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The State and Future of Autonomous Vehicle Regulation in the United States

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Abstract

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Autonomous vehicle technology is poised to revolutionize transit around the world. There are currently tens of private companies either testing or building autonomous vehicles, including industry juggernauts like Ford and Google. This new mode of transportation falls into a regulatory grey area. Once cars reach full autonomy, governments will have to decide what entities will regulate them, where they will be allowed to drive, who will be responsible for them and a host of other issues. In some municipalities like San Francisco and Phoenix, autonomous vehicles (AVs) are being tested on public streets in real life conditions. Meanwhile, in 2017, 33 US states have released frameworks on how they believe AVs should operate in real world environments. There is broad consensus that AVs should be programmed to prioritize safety, but the details in each plan vary to accommodate the specific circumstances of different localities.

If AVs are indeed inevitable as urban planners and futurists believe they are, then we must completely rethink the way vehicles use the road. The introduction of autonomous vehicles could bring massive reductions in greenhouse emissions, more efficient land use due to the elimination of parking structures, less traffic, safer roads, and other benefits.

Without proper forethought and planning however, business as usual automotive policy could create impenetrable walls of autonomous vehicles on cities in highways for elite drivers and limit transit options for everyone else.

Examining existing US federal and state law has shown that the burden of regulating future autonomous vehicles is on the states. Some states already have regulations concerning the testing of autonomous vehicles on the books. The US federal government plays an advisory role only. Guided by best practice principles ratified at the Kaohsiung conference, states should develop frameworks to encourage and regulate autonomous vehicle testing to make sure that it is safe and accountable.

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The History of Autonomous Vehicles

Autonomous vehicle technology has only recently reached a point where it can begin to be offered to the public. Although various industries have added robots and autonomous technology to their production lines, these devices all work in precisely mapped conditions. An autonomous robot in a factory, for example, does not make decisions because it programmed to behave the same way over and over again. Machine learning and artificial intelligence advances in the past few decades have allowed computers to make more independent decisions.

A computer must be incredibly sophisticated to perceive, analyze and respond to a complex environment like a road. It's difficult enough for a human to make split second decisions behind the wheel. According to a DARPA study, "successful driving requires attention, alertness, and instinctive responses to varying road conditions, obstacles, and safety conditions. For example, a car driving at 96 kilometers an hour traverses 26.5 meters per second. Drivers have a reaction time of three seconds, and the vehicle braking distance at that speed is typically 100 meters. A typical driver is alert to road conditions for about 11 seconds in advance of the vehicle. During this interval, the driver makes a stream of decisions based on 291 meters' worth of data spread across an arbitrary number of lanes. This does not include the processing of sensory data responsible for rearview image analysis that also impacts safety considerations. All these issues call for a steady stream of decisions without abandoning previous tactical choices for route navigation."[1]

[1]Seetharaman, Guna, et al. "Unmanned Vehicles Come of Age: The DARPA Grand Challenge." *Computer*, Jan. 2007, www.bing.com/cr?IG=FAE7924C8FD641A7BE213D7284799261&CID=1510EAC14992696E18A1E121489F6854&rd=1&h=od81jBPu1yOGtYAoTn9SaLHs0EExTQN69IgQusW-pT0&v=1&r=https%3a%2f%2fwww.researchgate.net%2fpublication%2f2961674_Unmanned_vehicles_come_of_age_The_DARPA_grand_challenge&p=SDevEx.LB.1,5201.1.

Driverless cars are divided into five levels that describe the degree of their autonomy. At level zero, a human driver completely controls the vehicle. At the second level, the car controls either the steering or the vehicle speed, but not both simultaneously. An example is cruise control. The third level allows the car to steer, brake and accelerate under certain conditions. The driver must respond to traffic signal and other hazards. A level four car completely drives itself without human input but only within a predefined geographical area. For example, a human driver may navigate the vehicle to the highway along local streets and then allow the car to fully take over. [2]

To enhance driver capabilities, autonomous computing can significantly aid in routine decision making: Manufacturers have successfully integrated automatic cruise control, automatic transmissions, and fully automatic parking in commercial cars. Remotely operated vehicles have performed successfully in space missions and hostile environments for more than two decades. Industry has used robotic systems for moving materials between locations on production lines for half a century.

The idea to automate cars has been around for more than a century. In 1925, Francis Houdina demonstrated a radio controlled car which drove through the streets of Manhattan.[3] The concept percolated for decades before technology reached a level where cameras and computers could work together to truly see and interpret the road.

The 1970s and 1980s saw the first experiments with cars that we would call autonomous. They had all of the necessary equipment and sensors to navigate themselves through normal

[2] Harner, Isabel. “The 5 Autonomous Driving Levels Explained – IoT For All – Medium.” *Medium*, IoT For All, 6 Nov. 2017, medium.com/iotforall/the-5-autonomous-driving-levels-explained-b92a5e834928.
[3] Dormehl, Luke. “Sit Back, Relax, and Enjoy a Ride through the History of Self-Driving Cars.” *Digital Trends*, Digital Trends, 26 Mar. 2018, www.digitaltrends.com/cars/history-of-self-driving-cars-milestones/.

traffic without human input. The Stanford Cart was a robot developed as a moon rover in the 1970s and was able to navigate a crowded room filled with chairs in about five hours. It used a camera to create a three-dimensional image of the room and the obstacles in it and interpret its surroundings.

Both private and government investment was crucial for the research and development of the technology that allowed cars to drive themselves. The Eureka Prometheus project, sponsored by Mercedes-Benz pushed the limits of then available technologies by operating an AV near an urban center. Project lead Ernst Dickmanns described the experiment: "At the end of the EUREKA-project PROMETHEUS (1987-1994), several Mercedes SEL-500 vehicles demonstrated visually guided autonomous driving with guests on board on Autoroute 1 near Paris in typical 3-lane traffic at speeds up to 130 km/h, including convoy driving and autonomous lane changes. A1995 long-distance test drive involved more than 1600 km driven at speeds up to 180 km/h."[4] Autonomous vehicles were becoming more sophisticated by the 1990s, but were still far from ready for public consumption.

US government research into autonomous vehicles was managed by DARPA. In 2004, that organization launched the DARPA Grand Challenge in which $1 million was offered to the contestant that could autonomously navigate an obstacle course. There was no winner the first year of the competition, but in 2005 a team from Stanford University and Volkswagen won the challenge using technology adapted from the Stanford Cart. By 2007, all six teams that entered the contest successfully navigated an urban obstacle course, demonstrating how quickly the technology was advancing.

[4] Dickmanns, Ernst. "The Fourth Conference on Artificial General Intelligence." *The Fourth Conference on Artificial General Intelligence RSS*, Aug. 2011, agi-conf.org/2011/abstract-ernst-dickmanns/.

Thus far the history of autonomous vehicle research has included contributions from governments, universities and private companies. In the last decade, however, automobile manufacturers and technology companies have come to the forefront of this research field and are eager to bring autonomous cars to the market.

One example is Google's company Waymo. This began in 2009 with a group of engineers that participated in the DARPA Grand Challenge. By 2015, a car with no steering wheel or pedals successfully transported a passenger through the streets of Austin, Texas. In 2017, Waymo began testing an autonomous minivan with real passengers in Phoenix, Arizona.[5] Another company working on automated vehicles is Tesla. The Tesla Model S vehicle debuted "Autopilot" in 2015, which allows the car to stay in lane, switch lanes and park without human input.

Although companies believe that autonomous cars will be wildly popular, the public has been skeptical about them for some time. In a Pew Research Survey from May, 2017, 56 percent of American respondents said that driverless cars are inevitable in the next 10 to 50 years, while 56 percent of respondents said that they would not ride in one.[6] 54 percent of US consumers indicated that they would feel safer riding in a self-driving car if the federal government were to implement regulations and standards.[7] However, there has been a dramatic increase in positive opinion of autonomous vehicles in the last year.

A Deloitte study found that more respondents in countries around the world were believed that autonomous cars were safer. For example, in South Korea, the percentage of people

[5] "Journey – Waymo." *Waymo*, waymo.com/journey/.
[6] Smith, Aaron, and Monica Anderson. "Automation in Everyday Life." *Pew Research Center: Internet, Science & Tech*, 4 Oct. 2017, www.pewinternet.org/2017/10/04/automation-in-everyday-life/.
[7] "Deloitte Study: Consumer Trust in Autonomous Vehicles on the Rise." *PR Newswire: News Distribution, Targeting and Monitoring*, Deloitte, 8 Jan. 2018, www.prnewswire.com/news-releases/deloitte-study-consumer-trust-in-autonomous-vehicles-on-the-rise-300578805.html.

who think driverless cars will not be safe dropped from 81 percent in 2017 to 54 percent in 2018. In Germany, 45 percent of respondents thought that autonomous vehicles would be unsafe this year, down from 72 percent last year. In France, the amount of respondents that believed that cars would be unsafe dropped from 65 percent to 37 percent. Finally, the report concludes that "the most notable change comes from China, where the percentage of people who think autonomous cars will not be safe dropped from 62 percent in 2017 to only 26 percent in this year's study."[8]

As consumers become more aware of and comfortable with self-driving vehicles, corporations like Google, Tesla have become keen on introducing driverless cars to the market. IHS, the business consulting group, predicts that 76 million autonomous vehicles will be sold by 2035. The US is expected to be the first country in which autonomy is fully deployed, while China will be the largest market.[9] There are still several hurdles to cross before autonomous vehicles can be fully implemented. The IHS report writes that "that continued challenges to autonomous vehicle deployment include potential technology risks for software reliability and cybersecurity, though both of these are showing improvements as technology evolves and the industry recognizes the threat. In addition, the implementation of local and federal guidelines and regulatory standards, as well as a legal framework for self-driving cars, continue to prove challenging. Various states and regions have taken appropriate measures to begin to develop these frameworks, while others are still crafting their approach."[10]

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[8] Ibid.

