Autonomous Vehicles

Engineering Ethics, Summer 2017

Discussion 1F

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0. Executive Summary

Autonomous vehicles have been researched and discussed for many years. In the late 20th century, the mainstream idea was to provide the guidance data by comprehensively constructing the road maps. Such idea is now achieved by the satellite navigation systems. With the development of global positioning system (GPS) navigation, onboard sensors, and associated driver assistance systems (ADAS), people can now get accurate road information self guiding cars. However, there are a few challenges needed to be solved before the popularization of automated driving.

One of the main hurdles for autonomous vehicles is the technological precision. One example would be that sensors are only able to identify pedestrians 95%. This means five percent of people can not be recognized as human to the driverless cars. Although current technology is well-developed, it is not enough for automated driving. Can the sensor still work in extreme weather or special situations including snowy days or hand signals? We should not allow any potential errors because it relates to life and property safety. Even if we solve all the technical problems, we can not make sure there would not be any malfunctions in for the thousands of hundred sensors on the autonomous vehicles.

Even if there are no technological malfunctions, ethical issues are prevalent. For example, if autonomous cars meet a dilemma where it has to decide who should be the victim in an inevitable accident, who should be responsible for the accident? Would the owner of the autonomous vehicle, the manufacturer, or the software engineer take responsibility? At what point should the driver take control of the vehicle? Should absolute trust be placed on a computer? There are a significant amount of ethical issues that need to be addressed in regards to autonomous technology.

One of the controversial aspects of driverless technology, is in regards to the ethics of autonomous cars. When any type of decision making is left to a machine, there seems to be a concern regarding which principles or morals the machine will act upon. One of the main points of having artificial intelligence in cars is the benefit of reducing the amount of accidents caused by human error. One of the primary selling points for driverless cars will probably be the increased safety and security. However, letting the machine make life or death decisions may be one of the most controversial points raised when discussing the morality and ethics of driverless cars. Many questions will have to be answered, such as how a car should react when faced with situations similar to the trolley problem and how that will affect the overall safety of the car.

Autonomous vehicles bring a technical and ethical issues that will have to be addressed by future programmers and engineers. One of these primary problems is the "handoff" problem, which talks about the issue that arises when an autonomous vehicle has to turn over control to the driver. Most companies have moved completely away from the handoff problem, since it is easier to just create a vehicle that is fully autonomous. Eventually driverless technology will reach a point where vehicles will be able to make decisions in a substantially more efficient manner than humans. Once that point is reached, many ethical problems will have to be solved relating to the decision making of autonomous vehicles. The most common ethical problem proposed by programmers is the trolley problem, where one has to choose the lesser of two evils. Many studies have been conducted in regards to that situation, and most have come to the conclusion that drivers favor utilitarian ethics.

Although it seems that through simulations and extensive research a universal code can be found, there are societal issues that prevent this from happening. Those include distrust in the technology, variation in public opinion, and differences in consumer interest. In order to solve these issues and successfully introduce autonomous vehicles, some solutions are suggested such as: programming an ethical network in the vehicle, modeling human behavior, and increasing awareness and acceptance of autonomous technology.

Autonomous vehicles, like their gasoline brethren, have significant environmental considerations that raise both technical and ethical concerns. The main goal for the conversion to an all electric fleet of cars is to reduce the carbon footprint produced by transportation. To do this, autonomous vehicles seek to increase the efficiency of everyday commutes through implementing car trains, reducing vehicle weight, and utilizing renewable sources of energy. Automotive corporations are able to achieve these goals through the use cutting edge hardware such as lithium ion batteries and sensor devices, and innovative software. These milestones cannot be achieved without raising some ethical concerns. Environmentalists and journalists are concerned about the drawbacks of converting to a completely electric fleet of cars. These concerts include include the reduction of carbon emissions, the end of life disposal of these electric vehicles, and the effect on local environments. For each of these ethical questions, automotive companies can implement both technical and non technical solutions to push the autonomous vehicle agenda forward.

Autonomous vehicles will dramatically affect the job market and economy, for both good and ill. The trucking industry may become fully autonomous, displacing many workers. Additionally, traffic officers would no longer be needed. Nor would drivers for ride-sharing services such as Lyft and Uber.

However, the new industry may create many jobs in computer science, manufacturing, research and data collection, urban development, and city planning.

In terms of law and policies, a lot of regulations need to be modified by the lawmakers from federal level and the State level. Different states in U.S. are competing with each other in legislation, trying to get a leading spot in the development of driverless vehicle industry. Michigan is the state that has the most progressive autonomous vehicle legislation. Driverless cars testing are allowed on street and autonomous car ridesharing services are permitted 2016. Compare to Michigan, lawmakers in California are more cautious about the new technology. A new proposal on driverless car legislation was released in 2017 and it shows Californians tend to ensure the safety of the new technology. In federal level, the Congress and the Senators shows great interest of the new industry. The variations in traffic laws in different states could be a challenge to the automobile industry.

Liability of driverless vehicles is one of the major concerns of the public. The 2016 Tesla Crash was a great example to analyze. The driver of the Tesla died after his Tesla ran into a truck and the Autopilot wasn't about to avoid the crash. The family of the driver sue Tesla for unethically releasing non-fully develop Autopilot system to the public. Investigation shows that it's the driver's responsibility in the crash and clear the accusation of Tesla.

Ethical concerns for driverless vehicle legislation are discussed by the public. Automobile industry might violate some ethical frameworks and the government should regulate their behaviors using laws and policies. Solutions are recommended for the legislation in federal and in states to integrated the new technology into our society smoothly.

1. Introduction

1.1 Methodology:

In the discussion section, we decided as a group to choose the topic of autonomous vehicles. We first broke up the duties to 6 subtopics: Safety-Moral, Safety-Products, Environment, Economic, Law and Policy, Advantages and Disadvantages. However, we found that the subtopic-Advantages and Disadvantages- has lots of potential overlaps with the other five subtopics. Dr. Browne recommended we move the subtopic-Advantages and Disadvantages- as the problem statement and background.

During the summer session, our group met twice a week during discussion to exchange ideas, update personal progress and revise each other's work. We created a google drive folder and used Google Docs to research across internet. Table 1.2 is our group's RAM Chart which is used to organize the tasks and duties for the report.

1.2 RAM Chart:

Table 1.2 : RAM Chart

	Ismael	**Jordan**	**Matthew**	**Han**	**Yuntian**	**Daxuan**
Front Matter	**P**	**R**	**P**	**R**	**P**	**P**
Introduction	**D**	**D**	**D**	**D**	**D**	**P**
Problem Statement & Background	**D**	**R**	**D**	**D**	**R**	**P**
Safety - Moral	**P**	**D**	**R**	**D**	**D**	**R**
Safety - Products	**R**	**P**	**D**	**R**	**R**	**D**
Environment	**R**	**R**	**P**	**R**	**D**	**D**
Economical	**D**	**R**	**R**	**P**	**D**	**D**
Law and Policy	**D**	**R, P**	**D**	**R**	**P**	**R**
Ethical Discussion	**P**	**P**	**P**	**P**	**P**	**P**
Recommendations	**P**	**P**	**P**	**P**	**P**	**D**
Conclusion	**D**	**D, P**	**D**	**D, P**	**D**	**D**
References Cited	**P, D, R**	**P, D**	**P, D**	**P, D**	**P, D**	**P, D**
Final Proofreading	**R**	**R**	**R**	**R**	**R**	**R**

P = Primary Responsibility for Writing

R = Review for content, form, and grammar

D = Discuss

2. Problem Statement and Background

2.1 Problem Statement:

In today's ever more interconnected world, it appears like technology has something to add to absolutely every industry. The same applies to transportation, with self-driving cars fast becoming a hot topic. It is obvious that the popularization of self-driving cars or autonomous will modify the automotive and transportation industries forever. However, the road to driverless cars is not an easy one. We have to overcome a lot of technical, ethical and legal before we can enjoy the benefits of autonomous vehicles. According to a recent report from engineering and architecture group IBI, it has outlined several ways that driverless cars can solve and improve some of the current transportation issues, but also the potential risks if improperly managed. Several automakers have already exhibited their technology on driverless cars and most of these companies plan to roll out driverless vehicles by 2020. A lot of industry experts expect that fully autonomous vehicles will come to our lives just a few years later. This paper will introduce the potential advantages and disadvantages of autonomous vehicles.

2.2 Background:

According to Gilles Duranton, People spend 90 minutes in average to travel around by cars daily in the United States. Vehicles are the crucial elements in our daily lives. As the technology of driverless cars develops, driverless cars are getting closer to our lives. Just like all the other new technological advances, driverless cars will bring us benefits as well as drawbacks inevitably. When people immersed in the advantages such as lower fuel cost, convenient parking, and fewer accidents, we, in contrast, have to face the following disadvantages such as potential hacking, privacy concerns, and traffic laws. There are two perspectives—technical and ethical—to analyze.

One of the technological advantages of driverless cars reduces the opportunity cost of driving by ourselves. Opportunity cost is an economic terminology describing that the loss of potential gain from other alternatives when one chooses to do something. According to Gilles Duranton, "the most significant cost of traveling for most of us is the time we waste behind the wheel. Research shows that it costs one-half of one's wage." (Duranton, 2016). When using driverless cars, people can save lots of their times that they used to spend on driving by themselves. They can work, study, or enjoy the scenery since our cars can drive themselves. In addition to reduce our cost to drive, driverless cars also provide more freedom for someone who can not drive a car like the children, the old, the disabled and the sick. Parents don't have to send their children to school by themselves. Instead, the parents can use driverless cars to do

that. The old do not need to worry and can travel around by themselves. Driverless cars are like well-trained drivers for them and provide enough safety for them. The sick and the disabled also enjoy this type of benefits the driverless cars bring to them in the similar ways. Apart from saving time during the process of traveling, driverless cars can also save our time during the process of parking. Driverless cars can drop us first and then park themselves. For example, I usually spend 10 minutes on driving to UCLA from my home and then use about 5 minutes to park and buy a parking permit. Then, I have to spend eight minutes walking from parking structure to my classroom. However, if I could have a driverless car in the future, I can simply let it drop me in a place where is close to my classroom and let it park itself, which process can save me about 10 minutes in total.

Self-driving cars will make driving more efficient on all fronts. Because cars will be automated, human behavior will not participate in the driving and therefore reduces the chance of accidents caused by human error. The driverless cars also lead to less traffic congestion. It's expected that increasing number of driverless taxis will alleviate the overall traffic by decreasing the total number of cars on the road. What's more, because driverless vehicles accelerate and brake in maximum efficiency, they will also help increase fuel efficiency and reduce carbon emissions. In fact, "popularization of driverless cars could reduce as much as 300 million tons' CO2 emissions per year" (McKinsey, 2017). Greater efficiencies cause more energy savings for our fleet. By 2050, commercial light trucks, buses and heavy-duty freight trucks will reduce their fuel consumption up to 18 percent by 2050. The necessary weight of vehicles will also decrease due to the risk of accidents decreases. While maintaining their size, cars could become 25 percent lighter by 2030. The light weight could save fuel consumption up to 7 percent (McKinsey, 2017).

Although driverless cars have the potential for reducing energy consumption, it is also possible for energy consumption increases. Reducing travel cost, longer commutes, faster highway speeds and increased accessibility of driving cause elderly or disabled people more easily to travel around. According to an NREL study, "depending on how these factors play out, fuel consumption could decrease by 80 percent or increase up to 200 percent by 2050" (Robinson, 2017).

Driverless cars also bring benefit to the environment from the perspective of less fuel cost. Since people waste lots of gasoline during the process of unnecessary accelerating and braking, for instance, "either slam on the brakes nervously or put the pedal with a rush" (Biocca, 2017), driverless cars are environmental and economic.

Most importantly, "Driverless cars will dramatically reduce the number of casualties which is about 30,000 Americans die on the road every year" (Duranton, 2016). Since human errors cause 81

percent of traffic accidents (Biocca, 2017), driverless cars can significantly reduce the number of traffic accidents through less human behaviors participating in the driving process. Also, the speed limits can go up due to driverless cars' safer driving (Goodman, 2017). "For most people, we typically keep about 1.5 seconds' time distance from the vehicle in front of us" (Duraton, 2016). Driverless cars will reduce that time by four times or more since the sensor can respond more quickly than human beings and the braking distance will remain the same if the speed of the vehicles increases. "Driving today at 60MPH, it is insane to keep three feet behind the car in front of, but tomorrow, it could be the winning formula to safely reduce traffic" (Biocca, 2017). In this way, the faster speed will save our time on traveling and alleviate traffic jam. While the sensors can sense and react quicker than humans, it is not as good at recognizing data. For example, is that object in the road a cat, a man or a bicycle? Whether a vehicle be able to perform in a dry, flat climate as well as a snowy one with steep hills?

How do driverless cars cause less congestion? Autonomous cars can act on the crowded street much more efficiently than human drivers. For instance, at a stop sign, all the waiting automated vehicles can easily coordinate their actions. Unlike human drivers who need to wait until the car in front has already moved out the way when the red light turns to green, all driverless cars can start running immediately. In the crowded cities such as Los Angeles, this will improve the effectiveness and capacity of existing roads. Infrastructure planning will be enhanced due to driverless cars' abilities to reduce congestion and increase the efficiency of roads. When automated cars become the mainstream, many roads which are being planned today may turn out not to be needed anymore. In this case, driverless vehicles will reduce a lot of money on infrastructure investments worldwide.

