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Ethical considerations facing the regulation of self-driving cars in the United States

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Introduction

Self-driving cars are here. Once an advanced technology that seemed futuristic, they are now closer than most believe. Many of the largest automobile manufacturers are working on autonomous vehicle technology of their own. Perhaps most well-known, though, are the cars being developed by Tesla and Google. Both companies have well-developed prototypes of fully autonomous vehicles, meaning they require no human input or supervision, and Tesla has promised widespread, consumer availability of this technology in the next one to two years.

Along with the availability of this technology to the public and transportation companies like Uber and Lyft, comes a need to establish a regulatory environment. Regulators need to contemplate a new, yet complex, technology with far-reaching implications and determine how best to regulate necessary components. In this paper, I plan to explicate and analyze the ethical impact of the proliferation of self-driving cars that regulators should consider when determining how they ought to regulate.

I will do this by first clarifying any technical terms one might need to be familiar with as well as discussing some of the requisite considerations. Then, I plan to explore some of the pitfalls regulators might be subject to as they navigate the associated complex issues. Finally, I will explain and analyze the likely benefits and potential risks resulting from roadways filled with autonomous vehicles.

Clarification of technical terms

Before proceeding, it is important to clarify how I define and will refer to autonomous vehicles in the sections that follow. I define an autonomous vehicle (AV) as any vehicle controlled in part or total by a computer. I will also clarify that, in this paper, when I refer to the term ‘vehicle,’ I explicitly mean ‘car’ or ‘automobile’ and do not intend to refer to any other

vehicle used to provide transportation. Further, given that most modern vehicles already have computer systems which control a portion of their operation, e.g. ABS brake systems, a system for classifying the levels of automation is imperative.

In this paper, I will abide by the levels of automation outlined by SAE International and referenced in the Federal Automated Vehicles Policy paper.¹ The levels are briefly summarized as follows: Level 0 – a human driver performs all driving-related tasks; Level 1 – automated systems occasionally assist people in performing driving-related tasks; Level 2 – an automated computer system can perform parts of the driving task while a human monitors its performance, monitors the driving environment, and performs the remainder of the driving task; Level 3 – an automated computer system can perform portions of the driving task while monitoring the environment around the vehicle, but a human must still monitor all functions performed by the automated system; Level 4 – an automated computer system can operate fully autonomously, a human is not required to monitor the vehicle, but it can only do so under certain conditions (e.g. not in rain, fog, dust, etc.); Level 5 – the automated computer system can drive the vehicle entirely in all conditions, humans need not monitor at all. I have also laid out the information in the table below as a helpful tool you can reference as needed.

¹ United States. National Highway Traffic Safety Administration,. Federal Automated Vehicles Policy: Accelerating the next Revolution in Road Safety. 2016. Print., Pg. 9-10

Automation Level	Description by SAE International
<i>Level 0</i>	No automation
<i>Level 1</i>	Automated system occasionally assists with some tasks
<i>Level 2</i>	Automated system performs some driving tasks; human must supervise
<i>Level 3</i>	Automated system performs some driving tasks and monitors the road using sensors; human must supervise
<i>Level 4</i>	Automated system can drive and monitor the environment, but only in certain situations; no human monitoring required
<i>Level 5</i>	Automated system can fully drive the vehicle, as good as if not better than a human

Many are familiar with autonomous vehicle function and may not realize it. Many cars have had autonomous features falling in levels 0-3 for many years. Consider technologies like ABS, lane keeping technology, automatic emergency braking, and adaptive cruise control. They are all technologies that allow computers to control certain aspects of the driving task, automatically. Most of these technologies have been available as options on luxury vehicles for many years, but many are now becoming standard on even the most basic cars. The 2017 Toyota

Yaris, for example, costs just under \$17,000 and has an automatic braking system that uses camera and laser sensors to determine when a collision is impending and applies the brakes.²

Given that the lower levels of autonomy are already standard on many vehicles, automotive technology is rapidly advancing toward Level 5 autonomy, the controversial nature of Level 5 autonomy, and the forward-looking nature of this paper, I will primarily focus on issues relevant to the widespread adoption and use of Level 5 autonomous vehicles. Assume that, unless otherwise stated, ‘autonomous vehicles’ or ‘AVs’ refers to ‘Level 5 Autonomous Vehicles’ per the SAE International definition.

A free-market approach to industry regulation considered

Before discussing some of the consequences that regulators, whether governments or other entities, ought to consider it is important to examine the extent to which autonomous vehicles ought to be regulated, if at all. Discussing how governments should regulate autonomous vehicles presupposes that governments should regulate at all. It is worth considering if a hands-off, free-market approach to autonomous vehicle regulation might lead to a better outcome.

In another section of this paper, I examine the argument for why delaying the rollout of as many autonomous vehicles as possible, as quickly as possible, might be detrimental to overall societal good. It seems equivalent to delaying the availability of a vaccine to a very deadly illness.³ This line of argumentation is also one that can support little government regulation of the autonomous vehicle industry. The government must, of course, verify that the vaccine is

² Hall-Geisler, Kristen. "The 2017 Toyota Yaris Points to the Future Of cars." TechCrunch., 22 Nov. 2016. Web. 01 Dec. 2016.

³ Watney, Adam Thierer and Caleb. "Every Day Matters with Driverless Cars." *The Hill*. 20 Oct. 2016. Web. 21 Nov. 2016.

effective and safe enough, but any bureaucratic delay used to accomplish anything other than that seems irresponsible. That is, little government regulation of autonomous vehicles ensures they reach the hands of consumers and the roads as quickly as possible.

Delaying the time it takes to bring the product to market due to government regulation is something seen when looking at empirical examples of product launches in both similar and dissimilar markets. Perhaps the best parallel is the aviation industry. When a new aircraft is engineered, it must be tested extensively by governmental regulatory bodies before it can be sold on the public market. The most recent government certification of the Boeing 787 Dreamliner by the FAA took approximately eight years, although other certifications typically took three to five years. The process also consumes a massive amount of regulator time that could arguably have been spent on other endeavors. The Boeing 787 regulatory evaluation took 200,000 hours. If a similar or better regulatory outcome can be reached by the free market alone, saving 200,000 hours is an enormous net benefit. Imagine what one might accomplish with this time. This is about 96 years of work for one individual, assuming they work 40 hours per week, 52 weeks per year.⁴

Beyond this, there are additional arguments to be made in support of little government regulation that do not have to do with the speed at which AVs become available to consumers. There is an argument to be made for leaving development solely in the hands of private companies because it results in *better* outcomes. There are several reasons this may be the case. I will examine this argument, but I ultimately aim to show that this would not result in the best-case scenario and that the government ought to intervene in regulation in at least some form.

⁴ This was calculation was arrived at by: $200,000 \text{ hours} / (40 \text{ hours per week} * 52 \text{ weeks per year}) = 96.1538 \text{ years}$

All companies stake their reputation on the products they manufacture and sell.⁵ Thus, there follows a reasonable assumption that companies do not want to risk their reputation by releasing a product that is dangerous or strongly disliked by consumers. If they did, they would face lawsuits and product boycotts in response. This logic is magnified for autonomous vehicle manufacturers, given that if they fail to perform in the way they are intended to, lives will be exposed to unnecessary risk. Tesla, Mercedes, Audi, Volvo, Ford, and other manufacturers will aim to differentiate themselves from other market players by providing superior autonomous vehicle technology. For one company's technology to be considered superior, consumers must believe that it is reasonably safer, more rich-featured, and more cost-efficient.

In a world where government regulation is non-existent, consumers will serve as the 'regulators' in the sense that they will dictate the types of products that companies do and do not engineer and sell. If most consumers want autonomous vehicles with a specific set of safety features or specific accident algorithms, they will not purchase vehicles that do not have that particular set of features. And if enough consumers agree, vehicles that do not have the features demanded by consumers, whether they be individuals, families, or ride sharing companies, will not be produced. Companies that produce types of vehicles not demanded by consumers will likely not succeed financially. That is, in the ideal free market, vehicles that ought to be regulated out of the market, as deemed by consumers, will be competed out of the market by better vehicles.

Many autonomous vehicle manufacturers have stated they will assume legal responsibility for particular types of accidents that occur in their vehicles. This is huge from a

⁵ Companies do seem to stake their reputation on the products they manufacture. Whether they or the customers always care about the company's reputation is another issue. It seems consumers will be particularly concerned with the reputation of autonomous vehicle manufacturers given they entrust their lives with them, but counterexamples will be made in the sections that follow.

regulatory standpoint because manufacturers are, in addition to being indirectly incentivized by reputation, directly incentivized financially to ensure vehicles are reasonably safe. If the vehicle's autonomous systems fail, the manufacturer will be held responsible, morally and financially for the damage caused. This leaves them vulnerable to legal recourse.

