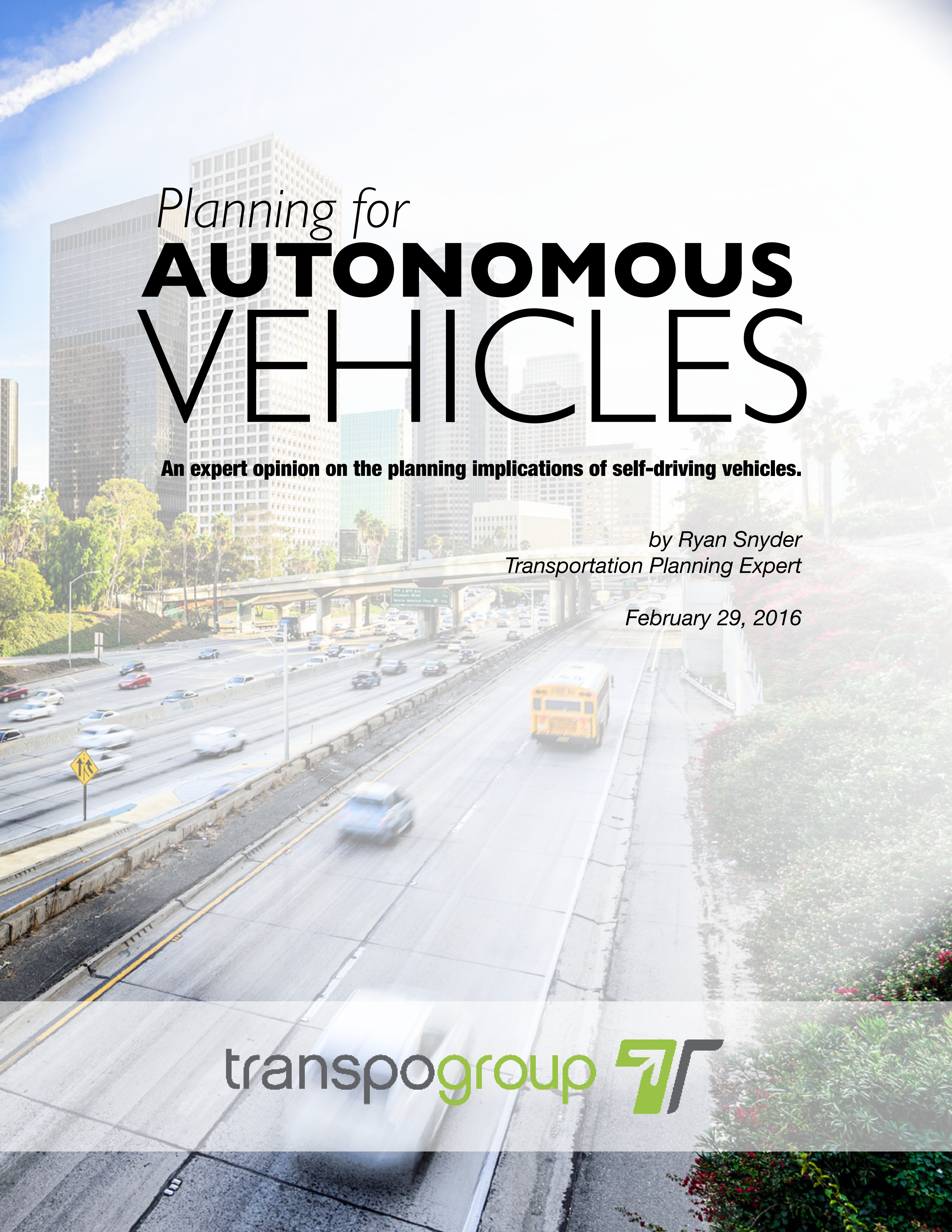


Planning for **AUTONOMOUS** VEHICLES

An expert opinion on the planning implications of self-driving vehicles.

by Ryan Snyder
Transportation Planning Expert

February 29, 2016

transpogroup

Planning for AUTONOMOUS VEHICLES

INTRODUCTION

Autonomous Vehicles (AVs) have been the subject of a plethora of articles in recent years. Many of these discuss the status of the technology, the benefits, possible drawbacks, and dates of likely deployment. This article is written from a Transportation Planning perspective, and focuses on AVs' potential benefits and drawbacks, along with a call for policy action that attempts to speed up the potential benefits while minimizing detrimental impacts.

We cannot forecast with certainty when fully driverless vehicles will be in normal operation on our streets, but they are within a near enough time horizon that we need to formulate and adopt policies very soon. By advocating the use of AV technologies to focus on the obvious beneficial outcomes, we can likely realize the positive benefits of AVs sooner rather than later.

ABOUT RYAN SNYDER

Ryan Snyder is a Principal with Transpo Group, a transportation planning and engineering firm that prepares sustainable transportation plans. Ryan is a member of the Bicycle Technical Committee and the Autonomous Vehicle Task Force of the National Uniform Traffic Device Committee. He has worked on hundreds of Complete Streets plans throughout Southern California, and has helped shape transportation policies for 30 years. Ryan serves on the faculty at the University of California Los Angeles (UCLA) Urban Planning Department, and he holds an M.A. in Urban Planning and a B.A. in Economics from UCLA.

DEFINITION OF LEVELS OF AVS

Defined by who does what when
Society of Automotive Engineers (SAE) International definitions

Level 0: Human driver does everything

Level 1: Vehicle assists with some parts of driving (lane assist, park assist, crash avoidance, adaptive cruise control, etc.).