Driverless cars also embody the power of multitasking. Although there are different levels of driverless vehicles, advanced levels only require the driver to monitor the drive to make sure it operate in the right way. As a result, drivers in autonomous vehicles can shift their focus to other tasks like meeting because they may not have to give their full, constant attention to driving vehicles. In addition, people can travel for a longer time because they do not need to pay their full attention to drive and are relaxed. Although the policies or traffic rules surround this issue, it's possible to extend the allowable driving time for the drivers.

On the other hand, driverless cars also have lots of disadvantages both from the technical perspective or ethical point of view. One of the technical challenges is computer vision process. How can we make sure the driverless cars can successfully capture and translate all the road signs? Can the technology of computer vision be mature enough to understand all the signs in all kinds of complicated

situation? Can the driverless cars recognize the traffic officers' gestures? I recently experience a perfect situation to illustrate this type of concern, the Westwood of Los Angeles recently had a large-scale blackout which lasts about 1 hour at 10 pm. The traffic signals on the road were all close and the streets were all dark. I happened driving on that night and all the drivers built the traffic order. All the drivers drove under 10 mph and passed the big intersection one by one. Could the driverless cars do the same or right things in that situation? Apart from that, according to Goodman, "A computer malfunction, even just a minor glitch, could cause worse crashes than anything that human error might bring about" (Goodman, 2017). Although we finally overcome all the technical and ethical difficulties, no one can make sure the all the components, parts and sensors could not have any failure in the future. If one of the driverless cars' parts broke down, it might cause a severe accident.

More optimistically, even if we can make sure all the components could work properly in the future or the driverless cars can immediately detect the hardware malfunction when some something goes wrong, how can people make sure the driverless cars' operating system to be safe enough to avoid any potential hacking?

In addition to technical issues, ethical issues are knotty as well. If autonomous vehicles can operate entirely on the roads, they will need to imitate or do better than the human decision-making process. However, some decisions are not merely to follow the traffic rules based on the road sign. They need to have the sense of ethics which is notoriously difficult to transfer to the codes for the computer to follow. Imagine in the future, the driverless car encounters a dilemma: it must either turn left and crash an eight-year old girl, or turn right and crash an 80-year old grandmother. The car's velocity would surely kill either victim on impact. Thus, the autonomous car must decide to turn one way or another. Which decision is ethically correct? Although such case is rare, how would we program the computer to behave if it ever encounters that case? For some people, striking the grandmother could be the lesser evil. The idea is that the girl still has a lot to enjoy. While the grandmother has already experienced the whole life. Further, Comparing to the adult, the little girl seems more innocent. We might agree that the grandmother's life is as valuable as that of the little girl. Nevertheless, if an accident is unavoidable, to weigh in favor of saving the little girl over the grandmother is unreasonable. If the grandmother was given the chance to choose, even the grandmother may insist on her own sacrifice, it is not reasonable.

According to the codes of ethics, neither choice is ethically correct. For instance, the Institute of Electrical and Electronics Engineers (IEEE) committed itself using the pledge, "to treat fairly all persons and to not discriminate others based on gender, race, religion, disability, age, national origin, sexual

orientation, gender identity, or gender expression" (IEEE, 2017). Therefore, to discriminate others based on their age is the kind of discrimination the IEEE prohibits.

The easiest ethical drawbacks to think of is the unemployment of most people like the taxi driver, bus driver, garage man, etc. Those drivers who rely on driving to earn money are weeded out due to driverless cars. Since there is fewer accident, the joint industries like garage have less business as well. How should the government deal with that huge unemployment?

While some people insist that driverless cars can improve the environment by costing less fuel and save a bunch of time due to the high-speed limit caused by its faster reaction time, Others believe that driverless cars will aggravate the environment and increase congestion since most people will buy a driverless car due to its convenience.According to Sami, people would buy themselves driverless cars if they find they are more convenient or they prefer their own autonomous car to ride-sharing service (Sami, 2017).

Since it is not the technical problem to choose a victim in an inevitable collision, people have to overcome lots of such ethical issues to design driverless cars. For example, how should the vehicle do when facing the dilemma when the cars can not avoid crashing a bunch of children or an old man? Should the vehicles always put the passengers' lives and comfort as a priority while driving? If an accident occurred, who should be responsible for the accident? The owner, the manufacturing company, or the software designer? Although these ethical questions are interesting, they are the major obstacles to design the driverless cars.

Meanwhile, many of the advantages of driverless cars including faster speed and constant velocity are based on the prerequisite that driverless cars are diffusive (Duranton, 2016). Since if only a small number of cars are autonomous cars on the road, human's driving cars and behavior still dominate the whole traffic condition. Consequently, the actual benefits of driverless cars are not noteworthy unless people popularize them.

How to make laws for driverless cars is also a hard task. There are lots of legal precedents over the last century about products liability litigation. The driverless cars' manufacturers get incentives from those legal precedents to make their autonomous cars as safe as possible. For most cases, they will succeed. However, despite these efforts, it is inevitable for automation systems to be defective and cause some accidents in the future. Although they are involved new liability questions, we should hold confidence that the legal system can resolve these liability issues.

In short, autonomous vehicles raised the liability concerns. Those concerns are reasonable and essential. However, the concerns can be addressed without preventing the consumer from accessing to the autonomous vehicles' benefits. Brookings Institution director Peter W. Singer observed, "We are still at the 'horseless carriage' stage of this technology, describing these technologies as what they are not, rather than wrestling with what they truly are" (Singer, 2017). Automation isn't merely replacing human drivers, just as human drivers in the first automobiles weren't simply replacing horses. It is the same pattern as thinking electricity can only replace candles. The influence of driverless transportation will change our lives in radical ways, and technology seems to be accelerating. As Singer puts it, "Yes, Moore's Law is operative, but so is Murphy's Law" (Singer, 2017). When technology does not work—and it will—thinking in advance about ethical design and policies can guide us how to deal with the responsibilities.

Considering the complex issues derived from driverless cars, we suggest it would be better to maintain some part of the human manual control. A lot more work are needed to be done before self-driving cars are ready for the mainstream. We still have a long way to popularize the autonomous vehicles.

3. Technological Issues

3.1 Safety - Technical:

3.1.1 Background:

One of the major areas of ethical concern for autonomous vehicles is their technical safety. The safety of a driverless car can be split into two main topics. First, the autonomous safety of the vehicle. This covers the sensors, redundancies, and programming of the vehicle to ensure accident prevention, and interfacing with both autonomous and non-autonomous vehicles. The second subtopic is accident safety. This area focuses on which crash safety features, such as seat belts, that should continue to be strictly regulated, and which should be updated or removed for autonomous vehicles. Automobile safety has been an iterative and expanding subject of concern for nearly one hundred years. One cannot draw a line in history to determine exactly where cars became as safe as we know them today. Rather, safety is an ever changing standard depending on the market demand, state laws, and available technology. Even though automobiles began to appear throughout the West from 1815 – 1880, it was not until 1922 that the first true safety feature was added to a vehicle: a four-wheel hydraulic brake system on a Dueseburg model A (Crashtest.org, 2016). By the 1930s, safety came more into the spotlight. Crash tests began in 1934, padded dashboards showed up in the '40s; 1949 brought the first standard disc brakes. In 1958, Volvo invented the three point seat-belt that is standard today. By the next year, it came standard on all Volvo's vehicles. 1966 saw the creation of the Department of Transportation. By 1979, the National Highway Traffic Safety Administration started crash testing vehicles and publicizing their results. Offset, side impact and roof impact tests were started in 1995, 2003, and 2009 respectively (Crashtest.org, 2017). In the present and coming years, there is an increased interest in more thorough 5-star crash test ratings, more detail on the specifics of each vehicle, where its strong and weak points are, and a quickly growing interest in enhanced safety technology (National Highway Traffic Safety Administration, 2017). Enhanced safety technologies are aids to drivers such as accidental lane departure warnings, drowsy driver recognition, rear-view cameras, automatic emergency braking, and assisted parking. These hybrid technologies are slowly taking control away from drivers and bestowing it to the vehicle, step by step leading to vehicle autonomy. Even though safety features and measures are updated every year, worldwide vehicular safety is far from where it needs to be. According to the Global status report on road safety 2013, 1.24 million people still die from road traffic deaths every year. Only 7% of the global population have robust safety laws on five important risk factors that the organization recognizes: drinking and driving, speeding, motorcycle helmets, seat-belts, and child restraints (World Health

Organization, 2013). Worldwide, the leading cause of death for people aged 15-29 is a car accident (World Health Organization, 2017). In contrast, vehicle safety has come a long way in the U.S. and Europe; total deaths and deaths per 100,000 people have both been declining in the U.S since the 1970's. But as always, there is still much more to be done both in the U.S. and abroad: 32,000 to 35,000 people are still killed each year in car accidents in the United States (IIHS-HLDI). If autonomous vehicles can deliver on their promises of safety, thousands of American lives will be saved, especially in younger age groups.

3.1.2 Technical Safety Goals:

According to the National Highway Traffic Safety Administration, 95% of all car accidents are the direct result of human error. The promise of autonomous vehicle would be to reduce the number of traffic accidents significantly. Through the use of a wide array of sensors, machine learning, and computer programming, autonomous vehicles promise to make traveling safer for all. All accidents where the primary cause is drunk driving/driving under the influence of drugs, speeding, the elderly, distracted driving, texting while driving, or sleeping while driving would all vanish. In a fully autonomous vehicle system, the disabled, children, elderly, those intoxicated or those in need of emergency medical care could all safely travel in an autonomous vehicle without risking anyone's safety. This is the promised future, but the road there is full of difficulty and challenges.

3.1.3 Technical Safety - Overview of Current Technology:

Currently, automakers are using or researching ultrasonic, image, RADAR, LIDAR, and cloud sensing (Gilbertsen, 2017). Ultrasonic sensors use sound waves and echolocation to determine where objects are near the vehicle. Currently, ultrasonic sensors are only useful for low speeds and very small ranges, such as for automated parallel parking. Image sensors use cameras to read traffic signs, traffic lights, lane markings, and for scanning the road. They are currently limited in range and poor weather or light conditions can have an adverse effect on their performance Also, currently the sorting and recognition algorithms only correctly recognize pedestrians 95% of the time (Gilbertsen, 2017). RADAR sensors use electromagnetic waves to determine the distances and velocities of nearby objects. One shortcoming is that they currently are mostly 2D and cannot determine the height of the object the waves strike. LIDAR sensors use invisible laser beams to measure distances over a 3D array of fine points, creating 3D images of the vehicle's surroundings. This can be paired with software to determine if an object is a rock, tree, garbage car or child. A shortcoming can be processing time and the expense of using rare earth metals in LIDAR technology. Cloud sensing is a more distant possibility than a current reality

at this time. The idea is to link every vehicle up to a real-time map. All vehicles share and have access to the cloud information. If one vehicle hits traffic, all vehicles on the cloud can be instantly updated and adjust accordingly. One shortcoming is that there needs to be many, possibly even a majority of autonomous vehicles on the road before this option becomes useful. Now that the basic safety features have been described, a more thorough investigation of the technical issues and challenges facing autonomous vehicle safety can be discussed. **(See Section 4.1 for Technical Challenges and Solutions).**

3.1.3 Technical Safety - Proposal of Standard Safety Features:

Building off the United States' long history of improving vehicular safety as outlined in **section 3.1**, lawmakers and manufacturers must continue to hold the safety of drivers and pedestrians paramount in the coming autonomous age. Until enough data can be collected and analyzed from autonomous vehicles operating at large in the public, existing laws regarding passenger safety should be kept to guarantee that those in driverless vehicles are at least as safe as those in driven vehicles. This means that until autonomous vehicles can empirically show their superior safety, they must be treated as equal to driven vehicles. If the time comes, passenger safety laws can be updated for autonomous vehicles if it is shown that the laws are outdated and no longer applicable. Until then, all passengers must be treated as equally at risk. First, to maintain the wellbeing of the public, interior safety features such as airbags, seat belts, seat placement, etc. must be at least as good as standard vehicles. Car seat laws for children and infants must still be enforced as well as seatbelt laws conforming to each state's regulations. Also, for manufacturers to treat their customers ethically, standard warning lights and signals on the dashboard must be kept including low oil, low fuel, low tire pressure, high engine heat, etc. In addition, automakers should supply warnings specifically pertaining to the autonomous vehicle. For example, if a distance sensor breaks or is obstructed, a warning should issue. Or, if the onboard computer cannot connect to an exterior network, the passengers should be notified. All pertinent and available information about the mechanical and automated processes of the vehicle should be provided to the passengers so that they may make real time decisions on what they deem is the safest course of action. In conjunction with these interior safety measures, current cabin exterior safety measures must also be rigorously followed. Crumple zones, structural reinforcements, safety glass windshields, soft bumpers, and safety crash ratings must all still be part of the autonomous vehicle. The National Highway Traffic Safety Administration (NHTSA) should consider adding autonomous specific crash safety tests. So, in addition to side impact, front impact and all the other standard testing. Regulated testing should be put in place to measure the effectiveness of autonomous sensors, reaction time, failure rate, etc. Finally, autonomous vehicles are being equipped with the latest sensor technology. The NHTSA should monitor which sensors each

manufacturer is using on their vehicles, their effective ranges, their strengths and their weaknesses. (**See Section 5.1 for Ethical Questions and Concerns for Technical Safety)**

3.2 Safety - Moral:

Currently, autonomous cars are being developed in a way that requires the least amount of human input possible. This is due to a problem that many engineering companies have run into when focusing on driverless technology. The problem is that, when testing self-driving cars with a person behind the wheel, the person failed to be engaged in the driving, possibly due to the trust the person gained as the car kept driving. This causes a problem because the person behind the wheel should be consistently watching the road just in case there's an emergency, this is known as the handoff problem (Davies, 2017). The solution of many self-driving companies was to ignore the handoff problem, and just focus on making the car completely autonomous, in order for it to not require the driver to be engaged.