Further, the manufacturer's reputation will be tarnished by the negative publicity and media coverage associated with their shortcoming. Although a different industry and product, consider Samsung's recent launch of the Galaxy Note 7 which caught fire in many consumers' homes and cars. Following this discovery, Samsung's stock price plummeted,⁶ and individuals decided not to purchase the phone despite it being one of the best phones on the market.⁷

Perhaps the most important case in which consumers will dictate the features of autonomous vehicles on the market is in regards to their accident algorithms. Mercedes, for example, has already programmed their vehicles to protect passengers at all costs. This decision assumes that consumers would not purchase an autonomous vehicle that would sacrifice their safety for the well-being of others', regardless of circumstance. If this assumption is correct, consumers will prefer Mercedes vehicles to other vehicles on the basis that Mercedes vehicles protect their passengers at all costs.

But I would like to consider alternative outcomes to a situation where autonomous vehicle manufacturers program their vehicles to protect their passengers at all costs. Allowing consumers and the free market to determine how vehicles behave in certain situations and thus possess all regulatory power, will likely ensure a purely self-interested approach to algorithm programming as well. This serves as a stark contrast to a system of autonomous vehicle

⁶ Chen, Brian X., and Choe Sang-hun. "Why Samsung Abandoned Its Galaxy Note 7 Flagship Phone." *The New York Times*. The New York Times, 12 Oct. 2016. Web. 22 Nov. 2016.

⁷ Seifert, Dan. "The Samsung Galaxy Note 7 Has Been Recalled." *The Verge*. 16 Aug. 2016. Web. 22 Nov. 2016.

operation that is organized to promote the greatest overall societal good, which is often imagined by many futurists and of autonomous vehicle proponents.

It seems likely that if all autonomous vehicles on the road were programmed solely to protect their passengers, without any consideration of the passengers of other vehicles, pedestrians, or cyclists, a couple of things could happen. First, the outcome dictated by accident algorithms in the case of an accident might be the result of a prisoner's dilemma. Second, individuals might fear more for their lives and trust autonomous vehicle algorithmic guidance less.

If autonomous vehicles make decisions with only their passengers in mind, a potential accident situation might result in a situation that resembles a prisoner's dilemma.⁸ The simplest situation to imagine is two cars with an equal number of passengers driving in opposite directions on a narrow mountain road. Assume that the vehicles are coming around a blind corner when suddenly the autonomous computers in both vehicles recognize they are on course to hit one another based on speed and trajectory. The road is so narrow that there is no room for one vehicle to move over safely, and, further, they are traveling so fast that they cannot simply stop to avoid collision. The vehicles can continue on their current trajectory and risk serious injury or death to all occupants of both vehicles, or the vehicle in the outer lane can swerve right, off the cliff. This maneuver would certainly kill all the occupants of the vehicle, but it would save the occupants of the other vehicle. This loosely resembles a prisoner's dilemma because if both vehicles are programmed to act selfishly, refusing to sacrifice oneself, the outcome will be worse. If there are four occupants in each vehicle, both vehicles refusing to sacrifice risks the death of 8 people. Whereas, if one vehicle behaves so that it maximizes total good, and drives off

⁸ Gogoll, Jan, and Julian F. Muller. "Autonomous Cars: In Favor of a Mandatory Ethics Setting." *Science and Engineering Ethics* (2016). Web. Pg. 7.

the cliff, four people will die, and four people will live. This outcome is clearly preferable from an objective standpoint, and it would not occur in autonomous vehicles programmed to protect their occupants at all costs. Further, the irony is that in attempting to protect by refusing to sacrifice, the vehicle will end up risking injury or death to its passengers regardless.

It follows that the same set of individuals who demanded – using the power of their wallets in the free market – that autonomous vehicles behave in a self-interested manner initially, desire outcomes that are completely different in other situations. Some passengers might be comfortable with their autonomous vehicle sacrificing the lives of others to save their life, but when the tables turn and another vehicle does something completely self-interested that sacrifices the same passenger's life, like in the example above, they may desire a more sophisticated algorithm.

Additionally, imagine is an autonomous vehicle driving along a mountain road when suddenly it encounters a peloton of cyclists around a blind curve. The autonomous vehicle could swerve off the road and sacrifice the life of its single passenger to save the lives of ten cyclists. Alternatively, it could crash into the ten cyclists, potentially killing all of them, but saving the life of its passenger. Mercedes-Benz vehicles and other similarly self-interested vehicles would choose the latter. One can imagine permutations of this situation that might involve other vehicles, differing environmental conditions, motorcyclists, trucks, falling freight and more. But the point remains in any similar situation. This outcome is problematic because, in terms of societal good, vehicles programmed this way make society worse off. Without consideration for the number of lives at stake in each situation, there is a significant risk that more lives could be lost than would have been lost otherwise, if decisions were arranged to optimize overall good in each outcome.

Cyclists and pedestrians would certainly not be supportive of having autonomous vehicles on the road that are killing machines with no consideration for the value of their lives. This situation is concerning and seems to be the outcome that makes the best case for at least some regulatory consideration and policy. That is, if regulators take a hands-off approach to the autonomous vehicle industry, manufacturers may design vehicles that might not be in the best interests of society. Of course, the degree to which the industry itself must be regulated is still to be determined, but it seems it should be at least minimally regulated.

The remainder of this paper will transition to focus on ethical issues facing regulators of and stakeholders in the autonomous vehicle industry. Regulatory considerations will come in two forms. There will be some topics which fall under the bucket of regulating the autonomous vehicle industry – meaning the manufacturers and the products they design and release. The second bucket of considerations falls under the category of policy response – i.e., how consumers and businesses are permitted to use autonomous vehicles, and what the government may want to consider to maximize good outcomes and minimize bad ones. Regardless of if you find the above argument against a self-regulating free-market compelling, the discussion of issues that follows will, in the least, serve as a catalyst for your consideration of ethical issues you may find compelling.

The time is now: self-driving cars are no longer a technology of the *distant* future

Despite the United States Department of Transportation's⁹ recent issuance of guidance regarding the development, testing, manufacture, and regulation of autonomous vehicles, concrete policy implementation is still lacking. If the government or another regulatory body does plan to regulate the autonomous vehicle industry to some extent, considerations need to be made – and concrete policies drafted – now. I write this paper, in part, as an urge to policymakers and manufacturers – begin deriving specific details from theoretical discussions. Autonomous vehicles are no longer a ‘moonshot’ technology of the future; they are today’s technology. A world in which autonomous vehicles comprise most vehicles on the road is near.

Tesla, for example, announced on October 19, 2016, that all vehicles produced thereafter would have the hardware necessary for Level 5 autonomy.¹⁰ Additionally, older models can be retrofitted to include hardware required for the same level of autonomy. Tesla announced that it plans to operate self-driving software in the background to collect data. It plans to compare what the software *would have* done to what the human driving the vehicle *does* to both improve its algorithms and build a case for the increased safety associated with fully autonomous vehicles. Tesla’s goal is to demonstrate a fully autonomous trip from New York to Los Angeles by the end of 2017 and to release its software to its broader consumer base shortly after that.¹¹

⁹ United States. National Highway Traffic Safety Administration,. Federal Automated Vehicles Policy: Accelerating the next Revolution in Road Safety. 2016. Print.

¹⁰ Golson, Jordan, and Dieter Bohn. "All New Tesla Cars Now Have Hardware for 'full Self-driving Capabilities'" The Verge. 19 Oct. 2016. Web. 21 Nov. 2016.

¹¹ Golson, Jordan, and Dieter Bohn. "All New Tesla Cars Now Have Hardware for 'full Self-driving Capabilities'" The Verge. 19 Oct. 2016. Web. 21 Nov. 2016.

Uber is currently running a pilot of a version of its service which replaces independent contractor-driven vehicles with fully autonomous cars. This pilot is already in effect in Philadelphia and utilizes autonomous vehicle technology developed by Ford and Volvo.¹²

Additionally, Mercedes have announced information regarding how its future autonomous vehicles will handle ethics algorithms. Christoph Von Hugo, from Mercedes-Benz, has articulated that all its autonomous vehicles will protect its driver and passengers at all costs. That is, in some of the scenarios like those outlined by Patrick Lin¹³, a Mercedes would not risk harm to the driver, regardless of how much harm might be caused to others.¹⁴

These decisions are currently in the hands of the private sector and will remain so until the government considers, debates, and enacts policy addressing issues related to autonomous vehicles. The government, manufacturers, and informed citizens *may decide*, as discussed above, that these decisions best remain in the hands of manufacturers, but an open dialogue ought to occur prior. The considerations that follow are an extensive, but by no means comprehensive, discussion of relevant ethical considerations that these discussions ought to include.

