Implementation of Autonomous Vehicles into Society in the United States

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Every day, 3,700 people around the world lose their lives on the roads. Every year, 1.35 million people are lost to road crashes, 38,000 of which are in the United States (ASIRT, 2022). Yet each day, people in the United States and around the world get into a car without a second thought. We drive because of comfort, convenience, and the poor ability to understand risk. However, the automotive industry is striving for a safer future with the implementation of autonomous vehicles.

There are seemingly many other issues with human operated vehicles aside from safety, such as traffic and congestion on the roads as well as poor public transportation. Autonomous vehicles allude to a brighter future, with safer, faster, and more convenient transportation, all relying on the assumption that computers can do everything, even driving, better than a human can. In this way, autonomy seeks to solve the issues associated with the interaction between humans and technology, either because humans are error-prone or have inherent limitations. There are many companies actively pursuing autonomous vehicle development, each promising multitudes of benefits without advertising the vast number of challenges and risks associated with such development. Because of these existing challenges and risks, it is not out of the question to consider the fact that autonomous vehicles might be more trouble than they are worth.

It is important to determine if self-driving cars should replace human-operated vehicles before companies continue to develop these vehicles and move towards an autonomous automotive future. In light of this question, research will be conducted through the lens of Bruno Latour's Actor Network Theory to determine how autonomous vehicles might control or shape human actions. The results from this analysis will be combined with a deeper understanding of

autonomous vehicle technology and the associated challenges to determine whether or not self-driving cars should be the next step in the development of automobiles.

Case Context: Autonomous Vehicle Technology

Autonomous vehicles do not require user input, and instead rely on hardware and software to control, navigate, and drive the vehicle. The Society of Automotive Engineers (SAE) has defined six levels of driving automation, as depicted below in Figure 1 (SAE International, 2021). The diagram breaks up the levels into two main categories: driver support (levels 0 - 2) and autonomous driving (levels 3 - 5). As the levels progress, the vehicle becomes more autonomous.

Figure 1. SAE Levels of Driving Automation (SAE International, 2021)

To effectively see its surroundings, an autonomous vehicle utilizes a sensor suite that includes a combination of cameras, microwave radar, ultrasonic sensors, and laser radar (lidar). Each type of sensor has its strengths and weaknesses: cameras show the environment but do not measure distance, microwave radar measures distance and speed but has limited resolution, ultrasonics can sense objects for parking but not driving, and lidar can measure distance and create a point cloud of the environment but has a limited range and is expensive. Due to the

ability of lidar to map out a high precision 3D structure of the environment, it is the key to the avoidance of objects and the most important device in autonomous vehicles, which makes range extension and cost reduction a critical focus. An ambitious but achievable goal is to replace the early spinning cartop lidars with powerful, compact, mass-producible lidars for under $100. However, despite this achievement, autonomous vehicles would still require a sensor suite with other technologies as lidar cannot do all the sensing that is needed for a self-driving car. To bring down the costs, lidar technology would need to rely on multiple stationary lidar sensors instead of the expensive spinning mechanical lidars. To increase the sensor's range, either the switch to a longer wavelength or an FM-continuous wave is required. Another possibility lies in solid-state scanning with optical phased arrays (Hecht, 2018).

The evolution from manually operated cars to autonomous vehicles will result in challenges that stem from the massive development of sensors on the car and amount of data that the car can acquire from its surroundings. Due to the need for efficient data processing and integration, autonomous vehicles will require a 5G internet connection to ensure operation even in high mobility situations or densely populated areas by ensuring continuity and a higher data rate. 5G technology is a key enabler for the Internet of Vehicles, as it provides a better way for intelligent transportation to become fully integrated into a smart city framework (Guevara & Auat Cheein, 2020). The internet of autonomous vehicles will be capable of making decisions about driving customers to their destinations. The Internet of Vehicles will consist of communications, storage, intelligence, and learning capabilities with the intention of anticipating the customers' desires. The Vehicular Cloud, a mobile cloud network that provides essential services such as content search and attack protection to autonomous vehicles, is the core system that makes the implementation of self-driving cars possible (Gerla et al., 2014).