However, there are some companies that believe that ignoring the handoff problem is not the way to go. For example, Audi has recently unveiled it's newest version of it's A8 sedan, that relies on driver input for maximum safety. This car tackled the issue by focusing on the technical sides of the problem, and providing solutions such as facial recognition and visual/audio cues that alert the driver when something is wrong. The car also is also aware of when the steering wheel is being touched or held and for how long, making it easier for the car to determine if the situation is appropriate for a handoff. The car comes with safety measures just in case the driver isn't responding to any of the cues, such as initially tightening the seatbelt and pumping the breaks, followed by slowing down to a stop with the flashers on and finally unlocking the doors (Davies, 2017). Cars like the Audi A8 bring to light questions regarding how autonomous a car really should be and if human decision making will be valued more than the decision making of artificial intelligence.

Autonomous vehicles have the potential of eliminating up to 90% of traffic accidents, as recent data suggests. The benefits seem to outweigh the costs with respect to autonomous vehicles, but there are situations where a crash will simply be unavoidable and the vehicle will have to make a tough ethical decision (Bonnefon et al., 2016). Usually these scenarios involve decisions that involve the person behind the wheel and the people that may be in danger in the immediate surroundings. Hopefully situations where a decision has to be made between two equally unfortunate outcomes never arise, but if the amount of driverless cars on the road are going to increase as predicted by many in the tech industry, then the cars must be prepared to make those tough decisions (Bonnefon et al., 2016). These hypothetical situations have to be treated before driverless vehicles become just another commodity, but this also implies that the

population needs to agree upon a certain set of rules that the vehicle will base its decisions on when faced with these types of situations. A challenge that the driverless car industry and regulators will have to face is the discussion of ethics and morality in regard to autonomous vehicles, where the public's opinion will carry a significant amount of weight since they will be the consumers.

To discuss the ethics and moral decisions encompassed by autonomous vehicles, one must first look at how human drivers make their decisions. Currently, most of the automated vehicles rely on human drivers to take over if part of the system fails, or if the vehicle encounters something unknown to it's algorithm, such as a construction site. But it has been seen through recent studies that participants can't really be relied on, since they take on secondary tasks and have too many head turns behind the wheel (Goodall, 2014). A recent paper by Jeffrey Gurney presents four different scenarios that are all examples of drivers that are not suited enough for the autonomous vehicle to hand over control when faced with a complicated decision. Gurney first presents the "distracted driver," defined as a user that is engaging in a task other than driving while behind the wheel, relying on the autonomous vehicle completely (Gurney, 2013). The second type of driver that brings trouble to the discussion is the "diminished capabilities driver," which is defined as a person whose driving capabilities are reduced to reasons like old age or intoxication (Gurney, 2013). The third case is a "disabled driver," which is a person that can't drive a vehicle due to a physical disability, in this case the person is also relying entirely on the car when faced with a negative situation (Gurney, 2013). The last case presented is interesting because it consists of a driver that is at first engaged with the driving but eventually gains enough trust that the person wants to believe that the car is good enough on its own (Gurney, 2013). This can go wrong since this persons is actually capable of recognizing the problem beforehand, but may decide not to take action and consequently result in an accident. This type of irrational and sometimes unfavorable behavior is what leads to the discussion of the ethics of decision making when behind the wheel.

In the future, when a truly autonomous vehicle is produced, it will be able to make accurate decisions with the help of software and sensors that will process data with a near perfect ability. Therefore, autonomous vehicles will be able to overcome the limitations experienced by humans (Goodall, 2014). The vehicle will be able to process the information and recognize if a crash is unavoidable, then decide on what the most optimal approach to the situation will be. This is an improvement to human driving since the decision will be based on different measurements, such as overall safety, the percentage likelihood of the desired outcome, and just overall higher precision than a human could ever calculate (Goodall, 2014). Now, this sounds great on paper, but it has to be noted that those precise and optimal decisions that the vehicle will be making were based off lines of code that may

have been written by a programmer from the very beginning. Though programmers will most likely have an agreed upon approach to avoiding accidents altogether, there will be instances where key decisions will have to be made that may put the lives of the driver and the passengers in jeopardy.

3.3 Environment:

Autonomous vehicles would be a huge step forward for technology and provide a great service for society as a replacement for modern transportation. The main goal for these all electric, autonomous vehicles is to bring about the reduction of global greenhouse gas emissions through the efficient use of clean and renewable energy, reduction of the dependence on oil, and increased efficiency (Wu, et al., 2016). It will also be available as an easy, and convenient means of transport for civilians while simultaneously upholding the safety standard set by the vehicle manufacturers and lawmakers. Unfortunately, the cost and benefit analysis for these vehicles differ from region to region indicating its global impact is inconclusive. Benefits from the implementation of autonomous vehicles include fuel efficiency, shorter travel times, and lower emissions while some of the costs include new types of harm to our environment, loss of life, and loss of rights. For autonomous vehicles to come into play, these are the changes that need to be implemented and embraced. It is imperative that the commercialization of fully electric autonomous vehicles consider both positive and negative environmental impacts before they are implemented. Some of the key and pressing matters regarding the use and commercialization of self driving cars would be the amount of fuel saved via electric transport, the changes to infrastructure required to accommodate for electric cars, the robustness of the software and hardware designed for passenger safety, and the complications of material recycling.

In an article by Time, Justin Worland talks about how self driving cars have the potential to either help or decimate our environment. He talks about how all electric, automated vehicles could either reduce the energy demanded for transport by 90% or increase consumption by more than 200%. The study that he based his article on was conducted by the Department of Energy (DoE) who was tasked with the analysis of the carbon impact that self driving cars would have. They based their conclusion of possible environmental effects on the efficiency and ease of transport that autonomous vehicles have to offer society. For example if someone were to leave an article of clothing at home and drove to work, they are inclined to leave it at home to avoid the hassle of driving back and forth (Worland). On the other hand, if autonomous vehicles were implemented that same individual may just take a ride back and forth to get their belongings. Another reasoning that he presented was that in places like New York, parking a car in a place can be very expensive and time consuming, so autonomous car owners could take the

cheaper option of allowing the car to drive itself around the block for an indeterminate amount of time. This would also increase the amount of energy needed for cars on a daily basis and consequently increasing the distance driven.

Even though there is the possibility increased fuel consumption, self driving cars can also reduce the energy required for everyday commutes because of weight reduction. The main idea for the utilization of autonomous vehicles is for transportation to be safe. This means that the safety equipment found in today's "safest" cars will become obsolete since computers can have faster and safer responses to unexpected events than humans could ever achieve. This means in an unfortunate situation, where a normal or even a skilled driver would lose his or her life, a computer can effectively maneuver the passengers to safety. Because the passenger is in the hands of a safe driver, automotive manufacturers have to option of ditching the bulky, deadweight safety equipment weighing down our current cars and create cars that are lighter (Worland). Some of the safety features that was previously needed include mechanisms such as anti-lock braking systems (ABS), air bags, and additional reinforcements can now be removed and thus increasing the fuel efficiency of the vehicle.

According to The Economist, decreasing the total weight of the car is not the only option in making transportation more fuel efficient. They proposed that the use of highway trains was another fuel efficient solution which is only feasible through the utilization of autonomous vehicles. Highway trains is the concept of lining up cars with a common or similar destination in a "train" like arrangement and having them travel together. Cars could freely enter the train from the end of the line and leave when their destination approaches since there was no physical connection between each car. In a 1995 study conducted by researchers from University of Southern California, they found that cars traveling in a car train would increase the efficiency of transport by up to 30% (Economist) though aerodynamics alone. They concluded that the reduction of drag for each car after the first would ultimately benefit the environment through lower carbon emissions.

Autonomous vehicles offer the promise of offering shorter travel times and higher fuel efficiency through the use of pre-determined commuting and commerce routes. Recently, Uber has obtained a small, 91 employee autonomous delivery truck startup in the attempt to bring a fleet of driverless cars to the market (Economist). Uber argues that the implementation of these trucks would allow software to decide the shortest and most fuel efficient routes rather than relying on a truck driver intuition. In the near future, truck drivers would still be required in the vehicle while it is en route. Uber explains that autonomous vehicles can bypass the need for stops by allowing drivers to sleep while the truck continues

its journey. This increases the fuel efficiency per delivery by minimizing the number of stops that the truck needs to make. This ideal of fuel efficient travel can be extend to regular commuters since it is also common for everyday traffic to consume more fuel because of "stop and go" traffic and driving patterns. The implementation of autonomous vehicles would help reduce the greenhouse gases emissions through better control of speed. It is in human nature, especially in Los Angeles, to accelerate and use more fuel when the lanes are unoccupied. Unfortunately, this type of driving is very inefficient since it has been determined that "fuel economy typically decreases at speeds over 50 miles per hour" (Worland). But with when the computer dictates the driving style, it is evident that the car would be almost perfect at maintaining the optimal speed for fuel efficiency (Bloomberg). Therefore, the use of autonomous vehicles would prove to make regular transportation more fuel efficient and better for the environment since nearly one quarter of the world's greenhouse gases comes from transportation (Worland).

Ideally, the transition to an all electric fleet of vehicles would bring the promise of a lower carbon footprint and cleaner emissions. This is not necessarily the case as highlighted by an article in Nature magazine. In the magazine, it discusses about the possibility that electric vehicles are more harmful to the environment when compared to their gasoline counterparts. Their reasoning behind this is that in different regions of the United States, electricity is produced in significantly different ways. In cities located in the western portion of the United States, such as Los Angeles, a significant portion of energy is produced through clean and renewable methods such as solar panels, wind turbines, and dams. While on the other hand, areas in the midwest obtain most of their electricity through coal powered plants.

We can see the distribution of energy sources in the following figure:

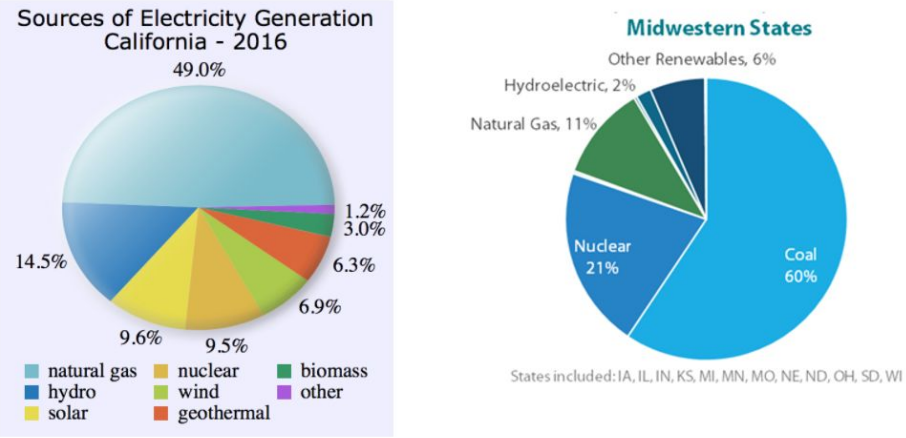


Figure 3.3.1: Energy Generation by Source: California (U.S. Energy Information Association) (Left) and the midwest (ACORE, 2013) (Right)

This poses the question of whether or not transitioning to all electric vehicles are actually beneficial to the environment or just another way to pollute the earth with our emissions. At the time the article was written, the government was paying a $7,500 subsidy to buyers who purchased an electric vehicle which potentially paid individuals to make the environment even dirtier. This study would be a duty for the engineers to evaluate actual benefits of the electric vehicles.

Based on current technology, lithium-ion batteries are the clear power storage choice for any autonomous automobile maker because of its qualities such as high energy density, long cycling life, and wide operating temperatures. Even with all these beneficial qualities, eventually these batteries will need to be recycled and processed. The immediate effects that we will notice from the recycling of the Lithium-ion batteries would be the environmental impacts that the recycling centers will experience in the regions they are implemented in. The recycling of Li-ion batteries involves the the separation of heavy metals through the process of leaching (Xiaohong, 2017).

