan to work every day. Yet no other American urban area has this density of jobs, and autonomous vehicles should be able to transport most if not all com-

muters into other downtowns and other job centers. This means that transit will be even less relevant in those areas than it is today. While transit may be able to evolve to supplement and make use of autonomous vehicles, one thing is certain: there is no need to build any more obsolete rail lines.

IMPLICATIONS FOR REGIONAL PLANNING

Congress requires metropolitan planning organizations to write and periodically update 20-year transportation plans for their regions. Although highly autonomous vehicles may dominate the road network in 20 years, not a single regional transportation plan has considered the effect of such vehicles or even, as near as I can tell after having read scores of such plans, even mentioned the possibility of such vehicles.

Regional transportation planners use computer models to estimate the demand for transportation in their regions and the effects of that demand on congestion, transit usage, energy consumption, pollution, and land uses. These computer models typically incorporate information gathered in surveys of how residents actually travel on a day-to-day basis in order to predict the effects of changing land-use patterns, new transit services, and new roads on travel.

There are a lot of good questions about the validity of these transportation models. For example, the travel surveys are based on self-selected samples. In other words, surveys of how people who live in high-density developments travel must be made of people who have chosen to live in such high-density developments. Those surveys may not be representative of how other people would travel if they were forced to live in such developments.

Even if the surveys are valid, there are many things planners can’t accurately predict, including future oil prices, future economic booms and busts, and regional population growth rates. Such unpredictable inputs make the outputs of transportation models of little value.

“Although self-driving cars may dominate the roads in 20 years, not a single long-range regional transportation plan has considered the effects of such vehicles on urban areas.”

“Rather than deal with the uncertain future, the current regional planning fad is to design for the past and then attempt to impose that past using regulations and subsidies.”

Yet planners use these models to make long-term, irreversible decisions about urban areas.

Autonomous vehicles introduce the ultimate in uncertainties about future transportation. While planners may not know if gas prices are going up, they can at least predict that, if they do go up, the growth in driving will decline. But such predictions about the effects of autonomous vehicles are impossible. No one today has a highly or fully autonomous vehicle shaping their day-to-day travel, so regional planners can't use travel surveys to answer such questions as

- Will autonomous vehicles lead to more miles of vehicle travel or less?
- Will they reduce congestion, and if so will that make inner cities more attractive because they are less congested? Or will they lead more people to become exurbanites?
- How will autonomous trucks and increased employee mobility determine the locations of new job centers?
- Will car sharing reduce the demand for parking?
- Will fully autonomous vehicles increase road capacities enough to reduce the need for more roads, or will increased driving offset this benefit?
- How will the use of fully autonomous cars as robotic assistants reshape retail and service sectors?
- How will autonomous vehicles affect transit?

Planners have techniques to deal with uncertainty, but they aren't very effective. One is to do “sensitivity runs” of their computer models with a range of assumptions built in. In the best case, they hope to find that the results are not very sensitive to changing the assumptions. If instead the results prove highly sensitive to the assumptions, the best they can do is guess which assumption is correct.

Rather than deal with the uncertain future, the current regional planning fad is in effect to design for the past and then attempt to im-

pose that past using regulations and subsidies. Under this fad, regional planners in Portland, Seattle, San Francisco, and other urban areas have proposed to locate nearly all new housing in high-density developments along new or existing rail transit lines. The plan for the San Francisco Bay Area, for example, requires that 80 percent of new housing and 66 percent of new jobs be concentrated near rail stations or along transit corridors.³⁶

In effect, they are trying to rebuild urban areas to look like they did before the automobile became dominant in the 1920s. The plans incorporate a combination of land-use restrictions and subsidies to insure that their plans come true. One goal of such compact development is to reduce driving. However, people aren't likely to behave as planners hope: a review of the research concludes that urban form's effect on driving is “too small to be useful” in saving energy or reducing pollution.³⁷ If the relationship between land use and travel is weak today, autonomous cars will make it even weaker by giving people one more way of escaping the restrictive regulations and high taxes needed to enforce the plans.

The total unpredictability of the effects of autonomous vehicles should give Congress cause to review and amend the transportation planning process it has imposed on the 50 states and 342 metropolitan planning organizations. The long-range planning process should be tossed out and replaced with a short-range planning process that focuses on fixing today's problems now without foreclosing future options.