Analyzing Autonomous Vehicle Implementation through Actor Network Theory

With autonomous vehicle implementation comes concerns regarding trust in the technology, potential unemployment, and the ability to ensure safety for all road users. In order to determine the effect that autonomous vehicles will have on society, these concerns must be explored and addressed appropriately. Bruno Latour's Actor Network Theory will be used to analyze the impact that autonomous vehicles have on society and human actions. Latour argues that technologies play an important role in society by the ability to replace, constrain, and shape human actions (Latour, 1992). The theory's various analytical elements describe how certain values and goals can be achieved through the development and deployment of technologies. The analytical elements that will be utilized in this research are program of action, delegation, prescription, and discrimination. The benefits and risks of autonomous vehicles will be identified by using each of the analytical elements as a separate category to collect evidence.

Program of action describes how certain values and goals can be inscribed into technology, and provides a deeper look into why a technology is being developed. In order to fully understand a technology, it is helpful to ask what values and goals are being achieved by its implementation and whose values and goals they are. If the technology is developed with only one set of values and goals in mind, this could result in potential issues when others who have different values attempt to use it.

Delegation refers to the action of humans giving work to technology, and allows for a full understanding of what the roles of the technology will be once it is implemented. There could be potential issues that arise if the technology does not complete the tasks that were previously assigned to humans in a better or more efficient manner. Additionally, there could be issues with

the task delegation if society is not comfortable with the technology performing a task that they are used to doing themselves, or perhaps enjoy doing themselves.

Prescription describes how technology can constrain human actions. Even if a technology might seem as if it will benefit society and provide people with more freedom, the reality might be slightly different in that when the technology is deployed, it could prohibit people from doing things that they usually would do or that they want to do. If the idea of human actions being constrained is not carefully thought out, this could result in society not wanting to adopt the technology into everyday life once they realize that they have lost some of their freedom.

Discrimination explains how technology can help or harm different groups of people. While a new technology might seem exciting and completely beneficial to society, it may be harming certain groups of people, such as minority groups that were not taken into consideration when designing the technology. Before allowing a technology to be deployed, the ways that the technology will interact with various groups of people must be considered in order to ensure that there is no potential for harm.

Research Question and Methods

This paper will address the question: Should autonomous vehicles be implemented into society in the United States? To focus the scope of this paper, this broad question will be broken down and answered through four questions that each correspond to an analytical element: What values and goals are being inscribed into autonomous vehicles and are they achievable? Who is deciding what tasks will be delegated to the car and what is our tolerance for the vehicle making mistakes? Will we lose control and freedom with the adoption of autonomous vehicles? What are the different ways in which autonomous vehicles can help or harm different groups of people?

In order to answer these questions, a literature review will be conducted and various individuals knowledgeable in the autonomous vehicle industry will be interviewed. The literature was surveyed first in order to get a better understanding of the potential benefits and drawbacks with the various aspects of autonomous vehicles. After the literature review was completed, more information was gathered from individuals knowledgeable in the field. The first source utilized was the 2019 documentary Autonomy, which provides a brief overview of the development of autonomous vehicles and the varying benefits and drawbacks of the technology through the perspectives of individuals from different backgrounds (Horwitz, 2019). The second source utilized is a January 2022 YouTube interview by John Simmerman with Peter Norton, an associate professor at the University of Virginia, where they discuss Norton's new book, "Autonorama: The Illusory Promise of High-Tech Driving" (Simmerman, 2022). Finally, the third source utilized is a direct interview with Andy Schaudt, the Chief of Staff at the Virginia Tech Transportation Institute (VTTI), a research institute that studies safety, mobility and vehicle autonomy (Virginia Tech Transportation Institute, 2022). The interviewees were selected due to their knowledge in the field and the fact that they have two very different perspectives on autonomous vehicle development. Additionally, neither individual represents a company developing autonomous vehicles, so both are unbiased in that they are not trying to advertise their company's technology or advance their business case.

