American University of Sharjah

ENG207 – Professional Communication for Engineers

Professor Philip McCarthy

Reducing Traffic Congestion by Implementing Communication Systems in Autonomous Vehicles

EMDP Final Report

Team: Underpaid Engineers

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TRANSMITTAL LETTER

May 28, 2021

Dr. Philip McCarthy,

Assistant Professor at Department of English

American University of Sharjah, Sharjah

Dear Dr. McCarthy:

Please find the attached report entitled "Reducing Traffic Congestion by Implementing Communication Systems in Autonomous Vehicles." This report was written to fulfil the Engineering Multi-Disciplinary Project (EMDP) requirement for the ENG 207 course. In this report, we suggested autonomous vehicles as a solution for traffic congestion on the road. Despite the problems that autonomous vehicles face in their technology, we offer various technical solutions to solve and improve these problems.

The project was a team effort that required the expertise of several engineering disciplines. Khalid Elshafey, a Computer Scientist, explored artificial intelligence implemented in autonomous vehicles that collect data from different sensors, cameras, and radars in the vehicle. Fatma Al Mheiri, a Computer Engineer, discussed how implementing vehicle to infrastructure and vehicle to vehicle communication systems helps in mitigating congestion. Mohammed Harb, a Mechanical Engineer, contributed to the mechanical components and design of the autonomous vehicles. Lastly, Leanne Shahin, a Chemical Engineer, discussed how an autonomous vehicle is eco-friendly as it reduces fuel consumption by increasing the engine's efficiency.

The research conducted in our report was supported by several people, each of whom we would like to thank. First, we would like to thank the AUS Librarians who guided us to various secondary academic sources, such as IEEE, WorldCat, JSTOR, and Google Scholar. Second, we would like to thank Dr. Taha Landolsi as he referred us to several IEEE research papers related to his area of expertise, which focuses on telecommunication systems and is related to the autonomous vehicle's communication system.

We hope this report fulfils all the criteria for the Engineering Multi-disciplinary Project (EMDP). We would like to thank you for your time in considering our proposal, and we hope that you would agree with us on encouraging governments and companies to implement autonomous vehicles on the road to lessen the current traffic congestion burden. If you have any further questions, please do not hesitate to contact us.

Yours Sincerely,

[Signature should be inserted here]

Team Underpaid Engineers: Leanne Shahin, Khalid Elshafey, Fatma Al Mheiri, Mohammed Harb

Encl.: EMDP Report "Reducing Traffic Congestion by Implementing Communication Systems in Autonomous Vehicles"

EXECUTIVE SUMMARY

Human error is one of the main contributors to traffic congestion. While autonomous vehicles (AVs) are a considerable first step to tackling this problem, AVs are missing one vital component, communication. By allowing AVs to communicate, they could regulate one another using signals, and effectively reduce traffic congestion. In this report, we propose the implementation of communication systems in AVs to reduce traffic congestion.

This report identifies four technical problems that must be resolved before implementing autonomous vehicles to lessen traffic congestion. First, autonomous vehicles' ability to communicate with other autonomous vehicles and manual cars is currently very limited. Second, the software system used in an autonomous vehicle is highly vulnerable to unauthorized access by hackers. This unauthorized access may cause intentional accidents, damage to the vehicle's operating system, and disturbance to the vehicle's operation on the road. Third, the sensors and radars that are used face a significant problem with unusual scenarios on the road. When the sensor faces unusual situations occurring outside of the system's regular algorithms, it cannot easily predict and react to these rare situations. Lastly, the vehicles' sensors are not capable of handling adverse weather conditions.

After conducting considerable research on the four main issues, we present a solution for each limitation. First, to enhance communication between different vehicles on the road, a vehicle to vehicle (autonomous or manual) and vehicle to infrastructure communication system are introduced, which also helps lessen traffic. The primary purpose of implementing these connected vehicles is to reduce the human error that causes daily traffic. Second, blockchain solutions and ethical hacking helped in creating hackproof systems to avoid cyber-attacks into the software. Third, a larger amount of data was provided to the sensors to allow the vehicle to react accurately towards corner cases. Lastly, to overcome the weather problem, unique and novel solutions are proposed for many various weather conditions, such as snow, rain, and sandstorms.

Although the solutions mentioned are effective in solving many of the problems, it is important to recognize the limitations. One of the primary limitations of autonomous vehicles is public trust. Studies from all over the world have been conducted and found that people still do not fully trust autonomous vehicle in their day to day lives. However, many other surveys and studies have been conducted, and they indicate that people are willing to trust autonomous vehicles if they have a better understanding of the vehicle's technology. In addition to public trust, another key issue is cybersecurity. Software systems are highly vulnerable to many cyber-attacks if not protected. Hackers could target people by hacking into their vehicles and potentially posing a threat to others. Having said this, the application of ethical hacking and blockchain solutions has proven successful in protecting against cyber-attacks in various car samples at Jeep and Tesla. Ensuring that autonomous vehicles are resistant to cyber-attacks is key for the implementation of an effective communication system between vehicles and infrastructures, which according to research, can perform two to three times better than traffic lights in terms of traffic regulation.