¹² Isaac, Mike. "What It Feels Like to Ride in a Self-Driving Uber." The New York Times. The New York Times, 15 Sept. 2016. Web. 21 Nov. 2016.

¹³ Lin, Patrick. "The Ethics of Autonomous Cars." The Atlantic. Atlantic Media Company, 8 Oct. 2013. Web. 6 Sept. 2016.

¹⁴ Taylor, Michael. "Self-Driving Mercedes-Benzes Will Prioritize Occupant Safety over Pedestrians." Card and Driver. 7 Oct. 2016. Web. 21 Nov. 2016.

Exploring specific regulatory pitfalls

Before discussing a handful of the larger factors that regulators should take into account when developing autonomous vehicle policy, I will raise a few specific considerations that regulators should be cautious of before debating, crafting, and enacting policy. Some of these considerations include addressing conflicting state and federal regulations, the timeline for regulation and implementation, the trap of accident algorithms, and standards for inter-vehicle communication.

Conflicting regulations at different levels of government

Regulators must determine at what level regulation should be mandated; state, federal, or otherwise. The federal government has instituted various loose recommendations regarding the use of self-driving cars, but state governments have also taken liberty to implement their own regulations. In some cases, these regulations seem to be beneficial to overall societal good because they encourage and promote the development and testing of autonomous vehicles. For example, California allows testing under specific conditions, and Florida, by law, does not regulate testing at all.¹⁵ But in other states, strict regulations, or no stance on regulation at all, may stifle the testing and development of autonomous vehicles, preventing them from reaching the market as quickly as they may otherwise. The main data point to consider here is that, as of the writing of this paper, only five states have *passed* laws related to the development, operation, or testing of autonomous vehicles.¹⁶

¹⁵ Gabriel Weiner and Bryant Walker Smith, Automated Driving: Legislative and Regulatory Action, cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action

¹⁶ Gabriel Weiner and Bryant Walker Smith, Automated Driving: Legislative and Regulatory Action, cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action

It seems regulators could benefit from a unified approach to the regulation of autonomous vehicles for a few reasons; in fact, the Department of Transportation has already recommended such an approach.¹⁷ First, a unified approach will result in the quicker development and implementation of regulatory policy. The importance of this will be discussed further in a section below, but in short, when a technology as potentially beneficial as autonomous vehicles is available, it seems prudent to ensure it reaches the public market as quickly as possible. On a more practical note, delaying the development of regulation is not beneficial for manufacturers. They will likely need to adjust hardware and software given new regulation; it is more practical for them to know what changes will be necessary as soon as possible, but ideally during early phases of development.

Second, competing regulations at the federal and state or local level are problematic because it can quickly become very complicated. Without discussing the details of federalism, it is reasonable to argue that transportation policy and regulation pertaining to autonomous vehicles ought to be determined at the national level. Practically, it is preferable for manufacturers to make one product that can be sold throughout the United States. It ensures more resources are allocated to a single product and not variations of the same product for different geographical markets, which will likely result in a better product, by any measure. Additionally, roads are often funded at the national level and cross state lines. As a consumer or business owner, owning and operating a vehicle that can only be operated in certain states is a nuisance.

Further, allowing competing regulations to develop at various levels in the governmental hierarchy is not cost-effective. Consider the resources, financial and other, necessary to develop a comprehensive set of regulations at any level of government. Now, multiply that by 50, since it

¹⁷ United States. National Highway Traffic Safety Administration,. Federal Automated Vehicles Policy: Accelerating the next Revolution in Road Safety. 2016. Print., Pg. 37

is possible that every state establishes its own policies for autonomous vehicles. Either, these resources could be better spent by each state on solving other problems, or each state could devote a portion of these resources to a committee at the federal level which will ensure progress can be made faster.

Consider an analogy: a group of business consultants is tasked with solving a complex business problem for a client. The firm contemplates two approaches. They could task a group of its brightest consultants to tackle the problem collectively, or they could task the same team to address the problem independently and present all of the potential solutions to their client. It seems that in the latter approach, a lot of work would be duplicated, thus creating a significant amount of inefficiency. One can, of course, imagine benefits to solving the problem independently, like more diversity of approaches, but it seems similar diversity can be achieved in a group problem-solving environment, but without the inefficiency of an independent approach.

Similarly, the federal government in the United States could work alongside the states to pool together resources – financial, intellectual, and otherwise – and tackle the dilemmas facing policymakers tasked with regulating autonomous vehicles. That is, they could tackle a complex problem as a group with a stellar team of consultants, and produce one complete result. This is contrasted by an approach where the federal government *and* all of the states create their own individual solutions; the consultants attempt to solve the problem individually. The latter would, not only be a much less efficient process, but would also result in competing, and perhaps contradicting, outcomes that would be difficult for the client – in this case, autonomous vehicle manufacturers and consumers – to interpret.

For the reasons above, federal and national governments ought to consider placing base requirements and regulations on state and local governments to ensure that the technology will be accessible to as many people as possible, as quickly as possible, and that a sufficient amount of efficiency is achieved during the process. There will, however, most likely be conflicting state and federal regulations in the United States, which will result in court cases that could potentially escalate to the Supreme Court. Federal regulators in the Department of Transportation and others, must be cautious of and consider how best to handle such situations.

The tradeoff between robust regulation and timely implementation

Regarding regulation, governments will need to seriously consider what constitutes sufficient testing. Regulation should delay autonomous vehicles' entry into the market long enough to ensure they are safe enough for use on public roads. But regulatory evaluation of products similar to autonomous vehicles have a track record of being longer than necessary. The NHTSA has stated intentions to institute testing guidelines similar to those used on aircraft by the FAA. Many policy analysts have expressed concern about using these guidelines as a benchmark for government testing and approval of autonomous vehicles because they are extremely stringent and may result in testing that lasts for years. In some cases, FAA tests have lasted upwards of a decade.¹⁸

Given the tremendous societal benefits of getting as many autonomous vehicles as possible on our roads, there would be substantial opportunity costs associated with stifling autonomous vehicle usage with unnecessary testing and regulation. Perhaps the most striking

¹⁸ Thierer, Adam, and Caleb Watney. "Every Day Matters with Driverless Cars." The Hill. 20 Oct. 2016. Web. 27 Oct. 2016.

opportunity cost is the number of lives lost. Nearly 35,000 individuals died on roads in 2015, and preliminary estimates for 2016 indicate that this number is increasing.¹⁹

Assuming that roads with *only* autonomous vehicles can prevent even 50% of the 94% of 35,000 deaths caused by human error, each day that this vision is delayed results in the death of roughly 45 people.²⁰ According to a paper published by the Center for Disease Control, the 9th leading cause of death is kidney disease, to which 48,146 deaths were attributed in 2014.²¹ Although this is slightly more than the number of deaths caused by automobile accidents, the sentiment remains the same: if society had access to a cure for kidney disease that worked on 50% of people with the disease, doctors and FDA regulators would likely rush to get the drug to market as quickly as possible. Further, most ethicists and, average citizens, would argue that they have an ethical obligation to do so. Similarly, this argument can be made regarding regulation of autonomous vehicles, because of their great impact on societal good. Therefore, to stifle delivery of autonomous vehicles to market beyond what is necessary, would be to do an injustice to society.²²

This is by no means a caution against regulation entirely because, it *is* possible that too little regulation or safety testing may result in unsafe products being released to the market. If an unsafe product is released that results in additional deaths, any attempt to speed up regulation

¹⁹ National Center for Statistics and Analysis. (2016, August). 2015 motor vehicle crashes: Overview. (Traffic Safety Facts Research Note. Report No. DOT HS 812 318). Washington, DC: National Highway Traffic Safety Administration.

²⁰ 50% was chosen because I believe that it is a very conservative estimate. If roads had entirely autonomous vehicles, as explained in the first part of this sentence, one would think nearly all deaths caused by human error would be prevented.

²¹ United States. Department of Health and Human Services. Center for Disease Control and Prevention. National Vital Statistics Report. By Kenneth Kochanek, Sherry Murphy, Jiaquan Xu, and Betzaida Tejada-Vera. 4th ed. Vol. 65. Web.

²² Note: This argument about the delay of implementation of policy was articulated in a similar form in the following article: Thierer, Adam, and Caleb Watney. "Every Day Matters with Driverless Cars." The Hill. 20 Oct. 2016. Web. 27 Oct. 2016.

and testing for an argument along the lines of the one above, will have been in futility. My point here is not that regulation should occur as fast or as minimally as possible, but rather, that regulators should aim to strike a balance between timeliness and sufficient safety and efficacy. It is also worth considering to what extent the free market effects, as discussed above, may account for a portion of regulation and testing. For example, if determined it accounts for certain requirements, it may reduce the regulatory burden placed on the government.