Level 2: Vehicle actually does some of the driving, while human driver continually monitors the driving environment and performs the rest of the driving.

Level 3: Vehicle can conduct some parts of the driving and monitors the driving environment sometimes, but the human driver must take control when the automated system requests.

Level 4: The vehicle conducts the driving and monitors the driving environment, while the human does not need to take control, but the vehicle can only operate in certain environments and under certain conditions.

Level 5: The automated system performs all the driving tasks

STATE OF THE ART

The technology behind AVs is not necessarily new. The National Highway Safety Administration (NHTSA) categorizes four levels of Autonomous Vehicle Technology (see sidebar.) Most cars sold today have Level 1 technology. Cruise control has been common for decades. In the late 1990s, *adaptive cruise control* hit the market, which adjusts the speed of cars to maintain a safe distance to vehicles ahead. Other helpful safety-driven features such as park assist, lane assist, automatic braking, and crash avoidance are becoming more common. The Insurance Institute of Highway Safety (IIHS) reports that 27 percent of vehicles sold today have automatic emergency braking available, while 52 percent have at least forward crash alerts[1]. On September 11, 2015, NHTSA and IIHS announced an agreement with 10 auto manufacturers – Audi, BMW, Ford, General Motors, Mazda, Mercedes Benz, Tesla, Toyota, Volkswagen, and Volvo – that will make automatic emergency braking a standard feature on all new vehicles as soon as possible. These manufacturers made 57 percent of all light-duty vehicles sold in the United States in 2014[2]. A small but growing number of manufactures offer a combination of automation, such as lane assist and crash avoidance. The **Mercedes Benz Intelligent Drive System** offers crash avoidance with automatic braking and lane assist simultaneously.

A critical point of readiness for AVs will be

1 Status Report Vol. 50, No. 7, August 26, 2015

2 NHTSA 43-15, September 11, 2015

when the crash rate of Level 4 vehicles is lower than today's crash rate. NHTSA reports that in 2013 there were 5.39 fatalities per 100 million miles driven, and 157 injuries per 100 million miles driven. This equates to one fatality per 18.55 million miles driven, and one injury crash per 637,000 miles driven[3]. The August 2015 Google Self-Driving Car Project Monthly Report states that in more than 2 million miles driven in California in the past six years, 16 crashes have occurred. This is one crash per 125,000 miles. The report does not break down the data by injuries or fatalities. **The self-driving car was not at fault in any of these crashes.** It should be noted that self-driving cars are not yet traveling at high speeds. But we are close to a point where AVs are at least as safe as human-driven vehicles. According to NHTSA, 93 percent of all crashes are caused by human error[4].

> *A critical point of readiness for AVs will be when the crash rate of level 4 vehicles is lower than today's crash rate.*

Cooperative vehicle-highway automation systems take in information from their environment to provide driving control assistance or fully automated driving. They use both vehicle-to-vehicle (V2V) communication and vehicle-to-infrastructure (V2I) technology. NHTSA is already experimenting with V2V communication. General Motors will have V2V technology in select models on the market in 2017[5]. V2I technology will allow the exchange of mapping data and communication with traffic control systems. The U.S. Department of Transportation is now testing V2I technology. The technology is a step beyond the Automated Traffic Surveillance and Control System (ATSAC) that Los Angeles has used since 1984 to activate traffic signals based on volume.

Google plans to have Level 4 technology by 2017. Audi, BMW, GM, and Nissan expect to sell self-driving vehicles by 2020. Continental Automotive Systems projects the ability to produce cars with a high level of self-automation by 2025. Based on past trends, 11 to 34 percent of vehicles on the road could be self-driven within five years, and 22 to 59 percent in 10 years[6]. While these numbers may be optimistic, there is no doubt that self-driven vehicles are on their way within the

3 NHTSA Traffic Safety Facts, December 2014

4 National Motor Vehicle Crash Causation Survey, DOT HS 811 059, July 2008

5 GM News, "Cadillac to Introduce Advanced Intelligent and Connected Vehicle Technologies on Select 2017 Models," September 7, 2014

6 Jerome Lutin, Alain Komhauser, and Eva Lerner-Lam, "The Revolutionary Development of Self-Driving Vehicles and Implications for the Transportation Engineering Profession," Institute of Transportation Engineers Journal, July 2013

SELF-DRIVEN CARS ARE ON THEIR WAY

A prototype of a self-driving car from google.com.

foreseeable future.

TECHNOLOGICAL POSSIBILITIES

With the rapidly evolving AV technology, it's not hard to imagine what could emerge. Here, I will introduce a couple of concepts that I believe are ***well within the range of possibility***. I have not read about these concepts in any of the current literature, and believe they could yield significant benefits.

Lane Clearance

With a combination of growing V2I and V2V capabilities, it would be possible to clear a lane of all vehicles except those that need or would benefit from an unobstructed lane. Instead of dedicated bus lanes, a lane could be automatically cleared when a bus is coming, and then open up for others to use the lane once the bus has passed. Similarly, when an emergency responder needs access, the lane could be cleared automatically.