Results

Overview

The implementation of autonomous vehicles will be beneficial to society in the United States despite the challenges associated with the technology. Most importantly, these vehicles

have the potential to make the roads a safer place and save the thousands of lives that are lost each year due to car accidents. While autonomy on the road is a great feat, critics and skeptics are advertising these challenges and hesitations as reasons to abandon its development. However, these challenges should be embraced and hesitations discussed in order to ensure these vehicles are developed in a way that enhances society. One area that is heavily debated is the safety of autonomous vehicles. The findings suggest that in utilizing autonomy on the road to eliminate the risky behavior of human drivers, these vehicles will lead to safer roads. Another area of concern surrounds outsourcing decision-making to the vehicle. This concern should be alleviated through the recognition that humans are extremely poor at making decisions in crash scenarios, and the vehicle will be programmed to prevent these situations from occurring. Additionally, job loss and cybersecurity concerns are discussed in the literature as well. However, the results suggest that these jobs will not be lost and while cyber concerns are valid, they should not be a reason to deter technology development. Finally, it is crucial to remember that this question is being asked in respect to the United States, where autonomous vehicle development has been underway for decades and business models are driven by society's dependence on convenience and comfort. Abandoning this technology would be extremely difficult in a society that has poured time, effort, and money into its development.

Program of Action

In the United States, the set of values and goals that have fueled autonomous vehicles are best described by Vision Zero. This can be seen on General Motors website, which advertises "a world with zero crashes, zero emissions, and zero congestion" (General Motors, 2022). Society is being promised that autonomous vehicles will be safer, expel less emissions, and be more

efficient than human-operated vehicles, however it is important to challenge these claims to ensure their validity. Some questions to consider are: Are these values and goals achievable? Are autonomous vehicles safer than human-operated vehicles?

Peter Norton argues that these goals will never be achieved and that autonomous vehicles will not be safer than human-operated vehicles. Norton argues that companies like General Motors are advertising goals that will never be reached (Simmerman, 2022). He also argues that autonomous vehicles are not on course to be safer. Norton takes General Motors as an example, and claims that the company is ignoring the fact that "robotic drivers have a lot of failings" and that "the things that have shown to make roads safer are prioritizing pedestrians and cyclists" (Simmerman, 2022). Norton is not alone in being skeptical of the claims that autonomous vehicles will be safer than human-operated vehicles. Braun and Randell argue that the claim that autonomy will reduce deaths and injuries on the road is due to the misleading statistic that more than 90% of crashes are due to human error (Braun & Randell, 2020). There have been several studies in the United States and Europe that come to the same conclusion and verify the 90% statistic, however each study approaches the problem in the exact same way. The causes for accidents are either attributed to the driver or the vehicle, with the vehicle only taking the blame if it can be identified as defective. Consequently, unless the vehicle was defective, the only place to assign the blame is to the driver. This approach to the problem is flawed, as it is impossible to attribute the blame anywhere else except to the driver, and so no causality could ever be attributed to automobility.

However, Andy Schaudt has contrasting opinions. Schaudt agrees with Norton that this idealistic goal is not achievable, but he notes that the reason that autonomous vehicle companies push this goal is because they want to be known as the leading edge. These companies are

businesses that must advertise their technologies to receive attention and funding. Without a goal like Vision Zero, it's hard to recognize the importance and significance of the technology. Additionally, he argues that Vision Zero is coming from places like the National Safety Council that are not selling cars. Schaudt believes that there are multiple organizations that are genuinely trying to get a stretch goal for saving lives on the road, which should not be framed in a negative light (A. Schaudt, personal communication, March 17, 2022). Schaudt also argues that autonomous vehicles will be safer than human-operated vehicles. While he agrees with Braun and Randell that the 90% statistic has been misused in literature, he argues that human error and behavior is still contributing to road accidents. He claims that the biggest risk we have on the road is due to humans not being able to stay vigilant, limitations of human nature, and our poor ability to understand risk. Schaudt also argues that we have saved lives by designing cars to eliminate risk with systems such as airbags and cruise control, and autonomous vehicles simply take advantage of all of the small systems working in unison to take away driving from the human when it makes sense (A. Schaudt, personal communication, March 17, 2022).

Delegation

By allowing autonomous vehicles to see, drive, and make decisions for us, we are outsourcing the risk on the road. With such a large delegation of tasks, it is important to consider the potential issues that might arise when the task of driving is delegated to the vehicle. Some questions to consider are: Who is deciding what decisions the car is making? What is our tolerance for the car making mistakes and how much risk are we allowing it to take?