Considering how autonomous vehicles ought to behave in the case of an accident

Given that autonomous vehicles will not always be able to avoid situations resulting in accidents (due to human error by other human-driven vehicles, pedestrians, or cyclists; or in rare cases of machine failure), autonomous vehicles and manufacturers must consider how autonomous vehicles ought to be programmed to behave in these situations. First, I will explicate the primary ethical dilemma that stems from such considerations as articulated, most notably, by Patrick Lin.²³ I, then, aim to explore the parts of this scenario and corresponding implications which regulators, companies, and consumers ought to consider. Finally, I will raise concern with the extreme focus on such dilemmas as a part of the autonomous vehicle discussion.

Patrick Lin and countless other philosophers, writers, bloggers, college students, and informed citizens have argued that the advent of driverless cars make the famous “trolley scenario” reality.²⁴ The most common scenario goes something like this: imagine that an autonomous car is traveling down a road when suddenly multiple crates of heavy cargo fall off of a truck in front of it. The car is not able to stop before it hits the cargo crates, so it has three

²³ The Ethical Dilemma of Self-driving Cars. By Patrick Lin. Dir. Yukai Du. Perf. Animated. The Ethical Dilemma of Self-driving Cars. Ted Ed, 8 Dec. 2015. Web.

²⁴ Nyholm, Sven, and Jilles Smids. "The Ethics of Accident-Algorithms for Self-Driving Cars: An Applied Trolley Problem?" *Ethical Theory and Moral Practice* 19.5 (2016): 1275-289. Web.

options. 1) The car could stay its current course, hit the crates, and risk injuring or killing the passengers in it. 2) The car could swerve right to avoid the crates, but strike a motorcycle rider, almost surely killing her. 3) The autonomous car could swerve left into an SUV, risking injury or death to the passengers of the autonomous vehicle and the unknown number of passengers in the SUV. The sensors on the autonomous vehicle and thus the computer system in the vehicle will be aware of the situation and the potential outcomes with enough time to make a decision; whereas, a driver in the same vehicle would not have a decision.²⁵ This scenario is one outlined by philosophy professor Patrick Lin in a popular, animated ethics video he posted online. I encourage you to watch the video for a more concrete understanding, as I have only summarized the key points above.

Another version of the same ethical dilemma consists of an autonomous vehicle driving along a stretch of Highway 1 in California, which straddles a cliff that overlooks the ocean on the southbound side, which is the same side on which the autonomous vehicle is traveling. Suddenly, the autonomous vehicle makes a blind turn and quickly comes upon a group of cyclists. The autonomous vehicle does not have enough time to stop and must decide between two outcomes. 1) The vehicle could continue on its current path and almost certainly kill the group of five cyclists, or at least seriously injure them, or 2) the vehicle could swerve right, sending the car off the cliff and into the ocean, killing the occupants of the car.²⁶

There are many things we must keep in mind when considering what manufacturers ought to program autonomous vehicles to do in such situations. We may argue that the number

²⁵ The Ethical Dilemma of Self-driving Cars. By Patrick Lin. Dir. Yukai Du. Perf. Animated. The Ethical Dilemma of Self-driving Cars. Ted Ed, 8 Dec. 2015. Web.

²⁶ Schwitzgebel, Eric. "Will Your Driverless Car Kill You so Others May Live?" Los Angeles Times. Los Angeles Times, 4 Dec. 2015. Web. 30 Oct. 2016. / Note: the example for which this article is cited is one that was inspired by the scenario outlined in this article.

of individuals involved matters. If the autonomous vehicle has fewer passengers than the number of cyclists, then a utilitarian framework would argue the car should choose the outcome which promotes the greatest good; in this case, the outcome which allows the most individuals to survive. The car ought to drive off the cliff to save the cyclists.

Manufacturers and regulators may consider the implications of a car which may sacrifice its occupants to save more occupants in another vehicle or a greater number of pedestrians. Consumers might not purchase a car, or ride-sharing users might not summon an Uber or Lyft that they know has the potential to intentionally kill them. If this is the case, autonomous vehicles might not catch on, and the potential for lives saved through the reduction in human error is eliminated entirely.²⁷

They also might consider the lack of certainty surrounding outcomes. Decisions are difficult when one is not entirely certain of the outcome that would result from the various options available to them. Imagine that there is a 50% chance that the five cyclists die if the car hits them; whereas there is a 100% chance that the two passengers in the autonomous vehicle die if the car goes off the cliff. Should the autonomous vehicle calculate an expected value of sorts, where it weighs 2.5 ($5 \times 50\%$) lives against two lives? Even more difficult, what if the autonomous vehicle in the cyclist scenario has five occupants, and the chance of death of the cyclists is 100%. It is even more difficult for programmers of autonomous vehicle software to decide which group of five people the vehicle should favor. Manufacturers will, no doubt, have the ability to program autonomous vehicles to take other considerations into account. It may have data on its passengers and, therefore, know that one of them is the CEO of a Fortune 500 company (whose life should be valued more or less depending on your point of view of the

²⁷ Greene, Joshua D. "Our Driverless Dilemma: When Should Your Car Be Willing to Kill You?" *Sciencemag.org*. Science Magazine, 24 June 2016. Web. 18 Oct. 2016.

company). Although I do not argue that certain lives should be weighed more heavily than others, there will certainly be manufacturers and policymakers who claim that such calculations might be acceptable in certain cases.²⁸

Regulators, autonomous vehicle manufacturers, academics, bloggers, journalists, and informed citizens should not be as distracted as they are by issues related to autonomous vehicle algorithms. Based on my extensive survey of existing literature on the subject matter, this seems to be the most thoroughly discussed question about autonomous vehicles. This indicates that many think it is one of the most relevant and pressing issues in the industry. Although dilemmas like the ones articulated in these papers and replicated above are fascinating to think about, they will rarely occur in practice, with one caveat: they will rarely happen if the grand vision of scaling autonomous vehicles such that they largely take over our roads. Even though accidents would still occur if 100% of the vehicles on the road were autonomous, it is safe to assume that all accidents and deaths attributable to human error would be eliminated. Details will be discussed later in this paper, but in 2015, for example, only 6% of deaths resulting from car accidents would remain were human error eliminated. If 25% to 50% of the road consists of autonomous vehicles, however, these considerations may become more relevant because there will still be a substantial number of human drivers on the road, still prone to more error than their autonomous counterparts. The requisite consideration, then, ought to be: what can regulators, manufacturers, academics, and citizens do to ensure that as many autonomous vehicles proliferate our roads, as quickly as possible. The closer the grand vision of an integrated network of vehicles that are always analyzing, communicating, and adjusting accordingly comes to being a reality, the less likely any accident is to occur. In a world where this vision is reality, my

²⁸ I only mean to utilize this example to demonstrate the moral intuition that may arise in response to an application of autonomous vehicle technology that will, no doubt, be suggested by consumers and maybe even manufacturers.

hypothesis is that the only instances in which accidents will occur are when incredibly redundant hardware and software systems malfunction entirely, pedestrians or cyclists break laws, human-driven cars (if they still exist) break laws or operate in error, or malicious hacking events occur.

Entertaining the possibility of a ban on driving

Given that human error is responsible for a large percentage of accidents resulting in deaths, regulators may want to consider at what point a driving ban becomes reasonable. There would be a huge societal benefit associated with roads that only have autonomous vehicles on them. This discussion may also be coupled with what measures the government might take to promote the adoption of this technology by as many consumers and businesses as possible. If adoption is heavily incentivized through policy and economics, such a ban may not be necessary. But, there will undoubtedly be individuals who do not trust autonomous vehicle technology with their own life (even though they will already be entrusting their life to AV technology because of the large number of AVs already on the road), do not have the means to purchase a new vehicle (although, as I will explain below, the economics of car ownership will likely change), or enjoy the feelings of freedom associated with being behind the wheel of a car. Others might complain about the large amount of money they spent on a vehicle that is now obsolete. At the societal level, there may be even more waste associated with the huge number of vehicles rendered obsolete by a ban on driving. Governments may consider banning human-driven cars on only certain roads, allowing driving enthusiasts to drive in designated areas or on tracks. They might also consider financial incentives that could be provided to get rid of non-autonomous vehicles. At the industry level, companies might also explore the possibility of upgrading and repurposing

already-existing vehicles so they may have the same autonomous capabilities as newly manufactured vehicles.

The benefits of a standardized inter-car communication protocol

In line with considerations between government and free-market regulation, regulators ought to consider to what extent manufacturers will have incentives to ensure their vehicles can communicate with autonomous vehicles manufactured by other companies. This is important because a number of the situations outlined in this paper, in which a large amount of societal good is created, rely upon the ability of *all* autonomous vehicles on the road to communicate with each other.