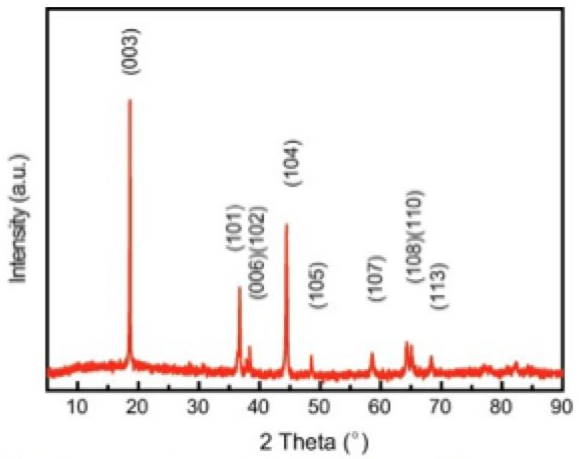


Figure 3.3.2: Concentrations of several toxins produced through lead battery recycling and their concentrations (Xiaohong, 2017)

Through leaching, the metals are subject to reductants such as H_2O_2 and $NaHSO_3$ and produces a low pH leachates posing a potential threat to the environment and subsequent waste water treatment. This means that the recycling centers must take the utmost care that there will not be an environmental spill. In recent history, Lead batteries were the 'go to' batteries and were found to be shipped overseas so that other countries could be paid to deal with their recycling. Taiwan was one of those countries that received lead batteries to be recycled. Unfortunately because of lax environmental regulations at the time, the Taiwanese environment and citizen health paid for the benefits of American companies. Regions in the proximity of the plant began to experience some environmental fall outs such as fish in local regions dieing, and citizens experiencing severe health problems which include chemical burns, lead poisoning, nervous system issues, reproductive issues, and variety of organ failures (I-chia, 2011). In Figure 3.3.2 above, we can see that there is a high concentration of toxins and other hazardous chemical when lithium ion batteries are recycled. Once all the environmental damage and health problems decimated the local community, the recycled goods were then shipped back to the United States, the vicious cycle could restart. In Figure 3.3.3, we can see the pH of ammonia as it is released into the environment when it is at several different concentrations. We can see that as the concentration increases, so does the pH. This increase in pH, like the leachates or even the heavy metals from lead acid battery recycling, could pose a threat to possibly destroying local environmental conditions (Xiaohong, 2017). Until we are able to effectively recycle the Li-ion batteries, it will be irresponsible to flood the market with even more heavy metals and toxic fumes.

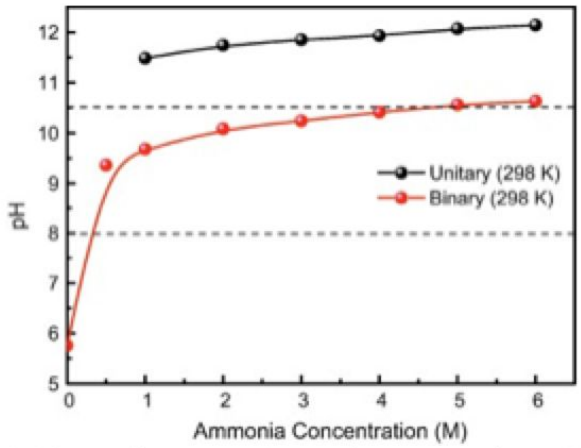


Figure 3.3.3: pH changes vs. Ammonia concentration at 298 K (Xiaohong, 2017)

Autonomous vehicle introduces several concerns such as how its performance would be on actual roads. Currently Uber and other large companies such as Google are conducting field tests to prove that their cars are ready. In a ABC article published in June, 2017, Jake Evans covers how autonomous vehicles are struggling with the accurate animal detection system when confronted with kangaroos. Even though this seems like a very localized issue, this shows that the software engineers clearly have not predicted every type of situation and would require a more robust program to operate the cars. This

shows that although in the present tests that the cars pass does not mean that it can handle any situation thrown at it. This can severely damage the wildlife since if for instance, the kangaroo was central to an ecosystem and all the autonomous cars could not correctly accommodate for them, then these cars can destroy the local ecosystem.

The introduction and utilization of fully autonomous electric vehicles is promising in its potential to provide a sustainable, safe, and efficient mode of transportation for all. Currently, we cannot determine its full impact on the environment until it has been implemented on a global scale, but we know change must be made in attempt to save our dying planet. Currently the main objective to for autonomous vehicles is to provide a way to reduce the carbon footprint for transportation. To do this, the vehicles are tasked with increasing efficiency through the use of only clean energy. If this technology were implemented on a global scale while maintaining the ethical economical transactions, autonomous vehicles could pave the way for a new and cleaner way of life.

3.4 Law and policy:

Since driverless vehicle have not existed before, new laws and regulations need to be made to regulate the technology. America was called the "country on the wheel," meaning automobile culture has played a significant role in people's lives and in society. Any new regulations and any changes of the old laws regarding driving would be widely discussed.

States have started competing in driverless car legislation to get a leading spot in the development of the new automobile. As early as in 2011, Nevada passed laws to become the first state to legalized driverless cars on public roads. This action stimulated states with a history and tradition in the automobile industry, such as Michigan and California. To catch up with Nevada, these states' lawmakers passed and implemented new laws to fill up the lack of autonomous car regulation (Lee, 2017). Also, from a federal level, Congress and Senate have also helped speed up the development of the autonomous automobile industry. Traffic laws in different states are various and it is a challenge for automobile industry when they develop new automobile vehicle. Liability of autonomous car accident is also a concern. The case study of 2016 Tesla crash is a good example to clarify the responsibility in the accident.

3.4.1 California:

Although California has so many leading high-technology companies developing driverless vehicle technology, the state's lawmakers took the new technology seriously and spent a long time to pass some actual regulations in the past few years. Compared to other states, the hesitation of California DMV was criticized by the automobile industry to be "draconian and anti-innovation" (Mitchell, 2017). Since the technology of autonomous driving wasn't fully developed, DMV of California required driverless car companies to take public safety into consideration. After years of criticism from the industry, California lawmakers finally announced a new proposal in March 2017 to supervise the utilization of driverless vehicles on public roads, including testing and deployment (Mitchell, 2017). According to the proposal, California DMV requires autonomous vehicles to follow both the federal law and the State traffic laws. Law enforcement agencies would also have access to take immediate control of the vehicle by a remote operator if necessary. On top of that, the new proposal allowed the deployment of driverless taxis and the sales of driverless cars to the public.

The new regulation removes and softens some of the tough restrictions on the autonomous automobile industry, compared to the previous version of the proposal in 2016. In the new proposal, a testing company only need to merely report the test plan to the local DMV and are not required to submit the testing data to the law enforcement after each crash. On one hand, the new proposal lowers barriers facing the autonomous vehicle industry and speeds up the development of self-driving technology. On another hand, the public shows concerns that some companies may utilize the new proposal to unethically develop flawed vehicle. A Santa Monica-based consumer watchdog criticized the proposal to be "too industry friendly and don't adequately protected consumers." (Mitchell, 2017).

3.4.2 Michigan:

Compared to California and many other states, Michigan's lawmakers turn out to be more progressive in driverless vehicle legislation. According to Michigan Economic Development Corporation, Figure 3.5.2-1 legislators legalized the testing of vehicles without steering wheels, and ride-sharing services of self-driving vehicles. Also, they allowed the vehicles

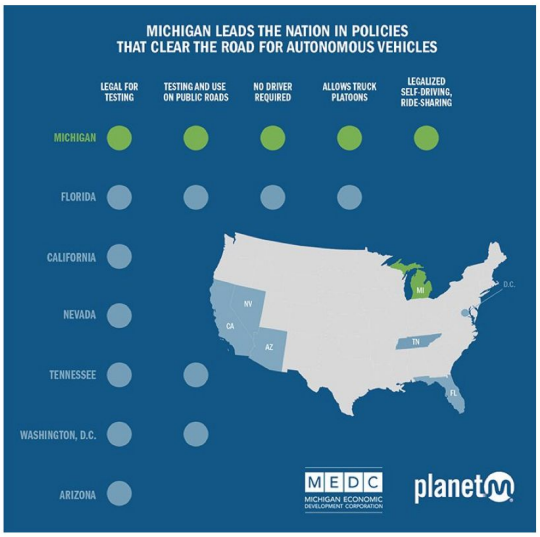


Figure 3.4.2-1 Current Autonomous Vehicles Policies by States (MEDC, 2016)

to be sold for public use when the technology is proved to be fully-developed (Achtenberg, 2016).

Because of the minimal restrictions on driverless vehicles, Michigan attracts attention from the industry. On the same day that Michigan legislation announced the new regulation in 2016, Google opened a 53000-square-foot, self-driving vehicle development center outside Detroit (Mitchell, 2017). The cooperation between Michigan and Google shows the determination of Michigan of carrying forward the automobile industry tradition, and its attempts to gain a leading position in the revolutionary technology of the 21st century.

3.4.3 Federal:

Legislators in Washington DC have realized the innovation of driverless car technology and showed interest in speeding up the development of autonomous vehicles. Recently in June 2017, a bipartisan group of senators developed a package of bills regarding driverless vehicles (Zanona, 2017). According to the lawmakers, their bill would put safety as priority and distinguish the role played by federal and states, because the conflicts between federal laws and state laws is one of the major concerns of the automobile industry (Zanona, 2017). Since current traffic laws are various among states, such as speed limits on a freeway, the automobile industry prefers federal level regulations instead of the patch-work of laws from different states. Uniform laws mean their product doesn't need to have different specifications in different states. In addition, some of the current regulations need to be modified. For example, current laws required every single automobile to have a steering wheel and floor pedals. Driverless car manufactures need to apply for exemptions for their new product, but only 3,500 exemptions have been granted each year (Zanona, 2017). To help develop the new technology, such outdated regulations should be updated or removed.

3.4.4 Variation in Traffic Laws:

In the United States, a major shift that needs to occur for autonomous vehicles to be universally applicable is more homogeneity of traffic laws between the 50 states. Currently, each state has its own laws regarding drinking and driving, speeding, seat belt laws, highway laws, and passing laws to only name a few. To highlight the messes and convoluted differences between states, here is a summary of seat belt laws throughout the different states:

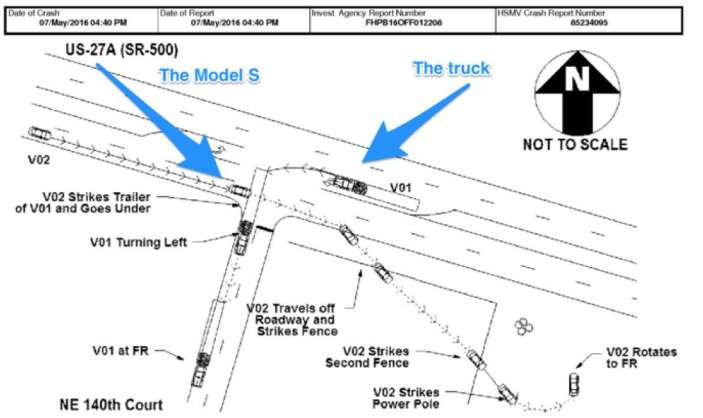
> 34 states… have primary seat belt laws for front seat occupants. Of these: 18… include rear seats as primary enforcement, 4 states include rear seats as secondary enforcement, [and] 12 states do not include rear seats. 15 states have secondary laws for adult front seat occupants. Of these: 6

> states also have secondary laws for rear seats, 9 states do not include rear seats. New Hampshire has enacted neither a primary nor a secondary seat belt law for adults… (Governors' Highway Safety Association, n.d.)

First, there are two types of categories, primary and secondary laws. Primary seat belt laws mean that an officer can issue a ticket for not wearing a seat belt. Secondary seat belt laws mean that the officer can issue a ticket for not wearing a seat belt only if the officer is also issuing a ticket for a different reason. This means that in states with only secondary seat belt laws, drivers cannot get pulled over solely because they were not wearing a seat belt. However, they may be ticketed for not wearing a seatbelt if they are pulled over for another reason, such as speeding. Not only do states split on secondary and primary laws, they divide further over whether the laws apply to only minors or adults and minors. Furthermore, states differ on how and if primary and secondary seat belt laws apply to front seat and rear seat passengers. And finally states differ on which ages belong to which age group, some consider 16 to belong to the adult category, some 17, still others put it at 18. This confusing system regarding seatbelt laws between states is not a unique example, each set of traffic laws is applied and interpreted differently in each state. As another example, interstate highway speed limit laws vary from state to state by as little as 55 mph and as much as 85 mph. Some states, such as California have different speed limits for cars and trucks. Both the seat belt laws and the speed limit laws are examples of how different each state's traffic laws are from another's, and the challenges this poses to autonomous vehicles. These issues are only between states. Once the scale is increased to different countries, the problems only grow; imagine an autonomous vehicle bought in England being imported to America. Now the signs, driving side of the road, and road markings have all changed. Humans are capable of relearning, and also developing a sense of how to drive in each area's traffic. The current adaptability required for autonomous vehicles to function smoothly across state and national borders may be too high of a challenge for current technology. A proposed solution is for the states to work alongside the federal government so that the laws and regulations regarding autonomous vehicles are more uniform than the laws regarding their driven counterparts. The United States government must be ahead of the technology of driverless cars. If it is not, automakers will self-regulate and states will each start writing their own codes and standards. This will create a nearly insurmountable challenge for autonomous car manufacturers as each must abide by the laws of the state they are selling and operating in. An autonomous vehicle cannot be trustworthy and viable if it is safe and legal in California, but not in Utah. Now that the background of automotive safety has been discussed alongside the current legal safety challenges and climate in the US, proposed safety features can be addressed.