One concern lies in outsourcing decision making to the vehicle. In the documentary Autonomy, Azim Shariff, associate professor at the University of British Columbia, claims that "because self-driving cars need to be programmed, moral decisions have to be baked into the

algorithms themselves, which means that now we have to explicitly decide what we want cars to do in those situations" (Horwitz, 2019).

The Moral Machine Experiment attempted to explore the moral dilemmas that autonomous vehicles would face and gather the resulting decisions from people across the world through an online platform (Awad, E. et al., 2018). The Moral Machine gathered 40 million decisions from people in 233 countries, and the developers of the experiment analyzed how these decisions resulted in preferences for saving lives. An example of the interface can be seen below in Figure 2, where the user must decide between the car crashing into a concrete barrier or swerving, a setup similar to the famous Trolley Problem.

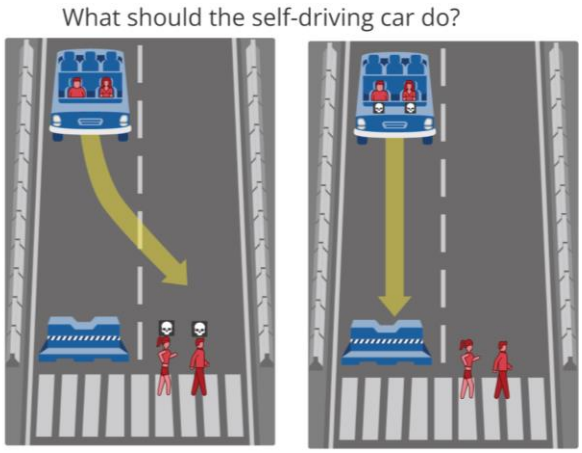

Figure 2. Moral Machine Interface (Moral Machine citation)

The scenario above targets fitness, where either the lives of a female athlete and a man (pedestrians) or of a woman and an overweight man (passengers) can be spared. The other categories that were analyzed were intervention, relation to the car, gender, fitness, social status, law, age, number of characters, and species. While the details will not be discussed here, it was found that there were similarities between preferences from the same region of the world, while there were significant differences in preferences in varying regions. This research suggests that

these opinions do exist and vary around the world, which is important to be cognizant of when dealing with society's adoption of these vehicles or the backlash from accidents.

In conflict with the Moral Machine, Chris Urmson, a roboticist and entrepreneur, argues "because self-driving cars are much better defensive drivers than people are and they're always paying attention, they shouldn't ever end up in a trolley car scenario (Horwitz, 2019). Andy Schaudt takes a similar stance, and his opinions on crash scenarios are based on the work done at VTTI over the last 20 years, where 70 million miles of naturalistic driving data has been collected so that they can analyze the causes of crashes (A. Schaudt, personal communication, March 17, 2022). Autonomous vehicle companies use VTTI's data to identify these rare crash scenarios, similar to how the Moral Machine identified those crash cases, then do their best to design the vehicles to incorporate those possibilities. From VTTI's research, Schaudt says that they have learned that humans do not make those decisions in anticipation of a crash, they either freeze or are in chaos when they make that decision. For example, a driver might steer when he/she should not, resulting in the car running off the road or crashing. So, Schaudt argues, these moral decision thought experiments are ludicrous, because humans are not currently making these decisions. Because humans are not trained to deal with every random situation that occurs, cars will not be either, and they will just attempt to avoid the worst crash scenario. Gill Pratt, the CEO Toyota Research Institute, claims that it is an issue of empathy rather than technology as to why we might be hesitant to trust a computer: "we can empathize with a person that panics at the wheel and runs over someone. It's hard to empathize with a machine making a decision (Horwitz, 2019).

Prescription

In an autonomous vehicle, human actions have the potential to be constrained when considering the fact that the job of driving is no longer that of the human. There is a worry that those who enjoy being in control of their car will not want to adopt self-driving cars into their everyday lives because of the associated loss of freedom. Some questions to consider are: Will we lose control and freedom with the adoption of autonomous vehicles? Could other forms of transportation result in more control and freedom?

Peter Norton argues that autonomous vehicles will result in a loss of freedom and control due to increased car dependency (Simmerman, 2022). He claims that we live in a car dependent society and ignore other valid transportation choices. Norton offers a new perspective where bikes, trains, and buses dominate the future, which he calls low tech, common sense mobility. He argues that prioritizing pedestrians and cyclists have been shown to make roads safer, as has been done in the Netherlands, where the traffic fatality rate is much lower than in the United States. Norton says that in countries like the Netherlands, people are truly autonomous and enjoy the freedom of choice when it comes to transportation.