Consider many of the benefits resulting from increased efficiency; maximizing route efficiency and decreasing the chances of traffic; all of which will be discussed extensively in the sections that follow. Although the sensors on autonomous vehicles can likely isolate them from being extremely effected by an inability to communicate with other vehicles, they will be much *better* at achieving such goals if they can.²⁹ Autonomous vehicles that can communicate may be able to follow one another much more closely, increasing gains associated with increased aerodynamics. If they cannot communicate, one autonomous vehicle may not be able to increase the following distance before the vehicle in front of it changes lanes. Additionally, if one vehicle senses an obstacle in the road, it can communicate this information to vehicles behind it so that they can change lanes well in advance and, thus, decrease the likelihood of traffic as vehicles avoid the object at the last minute.³⁰

²⁹ Warren, Tamara. "The Future of America Is Driverless." Theverge.com. Vox Media, 01 Nov. 2016. Web. 2 Nov. 2016.

³⁰ Warren, Tamara. "The Future of America Is Driverless." Theverge.com. Vox Media, 01 Nov. 2016. Web. 2 Nov. 2016.

Additionally, accident situations are better optimized when autonomous vehicles seamlessly communicate. In cases like the ones Patrick Lin articulates, but that involved only autonomous vehicles, vehicles can act in concert with one another. If the autonomous vehicle swerves left into the SUV which also happens to be an autonomous vehicle, it can communicate this in advance, and the SUV can respond accordingly. This may not avoid accidents entirely, but it will better the chances of more favorable outcomes. The important caveat here, though, is that autonomous vehicles must be able to communicate with one another using a standardized protocol.

I can only see a couple of potential downsides to a standardized autonomous vehicle communication protocol. One, connection between vehicles may exacerbate concerns of hacking. That is, if vehicles can easily communicate with and dictate the actions of other vehicles, and a hacker can gain access to one particular type of vehicle due to insufficient security, the hack will also be able to control more vehicles. Additionally, manufacturers might make arguments about free market competition. Tesla may argue, for example, that by adopting a protocol that will allow its vehicles to communicate with BMWs, it will lose some of its competitive advantage because it will have to build its software in a way that limits the capabilities of its products. Regulators must, however, take such concerns into consideration ahead of the regulatory discussions based on the points that follow in my paper. This is because many of the benefits described below will be enabled, or at least furthered, by the ability of autonomous vehicles to communicate with one another.

The potential for damage caused by malicious override of autonomous vehicle systems

We also ought to consider the potential for autonomous vehicles to be used as weapons in terrorist attacks or other similar situations, in the context of potential risks associated with autonomous vehicles. As mentioned above, this risk may be exacerbated by the ability of autonomous vehicles to communicate using a standardized protocol. Autonomous vehicle manufacturers, in particular, must place the utmost importance on the security of the computer systems in the vehicles as they must not be susceptible to hacking and control by individuals other than those who ought to be in control of the vehicles path and destination.

In a world where even the most secure computer systems with the strictest security requirements and regulations; government servers, banks, and healthcare systems, have been susceptible to hacking by those who intend to do harm, it is reasonable to assume similar risks associated with autonomous vehicles. Unsecured or insufficiently secured computer systems in autonomous vehicles may be susceptible to terrorist attacks in which high speed or mass crashes may be caused to harm or kill large numbers of people, or even target individual, high-value targets.

Manufacturers of autonomous vehicles have an ethical obligation to ensure that the security systems in these vehicles are as robust as possible. They ought to invest heavily in research and development of related technologies to minimize the risk that situations, like those above, occur. They also ought to consider developing technology which may reduce the possibility that multiple vehicles are hacked concurrently, so that, when a cyber attack on autonomous vehicles does occur, the number of vehicles involved is limited.

Governments, although typically not the gold standard for advanced technology, ought to consider implementing regulations which outline the levels of encryption and security these

systems must incorporate. Novel technology development or partnership with private companies may also be prudent to prevent the rise of an unexpected threat to national security.

How regulators ought to structure their thinking

Before considering the likely benefits and potential risks of an autonomous-vehicle dominant system of roads, regulators should attempt to determine a loose framework which may provide some structure for the outcomes resulting from considerations. At a high level, this paper will consider possible benefits and potential harms which may result from the rise of autonomous vehicles. Regulators will need to develop an ethical framework that weighs these benefits and harms. Based on the outcome of this exercise, they will ideally develop regulation such that the benefits are maximized, and the harms are minimized. From a theoretical perspective, one might imagine many philosophical and ethical lenses through which harms and benefits can be interpreted. In this paper I will not argue for the use of a specific theoretical, ethical framework; say, deontological, Kantian, Rawlsian, or Utilitarian because a detailed proposal of a theoretical, ethical framework does not seem to be extremely useful in this case. The loosely utilitarian framework that many policymakers typically utilize will result in similar outcomes to a certain point. Fringe scenarios and special topics, like discussions of accident algorithms, might be interpreted differently based on specific ethical frameworks, but policymakers, first, need a broad framework that will get them reasonably far in the regulatory process. Once a base level regulatory framework has been established, they can bring evaluative tools from each framework to special cases from the considerations below and contemplate what interpretive power each framework might bring to the table.

Reduction in automobile-related loss of life and injuries

In the section that follows, I will explore some of the likely benefits and potential risks policymakers should insert into their decision-making framework when determining how and to what extent autonomous vehicles should be regulated.

First, I will explore at least a portion of the benefits associated with autonomous vehicles. As discussed previously, autonomous vehicles have the potential to create a tremendous amount of ethical good in society; they have the ability to eliminate nearly all deaths and injuries resulting from automobile accidents caused by human error. The type of error that machines experience is not as widespread as that experience by humans. Rather, the only accidents which may remain are those that occur in cases of software or hardware malfunction. As much as 94% of the 35,092 deaths on roads in 2015 can be attributed to human error. The elimination of all or even a portion of these deaths is a huge benefit to overall good in society.³¹

Additionally, there are tens of thousands of injuries that occur as a result of automobile accidents each year; this includes injuries from car accidents with other cars, as well as car accidents that involve pedestrians and cyclists.³² A similar percentage of these accidents are caused by human error as well. It is important to note that the number of fatalities occurring in traffic accidents each year is trending upward; there were 32,657 deaths in 2014 and 35,092 in 2015. This constitutes a 7.2% increase, which is particularly concerning given the relative decline that had occurred over the past decade. There were nearly 42,000 deaths in 2007.³³ If this

³¹ National Center for Statistics and Analysis. (2016, August). 2015 motor vehicle crashes: Overview. (Traffic Safety Facts Research Note. Report No. DOT HS 812 318). Washington, DC: National Highway Traffic Safety Administration.

³² United States. Department of Transportation. National Highway Traffic Safety Administration. Fatality Analysis Reporting System Encyclopedia. Web.

³³ NHTSA. "Traffic Fatalities up Sharply in 2015 ." National Highway Traffic Safety Administration. 29 Aug. 2016. Web.

trend continues, the potential for autonomous vehicles to save a substantial number of lives becomes stronger, and their implementation becomes more imperative.

Further, analysis indicates that as many as 55% of accidents go unreported. This includes small accidents, mostly ones where cars are hit from behind.³⁴ Although they are not fatal, and may not cause injuries, they are still a nuisance, and to prevent a percentage of these would be tremendously beneficial. Even if the prevention of these accidents does not save lives, it may save car owners time and money which could be put to use doing more meaningful things than dealing with the complications of a small automobile accident.

Autonomous vehicles could avoid a significant number of these accidents in two ways. First, in the case that the crash (fatal or otherwise) would have been caused by an error made by the driver of the autonomous vehicle (had it not been autonomous), the accident would likely be avoided altogether. This is because the computers in autonomous vehicles, are less prone to error than humans.³⁵ Although it may seem counterintuitive to many individuals, computers scientists have strong data on this point.³⁶ This is certainly the vision for a number of autonomous vehicle systems manufacturers, including Google. The most common cause of error in autonomous vehicles will likely be failure of the technical systems. These types of failures may, however, be avoided by the installation of redundant computer systems which can, in aggregate, serve as a fail-safe mechanism, similar to those installed in autonomous aircraft systems.³⁷ Second, in cases where the accident would have been caused by the driver of another vehicle, there are a few theoretical outcomes, all of which would be better than an alternative scenario where

³⁴ Google. Monthly Report. Rep. no. October 2016. Google Self-Driving Car Project. Web.

³⁵ Naughton, Keith. "Robot Rides May Force Error-Prone Human Motorists Off The Road." Bloomberg.com. Bloomberg, 22 Sept. 2016. Web.