[9] "IHS Clarifies Autonomous Vehicle Sales Forecast – Expects 21 Million Sales Globally in the Year 2035 and Nearly 76 Million Sold Globally Through 2035." *IHS Clarifies Autonomous Vehicle Sales Forecast – Expects 21 Million Sales Globally in the Year 2035 and Nearly 76 Million Sold Globally Through 2035 | IHS Online Newsroom*, 19 June 2016, news.ihsmarkit.com/press-release/automotive/autonomous-vehicle-sales-set-reach-21-million-globally-2035-ihs-says.

[10] Ibid.

A Framework for the Development of Autonomous Vehicles Regulation

Corporations see the potential for billions of dollars in revenue at the introduction of autonomous vehicles. Consumers are increasingly more confident in the convenience this technology can bring to their lives. Behind the scenes, however, governments, think tanks and private companies are working to identify the costs and benefits of autonomous vehicle technology and plan for them using smart policies. A major development in the direction of autonomous vehicle regulatory policy occurred in 2017 at the Kaohsiung EcoMobility World Festival.

Shared Mobility Principles should guide the development of autonomous vehicle regulation as it does for other transit modes in cities around the ten shared mobility principles were developed by a working group of international NGOs to reflect equitable and fair practices for designing and implementing transit solutions. They were developed and adopted in 2017 at the Kaohsiung EcoMobility World Festival in Taiwan and have diverse signatories from countries like Italy, Japan, New Zealand and the US, and private corporations like Lyft and Uber. These stakeholders will be the decision makers when it comes to policies surrounding autonomous cars[11] though none of the recommendations made by the working group are binding, their suggestions will shape the way these stakeholders think about future policies. Each of the principles adopted at the Kaohsiung conference reflects the positive and negative future that technology, especially autonomous vehicles, will bring to transit in cites.[12] Following the recommendations adopted at Kaohsiung, city planners can make sure that autonomous vehicle

[11] "The Kaohsiung Strategies for the Future of Urban Mobility – EcoMobility World Festival 2017." *EcoMobility World Festival 2017*, 2017, kaohsiung.ecomobilityfestival.org/declaration/.
[12] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/.

technology is not concentrated in the hands of the wealthy, remains accessible to all and prioritizes safety. Since the Kaohsiung plan has so many signatories, both governmental and private, it makes sense to examine existing and proposed policy in this field through the lens of its recommendations. For every point of the Kaohsiung plan, the applications of autonomous vehicle technology and real world and proposed plans.

Principle 1: We Plan Our Cities and Their Mobility Together

"The way our cities are built determines mobility needs and how they can be met. Development, urban design and public spaces, building and zoning regulations, parking requirements, and other land use policies shall incentivize compact, accessible, livable, and sustainable cities."[13]

The first mobility principle defines the need for all future mobility policy to incentivize accessibility and compactness. Up to the present, the development of cities and their transit policy were not always intertwined and were often at odds with one another. An example of transit policy running at cross purposes with city development policy are the actions of New York City's Robert Moses. The famous city planner and Parks Commissioner amassed a tremendous amount of power in NYC from the 1930s through the 1970s and commissioned many highways and parks in the area. He is has been accused of prioritizing downtown business interests and car culture over the city inhabitants and fair development. This story is told in Robert Caro's book "The Power Broker" in a an anecdote which reveals Moses' disdain for planning equitable transit policy: Caro instructed his engineers to build bridges much lower over the Southern State Parkway than necessary to prevent buses using the highway to reach the park

[13] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/.

at Jones Beach. Caro assumed that public transit would be taken by poor African-Americans and Puerto Ricans, whom he despised.[14]

The first mobility principle instructs planners not to prioritize privileged groups when enacting city policy. It is easy to imagine a city planner allowing autonomous vehicles to take over the road with little regard given to pedestrians. Without proper forethought and regulation, autonomous vehicles could worsen the already terrible traffic of many urban centers. The LA Times writes, "Imagine a future where most adults own individual autonomous vehicles. They tolerate long, slow commutes on packed highways because they can work, entertain themselves or sleep on the ride, which encourages urban sprawl. They take their driverless car to an appointment and set the empty vehicle to circle the building to avoid paying for parking. Instead of walking a few blocks to pick up a child or the dry cleaning, they send the self-driving minivan ... The streets would be cluttered with robot cars."[15] This is certainly a worst case scenario, but it is entirely possible that without regulation it could happen.

Principle 2: We Prioritize People over Vehicles

"The mobility of people and not vehicles shall be in the center of transportation planning and decision-making. Cities shall prioritize walking, cycling, public transport and other efficient shared mobility, as well as their interconnectivity. Cities shall discourage the use of cars, single-passenger taxis, and other oversized vehicles transporting one person."[16]

This recommendation emphasizes that the subject of transit policy should be people not vehicles. In the modern era, cities have been built to accommodate vehicles rather than

[14] Campanella, Thomas J. "The True Measure of Robert Moses (and His Racist Bridges)." *CityLab*, 9 July 2017, www.citylab.com/transportation/2017/07/how-low-did-he-go/533019/.
[15] The Times Editorial Board. "If We Don't Plan for Them, Autonomous Vehicles Could Make Our Car-Dominated Transit System Even Worse." *Los Angeles Times*, 9 Mar. 2018, www.latimes.com/opinion/editorials/la-ed-autonomous-vehicles-planning-20180309-story.html.
[16] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/.

pedestrians. In cities like Los Angeles, for example, it is impossible to commute to work, go shopping or engage in recreational activity efficiently without a private vehicle. This is a shortcoming of the design and organization of the city, which was built with the automobile in mind. This mentality created low density urban sprawl, contributing to traffic, air pollution and wasted time and money from elongated travel times.

Ideally, the transportation policy of the future would prioritize the person rather than the car. In term of autonomous vehicle policy, that means that the algorithm that makes the decisions about the vehicles' behavior will prioritize the pedestrian over the vehicle and its occupant. In a variant of the "trolley problem," 880 New Yorkers were asked what a self-driving car should do if it only had two options: swerving to avoid hitting a pedestrian, which may cause the occupant of the car to be injured, or to continue and hit the pedestrian.[17] 80 percent of respondents answered that the car should swerve to avoid the pedestrian. This question is especially important in dense walking cities like New York or Boston, where there are many more pedestrians who do not necessarily obey the rules of the road when crossing the street. However, not all autonomous vehicle manufacturers are on board with prioritizing pedestrian over passenger safety. Mercedes-Benz Active Safety Head Christoph von Hugo said that "If you know you can save at least one person, at least save that one. Save the one in the car."[18] This policy is in direct opposition to the principles laid out in the Kaohsiung plan. Mercedes-Benz is not a signatory to this plan. This is an issue that will need to be addressed by autonomous vehicle manufacturers in partnership with regulators. If Mercedes-Benz favors prioritizes passenger

[17] "Driverless Car Makers Must Put Pedestrian Safety First, New Yorkers Say." *Transportation Alternatives*, 9 Jan. 2017, www.transalt.org/news/releases/9840.
[18] Taylor, Michael. "Mercedes Autonomous Cars Will Protect Occupants before Pedestrians." *Auto Express*, 11 Oct. 2016, www.autoexpress.co.uk/mercedes/97345/mercedes-autonomous-cars-will-protect-occupants-before-pedestrians.

safety in a no-win situation while Ford prioritizes pedestrian, for example, the conflicting software commands could cause cars to get confused and swerve into each other.

Principle 3: We Support the Shared and Efficient Use of Vehicles, Lanes, Curbs, and Land

"Transportation and land use planning and policies should minimize the street and parking space used per person and maximize the use of each vehicle. We discourage overbuilding and oversized vehicles and infrastructure, as well as the oversupply of parking."[19]

This point is the first one in which the Kaohsiung plan brings up its preference for and insistence on shared vehicles of all categories. The plan defines shared vehicles as "those used for hire to transport people (mass transit, private shuttles, buses, taxis, auto-rickshaws, car and bike-sharing) and urban delivery vehicles."[20] Vehicles must be multiple occupancy to increase their efficiency. The fewer individuals own private vehicles, the less space those vehicles will take up contributing to an increase in efficiency for the entire network.

Shared, autonomous vehicles could contribute to a kind of hyper efficiency. If no one in the city has a private vehicle, they could summon a roving autonomous car to get to their destination at any point. These cars would not take up parking spaces or lots or occupy curbside areas because they would be constantly in use. Former head of product development at General Motors Bob Lutz pessimistically described such a system thusly, "Now we are approaching the end of the line for the automobile because travel will be in standardized modules. The end state will be the fully autonomous module with no capability for the driver to exercise command. You will call for it, it will arrive at your location, and you will get in, input your destination and go to

[19] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/.
[20] Ibid.

the freeway. On the freeway, it will merge seamlessly into a stream of other modules traveling at 120, 150 mph. The speed doesn't matter. You have a blending of rail-type with individual transportation."[21] Lutz describes something of a dystopia, with people whisked around in pods with no ability to make decisions on their own. His conclusion is that "this is the demise of automotive retailing as we know it," because everyone's pod will be built to minimize air resistance rather than having any defining characteristics.

In crafting autonomous vehicle policy, it will important to prevent streets from becoming never ending trains of hyper efficient autonomous vehicles, cycling between pick up/drop off zones. At the very least, it will be difficult for pedestrians to cross streets in this world. At worst, only those with the resources to hire an autonomous will be able to travel at this level of efficiency, while everyone else will have to make do with public transportation, which is seriously lacking in many American cities.