This project's primary analysis approach was secondary research. To construct strong arguments, a wide variety of journal articles and books were examined. These references were found in the WorldCat database, as well as Google Scholar and IEEE Xplore. These academic sources provided reliable statistics that were used to provide an overview of the situation and emerging trends that aid in autonomous vehicles. Finally, the team worked on a daily basis to collect information and generate the requested report.

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GLOSARRY

AI (Artificial Intelligence): the ability for machines to perform tasks that are generally done by human intelligence.

Algorithms: a finite sequence of instructions designed to carry out specific tasks.

AV (Autonomous Vehicles): a vehicle that can operate on its own by sensing the environment around it and moving safely without the need of a human intervention.

Blockchain: a system that stores records of several databases within a network in a way making it impossible to change or hack the machine.

Cybersecurity: the protection of computer systems and their networks from unauthorized users.

DoS (Denial of Service Attacks): a cyber-attack performed by hackers to make a device unavailable to the user by disrupting the way it operates.

ICT (Information and Communications Technology): A technology that is able to access, store, and receive information through telecommunications.

NFV (Network Function Virtualization): a method to virtualize network services with portable software running on standard servers.

SDN (Software-Defined Networking): A network structure method that allows the network to be intelligently programmed by using software applications.

Sensor: A device that is able to detect motion around its environment and send information back to a computer processor.

Vehicle to infrastructure (V2I) communication system: A wireless exchange of data between vehicles and the road infrastructure such as lane markings and traffic lights.

Vehicle to vehicle (V2V) communication system: A wireless exchange of information about the speed and position of other vehicles on the road.

I.INTRODUCTION AND ANALYSIS OF SITUATION

Traffic congestion has become a reality of the modern age. According to the 2019 Urban Mobility Report, the average American commuter spends an average of 54 hours a year in traffic [1]. In addition, it is estimated that traffic congestion has grown at a rate of 1 – 3% every year since 2008 [1]. Following this trend, the average American commuter will be wasting up to 62 hours a year in traffic by 2025 [1]. While these statistics may already sound unpleasant, they barely scrape the surface of the consequences that arise as a result of traffic congestion. Therefore, there is a clear need to address and attempt to eliminate, or at the very least reduce, the main contributors to the formation of traffic congestion. However, before attempting to propose a solution to this problem of traffic congestion, a deeper and more comprehensive understanding of the issue must be established.

The U.S. Department of Transportation (DOT) defines two main categories of traffic congestion: recurring and non-recurring. The DOT claims that approximately half of traffic congestion is of the recurring kind, which is considered predictable, as it is usually caused by an obvious problem. An example of such a problem would be a road that simply has more cars driving on it than it can support. In contrast, non-recurring traffic congestion is caused by unpredictable problems such as traffic accidents or bad weather. Within the non-recurring category of traffic congestion, we can identify a major contributing factor: the human element.

Humans are a principal source of traffic congestion that could otherwise be preventable. For example, in the context of traffic accidents, while it is possible that there are rare cases where an accident is unavoidable, a significant majority of traffic accidents are caused by negligence or distraction. Similarly, another contributor to traffic congestion that is caused by humans is a phenomenon called phantom traffic jams. This phenomenon is used to

describe situations where traffic seems to halt to a standstill for no apparent reason, hence the term “phantom.” All it takes for a phantom traffic jam to form is one driver making a sudden lane switch or abruptly pressing the brakes, creating a chain of brakes reverberating through the whole lane and eventually causing traffic to grind to a halt.

Given that humans are prone to making mistakes that can affect themselves and others, the best solution is one where human judgement is not required. One possible solution that fulfils this criterion is autonomous vehicles (AVs) that havethe capability to communicate with one another. The solution builds on the foundation that is still currently being laid out by the development of self-driving vehicles, with the precise goal of reducing traffic congestion. While the development of self-driving vehicles is promising in and of itself, the fact that their algorithms and software do not necessarily conform to a certain standard is a lost opportunity to address the ever-growing traffic problem. With the implementation of a communication system, allowing for communication between the vehicles, self-driving cars can become more than just a quality-of-life upgrade, or a safety upgrade, but also a practical solution to a complex problem.

Autonomous vehicles (AVs) depend on many concepts familiar to computer science and engineering. These concepts allow the vehicles to make decisions without any human intervention by using a large number of sensors that collect data from the existing transportation system. In addition to the sensors, there is a reliance on artificial intelligence (AI) instead of human judgment to interpret and analyse the data to make decisions regarding the vehicle’s operation. One of the main advantages AVs have is their ability to collect information through open systems called vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication systems. Therefore, unlike humans, the autonomous vehicle’s

ability to calculate efficient path findings on the road according to collected traffic data will help in lessening traffic congestion.