³⁶ Haight, Joel M. "Automation vs Human Intervention What Is the Best Fit for the Best Performance." The American Society of Safety Engineers. Web. 27 Nov. 2016.

³⁷ Yoshida, Junko. "Autopilot: Flying vs. Driving | EE Times." EETimes. 25 Mar. 2016. Web. 23 Oct. 2016.

autonomous vehicles are substituted for human-driven vehicles. Specifically: (1) If both human-driven vehicles in this scenario are replaced with autonomous vehicles, they will be able to communicate with one another and avoid the situation entirely. (2) If only one of the vehicles is replaced by an autonomous car, and the other remains driven by a human, the chance of accident will decrease substantially but not be eliminated entirely. This is because the sensors will analyze and evaluate the situation more efficiently than a human. The computers in the autonomous vehicles will be able to consider all sensory and programmatic inputs to reach an output/decision faster and more intentionally than a human ever could. The autonomous vehicle can then react to a dangerous situation in a way that is safe and minimizes the chances that an accident does occur. (3) Cases in which autonomous vehicles encounter the potential for accidents with pedestrians and cyclists will also result in fewer accidents. This is also because of the vast array of sensors and fast computing and decision-making power available to the autonomous vehicle. It is reasonable to assume autonomous vehicles will primarily seek to avoid situations which could potentially result in an accident altogether, but in situations where an accident cannot be avoided, autonomous vehicles will be able to target specific outcomes, ideally minimizing the amount of damage. A discussion of considerations related to how autonomous vehicles should behave in instances in which accidents cannot be avoided occurs elsewhere in this paper, but the key point remains that an increased presence of autonomous vehicles on the roads will result in fewer deaths and injuries in aggregate. Regulators ought to take the huge potential reduction in death and injury into account when considering policy and legislation for autonomous vehicles.

The augmentation of freedoms associated with travel and mobility

Autonomous vehicles enable individuals previously unable to drive cars due to age restrictions, legal restrictions, or disabilities, to use cars as a reliable form of transportation. There is huge benefit to individuals and society. Disabled people for whom lack of transportation prevented from moving freely can now hold jobs. Elderly and disabled individuals will be able to experience the feelings of freedom associated with the ability to move around and travel as they please, without relying on assistance from others. Children can be safely transported to and from school, sports practice, and libraries. This prevents parents from having to make trade-offs between work obligations, for instance, and the well-being of their children. The benefits associated with the increased mobility of individuals are substantial.

As individuals age in the United States, many lose the privilege of driving themselves due to deteriorating health. They may have eyesight that is too weak to drive, or they may be too frail to respond quickly and safely in an accident. Autonomous vehicles give elderly individuals, both those who have formally lost the ability to drive and those who are less apt to drive, capacity to do so in a way that is safer than they ever could. This has tremendous benefit to these individuals. First, they regain access to mobility as they can now travel wherever they want, whenever they want, without relying on family members or public transportation for their mobility needs. Second, they become less of a burden to the family members upon whom they relied to provide transportation. Family members can now spend more time doing the things they enjoy, or working more to better provide for their families and society. These are just two of the many examples of how autonomous vehicles will better the lives of elderly individuals.

Similarly, many people with disabilities do not have the ability to drive themselves, or they can drive themselves, but in a way that is less safe than other drivers. Autonomous vehicles

will restore this expression of freedom by increasing mobility for those unable to drive, and it will provide a more reliable and safer form of transportation to those capable of driving in standard form or through modified apparatus.

Finally, children under the age of 16 in the United States are not able to drive themselves. As such, they must have family members transport them or utilize public transportation, ride sharing, or other forms of transportation. Transporting children, particularly those in middle or high school, can be a full-time job, especially for families with multiple children. Parents or siblings often sacrifice their own work or personal obligations to provide transportation to children who are unable to drive. Availability of autonomous vehicles will allow parents or children to request an autonomous vehicle to safely transport children to and from school, sports practice, music lessons, social events, etc. This will free up parents and older siblings to spend more time on the activities they enjoy.

This benefit will be magnified in two respects. First, in many families, the responsibility for caring for, and thus transporting, children often unequally falls on women. Although women may take maternal leave to raise young children, the responsibility of transporting school-age children to school, extracurricular activities, and social gatherings often continues for a decade or more after children begin school. These obligations can prevent women from pursuing full-time careers. Although autonomous vehicles will not solve a number of systemic issues that cause gender inequality, they may help address at least one of the outcomes in a meaningful way. Second, the effect will be magnified in the many households in the United States where it makes financial sense for both parents in the family to work to provide for their family adequately. Autonomous vehicles will allow both parents to work as much as they need if transportation

obligations were preventing them from doing so. As a result, they will provide a more comfortable life for their family.

Increases in efficiency

The next major benefits that will come with the proliferation of autonomous vehicles are those associated with increases in efficiency. This includes three subcategories: economic/financial efficiency, machine efficiency, and system efficiency. The first category I will discuss is economic efficiency.

It is important to understand that the increased availability of autonomous vehicles will likely change the economics of car ownership. Although I cannot say this will be the case with certainty, especially in the near-term, there are a number of arguments for why this may be the case in the long-term.

Car ownership, as it currently stands, is extremely costly. People typically lease or finance the cars they drive. In either case, they are stuck with a monthly payment of, in some cases, several hundred dollars for something they use for a few hours per day, at most. In addition to the cost of the lease or payment, car owners must pay for insurance, registration, maintenance, and gasoline (or alternative fuel). In fact, AAA's "Your Driving Costs" study estimates that car ownership costs the average American approximately \$725 each month.³⁸

It is reasonable to assume that when autonomous vehicles begin to hit the roads, some of the earliest adopters will be ride-sharing companies like Uber and Lyft. These companies' current business model creates partnerships with drivers who are independent contractors. When they go 'online' using the company's smartphone application, customers can request a ride from

³⁸ AAA Association. "Your Driving Costs: How Much Are You Really Paying to Drive?" AAA: Your Driving Costs 2015 (2015). Web.

nearby drivers. Both Uber and Lyft take at least a 20% commission for facilitating the trip, and the rest of the fare goes to the driver.³⁹ With a fully autonomous vehicle, cars can be owned or leased by Uber and Lyft themselves because a driver will not be required. Uber and Lyft will incur additional costs of acquiring and maintaining their fleet of autonomous vehicles, but they can also expect additional revenue because a driver will no longer have to take a cut of the sale. This situation is a win-win for ride-sharing companies and their customers. The cost to the customer can be decreased. Meanwhile, the sales revenue for the ride-sharing businesses can increase. This prospect seems so attractive that Uber is already running a pilot of autonomous vehicle technology in Philadelphia, Pennsylvania.⁴⁰

With cheaper ride-sharing costs and already-exorbitant costs of car ownership, it is more than reasonable to conclude that many individuals will begin to rethink their need to own a car. It will likely be cheaper and more efficient to summon an autonomous vehicle whenever you need it than to purchase and maintain an expensive car that sits in your driveway the majority of the time. Beyond saving would-be car owners money on monthly payments, a changing calculus behind car ownership will have tremendous benefits to society.

The elimination of the labor component from the economics of ride-sharing will substantially drive down the cost of transportation via ride-share; perhaps to 50% or less of current costs to consumers. This will enable individuals who could not afford to own a car to have all the benefits associated with car ownership, at a lesser cost. One may be able to hold a different job that is more interesting to them, but that may have been too far for them to get to without a car; be able to work more frequently to provide a more comfortable living for

³⁹ Huet, Ellen. "Uber Raises UberX Commission To 25 Percent In Five More Markets." *Forbes*. *Forbes Magazine*, 11 Sept. 2015. Web. 27 Nov. 2016.

⁴⁰ Isaac, Mike. "What It Feels Like to Ride in a Self-Driving Uber." *The New York Times*. *The New York Times*, 15 Sept. 2016. Web. 21 Nov. 2016.

themselves and/or their family; or be able to commute to college to achieve a better education. The decreased cost of transportation may enable more freedom associated with mobility which can create more good at the individual level and may increase the robustness of the economy at the societal level.

For those who can afford to own a car, the decreasing cost of reliable transportation in the form of autonomous vehicles summoned on ride-sharing platforms will allow them to put their capital to better use. They might donate more on an annual basis to non-profit organizations, afford to send their children to a better school, or invest more in savings for retirement. Regardless of how they spend their money, increased financial flexibility has a number of potential benefits at both the individual and societal levels.

Shifting economics of car ownership results in greater overall efficiency on the roads; this is what I described as system efficiency above. Increased efficiency comes in three ways. First, less car ownership enables greater utilization of the capacity of each car. This means that there will be fewer total cars on the road because each one will be used more. There are substantial benefits to the environment associated with the overall increase of efficiency. Fewer cars will be manufactured since each car will be used more, which means there will be a lesser volume of harmful byproducts produced during the manufacturing process. Additionally, fewer cars on the road mean a smaller volume of harmful emissions in the atmosphere.