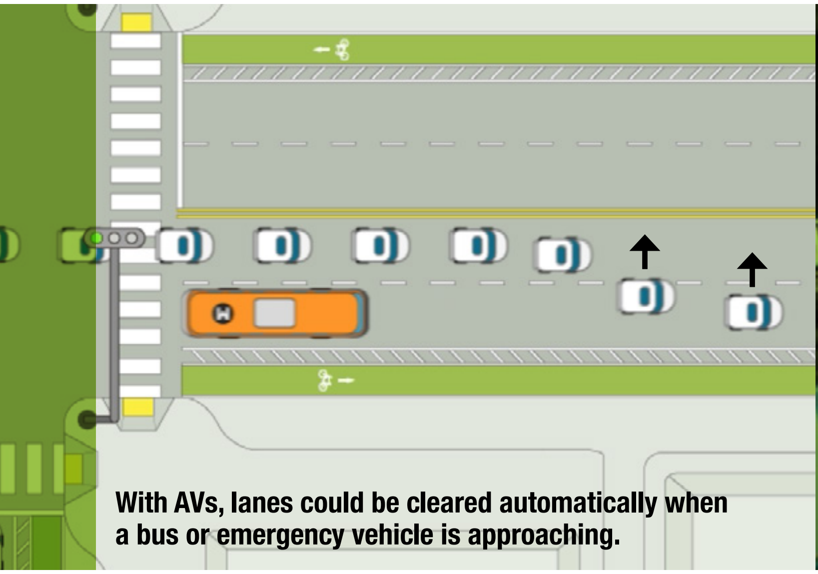
With V2V technology, our vehicles are becoming like two same-pole magnets that repel each other and cannot touch. This allows for virtual dedicated rights-of-way. Lane clearance could provide the same advantages of dedicated fixed rights-of-way

With V2V technology, our vehicles are becoming like two same-pole magnets that repel each other and cannot touch.

without expensive infrastructure.

Coordinated and Optimized Traffic Flow

Similar to the Los Angeles ATSAC system, V2I technology could allow for optimized traffic flow through central control. Just as the ATSAC system optimizes traffic signals, the same could be done over the whole system. Once drivers have given up direct operating control of their vehicles, coordinating the flow for everyone would make sense. This would be most effective when every vehicle is part of the system. At least in the early stages, not



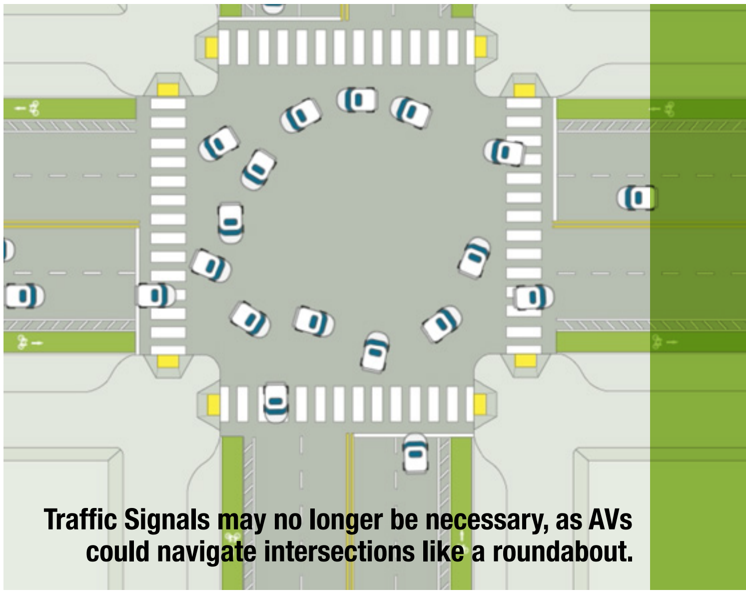
With AVs, lanes could be cleared automatically when a bus or emergency vehicle is approaching.

Los Angeles Department of Transportation ATSAC System every vehicle would be. A critical component would be to make sure the advantages of being a part of the system will entice everyone to join, as being left outside the system could leave one stuck in a much slower travel pattern. Central coordination could optimize flow, optimize signals, and provide priority for selected vehicles like buses, emergency access vehicles, or high-occupancy-vehicles. *It may even be able to eliminate traffic signals altogether and treat intersections like virtual roundabouts.* Coordination could also regulate speed based on the street, time of day, and other conditions. It could prevent speeding in residential neighborhoods and allow for greater speeds on larger streets at certain times of day.

Enhanced Detection of Pedestrians and Bicyclists

AV technology could help protect pedestrians by solving a common problem in street design: creating safe, convenient pedestrian crossings.

Today's hierarchical street networks space traffic signals significantly far apart to keep traffic flowing on arterial streets. Pedestrian crossings on streets carrying fewer than 20,000 vehicles per day need not be at a traffic signal to be reasonably safe. This allows for more regular pedestrian crossings. But beyond this point of traffic and past certain speeds, designing safe pedestrian crossings on multi-lane streets becomes challenging. On such streets, pedestrian crossings should be at traffic signals for pedestrians' safety. Since signals are spaced far apart, these streets become barriers to pedestrians.



Traffic Signals may no longer be necessary, as AVs could navigate intersections like a roundabout.

Crash avoidance technology already detects people walking. This could be further strengthened with small sensors (perhaps the size of a coin) carried by pedestrians. With sensors in pedestrians' pockets or perhaps a simple button for pedestrians to push at locations between signals, traffic would stop and allow people to cross the street. Older adults or those with disabilities who walk slowly could be detected crossing the street and allowed sufficient time to cross safely.

A similar approach could help ensure bicyclists' safety, since crash avoidance technology also detects bicycles. In this case, the sensors could be attached to bicycles.

Along with these benefits will also come potential economic opportunities that may help encourage and excelerate the use of AV technology, which is explored further in the following section.