Principle 4: We Engage with Stakeholders

"Residents, workers, businesses, and other stakeholders may feel direct impacts on their lives, their investments and their economic livelihoods by the unfolding transition to shared, zero-emission, and ultimately autonomous vehicles. We commit to actively engage these groups in the decision-making process and support them as we move through this transition."[22]

Engaging with stakeholders is important in introducing any new policy, but especially in an area like autonomous vehicle technology, where there is no road map for creating new procedures. The public will have to be educated about new policies surrounding autonomous

[21]Lutz, Bob. " Kiss the Good Times Goodbye." *Automotive News*, www.autonews.com/article/20171105/INDUSTRY_REDESIGNED/171109944/industry-redesigned-bob-lutz.

[22] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/.

vehicles. Business owners along major roads are an example of a stakeholders with whom there will need to be engagement. Currently, drivers traversing a city can stop any time they want (provided they can find parking) to visit roadside businesses. Signs can entice a person to pull over at any point. However, if people are just inputting their destination into their vehicle and then sitting back and looking at their phones or napping on the ride, how will businesses maintain customers? Why pull over at a motel if you can sleep in the car while it drives overnight? Audi's vice president of brand strategy Sven Schuwirth said ""In the future you will not need a business hotel or a domestic flight...We can disrupt the entire business of domestic flights… I think that vision is probably 20 years from now."[23] Besides pedestrian and vehicle owners, businesses that currently rely on the benefits and disadvantages of private vehicles will certainly be interested in influencing the process of policy development.

Principle 5: We Promote Equity

"Physical, digital, and financial access to shared transport services are valuable public goods and need thoughtful design to ensure use is possible and affordable by all ages, genders, incomes, and abilities."

Equity is very important because autonomous car technology should not be restricted to the rich. The branding around semi-autonomous vehicles now shows rich business people shuttling between meetings.[24] It is important to understand that not everyone will be able to afford an autonomous car, or even one of the autonomous pods postulated by Bob Lutz.

[23]Fairs, Marcus. "Driverless Cars Could Spell the End for Domestic Flights." *Dezeen*, 26 Nov. 2015, www.dezeen.com/2015/11/25/self-driving-driverless-cars-disrupt-airline-hotel-industries-sleeping-interview-audi-senior-strategist-sven-schuwirth/.
[24]*The Mercedes-Benz F 015 Luxury in Motion.* 6 Jan. 2015, www.mercedes-benz.com/en/mercedes-benz/innovation/research-vehicle-f-015-luxury-in-motion/.

Especially in low density small towns and suburbs, pre-owned private vehicles will most likely remain the only accessible transportation method for lower income people. When planning the autonomous car future, planners must remember to consider the needs and preferences of people who cannot afford the technology.

In general, automakers have skewed their offerings to the high end or luxury market in recent years. Due to wage stagnation in the United States, average incomes have not risen since the 1970s.[25] Meanwhile, a new vehicle costs more than $34,000 and the price keeps rising.[26] A shiny new autonomous, electric vehicle, as envisioned by self-driving futurists, could cost twice as much or more, depending on if it marketed as a luxury item. If autonomous vehicles are to be made an integral part of future cities' transportation infrastructure, there should be made affordability must be considered. If manufacturers charge high prices for those vehicles, then investment should be made in public transportation to benefit commuters that cannot afford the new technology.

Principle 6: We Lead the Transition towards a Zero-Emission Future and Renewable Energy

"Public transportation and shared-use fleets will accelerate the transition to zero-emission vehicles. Electric vehicles shall ultimately be powered by renewable energy to maximize climate and air quality benefits."[27]

[25] Nunn, Jay ShambaughRyan. "Why Wages Aren't Growing in America." *Harvard Business Review*, 24 Oct. 2017, hbr.org/2017/10/why-wages-arent-growing-in-america.
[26] "KBB: Average New-Car Price Rises Nearly 1% in August." *Top News - DP's Office - Top News - Auto Dealer Today*, 5 Sept. 2017, www.autodealermonthly.com/channel/dps-office/news/story/2017/09/kbb-average-new-car-price-rise-nearly-1-in-august.aspx.
[27] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/

The reality of human caused global climate must be addressed in every part of human life, but especially in transportation, since internal combustion vehicles produce greenhouse gases. In fact, the transportation sector represents 27 percent of total US emissions.[28] The University of Michigan found that autonomous cars bring a lifetime decrease of 9 percent of greenhouse gas emissions compared to conventional vehicles.[29] All of the autonomous currently being tested or proposed are fully electric. Though the way that electricity is generated could emit pollution, as in the case of coal or natural gas plants, the lack of a combustion engine reduces the emission of harmful gases significantly.

Principle 7: We Support Fair User Fees across All Modes

"Every vehicle and mode should pay their fair share for road use, congestion, pollution, and use of curb space. The fair share shall take the operating, maintenance and social costs into account."[30]

This principle especially pertains to the future of curb use and autonomous vehicles. If autonomous vehicles are to become mostly shared, there will be no need to park them inside the city. Streets will require much less parking. Parking revenue, a major source of income for many municipalities, would collapse.[31] The use of curb space could become much more varied and dynamic, with cafes setting up outdoor seating during busy hours and loading areas for deliveries at night.

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[28] "Sources of Greenhouse Gas Emissions." *EPA*, Environmental Protection Agency, 11 Apr. 2018, www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
[29] "Maximizing the Environmental Benefits of Autonomous Vehicles." *Phys.org*, 15 Feb. 2018, phys.org/news/2018-02-maximizing-environmental-benefits-autonomous-vehicles.html.
[30] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/
[31] Rice, Annibel, and Adie Tomer. "How Will Autonomous Vehicles Transform the Built Environment?" *Brookings*, Brookings, 9 Feb. 2018, www.brookings.edu/blog/the-avenue/2017/10/16/how-will-autonomous-vehicles-transform-the-built-environment/.

When it comes to ride sharing and autonomous vehicles, the major players in the American market have signed on to this guideline. Both Lyft and Uber are researching self-driving cars and currently subsidize the costs of their services. Keeping prices for ride sharing affordable would be a priority in a plan influenced by this policy. It could include something like tax breaks for ride sharing companies to lower their prices.

Many cities around the world have implemented congestion pricing to prevent their business districts from becoming congested, improve air quality by eliminating pollution emitting vehicles and raise revenue. One example is London, greenhouse gas emissions were reduced by 16 percent between 2002 and 2003 and generated 122 million pounds of revenue in 2006. Furthermore, there were between 40 and 70 percent fewer traffic fatalities depending on the year examined.[32] Congestion pricing is being considered in New York and other cities and could couple efficiently autonomous vehicles. A policy would prioritize electric vehicles like autonomous cars, making it cheaper for them to travel into downtown areas than other vehicles.

Principle 8: We Aim for Public Benefits via Open Data

"The data infrastructure underpinning shared transport services must enable interoperability, competition and innovation, while ensuring privacy, security, and accountability."

There is great danger from cybersecurity threats in the autonomous vehicle space. If a bug in the car's programming or a hacker disrupted the traffic pattern, self-driving cars could plow into pedestrians and property with no way to stop them from the inside. Recently, vehicles have become a weapon of choice for terrorists. Since 2014, there has been a rise in "vehicle

[32] "London's Congestion Charge." *Centre for Public Impact (CPI)*, 15 Apr. 2016, www.centreforpublicimpact.org/case-study/demand-management-for-roads-in-london/.

contact" terrorism, with terrorists ramming trucks or cars into crowds of people.[33] A hacker could take control of an autonomous vehicle and send it down a sidewalk from thousands of miles away. Security is an important pillar of autonomous vehicle policy.

Open access to data to the public and to city planners is also important. City planners can use the data to change traffic patterns and policy faster and more efficiently. The public could plug that data into smartphone apps to make their travel even more convenient and connected.

Principle 9: We Work Towards Integration and Seamless Connectivity

"All transportation services should be integrated and thoughtfully planned across operators, geographies, and complementary modes. Seamless trips should be facilitated via physical connections, interoperable payments, and combined information. Every opportunity should be taken to enhance connectivity of people and vehicles to wireless networks."[34]

As new technologies are introduced into urban transportation it will be important to have a seamless system of transfers between modes of transit and an easy method of payment. This already exists in some cities that allow commuters to tap their bank cards at turnstiles instead of buying a special ticket or pass. This technology is present in systems like the Utah Transit Authority, the Chicago Transit Authority and in Transport for London. The technology is being introduced in New York City as well.[35] Allowing consumers to pay for everything with one card or system rather than having them juggle several methods of payment would make the system more convenient and secure. In the case of shareable autonomous vehicles, allowing people to

[33] Petulla, Sam. "Vehicles in Crowds Are Becoming Terrorists' Weapons of Choice." *NBCNews.com*, NBCUniversal News Group, 7 June 2017, www.nbcnews.com/news/world/vehicles-are-becoming-weapons-choice-terrorists-n768846.
[34] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/
[35] "Smart Card Alliance." *About Smart Cards : Applications : Transit Open Payments Resources » Smart Card Alliance*, www.smartcardalliance.org/smart-cards-applications-transit-open-payments-resources/.

tap their bank cards at a terminal in the car would speed up payments and allow them to transfer seamlessly onto another mode of transit, like a bike share or bus.