The second way in which efficiency is enabled is through better route optimization and carpooling. Ride-sharing applications, for example, can match passengers headed in the same direction for reduced costs and greater efficiency, and the routes of autonomous vehicles can be optimized to be as efficient as possible, aiming to avoid travel without a passenger as much as possible. This additional gain in efficiency would further environmental benefits stated above.

These types of gains in efficiency could result in additional benefits; imagine if cars were almost always being used. If this were the case, cars would rarely have to be parked near homes or places of business. Instead, they could be parked in massive warehouses when not in use (most likely overnight). This would result in the potential elimination of parking lots, parking garages, and street parking, all of which are typically inconvenient particularly in urban areas.

Additionally, parking lots and garages take up a lot of real estate in cities, homes, and apartment buildings. Minimizing or eliminating the need for parking near the places people travel would free up property and allow for the most efficient use of it.

Third, routing of traffic will enable tremendous efficiency; automobile travel will be characterized by fewer traffic jams, and less waiting. Autonomous vehicles will likely be able to communicate with one another, assuming that there is a standardized protocol for communication (this topic was discussed above), eliminating the need for human-oriented traffic control devices, like traffic lights and stop signs. Instead, routing (speed and direction) can be altered to avoid entering an intersection at the same time as another vehicle. Additionally, vehicles will be able to travel at faster speeds since the computers operating autonomous vehicles are less prone to error than humans. This category of gains in efficiency will enable much faster transportation, which means that people will spend less time in cars and more time doing the things they enjoy and which benefit the social and economic good of society.

Autonomous vehicles will allow their passengers to do things that are more valuable to them than driving. The average individual spends 290 hours of their year driving; almost two weeks.⁴¹ Assuming a life expectancy of 79 years (15 of which will not be spent driving, in most states), the average American wastes two full years (every hour of every day) of her life

⁴¹ Johnson, Tamra. "Americans Spend an Average of 17,600 Minutes Driving Each Year | AAA NewsRoom." AAA NewsRoom. AAA, 06 Sept. 2016. Web. 23 Oct. 2016.

driving.⁴² This equates to something more like 3-4 waking, productive years.⁴³ Giving most people 3-4 years back in their life dramatically increases what a human can accomplish in her life. There is potential for the creation of additional, societal good. For example, a busy executive of a for or non-profit organization can hold conference calls without distraction, draft emails, or even catch up on sleep while commuting. Or a student can study for an upcoming test on her way to school. Autonomous vehicles enable greater good through allowing people to focus on the things they would like to focus on, rather than on the mundane, yet dangerous, task of driving.

Equitable access to transportation and safe transportation equipment

Another input regulators and organizations ought to consider when promoting and regulating the use of autonomous vehicles is their ability to ensure more equitable access to the safest transportation.

In the status quo, it is certainly the case that more expensive automobiles typically have the best safety features. A very expensive Mercedes-Benz that a wealthy individual can afford to purchase will have the latest safety technology, while a five to ten-year-old used car that a lower or middle-class individual might purchase will have dated safety technology, given the rapid advancement and development of automobile safety technology in recent years. This means that, in the current state of the automotive industry and the use of automobiles, those wealthier individuals are more protected than the average individual when driving because of the more advanced safety features in their more expensive cars. Now, it is difficult to quantify how many

⁴² The World Bank. "Life Expectancy at Birth, Total (years)." The World Bank Data. 2014. Web. 29 Oct. 2016.

⁴³ $(17,600 \text{ minutes per year} \times (79-15) \text{ years}) / 525,600 \text{ minutes per year} = 2.14 \text{ years}$

wealthy lives it saves or injuries to wealthy individuals it prevents, but it does not seem to be negligible.

Given that the rise of autonomous vehicles will likely change the economics of car ownership, as explained previously, more individuals with more diverse income levels will likely have access to the best safety features. Autonomous vehicles will no longer need to be driven by humans, so the cost of services like Uber and Lyft will drastically decrease, making owning a car, at least in the way we currently know ownership, obsolete. It will make more economic sense to hail an autonomous vehicle using a ride-sharing service, when needed, as you will no longer have to worry about the cost of a lease or monthly payment, insurance, registration, gas or electricity, maintenance, and parking. Additionally, the financial calculations involved in determining whether it makes sense to own a car will be the same regardless of economics status in society. Using an autonomous vehicle only when needed will be less expensive for a poor person and less costly for a wealthy person.

This argument does, however, come with caveats. Ride-sharing services will likely offer rides in premium vehicles, which may be safer, for a premium price, therefore replicating the same problem in a new market. Even if this is the case, it is still likely that the least expensive autonomous cars that the least wealthy consumers will have access to through ride-sharing platforms will *still* be safer than the aging cars they would otherwise have driven. The central assumption this line of argument relies upon is: since ride sharing with autonomous vehicles will maximize the efficiency of utilization, the lifespan of each vehicle, in years, will be shorter than privately owned cars in the status quo. Assume a liberal average lifespan of 200,000 miles. It may take the average person nearly seventeen years to drive this distance assuming they drive one thousand miles each month. Since ride-sharing vehicles will constantly be in use, they will

reach their lifespan in a fraction of the time. This means that they will be recycled and replaced more often with new technology, which will likely be safer.

One might argue that the same argument applies to taxis and ride-sharing services in the status quo. That is, they are typically rotated out for newer vehicles more frequently because they are constantly used to transport people and goods. This is true; however, the argument only delivers results when the economic conditions are right as well. Individuals must also have an incentive to use ride-sharing and taxi services. That incentive does not exist in the status quo for the average person. Instead, it is more expensive to take a taxi or Uber to work than to drive the ten to fifteen-year-old car they own. Because the availability of autonomous vehicles significantly impacts the calculations behind owning a vehicle, the incentive will now exist.

Considering the loss of a large segment of the job market

Now that I have examined some of the benefits associated with autonomous vehicles, and thus, at a cursory level, some of the ethical good that it generates for society, I will more carefully examine some of the potentially adverse effects associated with the rise of autonomous vehicles. The first significant negative effect is the loss associated with the elimination of an entire sector of the job market. As I previously mentioned, fully autonomous vehicles will not need to be operated or supervised by humans in any way, so individuals whose livelihood depends on operating vehicles in some form will theoretically no longer have jobs of this classification.

Transportation is a significant segment of the economy in the United States. Estimates indicate that as many as 4.6 million jobs in the United States are based in this industry.⁴⁴

⁴⁴ BLS. "Employment by Major Industry Sector." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, 2014. Web. 18 Oct. 2016.

Consider the large number of truck drivers required to make interstate commerce possible; taxi drivers who help individuals get from point a to point b on a daily basis; or the relatively recent rise of the ride-sharing industry, which consists of companies valued at over \$50 billion and large numbers of part and full time drivers working to provide for their families, pay tuition, or achieve other financial goals.⁴⁵

For this paper, let us assume that delivery and truck drivers will still have jobs in the near term as the tasks they perform that are not associated with driving vehicles will still need to be performed by humans. For example, a delivery driver will still need to manually deliver packages once they arrive at their destination. Additionally, having a human in trucks and other large vehicles, even if fully autonomous, provides an additional layer of security against theft and other potential types of damage to expensive cargo. Hiring a “driver,” although this person will no longer be driving, still makes economic sense given the high-value of the loads that these trucks carry. It is possible, however, that some truck drivers lose their jobs because a job created for the purpose of protecting cargo transported in an autonomous truck might require different skills. Additionally, in the long run, all truck drivers will almost certainly lose their jobs as the capabilities of autonomous vehicles and shipping technology improves. Similarly, delivery truck drivers may be replaced by autonomous drones. But, unfortunately, space and time constraints of this academic endeavor do not permit me to lend the level of detail required to this aspect of the discussion. I will, therefore, assume that the only group of individuals that will lose their jobs performing driving functions *in the short term*, as a result of increased prevalence of autonomous vehicles, will be those who drive for ride-sharing and taxi services.

⁴⁵ Lien, Tracey. "Lyft Defies Predictions by Continuing to Grow as a Rival to Uber." Los Angeles Times. Los Angeles Times, 5 Jan. 2016. Web. 23 Oct. 2016.