ECONOMICS

Along with these benefits will also come potential economic opportunities that may help encourage and excelerate the use of AV technology, which is explored further in the following section. Today, the average car costs 58 cents per mile to operate. Given average usage, this amounts to $8,698 per year, or $725 per month[7]. With the sunken costs of the car purchase and insurance, car sharing programs like Zipcar can be more cost effective than owning a car for people who use their cars less than approximately 72 hours per month (based on the $10 per hour rate for Zipcar). Car sharing is not yet competitive with car ownership for those who commute by car every day to work. But for some people who work from home, work part time, don't work, or take transit or bicycle for a portion of their trips, it is already cost advantageous to use a car sharing system instead of owning.

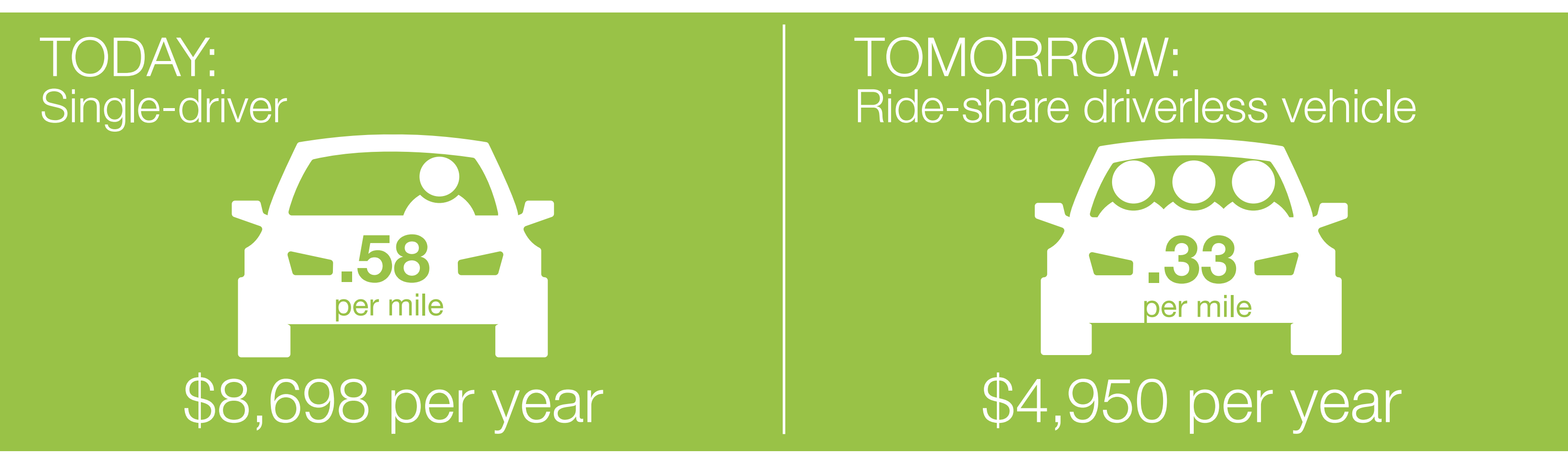
The same could be true of driverless vehicles. For people who don't need their own car every day, not owning would make more economic sense.

7 "Your Driving Costs 2015," American Automobile Association

Bus drivers account for 54 percent of bus operating expenses[8]. Transit agencies may be among the early adopters of driverless technology.

With autonomous vehicles, a whole range of travel options open, which I explore more in the "Transit Benefits" section of this paper. With today's "Uber Pool," people can choose to ride with other passengers who are traveling the same direction at the same time, and the fare is divided. The Uber Pool option is more cost competitive with driving one's own car for some trips, especially when one has to pay for parking. Remove the greatest cost of the taxi or ride-sharing service, the driver, and many more trips would be cheaper by sharing with others. At a cost of even $1 per mile, a 10-mile trip would cost $10. Split that cost with a couple of other people, and the trip might cost $3. As more people join the system, the opportunities for sharing grow as the pool of potential ride mates grows. At this point, why own your own car? For more and more people, it could become cheaper, more convenient, and less stressful to give up a personal car and let an AV do the driving.

8 American Public Transit Association, 2013 Public Transit Fact Book, p. 26



POTENTIAL BENEFITS

Illustration from gizmodo.com

As you can imagine, AVs offer many potential advantages. The following section highlights the most important, and in some cases obvious, benefits.

User Conveniences

AVs offer many advantages to users, including the following more obvious advantages.

Mobility for People Who Don't Drive

People who are too young to drive, too old to drive safely, or unable to drive would have much greater mobility. They wouldn't have to depend on their parents, their children, or their caretakers to take them where they need to go. This could restore independence. It could also relieve parents of driving children to school, soccer practice, or other activities. People who can't afford to own cars would also have more options.

Better Use of Time

When we drive, we are not using our time for anything else. If we didn't have to drive, we could use our time much better. We could read, eat, work, watch TV or movies, or respond to email. Cars could be equipped with 180-degree reclining seats for full sleeping capabilities. Some vehicles might be furnished with exercise equipment. Our time would be better spent on our everyday trips.

One could also imagine taking the trip from Los Angeles to the San Francisco Bay Area and sleeping the whole way. Such a trip would offer more time departure flexibility. It could start at 11 p.m. and allow us to arrive at 7 a.m. well rested.

Less Stress

Driving is stressful. Not having to drive would eliminate this source of stress.

Deliveries

Without the cost of drivers, the cost of deliveries would come down. It would be possible to go online, order groceries, dinner, or other goods and have the goods arrive at your door. This could save people time.