Principle 10: We Support that Autonomous Vehicles in Dense Urban Areas should be operated Only in Shared Fleets

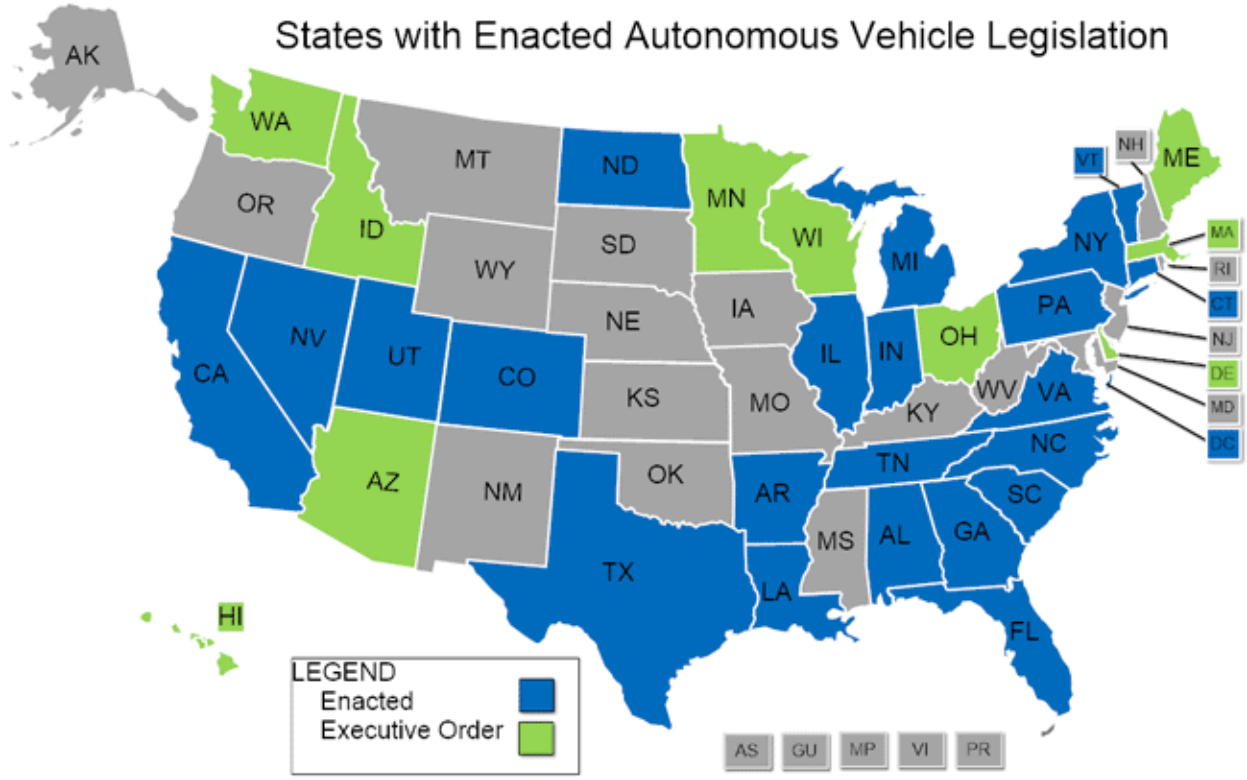
"Due to the transformational potential of autonomous vehicle technology, it is critical that all AVs are part of shared fleets, well-regulated, and zero emission. Shared fleets can provide more affordable access to all, maximize public safety and emissions benefits, ensure that maintenance and software upgrades are managed by professionals, and actualize the promise of reductions in vehicles, parking, and congestion, in line with broader policy trends to reduce the use of personal cars in dense urban areas."[36]

The final point of the plan calls for autonomous vehicles to be operated in shared fleets only. This point brings up many questions. If ride sharing companies are the only ones with fleets and there are no private vehicles left on the road after a few decades, there will be too much transportation power and responsibility concentrated in the hands of a company like Uber. Another way to organize a shared fleet would be to link cars of different services together into a cross-brand mega fleet. Users could pick their vehicle based on price and convenience from a single access point. To accommodate such a future in the US, two barriers must be overcome. The first is American aversion to active government and the second is, according to David Roberts of Vox, "an enormous amount of accrued habit and behavior on the part of affluent

[36] *Shared Mobility Principles for Livable Cities*. www.sharedmobilityprinciples.org/

Westerners, particularly in the US, who are attached to the current system of private ownership and low occupancy."[37]

Current US Regulation and Legislation



[38]

The ten principles summarized above effect existing policy, passed by the local and federal governments of many countries. Special attention is paid, in some municipalities, to cataloging and reporting autonomous vehicle use and testing. The United States' delegated

[37] Roberts, David. "Unless We Share Them, Self-Driving Vehicles Will Just Make Traffic Worse." *Vox*, 18 May 2017, www.vox.com/energy-and-environment/2017/5/18/15604744/self-driving-cars-cities.
[38]"Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation." *National Conference of State Legislatures*, 26 Mar. 2018, www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

governing authority allows different states to regulate autonomous vehicles differently. In the United States, federal, state and local governments have the power to regulate various elements of the transportation network. When it comes to autonomous vehicles, the US federal government issues guidelines and frameworks for the states, but these are entirely voluntary. Each state government can pass its own regulations on autonomous vehicle technology. The legislatures of twenty-two US states have enacted laws related to autonomous vehicles. The governors of ten states have issued executive orders related to autonomous vehicles.[39] Some states have fairly loose laws for autonomous vehicle testing to encourage economic development of those industries while others are stricter.

US Federal Laws

The National Highway Traffic Safety Administration (NHTSA), part of the US Department of Transportation, issued the first federal guidelines and has continued to be responsible for laws and guidelines concerning autonomous vehicles at the federal level. The NHTSA explains its role thusly: "NHTSA is responsible for developing, setting, and enforcing Federal motor vehicle safety standards (FMVSSs) and regulations for motor vehicles and motor vehicle equipment. NHTSA also is responsible for issuing and enforcing motor vehicle fuel economy standards and in exercising that authority works closely with the Environmental Protection Agency, which has parallel authority with regard to greenhouse gas emissions from

[39]Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation." *National Conference of State Legislatures*, 26 Mar. 2018, www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

vehicles."[40] This mission gives the NHTSA authority to issue regulations on autonomous vehicles. NHTSA is especially tasked with safety and highlights the potential safety benefits of autonomous vehicles in many of its documents on the subject. If one government agency can be said to represent the stance of the US federal government, then it can be said that the United States is positively inclined toward the introduction and mass adoption of autonomous vehicle technology.

In 2013, the NHTSA issued a preliminary policy statement on autonomous vehicles. This document makes several policy recommendations that the NHTSA believes states should follow. These include a recommendation that states mandate that operators of AVs have a separate driver's license and training course; that a driver always be in the driver's seat, regardless of the level of the vehicle's automation; that businesses that test self-driving vehicles submit their data to the state and report on their experiments.[41] Finally, in 2013, the NHTSA recommended against allowing automated vehicles on the roads for any reason other than testing.[42] Since that time, self-driving technology has progressed to the point that some companies are contemplating consumer versions of these vehicles within the next few years.

Since 2013, autonomous driving technology has advanced and public awareness of autonomous vehicles have shifted. The most recent federal guidelines, *Autonomous Vehicles 2.0: A Vision for Safety*, were released in September, 2017.[43] Again, this document is a non-regulatory approach; none of its recommendations are mandatory. The recommendations make clear that they are intended only for in state regulations, not for interstate travel. If a vehicle

[40] National Highway Traffic Safety Administration. *Preliminary Statement of Policy Concerning Automated Vehicles*. www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.
[41] Ibid.
[42] Ibid.
[43] National Highway Traffic Safety Administration. "Automated Driving Systems 2.0: A Vision for Safety." www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

travels between states, it falls under the jurisdiction of the Federal Motor Carrier Safety Regulations, which mandate that "a trained commercial driver must be behind the wheel at all times, regardless of any automated driving technologies available on the CMV (commercial motor vehicle), unless a petition for a waiver or exemption has been granted."[44] Thus, the recommendations apply only to state legislatures and not to any future federal regulations.

The *Vision for Safety* also outlines the responsibilities of federal and state government entities. The federal government is responsible for setting Federal Motor Vehicle Safety Standards (FMVSSs) for new motor vehicles and motor vehicle equipment; enforcing compliance with FMVSSs; investigating and managing the recall and remedy of non-compliances and safety related motor vehicle defects nationwide; communicating with and educating the public about motor vehicle safety issues.[45] Meanwhile, the states are responsible for licensing human drivers and registering motor vehicles in their jurisdictions; enacting and enforcing traffic laws and regulations; conducting safety inspections, where States choose to do so; regulating motor vehicle insurance and liability.[46] This summary of responsibility puts much of the regulatory burden on the states. They are allowed to decide whether to carry out safety inspections and how to license drivers and autonomous vehicles. This has the potential to create a fertile environment for testing. If a state government decides to limit its regulation of autonomous vehicles and allow businesses to test wherever they choose, they will attract more jobs to their state. However, such a permissive environment could bring dangers if the business testing its autonomous technology cuts corners or miscalculates when it comes to safety.

[44] National Highway Traffic Safety Administration. "Automated Driving Systems 2.0: A Vision for Safety." Page 20. www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.
[45] Ibid. page 20
[46] Ibid. page 20

The best practices for regulating autonomous vehicles proposed by the US government to state legislatures are liberal. The NHTSA recommends that states provide a "technology neutral" environment. This point recommends that state governments not limit their permissions to autonomous vehicle testing to automotive manufacturers only. According to the NHTSA, "no data suggests that experience in vehicle manufacturing is an indicator of the ability to safely test or deploy vehicle technology."[47] Thus, the state government should not deny a company like Waymo the right to test on the road simply because it does not manufacture vehicles of its own.