IMPLICATIONS FOR LAND USE

Urban planning advocates have been on a decades-long crusade to save the nation's farms, forests, and open spaces from “urban sprawl.” The rate of suburbanization has slowed in recent years, less due to this crusade than because of slower growth in the number of households. Between 1940 and 1980, the number of households in the United States grew steadily at 2 percent per year; since 1980, growth has averaged just 1.1 percent per year.³⁸

If highly and fully autonomous cars change the way people view travel, however, exurbanization could accelerate despite the slow rate of new household formation. This could lead to calls for more urban-growth boundaries and other restrictions designed to prevent so-called sprawl.

In reality, this is a big country, and urban and suburban areas occupy such a small portion of it that they are no threat to other land uses. The 2010 census found that only about 3 percent of the nation's land, or less than 70 million acres, has been urbanized, including all cities and suburbs in urban areas of 2,500 people or more.³⁹ The Department of Agriculture estimates that another 103 million acres, or about 4 percent of the nation's land, are in non-farm, "exurban" residential uses. These areas are likely candidates for suburban expansion in regions that don't have urban-growth restrictions.⁴⁰

Suburban and exurban development pose no threat to the nation's agricultural land base. More than half the land in the United States, or 1.16 billion acres out of a total of 2.26 billion, is considered agricultural land, but less than a third of these agricultural lands are used for growing crops.⁴¹ Moreover, the number of acres used for croplands is declining, partly because per acre yields of most major crops, including barley, canola, corn, cotton, flax seed, peanuts, potatoes, rice, sorghum, soybeans, sugar beets, sunflowers, sweet potatoes, and wheat, are growing faster than the nation's population.⁴²

Nor do suburbanization or exurbanization threaten forest lands. About a third of the nation is forested, which is actually more than was a century ago. The substitution of trucks and tractors for draft animals after 1920 allowed farmers to return tens of millions acres of pastureland to forests. By 1960, the United States had 26.7 million acres more in forest lands than in 1920.⁴³

Although about 15 percent of forests are reserved in parks and wilderness, this is not a problem as forest growth has exceeded harvests since 1950 and is expected to continue doing so for the foreseeable future. As a result, American forests have 51 percent more timber volume in them today than they did 60 years ago.⁴⁴ This is possible despite a stable forest

base because new technologies allow productive utilization of a steadily increasing share of the trees that are cut. As a result, per capita demand for timber is declining.

The nation is hardly short of open space. Federal, state, and local governments own more than 850 million acres of land, or 38 percent of the total.⁴⁵ More than 80 percent of this land is available for recreation and public enjoyment. Hundreds of millions of acres of private rural land also provide scenic vistas and, in many cases, recreation.

In short, urban and even exurban development is no threat to the nation's farms, forests, or open space. The use of urban-growth boundaries and other land-use restrictions to contain "sprawl" is needless and costly: nearly all urban areas that have used them have seen median housing prices rise by \$50,000 to \$500,000 or more.⁴⁶ Since exurbanization is no threat to farms, forests, or open space, there is little reason to heed calls for more restrictions on urban development.

CONCLUSION

Autonomous vehicles will transform America. In view of the unpredictable but large changes ahead, legislators and other policymakers should change the way they view transportation. At the very least, the following recommendations make sense.

First, Congress should eliminate the New Starts program that gives cities incentives to build obsolete rail transit systems that will have no place in a world of car sharing of smart cars on dumb infrastructure. Rail transit is extraordinarily expensive, doesn't significantly increase transit riders in most cities where it is built, and will play an ever-diminishing role in 21st-century cities.⁴⁷

Second, Congress should also eliminate the requirement that states and metropolitan planning organizations prepare endless rounds of long-range regional transportation plans. Planners are no better than anyone else at predicting the future, yet their plans often lock regions in to irreversible commitments of resources whose value proves to be far less than promised.

“Urban and exurban development is no threat to the nation’s farms, forests, or open space, and land-use restrictions to contain ‘sprawl’ are needless and costly.”

“State and local governments should focus on maintaining dumb infrastructure while taking cost-effective steps to solve today’s congestion and safety problems.”

Long-range plans also make regions susceptible to the temptation that they can and should attempt to reshape human behavior in order to conform to the plan rather than shape the plan to what people want and need.⁴⁸

Third, the National Highway Traffic Safety Administration should not mandate the installation of vehicle-to-vehicle or vehicle-to-infrastructure communications devices in new cars. Such mandatory devices will quickly become obsolete and may even impair innovations that would take place through the use of voluntary devices.

Fourth, state and local governments should focus on providing and maintaining dumb infrastructure that could be used by autonomous vehicles as well as other traffic including pedestrians and bicycles. The fact that autonomous vehicles may reduce congestion and improve highway safety in the future should not excuse state and local road agencies from taking steps to solve congestion and safety problems today, but those solutions should be cost-effective. For example, no major construction projects should be funded until all traffic signals in a region are updated using the latest dynamic coordination systems.