Select the Appropriate Vehicle for the Trip

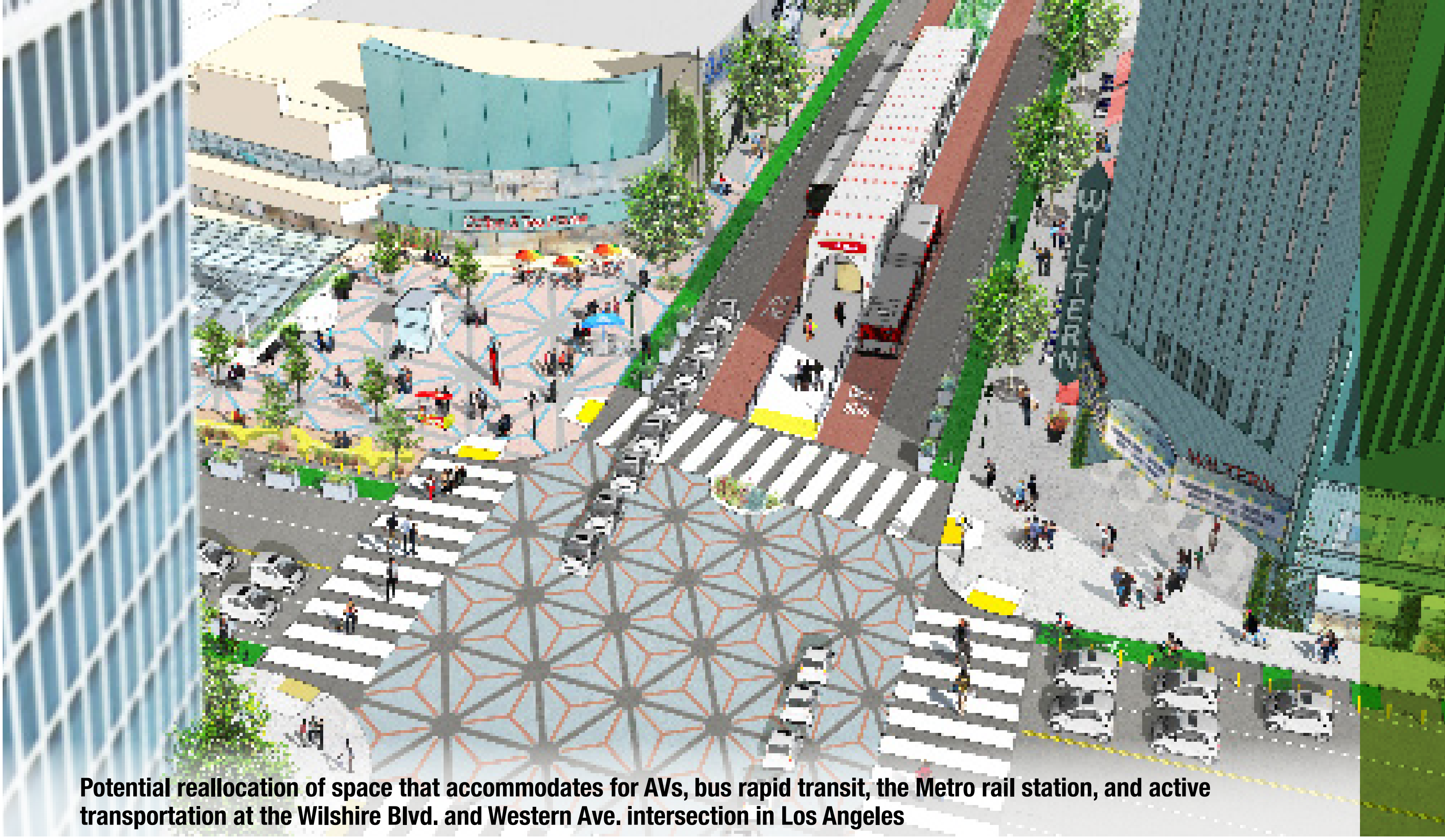
As we depend less on our own vehicles, which are just one type, we could choose a vehicle that is most appropriate for the particular need at the time. Many daily trips could be made in a small utilitarian car that is sufficient to transport one or two people. If we have a family or larger group, a larger vehicle could be chosen. If we need to carry large things, we may choose a pick-up truck or van.

Safety

Safety may likely be the first benefit we realize from AVs. Even the Level 1 and Level 2 vehicles sold today with adaptive cruise control, lane assist, park assist, or automatic braking should provide safety benefits in the form of fewer and less severe crashes. As reported in the "State of the Art" section of this paper, 93 percent of crashes are caused by human error. Removing human error from the equation could eliminate the vast majority of crashes. Crashes will still occur with autonomous vehicles, especially in the early years. But the standard for tolerating that shouldn't be zero crashes—the standard used for policy making should be the point where driverless vehicles are safer than those driven by humans.

Among the first beneficiaries of AVs on streets should be people on bicycles and those walking. With crash avoidance technology, these vulnerable users will gradually become less so. While I haven't seen any studies to document this safety benefit yet, as more cars have the technology it stands to reason that we are already benefiting some and will benefit more as the technology improves and as more vehicles have it. With the possibility of better pedestrian and bicyclist detection and technology to stop vehicles described earlier in this paper, conditions should become safer for these vulnerable users and their access and convenience should be enhanced.