3.4.5 Case Study: 2016 Tesla Crash

The recent 2016 tesla Model S crash brought in a lot of controversies upon the liability of driverless car in an accident. Joshua Brown, a former Navy SEAL member, died in a car accident on May 7, 2016 when driving his tesla Model S on Autopilot mode. The accident happened when Brown's Model S collided with an 18-wheel white tractor trailer because the Autopilot couldn't distinguish the white trailer from the background bright sky (Spector, 2017). Figure diagram 3.4.4-1, from Florida report shows that the tractor trailer(V01) was turning left and blocking the lane where Brown's Model S(V02) was in. The Tesla model S was torn apart by the force of the collision.



3.4.5-1 Diagram for 2016 Tesla Crash. (Highway Safety & Motors Vehicles)

Brown's family sued Tesla for releasing unreliable Autopilot system to the public. Tesla was accused of "not doing what a reasonable manufacturer would do" (Dave, 2016). Other automobile companies had developed similar technologies but they neither announced any of them to the public nor suggest customers using it. This argument placed Tesla in a vulnerable position because Tesla cut their testing period short in order to push their autopilot product into the market before its competitors (Dave, 2016). However, the founder of Tesla, Elon Musk, claimed that it was completely voluntary for the drivers to use Autopilot system and all the drivers were well informed of the risks. After the accident, a six months long investigation into Tesla's Autopilot technology was opened by the National Highway Traffic Safety Administration (NHTSA). The investigation concluded that there were no defects founded in the design or performance of Tesla's technology (Spector, 2017). The ethical controversy behind this case was whether the companies should push a non-fully tested product into the market or not. Due to the current autonomous mobile technology level, the autonomous driving system is not advanced enough to handle all situation on the road. Drivers need to have full engagement at all time when using Tesla's Autopilot. Brown was supposed to have enough time to react to the accident but he wasn't paying attention (Boudette, 2017). Since Brown had been informed about the risks, but he solely relied on the autonomous feature, he alone is responsible for his own death.

In the future, the liability of driverless cars in accidents need to be clarified by laws. Should the driver be responsible for the accident, or the artificial intelligence that controls the vehicle? What would be the punishment for AI after the accident? These questions need to be answered by legislators. U.S. car manufacturers might need to be responsible for the accidents caused by artificial intelligence because AI is part of the product they produced. However, if in some accidents, the vehicle requires the engagement of driver, but the driver was not paying attention, the driver might also need to be responsible for the accident.

4 Ethical Considerations and Issues

4.1 Safety - Technical:

The current main technical challenges regarding an autonomous vehicle's safety have to do with changing conditions. Currently, autonomous vehicles drive well when all the conditions are normative: the roads are clean and clear, the streets are well mapped, the weather is fine for driving in, etc. However, there are many technical issues when the conditions change to abnormal. For example, in rain, snow, or fog, autonomous vehicle's camera sensors can lose track of the lane lines. This is extremely dangerous. To combat this problem, Mercedes Benz has added 23 sensors to track objects such as roadside trees, guardrails, and oncoming traffic to help keep the vehicle in the lane, even if there are no visible lane lines (Boudette, 2016). Another technical issue involves physical changes to roads over time. Google's self-driving car relies upon precise, high-detail, 3D maps of roads. Even though such maps are becoming more and more common, they are still only available on select roads. Additionally, if there is construction, or a detour, or if the road changes lane numbers or if an intersection is redesigned, the maps must be updated accordingly or else the autonomous vehicle may not respond appropriately. Finally, autonomous vehicles have struggled with road surface conditions. A dark patch in the road may be a puddle, a pothole, a newer piece of asphalt, or simply a shadow. These pose challenges to automakers in programming the image processing. Some vehicles have struggled to interpret what they are sensing (Boudette, 2016). One hopeful solution is the development of more precise LIDAR sensors to scan road surfaces. Current LIDAR technology uses 905 nm wavelength lasers to scan the surroundings. Even though the laser light is near infrared and invisible to the human eye, it can still be focused on the retina and damage it, much like starring at the sun would. However, since the light is invisible to humans, they wouldn't even know they were damaging their eyes or looking into intense laser light until it was too late.

For this reason, the US has strict legal limitations on the intensity allowed for 905 nm laser light in public spaces. These restricts LIDAR on autonomous vehicles to a range of about 30-40 meters (Hecht, 2017). Luminar Technologies, a recent start-up, hopes it has a solution to the LIDAR problem. Luminar's product uses 1550 nm laser beams. The longer wavelength makes the laser much more eye-safe. This allows a LIDAR unit with 1550 nm beams to operate with a much higher intensity, extending the range from 30-40 meters to 200 meters. The Luminar LIDAR is using lasers that are 40 times as powerful, increasing range by a factor of 10 and resolution by a factor of 50 (Hecht, 2017). Besides the distance and resolution problems, LIDAR also struggles with cost. Conventional car-mounted LIDAR units have dozens of lasers and receivers mounted on the roof of the vehicle, spinning and whirling around multiple times a second, scanning the full environment around the vehicle. Unit costs are in the 10,000 dollar range; this is a steep cost for just a single sensor, when many economic automobiles cost $30,000 off the lot. Luminar's technology may help drive down costs too. Their idea is to use fixed LIDAR sensors on different sides of the vehicle; front facing, rear facing, side facing, etc. Then, each sensor only has one beam and one receiver. To move the beam around to cover the full surroundings, small mirrors inside the LIDAR unit adjust where the laser points. This design is mechanically simpler, and uses less beams and receivers. However, since the technology offered by this start-up is brand new, it remains to be seen how it will actually perform in all conditions.

One of the largest safety issues regards not the passengers of the autonomous vehicle, but those outside of it, especially pedestrians. Currently Google devotes a wide array of sensors and sensor types to detect pedestrians. Pedestrian detection has been a challenging, mistake filled, and costly problem for automakers. Some autonomous vehicles can only detect a pedestrian 95% of the time.

Researchers at the University of California San Diego may have found a solution though. UCSD engineers have developed a system that relies solely on video processing. This means their system only needs one type of sensor to detect a pedestrian. Previously, image processing has been a give-and-take; either the system works quickly through the use of cascading codes and is sometimes inaccurate, or the system uses deep-neural networks to engage in machine learning. This method is much more accurate, but is too time consuming to be used in real-time driving situations (Hsu, 2016). The engineers at UCSD combined both technologies for the first time ever, and have developed a cascading, real-time system with machine learning. Their hope is to get pedestrian recognition time down to 0.07 seconds (Hsu, 2016).

4.2 Safety - Moral:

In order for decisions to be made, a large amount of factors will have to be considered, a task that just seems almost impossible, and extremely time costly for programmers. For example, if the vehicle was deciding to save the most amount lives, will it place more value on women and children? How could it possibly know that? Or how could the vehicle know that the bus that it may crash into is in fact empty? These questions show how a certain set of rules that spell out the ethical values that the vehicles should follow cannot be implemented universally. There are values and outcomes that can't be quantified in order for the vehicle to properly assess the situation, for example, how much is the life of a person worth compared to the amount of damages the accident might cause in its surroundings. A fully autonomous vehicle would have to take all these factors into account and make a decision based on those quantifiable numbers (Goodall, 2014). This will eventually cause some dispute in the consumer population, since it is not favorable for the consumer to be valued less than the property it might damage, and it may hinder sales of autonomous vehicles.

It is worth pointing out that a little more than fifty years ago, scientists and engineers were already considering the ethical problems that automated machinery would bring. The biggest example is how Isaac Asimov foresaw the need of ethical rules to be applied to robots. He devised the Three Laws of Robotics, which basically state that: (1) A robot may not injure a human being or allow a human being to come to harm, (2) A robot must obey orders given it by human beings except where they conflict with the First Law, and (3) A robot must protect its own existence as long as it doesn't conflict with the First or Second Law (Wallach and Allen, 2009). These rules may be used as a basis to building morality into autonomous vehicles, but in reality engineers currently face a different problem. The rules lean more on fear of being hurt by the robots, whereas driverless vehicle technology companies are faced with the problem of the machine acting morally. The reality is that the vehicles will certainly crash, and no amount of mileage accumulated yet can disprove that according to research, so engineers must prepare for the accidents (Goodall, 2014).

Many studies have been performed regarding situations similar to the trolley problem. In such a situation, a person is presented with two not so favorable choices. With a train approaching, the person can either let a number of people die on the train or flip a switch that derails the train, saves the people inside the train, but consequently takes the life of a single person lying on the train tracks. Though this situation has been discussed thoroughly a large amount of times, recent data may suggest that there is actually a simple solution to the problem that can be programmed to the vehicles. Recently, a study from

the University of Osnabrück in Germany had volunteers be immersed in a virtual reality setting that exposed them to variations of the trolley problem (Gent, 2017). The study reported that, "Human behavior in dilemma situations can be modeled by a rather simple value-of-life-based model that is attributed by the participant to every human, animal, or inanimate object." This study implied that incorporating human like decisions into driverless vehicles would not be as complicated as previously thought, and therefore there might be a solution to the programming ethics problem (Gent, 2017). The study claims that more questions are then raised, first, they must decide whether they want to include moral guidelines for machine behavior, and secondly, if machines should act like humans (Gent, 2017). The latter issue has raised concern since many companies are trying to model autonomous decision making after human decision making, but no one is really considering if humans always make the best decisions. Autonomous vehicle decision making is an issue that involves the morality of decisions, not the humanity of it, and since we still don't have a complete understanding of ethics, this makes for a difficult situation.

Studies like the one previously mentioned conflict with other surveys that found that most people would prefer that autonomous vehicles be governed by utilitarian ethics. This means that the population decided that it is always in the best interest to reduce the total number of deaths even if this means that the driver and the passengers may be put at risk. Though, it gets even more complicated since the same study also concluded that drivers are less compelled to use cars governed by utilitarian ethics (Goodall, 2014). This creates a problem since consumers are an integral part of driverless technology. Car companies have to create trust in order to introduce and manufacture new driverless technologies, so if the demand and culture behind driverless vehicles is negative, then driverless technology won't prosper.

Another research group decided to conduct their own set of studies based off their own method of determining how people assess and respond to different situations. Their overall results suggest that participants strongly agree that it is more moral for autonomous vehicles to sacrifice their own passengers when doing so will prevent the loss of a larger amount of lives. Their first study consisted of asking participants if it is more moral for the autonomous vehicle to sacrifice one passenger in order to save 10 pedestrians. Three fourths of the participants decided that it was more moral for the vehicle to sacrifice the one driver instead of killing the 10 pedestrians (Bonnefon, 2016). Even though their first study suggested that participants would prefer that autonomous vehicles use utilitarian ethics to make their decisions, they also believed that in the long run, autonomous vehicles will not act in completely utilitarian ways. According to the study, 67% of participants believed that autonomous vehicles would be

less utilitarian than they should be in the future (Bonnefon, 2016). This implies that drivers still believe that in the future they will have some sort of control in how their vehicle will operate.

In their second study, participants were presented with various situations that varied with the amount of pedestrian lives that were involved. Eighty percent of people believed that if it is only one pedestrian, then the passenger should be favored (Bonnefon, 2016). But that number decreased as the amount of pedestrians started increasing, implying that people would approve of sacrificing themselves when it involved more lives that could be saved. It was also found that these numbers fluctuate depending on who is inside of the car alongside of the driver, for example, a family member. This is interesting because if driverless technology reaches a point where the car is able to recognize if the drivers family are part of the passengers, will the car add more weight to saving the passengers inside? There are multiple situations where, if technology allows, a large amount of variables will have to be considered in order to make a split second decision. An example of the situations that the participants were presented is shown in the following figures.

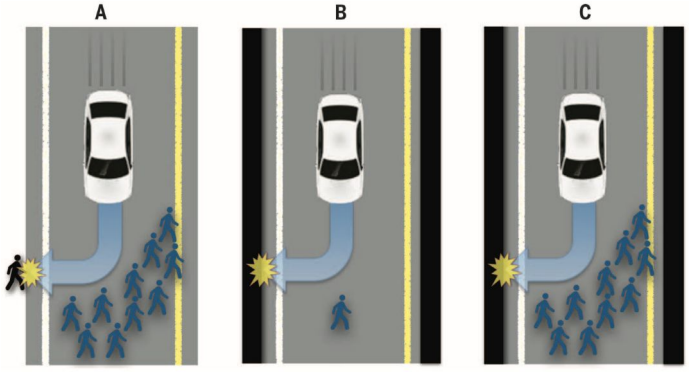


Figure 4.2.1: Three Possible Situations
Situation A represents the options of either killing several pedestrian or just one. Situation B represents killing one pedestrian or the passenger. Situation C involves a greater amount of people (Bonnefon, 2016).

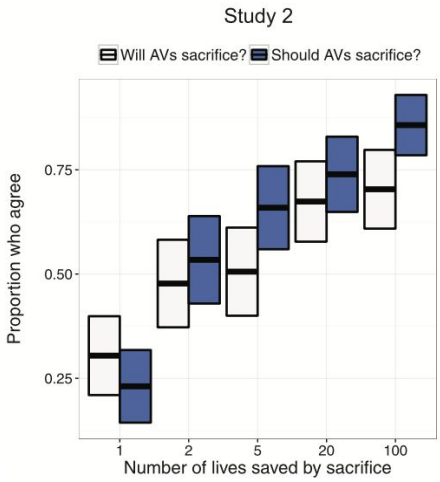


Figure 4.2.2: Greater Good vs. Life of Passenger
Figure represents the amount of people who agree that the autonomous vehicle should sacrifice the passenger with respect to the number of lives that can be saved (Bonnefon, 2016).