Finally, states and regional planning agencies should avoid land-use regulation aimed at trying to control where people work and live. States that have such regulation, including California, Hawaii, Oregon, Washington, and most of the New England states, should repeal it. Given reduced regulation, the congestion-reduction effects of autonomous vehicles may lead to increased job concentrations in downtowns and other job centers while they also lead to increased dispersal of residences in the exurbs. Neither of these are bad things, but neither are they guaranteed, so the best thing would be for government to get out of the way and permit whatever changes make sense, making sure only that everyone pays the full costs of their choices.

NOTES

1. Anders Tylman-Mikiewicz, Presentation to the Automated Vehicles Symposium 2014, Burlingame, California, July 16, 2014.

2. “Early Estimate of Motor Vehicle Traffic Fatalities in 2013,” National Highway Traffic Safety Administration, Washington, 2014, p. 1, tinyurl.com/q83cnnb; Paul A. Eisenstein, “Electronic Stability Control Systems Saving Thousands of Lives,” *The Detroit Bureau*, November 30, 2012, tinyurl.com/qchnn9s.

3. Andreas Schafer and David G. Victor, “The Future Mobility of the World Population,” *Transportation Research Part A* 34, no. 3 (April 2000): 171–205.

4. “Preliminary Statement of Policy Concerning Automated Vehicles,” National Highway Traffic Safety Administration, Washington, 2013, pp. 4–5; Bryant Walker-Smith, “SAE Levels of Driving Automation,” Center for Internet and Society, December 18, 2013, tinyurl.com/plp38ss.

5. As near as I can tell, the least expensive car available with these features is a 2015 Subaru Legacy that sells for about \$25,800 including delivery charges.

6. “Nissan Announces Unprecedented Autonomous Drive Benchmarks,” NissanNews.com, August 27, 2013, tinyurl.com/kblym6n; Joseph B. White, “Nissan Expects to Market Self-Driving Cars by 2020,” *Wall Street Journal*, August 27, 2013, tinyurl.com/le44frl.

7. “Carlos Ghosn Outlines Launch Timetable for Autonomous Drive Technologies,” NissanNews.com, July 16, 2014, tinyurl.com/nsy7czh.

8. Furhaad Shah, “Google’s Self-Driving Cars Expected in 2017,” *dataconomy.com*, May 28, 2014, tinyurl.com/pzf3agj.

9. Steven E. Underwood, “Automated Vehicles Forecast,” University of Michigan, 2014, pp. 24, 26, 31, tinyurl.com/q8jhrva.

10. Jerry Hirsch, “253 Million Cars and Trucks on U.S. Roads; Average Age Is 11.4 years,” *Los Angeles Times*, June 9, 2014, tinyurl.com/lyvpdkr.