93%
of crashes are caused by
HUMAN ERROR



Potential reallocation of space that accommodates for AVs, bus rapid transit, the Metro rail station, and active transportation at the Wilshire Blvd. and Western Ave. intersection in Los Angeles

Capacity

Because today's drivers have to leave space between vehicles to prevent crashes, AVs could move much closer to each other with crash avoidance technology, especially V2V technology. One study estimates that freeway capacity could increase from 2,200 vehicles per lane per hour to 4,000 vehicles per lane per hour if all vehicles on the freeway were equipped with cooperative adaptive cruise control (Steven Shladover and Xioa-Yun Lu, "Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow," Transportation Research Board conference paper, January 2012). City streets could also experience similar benefits. This would reduce congestion.

Greater efficiency could result in much less space consumed by cars. Today planners looking to reallocate space in the street with "road diets" often use a rule of thumb that 4-lane streets can be converted to 2-lane streets with a center-turn lane without losing capacity at 20,000 vehicles per day or less. With AVs, this guideline could be changed to perhaps 35,000 or 40,000 vehicles per day. The guideline for converting 6-lane streets to 4-lane streets might jump from 40,000 vehicles per day, to 70,000 or 80,000. Moreover, the width of travel lanes could be reduced. This means that many more streets could be candidates for road diets and reallocation of space to bike lanes, wider sidewalks, medians, landscaping, outdoor seating, recreation space, gardening, street vending, or other higher and better uses.


Current streets, which are wide and allow for parking, may be better utilized once fewer cars are on the road.

Land Use

A large portion of our land is taken by parking. The average car is parked about 95 percent of the time[9]. Counting the parking space and drive-in and ramp space, each parking space consumes 300 to 350 square feet. New buildings required to provide three parking spaces for 1,000 square feet of land use essentially have as much space taken by parking as by the land use, be it commercial office, retail, or other.

As fewer people own their cars, the need for parking will decrease. Since I believe that the advantages of AVs could outweigh those of owning for many people, I can imagine the day when very few people, or even no one, own a car.

With little or no need for parking, instead of cars sitting empty 95 percent of the time, a much smaller fleet would be available to pick people up. We could reallocate surface parking and our on-street parking to other uses. We could convert parking structures to other uses as well. Although some significant architectural retrofitting may be needed, parking structures could be converted to other uses. Today's parking structures may become tomorrow's reservoir for new land uses.

9 Don Shoup, The High Cost of Free Parking, American Association of Planning Press, 2005

Greenhouse Gas Reduction

A recently published article in Nature Climate Change[10] concludes that AVs could reduce greenhouse-gas (GHG) emissions by 87 percent to 94 percent below 2014 conventional vehicles, and 63 percent to 82 percent below expected 2030 hybrid vehicles. This reduction would occur through:

- Decreases in greenhouse-gas (GHG) electricity emissions
- Smaller vehicles used for autonomous taxis
- Higher annual vehicle miles traveled increasing electric vehicle technology

10 Jeffrey Gleenblatt and Samveg Saxena, "Autonomous Taxis Could Greatly Reduce Greenhouse-Gas Emissions of US Light-Duty Vehicles," July 6, 2015

These reductions assume that the fleet of AVs would be greener than today's vehicles and that more of our vehicles would use electricity. As fewer people owned cars, the fleet of vehicles on our streets and roads could be regulated to be greener. The article notes that reductions would occur through the use of smaller vehicles. As noted in the "User Benefits" section of this paper, many of our daily trips require something large enough for only one person. Such vehicles could be very small and energy efficient.

As more attractive options for public transit and ride-sharing become available, a larger portion of our trips could be made in higher occupancy vehicles (HOV).

Additionally, as walking and bicycling become safer, more people will do so. Surveys often indicate that the primary reason for people not bicycling is the lack of safe streets. AVs should change that. Also, as we need less space for cars and introduce more road diets, we could further improve conditions for walking and bicycling with more and wider bike lanes, wider sidewalks, and safer street crossings. Since walking and bicycling generally replace short trips, they eliminate cold engine starts, the most polluting part of a trip.

Transit

Transit could benefit in several ways through AV technology, and is likely to adopt the driverless technology first. Below are some of the most salient benefits.

Increased service

As mentioned in the "Economics" section, driverless buses eliminate the most expensive part of operating the bus: the driver. By reducing operating costs by half, they could offer twice as many buses for the same budget. In other words, buses that now have headways of 20 minutes could come every 10 minutes for the same transit money. Those that now come every 10 minutes could arrive every 5 minutes, offering passengers much better service.

Increasing travel speeds (described in the next bullet) would also enable buses to run their routes in less time and turn around and run them again, essentially improving service with no additional cost. If average speeds increase by 25 percent service, the public would receive 20 percent more service. Buses that now run every 15 minutes could operate with 12-minute headways. This compounds the time advantage described in the previous paragraph. Buses could save time further by adding pre-board fare payment systems to reduce dwell time at bus stops.

Adding the advantages just listed, transit operators could increase service by 250 percent to 300 percent with the same operating budget they now use.

Faster Service

The lane clearance function could significantly increase the average travel time of buses. This would be true on both surface streets and freeways. Increasing the average travel speed would make buses more competitive vis-à-vis traveling in a lower-occupancy vehicle. This should attract new passengers and improve service for those now using buses.

Self-driving high-speed intercity buses can offer enhanced seating and additional services.

New Viable Ride-sharing Services

Many of our trips take place on multiple streets and do not lend themselves to fixed-route transit. Shared-ride trips match our scattered travel patters well. As more people join services like Uber Pool, more people will find matches of people to share rides with. Sharing will become more viable and attractive. This should open more options to travel in HOVs. If coupled with public policy that favors HOVs with time and cost advantages, more people would opt for this type of service. Overall, this could greatly improve access.