The above figure represents three of the many different situations that the participants were presented. Figure 4.2.2 shows the relationship between the number of lives that may be saved and the amount of people that thought it was appropriate for the autonomous vehicle to sacrifice the passenger's life. The research group's third study asked how likely the participants were willing to purchase an autonomous vehicle that would be programmed to minimize casualties. The studies showed that they were only willing to purchase the cars in a situation where only the single participant would be sacrificed, not their family for example (Bonnefon, 2016). The fourth study that they conducted provided some insight on the previously posed questions that involved placing a quantifiable number on all the factors involved in the decision making process of the autonomous vehicle. The participants were given 100 points that were to be allocated between different algorithms in order for them to be ranked on how moral they are and how comfortable that program made the participants feel, along with how likely they would purchase a vehicle that was programmed in that fashion (Bonnefon, 2016). Here results showed that most people valued the utilitarian approach of driverless car ethics, but were not willing to actually purchase and use the item. As stated in the research paper "everyone has a temptation to free-ride instead of adopting the behavior that would lead to the best global outcome." In other words, people would be totally fine with autonomous vehicles that were programmed using a utilitarian approach, but would most likely not participate in purchasing them (Bonnefon, 2016). This social dilemma has consistently shown up across various research studies, pushing engineers, programmers, and regulators to look for a universally accepted global outcome that would regulate the utilitarian algorithms in the autonomous vehicles.

Their fifth study asked the participants questions on how the felt about regulation of driverless vehicles in regards to their decision making. It was concluded again that people favor decisions that are based on utilitarian ethics, but this time they were asked whether they would want human decisions or algorithms to be legally enforced. The study showed that the majority of participants would prefer that the algorithm be regulated and not the drivers, as shown in Figure 4.2.3 (Bonnefon, 2016). Information from their sixth study shows that people will favor an algorithm that sacrifices the driver, but will not favor and are actually opposed to purchasing the vehicles if they are regulated by the government. There was actually an inverse correlation, presented by the larger percentage of people willing to purchase the cars if they weren't regulated at all, shown in Figure 4.2.4 (Bonnefon, 2016). Again this is interesting because there is a dilemma between what people believe is "right" and what people are willing to follow in real life. The following figures show the data for the two studies described.

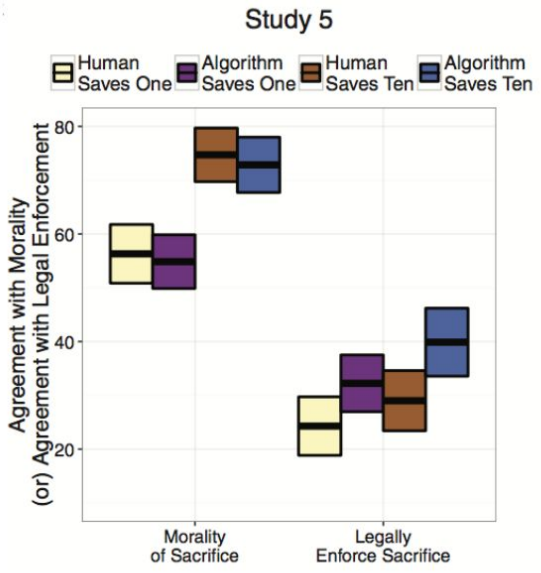


Figure 4.2.3: Morality vs. Legality of Sacrifices
Four situations were presented to the participants and their results are quantitatively showed in the figure for both aspects (Bonnefon, 2016).

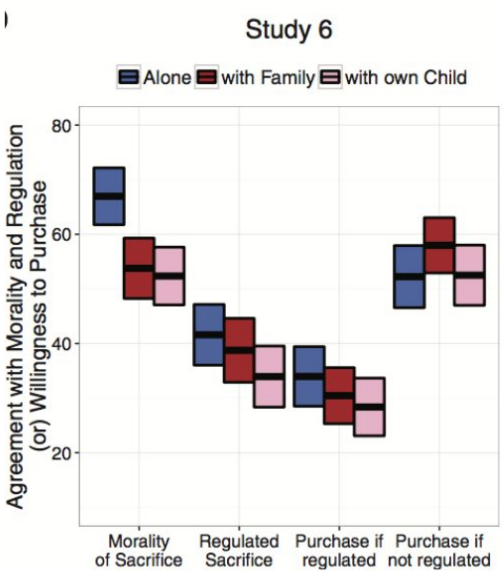


Figure 4.2.4: Morality vs. Purchasing
Three situations presented with additional questions about purchasing the vehicle that carried the desired ethical qualities if it was regulated (Bonnefon, 2016).

4.3 Environment:

With the introduction of new technology, questions regarding their ethical use and implementation are emphasized. Recently, autonomous vehicles are the the topic of discussion since it would introduce a new dynamic between man and machine. Some of the ethical concerns that were raised involve the efficiency of the vehicles, recycling of materials used in the cars, and the robustness of the on board system. As long as the rules of ethics are followed, the introduction of driverless cars will be considered moral.

A common argument for the implementation of autonomous vehicles is that their fuel efficiency alone should justify their usage. As of now there is not conclusive evidence that an all electric fleet is going to be cleaner than their petroleum counterparts. It is under duty ethics that engineers and product designers to determine if the current energy sources will be able to provide a cleaner alternative to gasoline. If autonomous vehicles were immediately implemented and it was found that powering the vehicles resulted in a larger carbon footprint, it is under the duty ethics that the vehicles should be decommissioned until power generation is beneficial to the environment.

As of now, it would be considered immoral to ship Li-ion batteries for other countries to recycle since it ignores their rights and violates rights ethics and the reciprocity principle. Rights ethics is a stance under deontology where there are inalienable human rights that should be upheld at all times. This is a clear violation of those rights since the companies who send the batteries overseas view the lives there as less than their own. They view it such that if the issues can be taken care of behind the scenes and the detrimental effects are left on another population, it must be the solution to how to "recycle" materials. This viewpoint violates the ethical ideology of rights ethics since the companies trampel on individuals rights to a safe workplace and providing knowledge of the dangers of working with battery recycling. Outsourcing recycling labor for batteries also violates another form of ethics, the reciprocity principle. The reciprocity principle is the second categorical imperative under deontology ethics, and is defined as: act as to treat humanity whether in your own person or in that of any other, in every case as an end, never as means only. The recycling centers for lead and lithium ion batteries would violate this principle since it currently sacrifices the wellbeing of the people working at the recycling plant with only the goal of obtaining materials to make more batteries.

If the cars were launched prematurely, there would not only be a high possibility of destroying the environment, there is also the violation of duty ethics. Duty ethics is a subcategory of Kantianism, a form of Deontology, and is defined by the morality of an act is more important that consequence of the act. The choice and moral decision is right if it is in within the conformity of a moral norm or one's duty. Since the cars struggle to properly adapt to the various environmental variables, as in the case with the kangaroos, its performance does not conform to the duty and responsibility of the engineers making it a clear violation of their of duty ethics. Here the engineers neglect their duty to provide a completed product and creating a possibility for local ecosystems to be destroyed.

The implementation of fully autonomous vehicles introduces uncertainty with the general populace. Currently, it can be speculated that these cars abide by moral guidelines as long as manufacturers dutifully follow regulation and create a complete product. To do this, the companies must agree to a common set of rules and follow through with their implementation. If done correctly, the world can experience new technology developed and utilized through ethical means.

4.4 Economy

4.4.1 Introduction:

From more than one hundred years ago, a car has changed the lifestyle of people. The improvement of a car, also, has made numerous changes in everywhere. But the effect of the driverless car is not even compared with the change people have been through. The driverless car is not even on the market yet, but it is already making an impact on the society. Already big companies like Google, Uber, Apple invested money to a driverless car to gain profit. To make a driverless car, engineers have to improve and synthesize many aspects of technologies. And, the improvement of technology due to a driverless car already making a difference in people's lives. According to the paper "ECONOMIC EFFECTS OF AUTOMATED VEHICLES.", there a are thirteen different industries which affect by a driverless car (2017, Clements and Kara). However, despite the positive effects of a driverless car, there are also the negative effects because of a driverless car. We can summarize the economic impact by each industry.

4.4.2 Issue

4.4.2.1 Auto industry:

There are countless effects of a driverless car in many industries, but one of the most affected industry by the driverless car is automotive industry. The auto industry is one of the biggest industry in United State economy system. The Auto industries employ 1.7 million people and spend $500 billion for their annual salary, also total revenue of them is accounting for about 3 to 3.5% of the United State GDP (Hill et al. 2010). The development of a driverless car will change this huge industry. First, an Auto design has to change because of the change of the system of a drive. There is no driver in driver seat anymore, so engineers can design a car which has a driver seat turn around to the backward, so people can hang out while the driving. And there will be no need side mirror and room mirror because a driverless car collects data from the sensors which do not have to be on those mirrors. Besides these, there are tons of change due to a driverless car which will result in the increases of designing job. The second effect of a driverless car to auto industries is they have to change the business strategy of a company due to the social change. There will be no restriction for driving age, in other words, everybody can buy automobile if they have enough money. Also, the distance people travel will increase because there is no driving fatigue anymore. According to the paper, "They 35 estimated regional VMT(vehicle-miles 30 traveled)

increases of 3.6 percent to 19.6 percent, except when marginal cost tolls 36 were applied, and VMT fell 35.4 percent, relative to the business-as-usual, no-automation case." (2017, Clements and Kara)

4.4.2.2 Car Rental (Uber and Lyft):

When we observe those facts above, the market expansion of car is obvious, but, as a matter of fact, the private ownership is predicted to decrease because of there is a lot less need to own a car. The company like Uber and Lyft already made a business model prepare when the driverless car is on the market. Imagine that if there are enough cars for picking everybody up, is there any need for the car? Of course, Uber or Lyft may cost more than own a car, but the advantage of using this kind of car rental company is you can use it anytime anywhere. Only 12% of all U.S. vehicles are in use/on the road at 44 the nation's peak moment. (2017, Clements and Kara) Consider that fact it looks like more efficient to use car sharing system for individual and society.

4.4.2.3 Trucking:

This industry might be the one which will have drastic changes in many ways. Trucking business considered the hardest driving job because at truck driver drives more than 12 hours a day to across the country. A normal person gets tired around 2 to 3 hours of drive. It is obvious that how hard the truck driver is compared to normal driving conditions. That is why they paid like top shelf professional. But, as soon as the driverless car hits the market, there will be no place for the truck driver. The company will save their wage and make that as their profit. According to the research of Mckinsey, the trucking company could save $100 to $500 billion per year until 2025 by saving the wage of drivers. (McKinsey 2013). The trucking industry already employs more than three million truck drivers. That means there is a loss of three million jobs when a driverless car hits the markets. But there is also the shortage of truck driver in the industry right now. According to the American Trucking Association, trucking industry needs 25,000 truck driver now because many people do not want to do it because they do not want to far away from home. There will be an advantage for people due to a decrease of logistics fee, such as decreasing the price of grocery and etc, but we need to think about the effect of a driverless car to the truck driver and to make protection for them to manage their future.

4.4.2.4 Traffic Police:

The driverless car is moving with a system which based on Road Traffic Act. Human not always follows the Road Traffic Act, but the system does. So there is no need to police roaming around to catch a person or car violates Road Traffic Act. This could cause many problems in society. Because the traffic

police will be unnecessary, there will be huge lay-off for them. Also, the United State itself will suffer because they cannot collect fine from traffic violation which is one of the good sources of tax. According to the CNBC's article:' Self-driving cars will disrupt more than the auto industry. Here are the winners and losers', "In 2014, Washington, D.C. issued an average of 773 tickets per day from cameras used to identify speeding cars — adding up to roughly $37.5 million worth of fines."

Also, the traffic attorney will be the one who gets a damage due to the driverless car. There are 76,000 people injury specialized attorneys in U.S. Most of the people would see that the display board which advertising attorney who says I can erase your ticket or I can get you every penny when you get in an accident. The liability business is really big. According to the paper, with an average liability claim for bodily injury of $15,443, a 43 total number of crashes of around 5.5 million in 2012, and an average contingency fee of around 44 33-40%, the revenue loss from personal claim lawsuits could be as much as $3.2 billion (2017, Clements and Kara). Those things will not be needed for the future.

4.4.2.5 Parking:

This business will be doomed for many reasons. If the driverless car can drive without any passenger in the car, and it can find parking spot still after dropping off the passenger, and it can come to a passenger when they call, parking space does not have to be working the place the passenger wants to go. The car can park anywhere near the destination and come back to the passenger when they call the car. That will result in huge destruction for the parking business. According to the CNBC, "The U.S. has about 144 billion square feet of total parking, which represents up to one-third of the total real estate in some large cities. Reports estimate self-driving vehicles have the potential to reduce parking space by about 61 billion square feet." So there will be no more parking rip-off in downtown Los Angeles.