11. Chuck Tannert, “Will You Ever Be Able to

- Afford a Self-Driving Car?" *Fast Company*, January 31, 2014, tinyurl.com/q5xfldq.
12. Ola Svenson, "Are We All Less Risky and More Skillful Than Our Fellow Drivers?" *Acta Psychologica* 47 (1981): 143–148, tinyurl.com/q23fwq2.
13. David Lux, "The History of American Technology: The Automobile Industry, 1920–1929," Bryant College, 1998, tinyurl.com/kcex4td.
14. Robert S. Lynd and Helen Merrell Lynd, *Middletown: A Study in Contemporary American Culture* (New York: Harcourt, Brace, 1929), p. 255.
15. Liz Gannes, "Tiny Startup Cruise Beats Google to Offer Self-Driving Car Tech to Consumers," *re/code*, June 23, 2014, tinyurl.com/ktrestv.
16. L. C. Davis, "Effect of Adaptive Cruise Control Systems on Traffic Flow," *Physical Review* 69 (2004): 66110.
17. Arne Kesting et al., "Jam-Avoiding Adaptive Cruise Control (ACC) and Its Impact on Traffic Dynamics," *Traffic and Granular Flow 2005* (Berlin: Springer, 2007), p. 663.
18. Patricia Mokhtarian and Cynthia Chen, "TTB or Not TTB, That Is the Question: A Review and Analysis of the Empirical Literature on Travel Time," *Transportation Research Part A* 38, nos. 9–10, (November–December 2004), pp. 643–75.
19. Tylman-Mikiewicz.
20. 2012 *American Community Survey*, Census Bureau, table B08134 for the nation. To calculate average travel times, I assumed the category "less than 10 minutes" averaged 7 minutes while "60 or more minutes" averaged 67 minutes.
21. Rémy Prud'homme and Chang-Woon Lee, "Size, Sprawl, Speed, and the Efficiency of Cities," *Urban Studies* 36, no. 11 (1999): 1849–58; Robert Cervero, "Efficient Urbanization: Economic Performance and the Shape of the Metropolis," *Urban Studies* 38, no. 10 (2001): 1651–71.
22. Norman Bel Geddes, *Magic Motorways* (New York: Random House, 1940), pp. 73–75.
23. Chuck Thorpe, Todd Johnson, and Dean Pomerleau, "Automated Highways and the Free Agent Demonstration," Carnegie Mellon University working paper, 1997, tinyurl.com/ma27pqe.
24. Sanghyun Cheon, "An Overview of Automated Highway Systems (AHS) and the Social and Institutional Challenges They Face," Princeton University working paper, 2003, tinyurl.com/or4wldh.
25. "Intelligent Transportation Systems for Traffic Signal Control," Department of Transportation, 2007, tinyurl.com/ljxbh42.
26. Ashley Simmons, "President Obama Calls for Vehicle-to-Vehicle, Vehicle-to-Infrastructure Communication," *FutureStructure*, July 15, 2014, tinyurl.com/q6joow7.
27. "SWOV Fact Sheet: Advanced Cruise Control," Institute for Road Safety Research, 2010, tinyurl.com/odkyhp6.
28. Mark Rogowsky, "More Than Half of Us Have Smartphones," *Forbes*, June 6, 2013, tinyurl.com/mrasa6t.
29. Interview with Steven Polzin, Burlingame, California, July 15, 2014.
30. Bill Howard, "What Are Vehicle-to-Vehicle Communications and How Do They Work?" *ExtremeTech*, February 6, 2014, tinyurl.com/kg5phmy.
31. House Bill 2815, Washington State Legislature, 2008 Regular Session, tinyurl.com/342npm.
32. Dollars and trips from 2014 *Public Transportation Fact Book, Appendix A Historical Tables* (Washington: American Public Transportation Association, 2014), tables 1, 68, and 90; transit's share of commuting in 1990 from "Means of Transportation to Work for the U.S.," Census Bureau, <https://www.census.gov/hhes/commuting/files/1990/mode6790.txt>; transit's share in 2012 from 2012 *American Com-*

munity Survey, table B08301.

33. 2012 *American Community Survey*, table B08141.

34. *Ibid.*, table B08519.

35. Melvin Webber, "The Marriage of Autos and Transit: How to Make Transit Popular Again," *Access*, no. 5 (Fall 1994), pp. 26–31.

36. *Draft Plan Bay Area* (Oakland: Metropolitan Transportation Commission, 2013), p. 26.

37. David Brownstone, "Key Relationships between the Built Environment and VMT," *Transportation Research Board* (2008), p. 7, tinyurl.com/y9mro58.

38. "Households by Type, 1940 to Present," *Census Bureau*, 2013, tinyurl.com/mkozttts.

39. "Percent Urban and Rural by State and County in 2010," *Census Bureau*, 2012, tinyurl.com/cn7st9j.

40. Cynthia Nickerson et al., *Major Uses of Land in the United States, 2007* (Washington: Department of Agriculture, 2011), p. 29.

41. *Ibid.*, Table 1.

42. According to *Crop Production Historical Track Records* (Washington: Department of Agriculture, 2014), the per-acre yields of all of these crops grew faster than the population between 1980 and 2010.

43. "Forest Area by Current State Boundaries for the United States, 1630–2000," *Forest Service*, tinyurl.com/loxd2mo.

44. *National Report on Sustainable Forests–2010* (Washington: Forest Service, 2011), pp. 1–39.

45. Nickerson et al., p. vi.

46. Randal O'Toole, "The Planning Tax: The Case against Regional Growth-Management Planning," *Cato Institute Policy Analysis* no. 606, December 6, 2007, p. 12.

47. For more on New Starts, see Randal O'Toole, "Paint Is Cheaper Than Rails': Why Congress Should Abolish New Starts," *Cato Institute Policy Analysis* no. 727, June 19, 2013.

48. For more on long-range regional transportation planning, see Randal O'Toole, "Roadmap to Gridlock: The Failure of Long-Range Metropolitan Transportation Planning," *Cato Institute Policy Analysis* no. 617, May 27, 2008.