High-Speed Buses

With the safety benefits of lane clearance technology and crash avoidance technology, we can imagine allowing buses to go faster, thereby providing a time advantage in traveling by bus. Our urban and suburban freeway systems could become transit corridors with stops every two to three miles, and transfer points at interchanges.

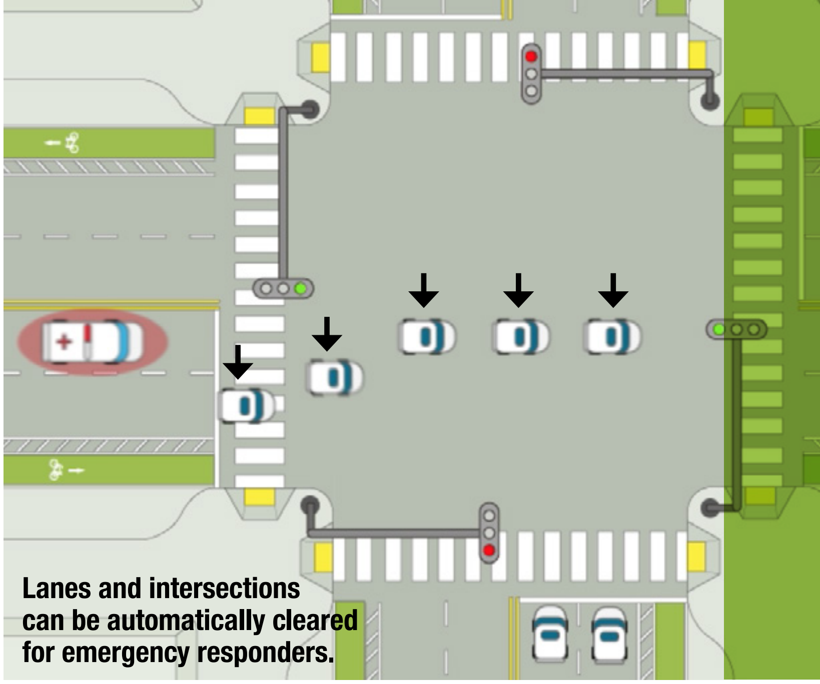
What if buses could be built and governed to travel 120 miles per hour, or 150 miles per hour? This is likely within the technological capabilities. With lane clearance and crash

What if buses could be built and governed to travel 120 miles per hour, or 150 miles per hour? This is likely within the technological capabilities.

avoidance, could buses travel this fast safely? I believe it is possible. This could make regional travel faster. Stations along the freeways could link with surface street buses, shared-ride services, driverless taxis, and bike sharing to take people to and from their destinations and origins.

Such buses could also service intercity travel. Instead of California spending $68 billion on high-speed rail, a comparable service that requires no special infrastructure, operates without subsidies, and is affordable may be possible. Today Greyhound sells tickets between Los Angeles and San Francisco for $34 to $40 for a bus trip that takes eight to nine hours. Greyhound does this with a driver, and with very little subsidy. If this trip could be made in three hours and with no driver, it's possible a passenger could take the trip for a very low fare, perhaps $20 or $25. It's also possible to imagine something like an 18-passenger luxury bus with airline-like first-class seats that recline for sleeping, restrooms, and other comforts that ferries someone between the two regions in three hours for $30.

As the number of people in the public system, which could be privately or publicly operated, grows, their autonomous travel options will grow. The advantages of not owning a car could outstrip those of owning for many people.



Lanes and intersections can be automatically cleared for emergency responders.

Emergency Access

As mentioned earlier, the "lane clearance" function could work to the advantage of emergency responders by essentially dedicating a lane to them. They could also be given priority at intersections with centrally coordinated flow. Further, the system could be optimized to reduce or eliminate the congestion emergency responders normally have to contend with. All of this adds up to faster response times.

POTENTIAL DRAWBACKS

Along with many benefits, there will of course be some downside to the advent of driverless vehicles, some of which are explored here.

Lost Jobs

I believe the largest drawback to widespread use of AVs would be the loss of jobs, which is not unlike what happened during the industrial revolution. ***And it is a big drawback.*** Many people depend on driving for a living. This includes bus drivers, taxi drivers, truck drivers, and delivery drivers. Many of these jobs pay better than minimum wage and are available to people without college degrees. Moreover, the future envisioned here would put more than drivers out of work. Many people are involved in manufacturing, sales, and servicing of vehicles and vehicle parts. The U.S. Bureau of Labor Statistics reports that the total number of people employed in auto manufacturing, trade, and services was 6,986,900 in July 2015. While we would still have some manufacturing, trade, and services with autonomous vehicles, a future with fewer vehicles would mean fewer jobs.

The loss of jobs would not only affect those directly employed, but would impact the economy as a whole. Those jobs would need to be replaced with comparable or better paying jobs. AV technology will create some new jobs. If many AVs run on electricity, we could reduce emissions by charging these vehicles with renewable energies. This would create new jobs. But we will a need deliberate effort to create new industries, and to retrain people for these jobs.

Since taking a two-ton car around with us wherever we go never was a sustainable transportation paradigm, we need to replace it and the jobs that go with it. Ideally, we will create jobs in sustainable technologies.

Encouraging Driving and Long Commutes

Others have written that AVs will encourage driving and longer commutes, thereby exacerbating suburban sprawl. Since reducing the lost time in long commutes can be replaced with time more productively spent, or more enjoyably spent, AVs will reduce the cost of time of long commutes. They will also reduce the stress cost of the commute. Reduced stress and time costs could very well make longer distance commutes more attractive. I suggest that we need to introduce public policies to help offset these advantages.