In the Netherlands, the traffic fatality rate has decreased from a value similar to the United States in the 1970s to a value 70% lower than that of the United States in 2019 (Garrick et al., 2022). This change was the result of activism in which the Dutch fought to completely reshape the role and function of streets, which led to new rules governing how streets were designed, funded, and governed. Examples of these changes are separated cycle tracks and controlling speed on vehicles so that cyclists and pedestrians have dominant roles on the streets. Garrick et al. argue that the U.S. “conveniently ignores the fact that it is the environment that we have built that has proven to be so deadly for people.” The changes in the Netherlands were

achieved without autonomy and high cost, whereas autonomous vehicle development in the United States has cost billions without full implementation.

While Schaudt agrees that Norton's vision of fewer cars on the road would be great, he claims that it's not feasible. He argues that convenience and comfort are two dominant things that are impossible to take away from human nature (A. Schaudt, personal communication, March 17, 2022). In order to advance and innovate in a capitalistic society, there must be a business model, and in the United States the business model lies in cars and the convenience of owning a car and being able to go wherever you want whenever you want. Elon Musk's tweet regarding public transportation just about sums up the American way: "public transport is painful. Why do you want to get on something with a lot of other people, that doesn't leave where you want it to leave, doesn't start where you want it to start, doesn't end where you want it to end? (Marshall, 2017). Additionally, it is important to think about the differences between the countries that are being compared. For example, the Netherlands is a much smaller country than the United States, at about a third of the size of New York. Because the United States is so much larger than the Netherlands and the space is so spread out, it is a bit naive to rely on public transportation to get better, if not just as naive as the thought that people are going to get rid of their cars or that autonomous vehicle companies are going to stop developing their technology.

Discrimination

A common hesitation with autonomous vehicles is the fear that jobs will be taken from the transportation industry. Two broader examples of potential harm reside in cybersecurity concerns and the claim that society is being promised an autonomous future that may never exist. Some questions to consider are: Should we be concerned about jobs being taken by autonomous vehicles? Should cybersecurity concerns deter us from deploying autonomous vehicles? Will a

future with autonomous vehicles exist? How might autonomous vehicles help certain groups of people?

In Autonomy, Debbie Desiderato, a long-haul trucker in the United States, worries, “will there be other jobs available in the field? How can you compete with a robotic forklift that doesn’t require a lunch break, doesn’t get sick, or require worker’s compensation?” (Horwitz, 2019). However, the United States is experiencing a truck driver shortage. Additionally, Schaudt suggests that no jobs will be taken away yet because most trucks will still need a driver, and that autonomy could lessen the number of hours that truck drivers are working, especially because fatigue is a big issue within the industry (A. Schaudt, personal communication, March 17, 2022). Similarly, Malcolm Gladwell, author and journalist, asserts that “there’s a million things that person does other than drive the truck. Those tasks don’t go away” (Horwitz, 2019).

Another threat to autonomous vehicle safety is the issue of cybersecurity, because these cars will now have the dangerous ability to be hacked by external systems. Malcolm Gladwell says “we have to accept the fact that if all cars on the road are part of a connected grid, somebody can hack into the Web and cause the cars to crash” (Horwitz, 2019). On the other hand, Schaudt believes that this should not be a reason to deter technology development. In his opinion, automation will be beneficial in the grand scheme of things through the potential to save thousands of lives even if there are fatalities (A. Schaudt, personal communication, March 17, 2022).

Another concern is that we will continue to be promised an autonomous future that may never exist, as this technology has been advertised for decades without large-scale deployment. To address this concern, Schaudt offers the Gartner Hype Cycle, a graphic used by clients to track the maturity, adoption, and future potential of technologies, as shown in Figure 3. The

cycle begins with an innovation trigger, where there is excitement around the technology, followed by inflated expectations, where investment skyrockets and money is being poured into research and development. The peak is followed by the downward slope to the trough of disillusionment, where companies begin to realize the difficulty of the problem and begin to either retract or come together with combined efforts. The cycle ends in the slope of enlightenment and plateau of productivity, where finally strides are made in the development of the technology.