4.4.2.6 Auto Repair:

With high tech sensor, there is far less uncertainty compared to human drivers. Human always has uncertainty such as drunken drivers and distractions which related to more than 90% of an accident in the United States (McKinsey 2013). But a driverless car only relies on the data accumulated by sensors. That could result in a decrease of the accident. The auto repair shop will lose most of the income. $30 Billion spent for people in U.S to repair the vehicles in 2013. But this amount of money will decrease 90% which is same as 27 billion decreases in income based on the study. (2017, Clements and Kara). To reduce the reduction of revenue auto repair shop could specialize the aftermarket personalization of vehicles, but the revenue from that will not compensate the loss. For conclusion, the auto repair shop will be decreased.

4.4.2.7 Infrastructure:

The invention of the driverless car is also meaning that the structure of the city, infrastructure, has to change. Since the driverless car will reduce the demand for the parking lots and will change the road structure with innovated traffic system, the technology of the infrastructure has to develop to walk along with. The efficiency of traffic increasing along with the new traffic system will lead the less need of roadways. One case can be imagined is the road does not have a central reservation anymore. In another word, there will be no more distinction between road, and a driverless car will drive road to respect the traffic condition. The driverless car will synchronize with other and one main control tower. It will gather all of the information for finding the optimized route to get the destination. And Everybody should have thought when they are driving on a packed road and another side is completely empty that What if I can drive that road. The driverless car will make the dream to come true. The control tower will send a signal to the driverless car, and it automatically adjusts the road which it can go. KPMG estimates that intelligently controlled intersections could perform 200-300 times better 23 than current traffic signals (Silberg et al. 2012).

On the other hand, because of the need of the parking decrease, the existing parking lots have to be redeveloped. Due to the change of need of parking structure, the construction cost to build new architecture will be decreasing as well. The space people can use is also increased because of the decrease in need for parking lots. That means the more people can live in the same area. The population of the city will be increased more than ever, and the economy in a city also grow.

4.4.2.8 Fuel:

Gas has been a main resource for the car since it was developed. The development of driverless car results in the more efficient way of driving and also the more effective at fuel consumption. The congestion costs being estimated by The Texas Transportation Institute Americans is 4.8 billion hours of time, 1.9 billion gallons of fuel, totaling $101 billion in combined delay and fuel costs (Silberg 2012) The decreased need for parking will improve fuel efficiency as well, as one MIT study found that 40% of total gasoline use in cars in urban areas is spent looking for parking (Diamandis 2014). Moreover, if the electric car becomes the main fuel for a car, the efficiency of fuel increase more than ever. How much the fuel efficiency increases will limit the total uses of fuel. leading to a total fuel use increase of around 5%, resulting in an annual revenue increase of $14 billion out of the $284 billion market. An integral part of creating driverless car is Vehicle-to-Infrastructure (V2I) communication. GPS, sensors, 3D planning, design, and construction tools can be used to help plan, design, and build more integrated and efficient

transportation systems. With wireless transponders called Roadside Units or other smart embedded sensors, cars and infrastructure can exchange information about curvy roads and low bridges, risks such as construction and information about traffic density, flow, volume, and speed (Bennett 2013). In order to remain competitive, contractors that base their business on large government commissions for highway and infrastructure construction will need to be on the cutting edge of this technology.

4.4.2.9 Wide Economic Impact:

The driverless car will impact many aspects of people's life except the facts which mentioned at above. Transportation system will be one which improves a lot compare to now. According to the research from 'Forecasting Americans' Long-term Adoption of Connected and Autonomous Vehicles Technologies' by Bansal and Kockelman, due to the developed and accurate computing system in a driverless car, traffic accidents which makes 25% of traffic delay, will be decreased by approximately 93% of error which due to human error. (Fagnant and Kockelman 2015). That reduction of accidents will result in saving $488 billion due to fewer injuries and deaths from it. (Jonas et al. 2014). In addition to that, traffic flow will increase due to the increased efficiency of a driving system. Cars will shear the data between them, and the traffic signal will synchronize respect the flow of the traffic. Based on the research of Pinjari, driverless car will increase the capacity of the highway by approximately 22%(Pinjari 2013). Also, easier driving means people can travel easier than before. No matter how far the destination is from the where people live, people will just go because there is no need to drive by themselves. Because of that fact, the amount of road trip will increase and the economy at the tourist spots will increase as well. Furthermore, 'drivers'; we might have to call them as a passenger in future, can do their work at their car. So that will eliminate the loss of time between commute to work. People will work on their car while they are going to their destination or while they traveling. Diamandis estimates that driverless car could save over 2.7 billion by saving unproductive hours in commutes, making an annual savings of $447.1 23 billion per year in just the U.S. alone (Diamandis, 2014). This total saving costs which include the collision cost $488 billion are estimated $1.1 trillion in the U.S which is same as 8% of the United States GDP, and as much as $5.6 trillion worldwide (Jonas et al. 2014).

Table 4.4.1. Summary of Economic Effects (Industry and Economy-Wide)

Industry-Specific Effects				
Industry	Size of Industry (billions)	Dollar Change in Industry (billions)	Percent Change in Industry	$/Capita
Insurance	$180	-$108	-60%	$339
Freight Transportation	$604	+$100	+17%	$313
Land Development	$931	+$45	+5%	$142
Automotive	$570	+$42	+7%	$132
Personal Transportation	$86	-$27	-31%	$83
Electronics & Software	$203	+$26	+13%	$83
Auto Repair	$58	-$15	-26%	$47
Digital Media	$42	+$14	+33%	$44
Fuel	$284	+$14	+5%	$44
Medical	$1,067	-$12	-1%	$36
Construction/ Infrastructure	$169	-$8	-4%	$24
Traffic Police	$10	-$5	-50%	$16
Legal Profession	$277	-$3	-1%	$10
Industry-Specific Total	$4,480	$418	9%	$1,312

Economy-Wide Effects		
Type of Savings	**Dollar Change in Industry (Billions)**	**$/Capita**
Productivity	$448	$1404
Collisions	$448	$1530
Economy wide Total	$936	$2934
Collision Value Overlap	$138	$432
Overall Total	**$1,217**	**$3814**

+ = Industry Gain - = Industry Loss

$/per capita and Total: All values added due net economic/consumer benefit

(2017, Clements and Kara)

The main goal of this research was to find out and identify the impact of a driverless car to many industries and worldwide. The table above shows that the thirteen industries which affected by the invention of the driverless car. There will be some industries which will gain from the driverless car, but many of the work which requires manpower, driver, will be facing the huge layoff, such as trucking, traffic police. The Uber and construction companies will be one of the industries which will get a benefit from it because of the less need of employers. The indirect impact to the economy by saving time during a commute is estimated potentially more than $1.1 trillion in worldwide. The driverless car will be the one technology which will change a life forever just like the normal car did before. We must be prepared to the effect of the driverless car and try to reduce the negative effect to the human in order to thrive in rapid change due to it.

4.5 Law and policy:

In terms of laws and regulations, the government and the automobile industry are the two major parties involved in the discussion of ethical issues. Since the automobile industry tends to gain profits by any means, car companies might have unethical behaviors such as releasing products with known flaws. They might violate the universality principle and reciprocity principle of duty ethics and the framework of

consequentialism. People usually have positive expectations for the government to regulate the market and ensure the safety of the public. Government regulation and legislation should follow the framework of duty ethics to regulate the automobile industry.

Duty ethics is based on the agreement of certain moral rules, including the universality principle and reciprocity principle. Universality principle can be used to evaluate the behavior that whether the act can become a universal law and apply universally among other cases. Reciprocity principle requires people to treat themselves or other humans as an end and not a means. On another hand, consequentialism is the ethical framework that the morality of the act should be judge by the consequence it causes (Poel & Royakkers, 2011).

From the perspective of regulations, the automobile industry might violate the universality principle of duty ethics. To gain more profit in the autonomous car market in the future and develop new technology, the automobile industry tends to lobby and put pressure on the legislators because they want more congenial policies and less restrictions. U.S is such a large country that traffic laws in different states various so differently. From speed limits to highway lane numbers, the industry prefers to find a fixed standard that they can follow when designing the next generation automobile. As for automobile company, matching different safety standards and traffic laws would increase the cost of R&D for their next generation product. Hence, companies have preference to invest in the state that had less regulation to minimize their cost. One of the examples was Google building their testing facility in Michigan, which is a state has the most progressive driverless vehicle legislation (Mitchell, 2017). Because of Michigan's breakneck pace to revitalized its automobile industry, lawmakers in Michigan soften regulations and removed a lot of restrictions. Hence, a lot of not fully developed driverless technologies might be tested on the road. Ethically speaking, it is each company's duty to offer the public safe and well-developed product. Every single company in the world should follow this principle and it should be applied universally, which matched the definition in universality principle in duty ethics. If a company offers flawed technology to the market to lower their cost, many other companies might follow and eventually lead to traffic accidents and deaths of customers. Driverless vehicles are not consumer electronics such as cellphones and laptops. The safety of an automobile has a huge impact on peoples' lives, which makes the duty for driverless automobile manufacturers much greater than a consumer electronics company. Relatively, traditional automobile industry behaves more cautiously and conservatively, compared to the Silicon Valley-Based driverless vehicle companies, such as Tesla. The traditional automobile industry has gained experience and realized the importance of a fully-developed technology rather than pushing a new product into the new market with defects. One of the accusation for Tesla in the 2016 crash was that Tesla

cut their testing period to push the non-fully developed Autopilot system into the market before its competitors. If both the traditional manufacturer and the new companies can have the universal morality to ensure the quality of their product, the automobile industry would have a better public image, ethically.

Secondly, companies should prioritize the customer's life and safety, according to the reciprocity principle of duty ethics. The engineers or the management team members of a company are also automobile passengers. He or she would prefer to drive a safe and well developed car instead of a prototype that is still in beta testing. Hence, if an automobile company has moral awareness of its responsibility and places safety of all customers as a priority, it should think twice before making decisions to sale undeveloped product in the market. When potential customers are looking to buy a new vehicle, safety usually is the major concern. Assuming Tesla's founder Elon Musk purchases a Tesla for private use, he should be 100% confident about the product manufactured by his own company. In such way, the public would be convinced that Tesla is a company that is ethically and morally right, and could trust the quality of the Tesla's vehicle.

Some driverless automobile companies might also violate the ethical frameworks of utilitarianism. Utilitarianism is a type of consequentialism that moral judgement would base on the action that brings the greatest numbers of happiness (Poel & Royakkers, 2011). As mentioned before, safety of vehicle outweighs any other features in an automobile and it's the reason why traditional automobile industries are cautious about new technology. They try to avoid as many potential risks as possible because they have learned lessons during the development of the automobile. Not like those old brands in automobile industry, new companies like Tesla and Google do not have the same level of the awareness of safety. Any flaws in their new systems could potentially lead to the death of the passengers in the automobile, not to mention harming the stock price and reputation of the companies. Fully-developed products could bring the greatest amount of happiness to customers and the company itself. They should change their current over-progressive business strategy and spend enough time for testing instead of trying to get a leading position in the competition.

Governments want to spend more time and stay cautious to ensure the driverless car legislation is ethically right, which follows the framework of duty ethics. States such as California took a long time to figure out regulations for driverless vehicle. This is an example that the State of California is following its duty ethics. By the reciprocal principle, California lawmakers put safety and life of customers as priority. It's government's duty to regulate the industry and keep potential risks from customers. Being cautious and less progressive shows California legislators' conscience. Indeed, as a state famous for its technology

innovation, California might lag behind in the competition with other states. However, the automobile is so important that tens of millions of passengers' lives would be affected, due to the enormous amount of drivers in United State. Any minor loophole in new policies or regulations could be the cause of serious consequences. Since being a profit-seeker is the inevitable defect in the nature of businessmen, in modern society, it is the government's duty to set up laws and restrictions for greedy businessmen so that their profit-seeking nature won't hurt the society. Without laws and regulations, the automobile industry might make evil decisions such as lowering safety standards. From this perspective, there's reasons why California legislation being cautious and takes longer time to make regulations on driverless vehicle, compare to other states such as Michigan.

5 Recommended Solutions

5.1 Safety - Technical:

The chief ethical problem with technical safety is the question, "how safe is safe enough?", meaning how robust do the designs have to be in order for the manufacturer to no longer be ethically responsible for system failure after the vehicle has been sold? Under the framework of duty ethics, the autonomous vehicle manufacturers have a responsibility to ensure safety to their customers. This is seen in both the reciprocity principle of treating their customers as the ends and not the means to sell a product, and through the universality principle; if a vehicle is known to have safety issues, but is released to the market anyways, the universal maxim the manufacturer is operating under is that financial profit is more valuable than road safety. If every autonomous vehicle manufacturer operated under this maxim, they would ironically lose all business and progress, and human driven vehicles would remain the staple of the United States transportation system. The flip side of duty ethics is the rights ethics of the consumers. Those who decide to be transported by an autonomous vehicle must understand the risks involved. Yet, they still retain their rights to health, life, personal well-being, freedom, and autonomy. A violation of safety on the part of the manufacturer is ultimately a violation of human rights, and becomes a form of injustice. The challenge is that nothing can ever be 100% safe. Every mechanical component experiences fatigue from cyclical loading and will eventually wear out. Headlights burn out. No sensor or computer program is perfect, nor can they account for every possible driving scenario. Accidents will still happen; vehicles will still be recalled each year to modify errors just as they are now. The ethical question to consider though, as humans give up more and more driving control to programs and machines, is what

level of safety is the manufacturer responsible for? How many deaths and accidents a year should a society allow without claiming that due diligence was not taken by the manufacturers? Not every accident is the result of negligence from the manufacturer, as the Tesla Case Study in **section 3.4.5** discusses.