THE POLITICS OF ALGORITHMS

As our vehicles on the streets yield more control to central computing systems regulating traffic flow, determining which groups get priority will become both a policy and a political process. These systems' algorithms could be set to maximize flow of vehicles carrying a number of people, or to maximize flow of single-occupant vehicles. The algorithms' design could ignore pedestrians and bicyclists, or give these more vulnerable street users priority. Privately operated transport services and freight haulers may start lobbying for preferential treatment over their competitors.

Ensuring the eventual decisions reflect good public policy, rather than the will of politically powerful groups, will be extremely important. The outcome could determine the direction and impact AVs have on society, with a broad spectrum of possibilities.

It will be important to avoid a tragedy of the commons situation where drivers traveling alone take precedence over multi-occupant vehicles, bicyclists, and pedestrians. Many local political debates today focus on the priority we give each of these groups. If the forces lobbying to maintain primacy of the solo driver win, with induced travel the whole system could break down, leaving severe congestion. On the other hand, everyone stands to benefit, including those driving alone, if we prioritize movement of higher-occupancy vehicles.

> *...everyone stands to benefit, including those driving alone, if we prioritize movement of higher-occupancy vehicles.*

POLICIES

We need an active effort to create policies to speed the advent of AVs and to ensure that their impact is positive. Some of the policies that should be discussed follow.

Research and Development

While AV technology is rapidly advancing through the private sector, which stands to gain from it, government can look to fill research gaps to speed the development of safe and practical use of AVs on our streets and roads.

Pricing Strategies

Many benefits of AV technology will result from people driving less and using greener vehicles. If they choose buses, HOVs, bicycles, and walking for many trips, the benefits described above will be realized to a greater extent. As fewer vehicles use gasoline, we have to switch to other methods of taxing users for the use of vehicles. A pricing mechanism that provides incentives for people to travel in buses and HOVs, to travel shorter distances, and to use greener vehicles will result in that. Ideally, that pricing should be based on miles driven/ridden, the number of people in the vehicle, emissions of each vehicle, and energy consumption per vehicle. Someone traveling alone in a large vehicle that uses lots of energy and emits significant GHG should pay significantly more per mile than someone traveling with others in a more efficient vehicle. This would be the most equitable and most neutral form of pricing—you pay for what you use and the impact your use creates. For owners of vehicles, this could be done through electronic billing. For passengers, the incentive could come with fares and fees on private operators.

Time Advantages

Door-to-door travel time can be a powerful motivator when selecting a mode of transportation. Lane clearance and central coordination could provide a time advantage to buses and HOVs. The more people in the vehicle, the more favored speed treatment the vehicle could receive as it travels.

Liability Issues

One of the key issues that experts discuss relates to assigning responsibility and in turn, liability when a crash occurs. In a driverless car, the driver wouldn't be responsible. Would it be the manufacturer, vehicle operators that the crash occurs with, an insurance company, the city, or whom? This seems like a very resolvable issue. Public policy makers should take this up and develop the policy with manufacturers, technology experts, and other key stakeholders involved.

MUTCD Issues

The National Committee on Uniform Traffic Control Devices (NCUTCD) works with the Federal Highway Administration to write the Manual on Uniform Traffic Control Devices (MUTCD), which sets standards and guidelines for traffic control devices, such as signs, pavement markings, and signals. A new task force to the NCUTCD has just been formed to address issues related to AVs, including issues related to AVs' needs. For example, are there markers that AV lasers or radar could use to better operate that could be added to the streets? Is there a role for street devices as part of V2I technology? What else can be done with our streets to better accommodate AVs?

Parking Codes

If AVs reduce the need for parking, they would strengthen the arguments against parking codes and for requiring less or no parking.

CONCLUSIONS

AVs offer many potential advantages over human-driven vehicles. They bring promise to address some of the most important policy issues of our time. Improvements in safety, mobility for non-drivers, reduction in greenhouse gases, and opportunities to improve our streets through more optimal use of space should be seen as opportunities to seize. If we can significantly improve public transit with existing funds, and not have to invest in expensive infrastructure, this should be seen as something worth pursuing. Many cities are reallocating street space for bus lanes, bike lanes, and wider sidewalks, and this is causing significant friction with motoring interests. AVs offer the opportunity to circumvent local political squabbles over competition for street space through much more efficient use of the space.

AVs can change the way we live and travel. Policy makers should consider this for the long run and how it impacts assumptions and decisions we make today. Does it make sense to invest in billions of dollars' worth of freeway improvements and road widening, when AVs may significantly reduce the need for these? Similarly, does it continue to make sense to invest in high-speed rail infrastructure, subways, and light-rail lines when AV technology may create virtual dedicated rights-of-way without the expensive infrastructure?

Many people now debate how AVs will impact our cities and our daily lives. There has been significant discussion on the benefits and potential negative outcomes, and debates over the time frame of when Level 3 and 4 vehicles will be available. Rather than attempt to predict potential random outcomes, and assume things will happen on their own somehow, I'm urging policy makers to seize the opportunity to speed AVs' development and to ensure that the outcomes are positive and protect the future from negative outcomes. Let's take the wheel to control policy development; this is where we need drivers, and we have none now.

For more information on the ideas shared in this paper, contact Ryan Snyder @ Transpo Group at ryan.snyder@transpogroup.com.

Animation screen shots on pages 6, 7 & 15 created for Transpo Group by Justin Roth.