Another best practice advocated by the NHTSA is that states provide licensing for both drivers and vehicles. The NHTSA recommends "defining 'motor vehicles' … to include any vehicle operating on the roads and highways of the State."[48] This practice would allow a state to regulate any vehicle on the road rather than have autonomous passenger vehicles and freight vehicles from falling through loopholes. Furthermore, the NHTSA recommends "registering all vehicles equipped with ADSs [autonomous driving system] and establishing proof of financial responsibility requirements in the form of surety bonds or self-insurance."[49] This practice avoids issues involving insurance and responsibility in the event of an accident which is especially important for technology which is still in the testing phase.

State Laws

The guidelines that the US Department of Transportation sets out are comprehensive but not binding. Different US states interpret these guidelines and apply laws depending on their needs and circumstances. California and Arizona are two US states in which autonomous car

[47] Ibid page 21
[48] Ibid page 21
[49] Ibid page 21

testing is being carried and is regulated to various degrees. In each case, state governments have responded differently to the challenges that testing autonomous vehicles out of a controlled environment bring to the real world.

California is a hotbed for autonomous vehicle testing. Technology companies like Google and Uber have their headquarters in California so it is easy for them to deploy personnel for testing. California also has a varied geography, with dense urban settings, highways and rural areas for cars to be tested in. Finally, California has a mild climate, which allowed autonomous car testers to focus on responding to dynamic traffic conditions rather than dealing with inclement weather. This last concern has faded away with time as autonomous vehicles have become more sophisticated.

California has been at the forefront of legislation that allows and regulates autonomous vehicles. There have been five laws passed in California since 2012 that detail how businesses must license and operate their self-driving cars.[50] So far, these laws regulate testing, not commercial use.

The first law on the books was passed in 2012. SB 1298 authorizes "the operation of an autonomous vehicle, as defined, on public roads for testing purposes, by a driver who possesses the proper class of license for the type of vehicle being operated if specified requirements are met, including that the driver be seated in the driver's seat, monitoring the safe operation of the autonomous vehicle, and capable of taking over immediate manual control of the autonomous vehicle in the event of an autonomous technology failure or other emergency. "[51] The bill has main points: that autonomous vehicles be used for testing purposes and that a driver be in the

[50]Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation." *National Conference of State Legistlatures*.
[51] State of California. "Senate Bill No. 1298, Chapter 570." 25 Sept. 2012, p. 91., www.leginfo.ca.gov/pub/11-12/bill/sen/sb_1251-1300/sb_1298_bill_20120925_chaptered.pdf.

driver's seat, able to take over in an emergency. Many states have similar versions of this bill, including Arkansas (HB 1754 [2017]),[52] Connecticut (SB 260 [2017])[53] and Florida (HB 1207 [2012]).[54] California has continued to expand its autonomous vehicle legal framework. The most recent addition was passed in April 2018. The new law allows companies to test vehicles without human drivers in them. New rules allow cars without steering wheels, pedals, mirrors and human drivers.[55]

California's laws regarding autonomous vehicles have been put to the test several times since their passage. There have been 66 crashes or accidents involving self-driving cars in California since 2014.[56] A high profile example was the Tesla car crash of March 23, 2018. The owner of a Tesla Model X crashed into a highway divider and ended up dying. One of the Tesla's most advertised features is the Autopilot. The newest update to that technology, Enhanced Autopilot "can control the vehicle's speed based on the traffic around it, determine whether to stay in or change lanes, move between freeways, and take exits" while driving on the highway.[57] However, "Autopilot makes sure the driver's hands stay on the wheel. If the driver's hands leave the wheel for too long, the car will make the driver pull over and park before

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[52] State of Arkansas. "House Bill 1754." 1 Apr. 2017, pp. 1–2., doi:10.5040/9781474201308.ch-004.

[53]State of Connecticut. *Senate Bill 260*. 6 June 2017, www.cga.ct.gov/asp/cgabillstatus/cgabillstatus.asp?selBillType=Bill&bill_num=SB00260&which_year=2017.

[54]State of Florida. *House Bill 599*. 1 July 2012, www.myfloridahouse.gov/Sections/Documents/loaddoc.aspx?FileName=_h0599er.docx&DocumentType=Bill&BillNumber=0599&Session=2012.

[55] Hawkins, Andrew J. "California Green Lights Fully Driverless Cars for Testing on Public Roads." *The Verge*, 26 Feb. 2018, www.theverge.com/2018/2/26/17054000/self-driving-car-california-dmv-regulations.

[56] California Department of Motor Vehicles. "Report of Traffic Collision Involving an Autonomous Vehicle (OL 316)." *Dmv.ca.gov*, 18 Apr. 2018, www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/autonomousveh_ol316+.

[57]Matousek, Mark. "The Most Impressive Things Tesla's Cars Can Do in Autopilot." *Business Insider*, 29 Jan. 2018, www.businessinsider.com/tesla-autopilot-functions-and-technology-2017-12#all-new-tesla-cars-have-the-necessary-hardware-for-enhanced-autopilot-but-customers-have-to-pay-to-turn-the-semi-autonomous-system-on-enhanced-autopilot-costs-5000-at-the-time-of-purchase-or-a-buyer-can-activate-it-later-for-6000-5.

reactivating the system."[58] In this case, the driver was given visual and auditory warnings to keep his hands on the wheel, but did not do so, leading the car to slam into a concrete barrier. While the investigation by the National Transportation Safety Board is still ongoing, the organization rebuked Tesla. Chairman Robert Sumwalt of the NTSB said that "The combined effects of human error and the lack of sufficient system controls resulted in a fatal collision that should not have happened."[59] While Tesla was compliant with both federal guidelines and state laws, that was not enough to keep the driver of the car safe or to let Tesla off the hook when it came to responsibility. Even though the driver was fully licensed and Tesla's Autopilot technology followed California autonomous vehicle law, there were gaps in the procedures that led to the death of the driver. The laws that governed the oversight of autonomous vehicles in California were not robust enough to prevent this death. There could have more stringent regulation about how to notify drivers to keep their hands on the wheel, for example. In fact, Tesla has since modified the Autopilot program to flash the hazard lights and pull over when it senses that the driver is ignoring multiple warnings to take control.[60] While both the technology and the legislation of this field are still in their infancy, it is clear that more thought needs to be put into creating rules and procedures that could prevent accidents and deaths.

Another state in which autonomous car testing is popular is Arizona. This state had a different, more lax approach to laws regarding autonomous vehicles. There is no legislation is Arizona, only two fairly broad executive orders. In 2015 Arizona's Governor Doug Ducey signed an executive order to "undertake any necessary steps to support the testing and operation

[58] Ibid.
[59] Marshall, Aarian. "Tesla Bears Some Blame for Self-Driving Crash Death, Feds Say." *Wired*, Conde Nast, 13 Sept. 2017, www.wired.com/story/tesla-ntsb-autopilot-crash-death/.
[60] Stewart, Jack. "Tesla's Self-Driving Autopilot Involved in Another Deadly Crash." *Wired*, Conde Nast, 31 Mar. 2018, www.wired.com/story/tesla-autopilot-self-driving-crash-california/.

of self-driving vehicles on public roads within Arizona." He also ordered the enabling of pilot programs at selected universities and developed rules to be followed by the programs. The order allows vehicles to travel without a human driver at the wheel as a backup. In March, 2018, Governor Ducey expanded this with Executive Order 2018-04. The order includes updates to keep pace with emerging technology, including advancements toward fully autonomous vehicles, as well as requiring all automated driving systems to be in compliance with all federal and state safety standards.[61] Policies in this state were specifically designed to minimize red tape and allow businesses to test their autonomous vehicles as much as possible. The state government wanted to stimulate technological companies to invest their resources and personnel in local town. This was specifically a response to regulation that was emerging from California. In San Francisco, the Department of Motor Vehicles shut down a self-driving Uber pilot program, saying that the company had to register its autonomous cars and pay a fee.[62] Arizona Governor Ducey attempted to lure self-driving companies' business to Arizona, away from regulations he considered burdensome, even using the hashtag "#ditchcalifornia" when tweeting about self-driving regulation.

Companies responded by relocating much of their resting to Phoenix and surrounding suburbs. There, they did not need to register or report their testing to the state government. In fact, the suburb of Chandler will host the first "robotaxi" service, available from Google parent company Alphabet, Inc.[63] While California has taken a very cautious approach to testing,

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[61]Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation." *National Conference of State Legislatures*.

[62]Coppola, Gabrielle, et al. *Arizona Became Self-Driving Proving Ground Before Uber's Deadly Crash*. Bloomberg, 20 Mar. 2018, www.bloomberg.com/news/articles/2018-03-20/arizona-became-self-driving-proving-ground-before-uber-s-deadly-crash.

[63]Bergen, Mark. *Alphabet Launches the First Taxi Service With No Human Drivers*. Bloomberg, 7 Nov. 2017, www.bloomberg.com/news/articles/2017-11-07/waymo-driverless-cars-are-now-driverless-in-ground-breaking-test.

requiring that companies register with the state, license their vehicles and drivers and submit reports, Arizona has taken the opposite, *laissez-faire* approach.

Certainly this approach has led to an explosion of autonomous vehicle testing in the state that would most likely not have happened otherwise. However, this attitude leads to dangers as well. On March 18, 2018, an Uber self-driving car was involved in a fatal crash in Tempe, Arizona. The autonomous vehicle, which had a human safety operator, struck and killed a cyclist crossing a street at night.[64] The driver did not have her hands on the wheel, nor did the vehicle warn her that a hazard was approaching. After the crash, John Simpson, the privacy and technology project director for the nonprofit advocacy group Consumer Watchdog, which has called for a national moratorium on autonomous-vehicle testing on public highways said "Arizona has been the wild west of robot-car testing with virtually no regulations in place... When there's no sheriff in town, people get killed."[65]

Although California and Arizona have different approaches to regulation of autonomous vehicles, both of which conform to federal guidelines, both experience deadly crashes. It is difficult to say whether increased regulation or oversight of the businesses that test autonomous vehicles could have prevented these crashes. California, a state with high levels of oversight where every car and driver must be registered and tracked still experiences accidents. We can determine this because the state requires that they be reported. Arizona, with its lax regulations, experiences fatal crashes also. There have been and will also be other crashes, but we cannot know because they are not reported on by the companies that test the vehicles.