The possibility that autonomous vehicles replace humans who drive as a form of livelihood is very real. The number of individuals in the United States alone, whose jobs involve driving vehicles on the road is substantial. Specifically, the number of Uber and Lyft drivers in the United States alone amounts to over 700,000 people.⁴⁶ And according to 2014 data from the Bureau of Labor Statistics, 233,700 people hold jobs as taxi drivers and chauffeurs.⁴⁷ Combined, this amounts to nearly 1,000,000 jobs in the United States. When considering how the government ought to regulate autonomous vehicles, they should, no doubt, consider the ethical implications of autonomous vehicles from the standpoint of their impact on this sector of the job market.

Uber and other ride-sharing platforms, like Lyft, have enabled the rise of a new sector of the economy, the on-demand economy. This segment is characterized by flexible jobs in which nearly anyone can start a small business to provide some category of service: providing transportation, delivering lunch, or shopping for and delivering groceries. This job market is typically easy to enter and provides a flexible stream of income; students can earn a small amount of money in exchange for a few hours of work between classes, or an individual in between jobs can earn enough to pay their mortgage and put food on the table for their family.

As autonomous vehicles become more capable over the next few years, they will no longer need human supervision in the driver's seat. Autonomous vehicles of the near future will no longer have the capability to be overridden and controlled by human inputs; steering wheels and gas pedals will be artifacts of the past. Google's self-driving car prototype, for example, does

⁴⁶ Lien, Tracey. "Lyft Defies Predictions by Continuing to Grow as a Rival to Uber." Los Angeles Times. Los Angeles Times, 5 Jan. 2016. Web. 23 Oct. 2016.

⁴⁷ Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2016-17 Edition, Taxi Drivers and Chauffeurs, on the Internet at <http://www.bls.gov/ooh/transportation-and-material-moving/taxi-drivers-and-chauffeurs.htm> (visited November 29, 2016).

not have any means for a human to control the vehicle.⁴⁸ Although the prospect that vehicles will be able to operate without human supervision is exciting for many reasons – reduced accidents caused by human error, ability for anyone (children, disabled, elderly) to have access to transportation, and reduced costs associated with transportation (human labor is the most expensive cost in ride-sharing) – these benefits come with a huge primary cost that must be considered ethically: the elimination of decent-paying jobs.

The most obvious, and perhaps most quantifiable effect of the reduction of a large segment of the job market, is the total wages lost. The individuals that typically hold these jobs will no longer have the opportunity to hold these types of jobs since a machine will be able to perform their jobs. This is a lot of potential wages no longer available to the job market.

Take Uber, for example, which is one of the largest ride-sharing platforms in the United States. Although official numbers have not been released, leaked data shows gross bookings (the fares collected from customers before drivers get their share) from the first half of 2015 of \$3.63 billion. Based on revenue numbers (after drivers receive their commissions) of \$663 million over the same period, drivers on the platform received roughly \$2.97 billion in commission.⁴⁹ Factor Lyft, taxi services, and other, smaller ride-sharing platforms into the mix, upwards of \$5 billion in wages are lost.

Additionally, when people earn less income, they spend and save less money. Consensus on economic theory holds that less spending and less saving is not good for the economy overall. Although the full economic impact of decreased saving and spending from the elimination of

⁴⁸ Griggs, Brandon. "Google's New Self-driving Car Has No Steering Wheel or Brake." CNN. Cable News Network, 28 May 2014. Web. 29 Nov. 2016.

⁴⁹ Solomon, Brian. "Leaked: Uber's Financials Show Huge Growth, Even Bigger Losses." Forbes. Forbes Magazine, 12 Jan. 2016. Web. 17 Oct. 2016.

ride-sharing jobs has yet to be quantified by economists, and I am unqualified to conduct such analysis, it seems reasonable to argue that the impact would not be petty.

Another important facet of the type of job elimination that will occur as a result of the prevalence of autonomous vehicles is that this instance is one example of a broader overall trend. This trend is the elimination of certain jobs as they become automatable by machines. The elimination of driving-based jobs is perhaps one of the biggest instances in which machines will replace humans.

Regardless of the level of skill of individuals driving for taxi services and ride-sharing applications – many are highly skilled and may be able to find other employment – this still results in the elimination of a huge number of jobs. It is not likely that all 700,000+ individuals who were driving for Uber, Lyft, and other services will be able to find employment. Some may find jobs after a long period of searching, or they may find jobs that do not pay as well as being a ride-sharing independent contractor. But an insubstantial number of people will be unemployed for some period of time. The impact of any period of unemployment can be devastating to individuals, their families, and the economy.

Given this phenomenon, policymakers ought to consider if policies should be implemented to decrease the likelihood that large percentages of the workforce remain permanently unemployed. They may want to increase funding for programs available to high school graduates which train students that do not attend colleges or universities to maintain certain skills that robots and computers cannot perform.

Alternatively, they may want to consider what will happen as more and more of the economy becomes automated and the barrier to entry for the few jobs that remain becomes higher. By this time, the economy will be producing at least as much as it is currently producing,

but with a fraction of the human labor. Companies, therefore, will be much more profitable.

Should it be expected that companies of the future pay larger taxes to support a basic wage or stipend for all citizens? This is a seemingly socialist and utopian suggestion, but considerations like these may be required in the near future to sustain a basic standard of living.

Finally, people who hold these types of jobs may truly enjoy driving; it may be their passion, and they may not enjoy other types of jobs. In these cases, regulators, autonomous vehicle manufacturers, and ride-sharing companies will want to consider the reduction in good (as a proxy for satisfaction and happiness) associated with eliminating the ability for a worker to do something they truly enjoy and about which they are truly passionate.

But even if regulators adopt a utilitarian framework to guide regulation, there are other considerations that must be taken into account. Most importantly, they ought to consider how they should define utility. They could, for example, define utility as a dollar amount and compare the wages eliminated to the amount saved in efficiency. Alternatively, regulators could somehow estimate happiness or good generated and removed by the use of self-driving cars; it might account for lives saved, freedom promoted, happiness promoted, as well as the inverse of each these considerations. The most obvious problem, however, with such an approach is that each of these is incredibly difficult to quantify, primarily because of the subjective nature of loss of work, access to mobility, etc. Thus, even with the right pieces of the regulatory puzzle, regulators will still have an incredibly difficult path ahead.

Conclusion

The widespread adoption of autonomous vehicles is inevitable. The only aspects still to be determined are the speed at which consumers and businesses begin to adopt them and the conditions under which they will be permitted on public roads. My hope is that this paper serves as a catalyst for conversations amongst legislators, manufacturers, and consumers that result in the formation of concrete policy which addresses some the ethical concerns associated with the prevalence of autonomous vehicles. At this point, it seems clear that the benefits resulting from roads abundant with autonomous vehicles are impressive, but the pitfalls and risks are also evident. The primary, quantifiable benefit is the number of lives saved driven by the reduction in deaths attributed to accidents caused by human error, but there are a number of advantages that are not as quantifiable: increased equality, mobility, and efficiency, amongst others. On the other hand, there are pitfalls, which can be addressed almost entirely through effective development and regulation of autonomous vehicles, and there are potential risks, like the loss of nearly one million jobs that will be difficult to address, even with effective policy implementation.

Detailed next steps for all involved parties are unclear, but one thing is clear: a perfect approach need not be devised before progress can be made because any discussion about the issue is helpful. A rough outline of the general direction interested parties should be headed might begin with discussion and debate about a number of the risks and benefits resulting from the prevalence of autonomous vehicles. Those outlined in this paper should, no doubt, be included, but there are others that will inevitably result from an in-depth discussion of the issue. Following this discussion, those tasked with regulating should attempt to weight each of the outcomes and place them into a framework similar to the one articulated in this paper. Regardless of the framework, its goal will be to arrange the regulatory environment such that the

benefits are maximized and harms minimized, but one of the key questions will be for whom. As you saw in this paper, achieving this goal on the societal level might result in regulation that looks much different from that oriented toward the personal level – recall the prisoner’s dilemma arising from a focus on self-preservation.

Following agreement on an evaluative framework, regulators must begin to enact policy. This piece is most important because complex problems can often lend themselves to discussion and debate that result in policy paralysis. In other words, there are so many issues at hand when thinking about regulation of autonomous vehicles that it will be tough for governments, manufacturers, and consumers to agree on the policies that ought to be implemented. Regulators need to be cognizant of this outcome and keep in mind that breaking regulation into smaller pieces and enacting them separately might better appease all interested parties. As regulators navigate this complex environment, they will also want to remember that the government might also need to play a substantial role in the promotion of autonomous vehicle through marketing efforts; AVs require an incredible amount of trust from their passengers, and this is fragile and will be difficult to earn. This is important to remember because any misstep in regulation could potentially result in a public backlash that renders the initial goal of regulating impossible to attain. But the complicated and fragile nature of the regulation of self-driving cars is not to say that regulators should shy away from the challenge. It is a set of issues from an inevitable technological advancement that must be tackled with confidence and urgency.⁵⁰

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