RELATED PUBLICATIONS FROM THE CATO INSTITUTE

Rapid Bus: A Low-Cost, High-Capacity Transit System for Major Urban Areas by Randal O'Toole, Cato Institute Policy Analysis no. 752 (July 30, 2014)

The Worst of Both: The Rise of High-Cost, Low-Capacity Rail Transit by Randal O'Toole, Cato Institute Policy Analysis no. 750 (June 3, 2014)

Reducing Livability: How Sustainability Planning Threatens the American Dream by Randal O'Toole, Cato Institute Policy Analysis no. 740 (October 28, 2013)

“Paint Is Cheaper Than Rails”: Why Congress Should Abolish New Starts by Randal O'Toole, Cato Institute Policy Analysis no. 727 (June 19, 2013)

The Great Streetcar Conspiracy by Randal O'Toole, Cato Institute Policy Analysis no. 699 (June 14, 2012)

Ending Congestion by Refinancing Highways by Randal O'Toole, Cato Institute Policy Analysis no. 695 (May 15, 2012)

Defining Success: The Case against Rail Transit by Randal O'Toole, Cato Institute Policy Analysis no. 663 (March 24, 2010)

Fixing Transit: The Case for Privatization by Randal O'Toole, Cato Institute Policy Analysis no. 670 (November 10, 2010)

Defining Success: The Case against Rail Transit by Randal O'Toole, Cato Institute Policy Analysis no. 663 (March 24, 2010)

Getting What You Paid For—Paying For What You Get: Proposals for the Next Transportation Reauthorization by Randal O'Toole, Cato Institute Policy Analysis no. 644 (September 15, 2009)

Roadmap to Gridlock: The Failure of Long-Range Metropolitan Transportation Planning by Randal O'Toole, Cato Institute Policy Analysis no. 617 (May 27, 2008)

Does Rail Transit Save Energy or Reduce Greenhouse Gas Emissions? by Randal O'Toole, Cato Institute Policy Analysis no. 615 (April 14, 2008)

Do You Know the Way to L.A.? San Jose Shows How to Turn an Urban Area into Los Angeles in Three Stressful Decades by Randal O'Toole, Cato Institute Policy Analysis no. 602 (October 17, 2007)

Debunking Portland: The City That Doesn't Work by Randal O'Toole, Cato Institute Policy Analysis no. 596 (July 9, 2007)

**RECENT STUDIES IN THE
CATO INSTITUTE POLICY ANALYSIS SERIES**

757. **Opening the Skies: Put Free Trade in Airline Services on the Transatlantic Trade Agenda** by Kenneth Button (September 15, 2014)
756. **The Export-Import Bank and Its Victims: Which Industries and States Bear the Brunt?** by Daniel Ikenson (September 10, 2014)
755. **Responsible Counterterrorism Policy** by John Mueller and Mark G. Stewart (September 10, 2014)
754. **Math Gone Mad: Regulatory Risk Modeling by the Federal Reserve** by Kevin Dowd (September 3, 2014)
753. **The Dead Hand of Socialism: State Ownership in the Arab World** by Dalibor Rohac (August 25, 2014)
752. **Rapid Bus: A Low-Cost, High-Capacity Transit System for Major Urban Areas** by Randal O'Toole (July 30, 2014)
751. **Libertarianism and Federalism** by Ilya Somin (June 30, 2014)
750. **The Worst of Both: The Rise of High-Cost, Low-Capacity Rail Transit** by Randal O'Toole (June 3, 2014)
749. **REAL ID: State-by-State Update** by Jim Harper (March 12, 2014)
748. **State-Based Visas: A Federalist Approach to Reforming U.S. Immigration Policy** by Brandon Fuller and Sean Rust (April 23, 2014)
747. **Run, Run, Run: Was the Financial Crisis Panic over Institution Runs Justified?** by Vern McKinley (April 10, 2014)
746. **State Education Trends: Academic Performance and Spending over the Past 40 Years** by Andrew J. Coulson (March 18, 2014)
745. **Obamacare: What We Know Now** by Michael Tanner (January 27, 2014)
744. **How States Talk Back to Washington and Strengthen American Federalism** by John Dinan (December 3, 2013)



Published by the Cato Institute, Policy Analysis is a regular series evaluating government policies and offering proposals for reform. Nothing in Policy Analysis should be construed as necessarily reflecting the views of the Cato Institute or as an attempt to aid or hinder the passage of any bill before Congress. Contact the Cato Institute for reprint permission. All policy studies can be viewed online at www.cato.org. Additional printed copies of Cato Institute Policy Analysis are \$6.00 each (\$3.00 each for five or more). To order, call toll free (800) 767-1241 or email catostore@cato.org.