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[64] Garcia, Uriel J., and Ryan Randazzo. "Video Shows Uber Operator Moments before Self-Driving Car Crash That Killed Pedestrian." *USA Today*, Gannett Satellite Information Network, 21 Mar. 2018, www.usatoday.com/story/tech/nation-now/2018/03/21/fatal-uber-crash/447770002/.

[65] Coppola, Gabrielle, et al. *Arizona Became Self-Driving Proving Ground Before Uber's Deadly Crash*. Bloomberg, 20 Mar. 2018.

Even though companies like Uber and Google considered California's regulations to be burdensome enough to relocate to a different state, those regulations are still the proper way to handle legislating autonomous vehicle licensing and testing. Unfortunately, even the most stringent regulation cannot prevent crashes and accidents. The Arizona crash would likely have occurred even if the state had similarly extensive laws covering reporting of accidents. However, it is much better that the public and government be informed to create more accountability for the businesses testing autonomous vehicles.

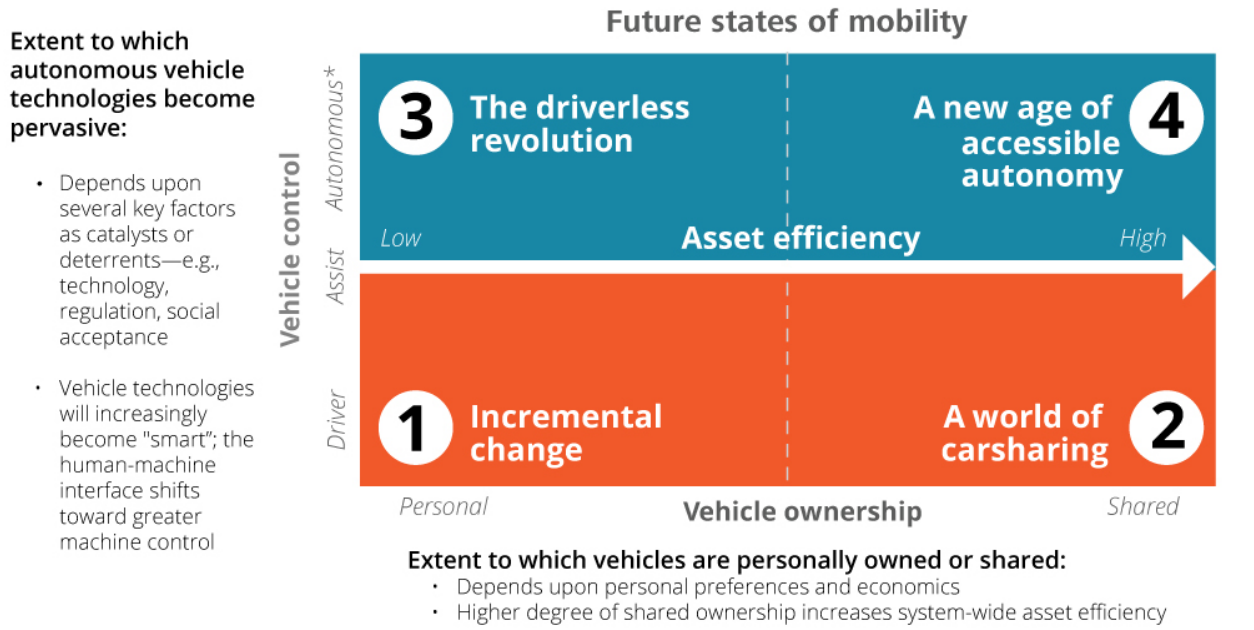
Autonomous Vehicles as a Ridesharing Platform

So far, we have discovered that autonomous vehicle technology is progressing fairly quickly, helped along with investments from technology and automobile firms. Level 4 vehicles are currently being tested on American streets in various states, all under varying degrees of regulation. In an ideal world, as promulgated at the Kaohsiung conference by many stakeholders, these vehicles would be safe for riders and pedestrians and would be available to all. Importantly, the companies testing autonomous vehicles are not proposing that every American own their autonomous car.

To the contrary, companies like GM and Google envision autonomous car fleets servicing urban and suburban communities. Only at scale would these technologies achieve their full potential for efficiency and safety in transit. If every current human driver replaced their current car by buying an autonomous vehicle, the effects on the transportation network would be small. Certainly former drivers, now passengers, would be more comfortable resting or working during their commutes; accidents and injuries from car crashes would also decrease tremendously. However, if self-driving cars were to be used in the exact same way human

operated cars are, they would spend the majority of the day and night in storage in lots or garages, minimizing their use. Ideally, autonomous vehicles would operate in a system that would never rest, picking up and dropping off passengers as cars were summoned. The more autonomous vehicles are shared, the higher the efficiency of the entire system will be. This continuum, based on the degree of autonomy and the degree of vehicle ownership (from wholly private to wholly sharing) represents the possibility matrix for the futures introduction of autonomous vehicles. It is summarized in the below chart from DeLoitte:[66]

Figure 1. The future states of mobility



*Fully autonomous drive means that the vehicle's central processing unit has full responsibility for controlling its operation and is inherently different from the most advanced form of driver assist. It is demarcated in the figure above with a clear dividing line (an "equator").

Source: Deloitte analysis.

Deloitte University Press | dupress.deloitte.com

[66]"Future of Mobility Trends | Deloitte US." *Deloitte United States*, www2.deloitte.com/us/en/pages/consulting/solutions/future-of-mobility-trends-industry-ecosystem.html?id=us%3A2ps%3A3bi%3Aconfidence%3Aeng%3Acons%3A%3A%3Ana%3ADUCmzMfu%3A1077703201%3A76690968088885%3Abb%3AFuture_of_Mobility%3AFuture_of_Mobility_BMM%3Anb&msclkid=c58151a934351a3c528c0b7a816c7571.

The optimists at the heads of major corporations testing autonomous vehicles view their future as shared. In their conception, few people will want or need either human operated vehicles or personal autonomous vehicles. Cars will be integrated into a massive, efficient network. The fact that ride sharing services are already disrupting and changing city planning and traffic patterns gives us a readily available example of how autonomous car fleets can change cities and what policies could be enacted to control these changes.

There are some general problems that companies face when introducing autonomous vehicles to the public. These include safety, both physical and digital, insurance and liability and cost.

Michael Ableson, GM's vice president of global portfolio planning and strategy calls the company's vision for self-driving cars "on-demand autonomous."[67] GM is planning to deploy all electric autonomous vehicles in more densely populated urban areas to maximize their use and efficiency. This idea presents a myriad of complex policy challenges. Besides the physical safety of drivers and pedestrians, companies that plan to put autonomous fleets on the road must consider their cyber security. One hacked vehicle in a stream of self-driving cars could wreak havoc on the system.

In an interview with Autotrader, Ableson, the GM vice president, said that the biggest challenge autonomous vehicles face is safety regulation.[68] We have seen that when autonomous vehicles are involved in crashes, especially deadly ones like ones in Tempe, Arizona, federal and state investigators call for tighter regulation and reporting of tests. Certainly, more information about testing is preferable to less.

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[67] Krebs, Michelle. "Autonomous Cars With Ridesharing Key to GM's Vision for Future Mobility." *Autotrader*, June 2016, www.autotrader.com/car-shopping/autonomous-cars-ridesharing-key-gms-vision-future--254768.
[68] Ibid.

Another issue is insurance. GM's vice president brushed off saying that "insurance is less of an issue. Insurance rates should drop because there will be fewer accidents, a trend that will accelerate over time."[69] This seems like a glossing over of a potentially major issue. The question of who is at fault in a car accident is one of the most important. In a crash, one could say that the computer driving the car is blame, thus the company that programmed and manufactured the car. Or that the passenger is to blame, for not taking control of the vehicle before the crash occurred.

In real life cases, the manufacturer has taken the blame when test autonomous vehicles get into accidents. There is, however, a ready-made example of how autonomous vehicle insurance could work: the airline industry. Airplanes have the capability to be level 2 autonomous vehicles, given that pilots can activate autopilot on a plane while still monitoring the controls and taking over in necessary situations. In fact, during a 2.5 hour flight, 95% of the work is done by a computer.[70] The airline takes the liability of accident onto itself in these situations. Autonomous car manufacturers could do the same thing. In fact, Michigan enshrined this idea into law in 2016. SB 266 of the Michigan State Legislature provides that "a motor vehicle manufacturer shall insure each vehicle in a participating fleet... during the time that an automated driving system is in control of a vehicle in the participating fleet, a motor vehicle manufacturer shall assume liability for each incident in which the automated driving system is at fault."[71] If this approach was adopted across all states or at the federal level, it would answer the question of who is at fault in the case of every autonomous driving accident.

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[69] Ibid.

[70] Reiner, Arnold. "Towards the End of Pilots." *The Atlantic*, Atlantic Media Company, 3 Mar. 2016, www.theatlantic.com/technology/archive/2016/03/has-the-self-flying-plane-arrived/472005/.

[71] State of Michigan. "Act No. 333." *Michigan Legislature*, 29 Dec. 2016, www.legislature.mi.gov/documents/2015-2016/publicact/htm/2016-PA-0333.htm.