The proposed solution to these questions is two-fold: properly functioning autonomous vehicles should decrease the yearly number of vehicular deaths, pedestrian accidents, car crashes, and property damage when compared to current data. If these statistics do not dramatically decrease from where they are today, autonomous vehicles should be abandoned. If passengers are at equal risks of death or injury in a driverless car as in a driven car, they should not give up their personal autonomy by placing their lives in the hands of others. If both options were equally dangerous, people would wish to remain the masters of their own fate. Therefore, autonomous vehicles must prove they are significantly safer than current vehicles. The second aspect of the solution is more related to technical safety. How many sensors and subsystems can fail and the vehicle still manage to at least take its passengers to safety? The proposed solution is that all sensing and actuating subsystems have a factor of safety of at least 1.5. This means that one third of all the sensors and actuators could malfunction and the vehicle would have enough redundancies to still be functional enough to get the passengers to safety. There cannot be one essential sensor or processor or actuator method. If one part fails, there must be robustness and redundancy to still provide safety to the passengers and to those in the surrounding environment. With this in place, the manufacturers will be doing their due diligence and the rights of the public will be upheld.

5.2 Safety - Moral:

As seen with the extensive studies presented, there are many issues and factors that lead to an ethical dilemma when it comes to deciding on how to program a driverless vehicle. The data implies that the manufacturers, consumers, and regulators will all have to come to an agreement in order to effectively come up with some type of universal moral code. A possible solution to this problem is to basically find a way to program the vehicles in a way that they "learn" as they make decisions and eventually build an ethics network of their own encompassing what drivers believe to be "good" decisions. This will eliminate the need to come up with some type of specific program that governs all ethical decisions made by autonomous vehicles. Actions can be scored by humans showing how ethical the decision the autonomous vehicle made, basically teaching the car how to react when presented with similar situations.

The other suggested approach would be to model human behavior and then come up with rules based on that behavior that can be translated to code. This would require a lot of data, this data would be obtained by including large amounts of sensors in traditional cars in order to analyze how drivers react

when presented with real life situations. This solution implies that technology will eventually reach a point where we can arrive to a certain range of ethical decision making that is acceptable to implement in driverless vehicles. Even though this solution sound like it would provide the most realistic approach to the problem, one also has to consider that modeling human behavior might produce results with less than ethical decision making. Drivers will also not have access to the same amount of information that a driverless vehicle may have when encountering an accident, so modeling vehicle behavior based on humans might even lead to a less than ideal set of rules. It is clear though, that creating the technology needed to successfully implement morality in autonomous vehicles is a huge challenge for programmers and the vehicle industry.

One of the other biggest issues that autonomous technology will face will be the acceptance of the implementation of the technology. This can be seen, for example, by recalling the accident that occurred in Florida when the person involved was driving a Tesla that was operating on autopilot. It was later found that the driver actually ignored the safety warnings from the car and was acting in an irresponsible manner that ultimately led to his death. That fact did not change the effect the fatal accident had on public opinion of autonomous vehicles, it raised many ethical issues for the following months. Some believe that it will be hard to gain trust, specially in Western countries, since drivers have emotional attachments to their vehicles. People will have to actually want the benefits that autonomous vehicles will bring. Since most of the repetitive actions of driving will be removed, lives may be substantially changed, people will have to realize that they are benefiting by saving time from making those repetitive calculations needed to drive a regular vehicle. Overall, the technology may eventually be very close to perfected, but if the public does not trust the technology, or does not feel the need for it, then it will be harder to implement the safety benefits that driverless vehicles carry with them.

Figuring out how to construct autonomous vehicles that encompass all moral decisions and ethical scenarios is a huge obstacle that companies currently face and that will require more research in human behavior in order to provide a complete picture. A possible solution would be to incorporate a sort of learning algorithm that would use technology in order to see what experiences were more favorable than others. In an age where large amounts of user data are primarily used to enhance user experience, driverless car companies must find a way to collect as much data as possible regarding real life situations in order to widen the scope of decision making that driverless cars will face. Though, as mentioned plenty of times before, this would require consumers to be comfortable enough to purchase autonomous vehicles in the first place, and this has proved to be one of the major issues when it comes to cars with programmed ethics. Hopefully in the future, car companies, regulating agencies and consumers can all

agree on a certain way to approach the problem. Though society seems to be on a disagreement on how to approach the problem, public opinion is certain to change in the near future, bringing new arguments to the table or hopefully a proposed solution that may be globally accepted.

5.3 Environment:

Although there are possible ethical and technical dilemmas with the universalization of autonomous vehicles technical and non technical solutions can be implemented to bring them into the market. In *The Tragedy of the Commons* by Garrett Hardin he talks about how both technical and non technical solutions can be used to solve open ended questions and crises.

The push for the use of electricity to power the majority of our transportation is a big change for communities around the world. Under the claim of reducing the carbon footprint engineers and electric vehicle activists must ensure that their statements hold true otherwise they are violating duty ethics. By giving the community false information, the companies and engineers are violating their duty to provide correct and well researched information to the public. The solution for giving biased or false information to the public would be to educate employees to only make statements based on conclusive information. Currently this is an issue when companies advertise and only give half the story often misleading consumers about their products.

A possible solution that would make recycling centers adhere to rights ethics is to properly educate employees or contractors on the hazards of the work or develop technology to nullify the hazards. A possible solution would be to create a pamphlet or required briefing on the danger and hazards of the job before workers or contractors undertake the task of recycling the batteries to ensure that they have the right to refuse the job and maintain their health if they so chose. This would be a non technical solution since it provides education to those who were otherwise unaware of the danger their workplace posed to their well being. A contrasting technical solution to battery recycling would be to restrict the amount of batteries used until a new recycling process and technology is developed that makes it so that recycling is much safer and has minimal to no effect on the environment. This would make it so that worker's rights of a safe work environment are impeded because the danger in the process are removed. These two approaches are proposed solutions to fix the ethical dilemma of implementing Li-ion batteries and its recycling. Like the violation in rights ethics, to correct the reciprocity principle violation companies would need to prioritize the wellbeing of workers over the product. In the current recycling system, a solution would be to add safety features for the worker and add a variety of ways to deal with heavy metal

waste and toxins. This would make it so that the health of the environment and people are the center of attention and a priority while obtaining the recycled material is merely the product of their labor.

The potential to disrupt local ecosystems and wildlife due to insufficient software is an issue that cannot be ignored since it can lead to the destruction of local biomes. The only way to resolve this issue would be to test the cars in all possible situations and implement a learning process in the cars incase there are unpredictable changes in the environment. This way, the cars can adapt before a whole ecosystem is disrupted and the engineer's duties to create a car that will safely operate will be fulfilled. Another solution would be that developers are required to receive feedback from the vehicles in the event of an accident. This allows for the immediate feedback and development of software that allows the cars to respond to the previously unknown conditions.

Although the public is skeptical about the universalization of autonomous vehicles, there are many solutions that can be implemented to guarantee their performance. These solutions, both technical and non technical are implemented so that mankind as a whole can benefit. Currently companies and developers are putting in their full effort in order to gain the public's trust and implementing immediate fixes to any issues that may arise. Through corporate efforts and public patience, autonomous vehicles can be brought to the average consumer in the recent future.

5.4 Laws and Policies:

To solve the ethical problems of driverless car using regulations and laws, not only do government need to formulate policies in detail, but also ensure the automobile industry's decisions are ethically right. Also, some education programs should be set up by government to raise the awareness of the public about driverless vehicle. Ethically, it is the government's duty to ensure the revolutionary technology can integrated into our society smoothly.thout steering wheel such that the industry would be able to increase production and speed up the testing process. Eventually, vehicle without steering wheel should be allowed on the road without any restrictions.

From state level, more laws and policies should be used to regu

From the federal level, both Congress and Senate need to realize changes caused by the innovation of technology in automobiles. New laws and regulations need to be made so that there won't be conflicts between the federal law and the state laws. The current automobile regulations need to be altered to help speed up the development of the autonomous automobile industry step by step. Currently, more exemptions should be issued for vehicle wilate the automobile industry. Any new technologies need

to be fully inspected by government agency before they come to market. NHTSA agents and specialties should get involved in the road test of vehicles and evaluate potential risks. In such way, design flaws that may or may not have been caused by unethical motivations can be avoided. Also, the DMV and law enforcement agents should be allowed to remotely take control of autonomous vehicles to handle emergency situations, such as chasing criminals on a highway.

The government should also set up some education programs for public to raise their knowledge and ethical awareness about driverless vehicle. Autonomous vehicle education should be taught in high school and driving school. Basic knowledge of driverless vehicle, such as the shape and appearance of driverless vehicles, should be included in the driving testing in DMV. Hence, the public should be able to recognize and distinguish the difference between a non-autonomous vehicle and a driverless vehicle such that people would be more cautious when they handle situations on the street. When the public are familiar with the new technology, the development of driverless vehicle would be speed up.

6. Summary Conclusion

Driverless vehicles promise to change the way people move from A to B. They can provide faster, more efficient, more sustainable, safer, cleaner, and more a democratic driving experience for all. However, as has been shown, driverless cars are not without their setbacks and challenges. A summary is discussed below.

6.1 Technical Safety Summary:

For technical safety, a brief history of automobile safety was provided, as well as a status quo of current safety. Challenges and advancements in sensor technology was investigated. It was also proposed that autonomous vehicles stay at least as safe as current vehicles in terms of onboard safety features. Additionally, it is recommended that all sensors and actuators have a factor of safety of 1.5, so that one third of the subsystems could completely fail, and the vehicle would still be able to maintain the safety of its passengers.

6.2 Moral Safety Summary:

In an ethical aspect, a driverless car is facing serious issues regarding how it has to react ethically conflict situation, such as like if the accident is an unavoidable situation who has to be the victim, and who will take the responsibility for the accident. This incident contains many issues for the driverless car to resolve. Can it be ethical that the machine can decide the life or death of human being? It might not be possible for a driverless car hitting the market before people make the social agreement about it. There are few suggested solutions. The first solution is making a universal moral code which made by the agreement of the manufacturers, consumers, and regulators. The second solution is making translate the moral people's behavior to computer code and make the driverless car behave that way. It will be a hard task for the engineers to make a driverless car which has acceptable morality for every human being, but that is the engineers have overcome it for the centuries and will do it again.

6.3 Environment Summary:

For the environmental impact of driverless cars, two key categories were investigated. First, it was demonstrated that the climate change and environmental impact of an all-electric fleet of autonomous vehicles varies significantly by region. The environmental impact is no longer measured vehicle-to-vehicle, but by power source to power source. For example, an all electric fleet in California, which has more renewable energy sources, would be more green than an all electric fleet in Pennsylvania which might actually be less green than current vehicles. Second, Lithium-Ion battery recycling poses a large obstacle for autonomous electric vehicles being cleaner than the current system. But by education and public awareness, as well as ever-improving battery technology, these challenges will be addressed as the autonomous age matures.

6.4 Economic Summary:

For the economic issue, people facing many challenges from the invention of the driverless car. Many jobs which are human's task now will be replaced by driverless car such as a commercial truck driver, valet parker, traffic police. It will be a disaster for one human being because he or she will lose a job, however, driverless car will, also, give many benefits to a human for quality of the life. The boring commuting time will be the time we can relax and do whatever we want to do, and people will travel more due to the less burden for going long distance trip. But, a company will be the one which will get most benefits from the driverless car because there will be less need for human worker which is the same

meaning for the companies that they can cut down most of the total salary they spending now. The driverless car will give people many economic benefits, but we have to prepare the side effect of it.

6.5 Law and Policy Summary

The driverless vehicle will change the whole social structure and many aspects of our life. To keep up with the innovation of the technology, people have to adjust or make new laws. Regulation could result in either hindering the innovation of technology or stimulate of it. There are some states which already took a step ahead about the regulations of a driverless car. Michigan is the frontrunner for the regulation of driverless car. Michigan approved most of every driverless driving and considered the place for researching driverless car due to less strict laws compare to others. The main technological issue for law and policy making is a liability of accident and cyber security to make sure the safety of the driverless car to people. The ethical issue of law and policy making is a company which will earn money from the driverless car will try to lobby lawmakers to make a law favor to them. To resolve this issue, a government should take more time to take a look at the law what they making, and let people know about the detail to reach the social agreement of it.

6.6 Conclusion:

Through the investigation of many subtopics related to autonomous vehicles and their impact on American society, economy, policy, safety, and culture, it is evident that driverless cars offer many advantages over human driven vehicles. Autonomous vehicles will make the transportation system more efficient, it will alleviate traffic congestion, reduce fatal accidents, create jobs, and give transportation access to all peoples. However, these benefits do not come without their own challenges and costs. By thoroughly investigating the technical and ethical challenges, and by providing counter-arguments and solutions, it can be concluded that autonomous vehicles, although imperfect and in need of improvement, are an incredible technical solution to many of the largest problems engineers face in the US today. If the recommendations outlined in this essay are followed by lawmakers and manufacturers, autonomous vehicles will be the way of the future and will bring the next transportation revolution.

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