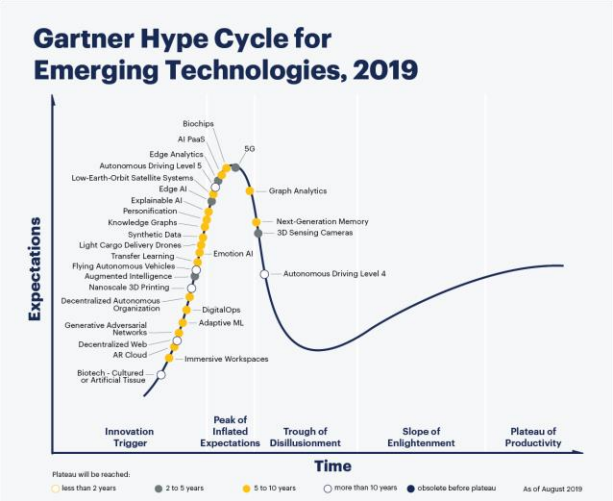

Figure 3. Gartner Hype Cycle (Gartner, 2019)

Although this chart is from 2019, Gartner has placed Autonomous Driving Level 4 on the downwards slope to the trough of disillusionment. This cycle has been observed for many other technologies as a normal progression in development, and it is predicted that autonomous driving will soon reach the slope of enlightenment.

Autonomous vehicles can also help a multitude of different groups of people such as the blind, elderly, young, those with medical conditions that prohibit them from driving, and those who feel unsafe in taxi services such as Uber. Direct evidence from an individual in one of these categories has been acquired in order to show that this technology can help people who do not currently benefit from human-operated vehicles. Paul Parravano, co-director of the Office of

Government and Community Relations at the Massachusetts Institute of Technology who is blind, says “for people who are unable to drive and have to rely on other modes of transportation, the new technology with autonomous cars really adds a significant degree of liberation and independence” (Horwitz, 2019).

Discussion

This research surveys varying perspectives from both the literature and experts in the field on the benefits and drawbacks of the development and implementation of autonomous vehicles, as well as the challenges associated with the technology. As can be seen from the results, this research connects to a broad scope of opinions, theories, and evidence that has been captured both in literature and in documentaries such as Autonomy, and in interviews with experts in the field, such as Peter Norton’s interview about his book Autonorama. Overall, this paper takes the stance that autonomous vehicles should continue to be developed and implemented into society, despite the challenges and skepticism presented in various articles such as the Moral Machine Experiment and Braun and Randell’s article on the misleading 90% statistic.

The limitations of this research include the focus on the United States and the lack of direct information directly from autonomous vehicle companies other than what is advertised on their websites. The transportation system in the Netherlands was briefly analyzed in order to dive into Norton’s argument regarding a system of bikes and buses rather than cars, however no other country’s transportation system was analyzed. Therefore, the results from this research only apply to the United States, and more research must be done in order to answer the research question in areas in other parts of the world. Initially, the research plan included direct interviews

with representatives from autonomous vehicle companies in order to ask STS-framed questions related to the analytical elements. However, the companies that were contacted had to decline the interviews due to strict media policies on who can speak to the public on their technology.

For future research, it would be attempted to mitigate the identified limitations in order to provide an answer to this research question in a broader scope with information acquired directly from autonomous vehicle companies regarding their thoughts on how their technology could potentially harm society. These answers from companies could be very insightful in order to understand the level of awareness that they have regarding the impact of their technology on society. For example, if these companies are oblivious to the fears of potential harm that could be created by their technology or do not have valid responses for how they will solve these challenges or mediate these issues, this could be a large warning sign that these technologies are not ready to be implemented into society.

Although my engineering degree and role in society after graduation will be in the aircraft industry rather than the automotive industry, this research can be directly applied to advance my engineering practice. The type of analysis conducted here can be conducted in any field to any technology, and so these analytical elements and associated questions will be in the back of my mind as I enter the industry. Whether an engineer's job is in design, test, or safety, these questions can be asked at any point in the design cycle and about any company, which is important to ensure that every company and the technologies that are being developed are not harming any groups within society.