A final challenge of autonomous vehicles is cost. The company line from GM is that although autonomous vehicles will be initially expensive, they will become cheaper over time, like any new technology. Ableson said that “those costs will drop as volume increases."[72] Furthermore, he predicted that ride sharing fees will decrease with greater numbers of ridesharing autonomous vehicles on the road. Ride sharing is definitely cheaper than owning your own car, but the initial upfront costs of autonomous vehicles have to be paid by someone. Today, automating an existing car costs around $5,000. Upgrading a regular Tesla with Autopilot costs this much. This cost could be borne by the firm, the consumer or the government through subsidies. Taking the rideshare model of Uber and Lyft could be preferable in this case. Uber heavily subsidizes the costs of its trips through with investor funds.[73] In 2015, those subsidies cost Uber $2 billion. Uber raises money through investment rounds so it can afford these sky high costs. Companies like GM and Google have income from other sources that can be used to subsidize autonomous vehicle costs to make their services competitive. This model completely blocks smaller companies from competing with the giant transportation network companies. There would be no incentive to choose a smaller company with more expensive trip prices rather than Uber which can subsidize its costs.

Uber Vice-President of Self-Driving Technology Anthony Levandowski and Uber CEO Travis Kalanick say that the future of their company will include both people driven and autonomous vehicles. They say that “this is because of the limits of self-driving software and the skyrocketing demand for better transportation, which people-powered transport is uniquely able

[72] Krebs, Michelle. “Autonomous Cars With Ridesharing Key to GM's Vision for Future Mobility.” *Autotrader*, June 2016.
[73]Harris, Ainsley. “Investors Are Paying $2 Billion per Year to Subsidize Your Uber Ride.” *Fast Company*, Fast Company, 1 Dec. 2016, www.fastcompany.com/4026256/investors-are-paying-2-billion-per-year-to-subsidize-your-uber-ride.

to solve."[74] This could be an argument made to appeal to their current employees. Paying their drivers accounts for a large part of ride sharing companies' expenses. If those drivers could be eliminated and replaced by computers that would only benefit the company. The Uber CEO and VP compare autonomous vehicle technology to the introduction of the ATM. The ATM's invention was predicted to make bank tellers obsolete. Instead, tellers have become more specialized and provide specific services to customers.[75] In the same way, argue the Uber heads, self-driving cars will eliminate drivers but employ techs to keep the software running and car mechanics to keep the hardware running. Since autonomous vehicles are at their highest level of efficiency if they are used round the clock, they will require more maintenance than regular vehicles, which spend the majority of their time in storage.

Lyft, Uber's major competitor, is also pursuing an autonomous rideshare fleet. John Zimmer, Lyft's president, predicted that Lyft's entire fleet could be automated in five years. Furthermore, it could run on a subscription model like Netflix or Spotify.[76] Lyft is even more aggressive than Uber, saying that as soon as the technology is advanced enough to eliminate human drivers, the company will do so, rather than preserving some human drivers.

According to industry stakeholders, the future of cars are ride sharing autonomous cars. This is preferable to firms because it would be efficient and cost effective and also conform to the preferable ways to implement autonomous vehicles laid out in the Kaohsiung conference. In that way, it is easy to see how autonomous cars will impact cities in a situation where ride sharing vehicles and autonomous ones are on the road side by side. In cities around the country,

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[74] Levandowski, Anthony, and Travis Kalanick. "Pittsburgh, Your Self-Driving Uber Is Arriving Now." *Uber Global*, 14 Sept. 2016, newsroom.uber.com/pittsburgh-self-driving-uber/.
[75] Ibid.
[76]Murphy, Mike. "Lyft's Cofounder Has His Own Vision for a Self-Driving Taxi Fleet." *Quartz*, Quartz, 26 Oct. 2016, qz.com/819335/lyft-cofounder-john-zimmer-has-his-own-vision-for-a-self-driving-taxi-fleet-to-take-on-uber-and-tesla-tsla/.

ride sharing vehicles ride alongside public transit and private vehicles. The effects of ride shares in cities are not completely analogous to autonomous ride sharing vehicles. Current ride shares always have a driver, so their capacity is one less passenger than a driverless car by definition. Existing vehicles do not travel in platoons, the most efficient vehicles configuration, which entails separate vehicles traveling tightly behind one another to minimize drag and space on the road. The computer system would be able to shift the entire traffic pattern based on accidents or hazards, eliminating the necessity of keeping a car length or two away from the car ahead to allow room for breaking. Finally, rideshare vehicles are parked when they are not in use by their driver, occupying a parking spot or space in a garage. These differences point to autonomous rideshares being able to travel more efficiently, closer together, with higher capacity and more safely.

These differences aside, the effects of rideshares on cities have not been entirely positive. They have provided travelers with an on demand option when others are not available. However, in New York City, for example, "rapid growth in on-demand vehicles roving the roads—with and without passengers—is contributing to markedly slower traffic, as numerous analyses of Taxi and Limousine Commission data by Bruce Schaller, a transportation consultant and former NYC DOT official, have shown."[77] As commuters supplement their trips with ride shares when public transit fails the streets are filled by rideshare vehicles. Without management, these vehicles contribute to congestion and pollution as much as private ones. Uber and Lyft are not willing to publicize their trip data, making it difficult for city planners to mitigate their effects.[78]

[77] Bliss, Laura, and CityLab. "How 3 Cities Are Measuring the 'Uber Effect'." *CityLab*, 16 Jan. 2018, www.citylab.com/transportation/2018/01/to-measure-the-uber-effect-cities-get-creative/550295/.
[78] Zipper, David, and Marshall Fund. "The Mad Dash for Urban Transportation Data." *CityLab*, 7 Jan. 2018, www.citylab.com/transportation/2018/01/who-owns-urban-mobility-data/549845/.

Autonomous ride sharing could exacerbate these problems. It will take at least five years (Lyft's earliest prediction) for a fully autonomous ridesharing to fleet to be deployed. Even then, autonomous vehicles will share the road with human drivers. The safety and efficiency promised by the autonomous system can be compromised by a single erratic human driver. Currently, the New York State Assembly is proposing a "$1 fee on each trip arranged through a ride-hailing app, such as Uber or Lyft. In much of Manhattan, the fee would be higher: $2.75 per trip."[79] Such a tax could deter some people from hiring a rideshare vehicle, thus decongesting areas of the city that are more expensive to travel to. In New York State, the Assembly proposes the estimated $48 million in tax revenues to fund public transit. The same system could be applicable to an autonomous rideshare. If however, the majority or all cars become autonomous, such a system would be unnecessary. In this perfect world, from the point of view of autonomous rideshare providers, vehicles would travel at optimum efficiency, meaning no clogged streets or excessive traffic.

The advent of autonomous ridesharing will change cities in other ways. One of the greatest impacts will be the disappearance of parking lots and garages. Professor Marshall Brown of the Illinois Institute of Technology has predicted the demise of parking garages inside cities. When an autonomous ride sharing drops a commuter off it goes on to pick up the next one instead of parking. According to Crain's Chicago Business "a decline in vehicle ownership could cut U.S. parking needs in half within three decades. That would eliminate 75 billion square feet of parking space, more than the combined area of all apartment, office, shopping mall, retail strip

[79]Campbell, Jon. "Higher Tax for Uber, Lyft Trips Could Be on the Way." *Rochester Democrat and Chronicle*, Democrat and Chronicle, 19 Mar. 2018, www.democratandchronicle.com/story/news/politics/albany/2018/03/19/higher-fee-uber-lyft-trips/438107002/.

center and warehouse buildings in the country today."[80] The disappearance of parking lots inside cities would provide space for commercial or housing development. On the other hand, the lack of need for parking would destroy municipal parking taxes. This revenue could be recouped from the above mentioned congestion pricing and eventually from increased safety, efficiency and productivity gains with the elimination of traffic.

Toward a Fully Autonomous Future?

A major issue in introducing widespread autonomous transportation to the US is how Americans can be convinced to give up their private vehicles for autonomous vehicles. On one hand, if autonomous vehicles prove to be more comfortable, convenient and cheaper, people will likely switch to them. On the other hand, people, especially Americans, value personal freedom and the myth of driving down the interstate is deeply embedded in American culture.

Tech CEOs are optimistic that people will be ditching their personal vehicles in favor of autonomous ones in the near future. "The next generation will have no problem getting in these vehicles," said Karen Francis, the board director and strategic advisor for tech companies like AutoNation, Telenav and Nauto.[81] Perhaps the concerted public relations campaigns of companies like GM and Google in partnership with government policy will convince people that autonomous vehicles are the way to go. Certainly, American corporations and government investment have made Americans change their lifestyles in the past. The construction of the

[80]Ori, Ryan. "Will Uber and Driverless Cars Turn the Parking Biz into Roadkill?" *Crain's Chicago Business*, 5 Nov. 2016, www.chicagobusiness.com/article/20161105/ISSUE01/311059991/will-uber-and-driverless-cars-turn-the-parking-biz-into-roadkill.
[81] Bliss, Laura. "Self-Driving Cars Will Be For Sharing." *CityLab*, 6 Jan. 2017, www.citylab.com/life/2017/01/the-future-of-autonomous-vehicles-is-shared/512417/.

interstate highway system, for example, allowed for the automobile revolution in post war America.

At some point in the future, however, the autonomous vehicle industry will seek to ban personal vehicles from the road entirely. To achieve a truly hyper efficient system all vehicles on the road would have to be autonomous. Furthermore, streets and highways would have to have embedded smart technologies that would guide and direct traffic flows. These goals would require huge government investment and regulation. This could only happen if the American public were truly supportive of switching to autonomous vehicles and support is currently mixed.

If overcoming cultural preconceptions about private car ownership can be done at all, it can be achieved through an appeal to the pocketbook. Whether shared autonomous cars will be cheaper and more comfortable than private vehicles will make or break the fully autonomous future scenario.

There have been several studies about the feasibility of autonomous vehicles and their cost effectiveness. Kornhauser et al. explored a hypothetical autonomous taxi system in New Jersey. They write that shared autonomous taxis can "provide auto-like service where demand is diffuse in space and time while facilitating casual ridesharing to serve demand that happens to be correlated spatially and temporally. This casual ridesharing substantially improves transportation efficiency and eliminates congestion."[82] Their results found that the availability of ridesharing would increase ridesharing travel behavior. Specifically, the paper advocates for introducing the system of shared vehicles in the morning rush hour, from 6 am to 9 am, during which the authors found the highest jump in traffic.

[82] Hayes, B. (2011). Leave the Driving to it. American Scientist, 99, 362-366. Kornhauser, A., Chang, A., Clark, C., Gao, J., Korac, D., Lebowitz, B., & Swoboda, A. (2013). Uncongested Mobility for All: New Jersey's AreaWide aTaxi System. Princeton University. Princeton, New Jersey

Burns et al. (2013) modelled the costs of using shared autonomous fleets based on current costs.[83] They model three localities. The first is Ann Arbor, Michigan is an example of a typical American city in which residents rely on their personal car for all transportation. A resident of Ann Arbor drives their car about 30 miles a day with a cost of about $0.60 per mile. This price includes depreciation, insurance, gasoline prices, maintenance, taxes and other fees. The authors estimate that in a shared autonomous vehicle system, it would cost the Ann Arbor resident about $0.15 per mile to travel. The second scenario was a suburb in Southwest Florida. The residents there spent about $16 a day on car ownership. When autonomous car sharing was modelled, this fell to $4 per day per customer. The final scenario was a Manhattan resident. Unlike the previous examples, the Manhattan resident did not own a car and used a combination of public transportation and for hire vehicles to commute. The authors estimated that this resident spent $200 a month on commuting. Included in that cost are some of the hassles of New York City commuting, including crowded and sometimes unreliable trains and buses and the difficulty of getting across town on the subway. In Manhattan, the price of the Metrocard would not be affected by the introduction of a shared autonomous vehicles system. However, the cost of taxis and existing rideshare like Lyft would be impacted. The authors estimate that those costs would decrease from $5 per mile for the customer to $0.50. Thus, across most environments in America, and especially as communities get denser, shared autonomous travel has the potential to vastly reduce costs for commuters. Three factors contribute to these cost reductions. First is better capital utilization. Fewer shared vehicles are required to provide the same service as personal vehicles. The second is better capacity utilization. During peak times, a shared vehicle

[83] Burns, L. D., Jordan, W. C., & Scarborough, B. A. (2013). Transforming personal mobility. The Earth Institute.
http://sustainablemobility.ei.columbia.edu/files/2012/12/Transforming-Personal-Mobility-Jan-27-20132.pdf

is occupied 90% of the time, as opposed to a private vehicle, which is only occupied during rush hours on weekdays. The final factor is more efficient energy use. The major players in autonomous vehicle research are developing only all electric vehicles which are more efficient and use less energy than conventional vehicles. Major cost reductions compared to conventional vehicles could convince many people to switch from personal vehicles to autonomous ride shares.

Another factor that could convince Americans to switch over to shared autonomous vehicles is that those vehicles are far better for the environment than personal cars. Fagnant & Kockelman (2014)[84] modelled the environmental sustainability of a shared autonomous vehicle fleet. The results show that each individual autonomous vehicle would replace the greenhouse gas and pollution emissions of around 11 private vehicles. In America, public opinions on the environment are often split on ideological and party lines. Liberal Americans, mostly supporting the Democratic Party, profess to care much more about the environment than their conservative, Republican supporting counterparts. In a 2016 Pew Survey, 74% of American adults answered "yes" to the question "Should the country do whatever it takes to protect the environment. Thus, the vast majority of Americans support initiatives and policies that would protect the environment. However, 90% of Democrats believe that the environment should be protected versus 51% of Republicans.[85] If Americans are going to adopt shared autonomous travel because of its environmental benefits, more liberal Americans will be more willing to do so. Furthermore, more liberal Americans tend to live in urban settings, while conservative Americans tend to live

[84]Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. Transportation Research Part C: Emerging Technologies, 40, 1-13 http://www.ce.utexas.edu/prof/kockelman/public_html/TRB14SAVenergy_emissions.pdf

[85]Anderson, Monica. "For Earth Day, Here's How Americans View Environmental Issues." *Pew Research Center*, 20 Apr. 2017, www.pewresearch.org/fact-tank/2017/04/20/for-earth-day-heres-how-americans-view-environmental-issues/.

in suburban or rural settings.[86] If urban liberals adopted shared autonomous fleets first, they would receive the greatest benefit because shared fleets would operate at greater efficiency in more populated areas. As the benefits of autonomous vehicles proved themselves in cities, conservative Americans would be more inclined to switch to them for economic and environmental reasons.

The reality of the riding experience, however, might not be as rosy as industry advocated of autonomous vehicles suggest. There are many potential problems with the development and implementation of a shared vehicle fleet, beyond overcoming the American value of owning a private vehicle.

The autonomous vehicles that are being tested today can only operate under certain conditions. With time, funding and testing they will improve but it could be many years before autonomous vehicles are ready to operate in snowstorms and on uneven road surfaces. Furthermore, the benefits (such as congestion and pollution reduction) predicted by the above cited studies would only manifest themselves if localities took it upon themselves to create dedicated lanes for autonomous vehicles. Dedicated lanes would allow for platooning, which is numerous vehicles driving one behind the other, close together, as very high speeds to reduce wind drag. If dedicated lanes are not created, autonomous vehicles would merge into existing traffic and participate in the stop and go traffic that is already prevalent.

Self-driving vehicles are often depicted as futuristic spaces, filled with comfortable seats and giant screens. Well-dressed passengers recline on comfortable chairs while their robot chauffeur whisks them away. The reality will likely not be so glamorous, at least not for the majority of the population. Autonomous ride sharing vehicles, be they four door sedans, vans or

[86] Graham, David A. “Red State, Blue City.” *The Atlantic*, Atlantic Media Company, 2 Feb. 2017, www.theatlantic.com/magazine/archive/2017/03/red-state-blue-city/513857/.

micro-buses, would still be like any other shared space. People would leave their garbage and odors. Some may vandalize or accidental damage the interior of the vehicle. To minimize the vandalism, companies may opt to manufacture vehicles out of plastic and stainless steel rather than more comfortable materials. There will be no driver to help carry packages or assist a disabled or elderly person into the vehicle.[87] The elimination of comforts that people have come to associate with cars would be a major deterrent to the acceptance of shared travel.

Conclusion

Summary of Costs and Benefits

The benefits of introducing autonomous ride sharing vehicles are numerous. First, as a passenger of an autonomous vehicle, the former driver finds their stress reduced from not having to navigate the streets and highways and finds they have more time for rest, work or recreation while travelling. Second, cost are reduced for passengers and businesses that employ drivers. Third, there is increased safety because autonomous vehicles cannot make human errors, which account for 94% of road accidents.[88] Fourth, autonomous vehicles allow for greater utilization of existing infrastructure like roads, bridges, and highways and reduce congestion. Fifth, autonomous cars would have better fuel efficiency, leading to less pollution and a healthier environment. Finally, there would be reduced parking costs because of vehicle sharing.

There are also costs to a world of autonomous ride sharing vehicles. Initially, manufacturing or retrofitting old cars with autonomous technology would be expensive. There would be far less privacy because of car sharing, unless people would be willing to pay for private rides. Third, there is the risk that cars could be hacked, turning them into hazards or

[87] Litman, Todd. "Autonomous Vehicle Implementation Predictions Implications for Transport Planning." 24 Apr. 2018, www.vtpi.org/avip.pdf.
[88] "Traffic Safety Facts." *National Highway Traffic Safety Administration*, US Dept of Transportation, Feb. 2015, crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.

weapons. Fourth, autonomous vehicles could encourage people to travel further because of their convenience, contributing to sprawl and pollution. Fourth, jobs for drivers would inevitably be lost. Lastly, an over reliance on autonomous vehicle travel would reduce support for pedestrian, bicycle and public transportation options and funding.

Policies to Implement

In the United States, state governments can implement various policies to ensure that the implementation of autonomous cars will be safe and equitable. States should follow in the footsteps of lawmakers in California to develop robust regulations for the testing of autonomous vehicles. Firms testing those vehicles should be listened and required to report their findings to the local Department of Motor Vehicles. Municipalities should efficiently regulate and price curb spaces and roads to prevent traffic congestion. Congestion pricing plans have had great success in places like London, where traffic levels have reduced by 10.2% percent in the past 10 years.[89] Similar plans can be implemented in New York or Los Angeles to incentivize car sharing and autonomous car sharing. These pricing plans should favor high occupancy vehicles over low occupancy vehicles. From a development perspective, municipalities should zone and price future development efficiently to prevent sprawl. They should also repurpose obsolete spaces such as parking lots and garages for their community's benefit. Finally, streets can be redesigned to take advantage of the increased safety and less requirement for parking. With these regulations in mind, American cities can ensure that autonomous vehicles are safe and inclusive for all residents, rather than a technology that would only benefit those who could afford it and worsen traffic and environmental conditions.

[89] Timms, Claire. "Has London's Congestion Charge Worked?" *BBC News*, BBC, 15 Feb. 2013, www.bbc.com/news/uk-england-london-21451245.

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