Conclusion

Autonomous vehicles should continue to be developed with the goal of future implementation into the United States. Companies are attempting to reach Vision Zero to achieve a safer, cleaner, and more efficient world. While this vision may never be achievable, innovation is driven by the attempt to save lives and improve our world. Efficiency also speaks to two dominant values in American society: convenience and comfort. While some might argue for a society that is not dependent on cars, these two values are paramount and speak to the American need for being able to own a vehicle that will take you anywhere at any time. The fear-inducing thought of a car being in complete control and making decisions for humans should be relieved by the fact that the goal of autonomy is to take away the task of driving from the human only when it makes sense in an attempt to save lives on the road. Additionally, these vehicles have the potential to help many groups of people that do not currently benefit from human-operated vehicles. We have the potential to make the roads a safer place, and there is no reason why we should not chase the Vision Zero goal in an attempt to save thousands of lives.

References

Association for Safe International Road Travel. (2022). *Road Safety Facts*. Retrieved March, 20, 2021 from https://www.asirt.org/safe-travel/road-safety-facts/#:~:text=More%20than%2038%2C000%20people%20die,enough%20to%20require%20medical%20attention

Awad, E., Dsouza, S., Kim, R., Schulz, J., Henrich, J., Shariff, A., Bonnefon, J., & Rahwan, I. (2018). The Moral Machine Experiment. *Nature*, *563*, 59 - 64. https://doi.org/10.1038/s41586-018-0637-6

Braun, R. & Randell, R. (2020). Futuramas of the present: the "driver problem" in the autonomous vehicle sociotechnical imaginary. *Humanities and Social Sciences Communications, 7*(163). https://doi.org/10.1057/s41599-020-00655-z

Garrick, N., Shi G., & Atkinson-Palombo, C. (2022). *How the Dutch Delivered a Traffic Safety Revolution*. Bloomberg CityLab. Retrieved March, 20, 2021 from https://www.bloomberg.com/news/articles/2022-01-26/u-s-lessons-from-the-dutch-traffic-safety-revolution

Gartner, Inc. (2022). *5 Trends Appear on the Gartner Hype Cycle for Emerging Technologies, 2019.* Retrieved March, 20, 2021 from https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019

General Motors. (2022). *About Us*. Retrieved March, 20, 2021 from https://www.gm.com/company/about-us

Gerla, M., Lee, E., Pau, G., & Lee, U. (2014). Internet of Vehicles: From Intelligent Grid to

Autonomous Cars and Vehicular Clouds. IEEE Network. Retrieved October 15, 2021 from http://www.cs.toronto.edu/~chechik/courses19/csc2125/extra_readings/internet-of-vehicles.pdf

Guevara, L. & Auat Cheein, F. (2020). The Role of 5G Technologies: Challenges in Smart Cities and Intelligent Transportation Systems. *Sustainable Urban and Rural Development*, *12*(16), 64 - 69. https://doi.org/10.3390/su12166469

Hecht, J. (2018). Lidar for Self-Driving Cars. *Optics and Photonics News.* Retrieved October 15, 2021 from https://www.osapublishing.org/DirectPDFAccess/20F633C9-10FA-4539-BABC5F476EBB2163_380434/opn-29-1-26.pdf?da=1&id=380434&seq=0&mobile=no

Horwitz, A. (Director). (2019). *Autonomy* [Film]. Production company.

Latour, B. (1992). Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. *Shaping Technology-Building Society. Studies in Sociotechnical Change*, *1*, 225-258.

Marshall, A. (2017). *Elon Musk Reveals His Awkward Dislike of Mass Transit.* Wired. Retrieved March, 20, 2021 from https://www.wired.com/story/elon-musk-awkward-dislike-mass-transit/?mbid=social_twitter

Massachusetts Institute of Technology. (2022). *Moral Machine*. Retrieved March, 20, 2021 from https://www.moralmachine.net/

SAE International. (2021). SAE Levels of Driving Automation Refined for Clarity and International Audience. Retrieved October 30, 2021 from https://www.sae.org/blog/sae-j3016-update

Simmerman, J. (2022). *Peter Norton and I discuss his new book* [Video]. YouTube. https://www.youtube.com/watch?v=fDb7PjYbQXU

Virginia Tech Transportation Institute. (2022). *About.* Retrieved March, 20, 2021 from

https://www.vtti.vt.edu/about/index.html