In addition to AVs' ability to reduce traffic, AVs will be able to eliminate the human error that causes countless fatal accidents yearly. For instance, Japan experiences around 4000 fatal accidents yearly, China around 260,000 fatalities, the US over 35,000 fatalities, and globally, more than a million fatal accidents occur each year [2]. Therefore, implementing AVs can reduce the leading cause of these accidents: human error. These errors can be avoided since AVs are manufactured to operate under traffic rules only. For example, studies estimate that many accidents could have been avoided if autonomous braking were used [2]. Additionally, over 40 % of fatal crashes in the US are caused by a combination of alcohol, drug involvement, or distraction [3]. Thus, implementing AVs will suggest a potential reduction in fatalities as AVs are not affected by such human failings. Eliminating other factors involving car accidents including inexperience, speeding, slow reaction times, inattention, and reckless driving may further reduce the number of fatal accidents yearly [3]. Therefore, implementing autonomous vehicles in our current transportation system may have various advantages to the society.

II. IDENTIFICATION AND DISSCUSION OF PROBLEMS

Using autonomous vehicles (AVs) provides many benefits on the road. Unfortunately, AVs are still facing many problems regarding their technology. The first problem is that AVs' ability to communicate with other AVs and manual cars is very limited [4]. Enabling a communication system that allows cars to send and receive data from traffic signals, other AVs, manual vehicles, and parking spaces can be very useful. The communication system may lead to more efficient path findings and consequently mitigate the congestion burden. However, the communication system will require a massive amount of data to be stored. "Big

data'' is a term used to highlight an unprecedented amount of data for which special provisions in software and hardware are required [5]. In brief, implementing an advanced communications system, which handles large amounts of data, is crucial in lessening traffic.

A further problem with AVs' software systems is that they are highly vulnerable to cyber-attacks by hackers. These hacks primarily arise from the interaction of cyberspace with ICTs, which is the integration of multiple telecommunication systems, including wireless signals, computers, and telephone networks [2]. As AVs require the use of external network systems, this involves a risk of third parties hacking into the system, causing safety concerns. A hacker may easily hijack the car's software causing intentional accidents and injuries, stealing passenger's personal data, or disturbing the car's operation on the road [4]. These scenarios may happen in various ways including jamming the AVs' GPS system, hacking the AVs' wireless Event Data Recorder system, creating Denial of Service Attacks (DoS) to the data, and modifying the AVs' maps and sensors to disturb the car's operation [2]. Furthermore, the vehicle's user may be harmed financially if the hacker intends to destroy the vehicle's operating system. Therefore, novel solutions must be implemented to enhance the vehicle's security and the public's trust in AVs.

Similar to the cybersecurity problem, AVs have some privacy concerns regarding personal data. These AVs require the storage of a large amount of sensitive information through external communication systems from other autonomous vehicles on the road, GPS systems, and infrastructure communication systems. This data, which is transmitted through third-party communication networks, is important for efficient traffic management, path findings, and accurate assignment of liability in case of accidents occurring between vehicles [2]. As a result, enabling data sharing between vehicles and infrastructures to obtain the full benefits of increased connectivity between vehicles may create privacy concerns for users.

For example, insurance companies may use personal data from AVs to predict insurance premiums that can be very inaccurate [2]. Another example is using AVs' travel history to predict the users' behaviour and harass them using tailored advertising strategies [2]. In addition to these examples, there are many more scenarios that could arise as a result of misusing personal data yet are hard to predict unless AVs are widely implemented in cities. Therefore, informational privacy in AVs is important not only to ensure the safety of the users but also the public's trust in sharing their personal data.

In addition to the limited communication problem, AVs' sensors face a significant problem with corner cases. Corner cases, which are rare and unusual situations occurring outside of the system's operating parameters, cannot easily be predicted by the system [6]. It is simple for a human driver to handle such unusual scenarios. However, artificial intelligence cannot perceive, recognize, or act towards unusual obstacles on the road as humans do. For instance, Volvo producers carried out various tests in Australia to measure the capability of their AVs' sensors in corner cases. The results show that kangaroos were very confusing to AVs even though the same AVs could recognize other big animals such as deer, caribou, and elk. When a kangaroo jumps, it jumps very high to the point that the detection system senses the kangaroo as a distant object. Nonetheless, when the kangaroo lands on the ground, it looks much closer to the system, causing confusion [6]. Thus, AVs' sensors must be improved to deal with different encountered situations on the road.

An additional problem in AVs' sensors is that they are not capable of handling adverse weather conditions. Conditions such as snow, rain, hail, and fog may lead to poor performance by the sensors. For instance, raindrops in the air on a rainy day can degrade the quality of the images captured by AVs' cameras [7]. Furthermore, if the raindrop hits very close to the laser emitter used in the sensors, false detection may occur, causing the car to

stop or crash suddenly [7]. Sensors and cameras in AVs can also be sensitive to day-night cycles, as shown on the left in [4, Fig. 1]. In contrast, the right side illustrates another problem where the sensors perceive different areas with high similarities as the same area [6]. Consequently, it is essential to improve the quality of AVs'sensors.

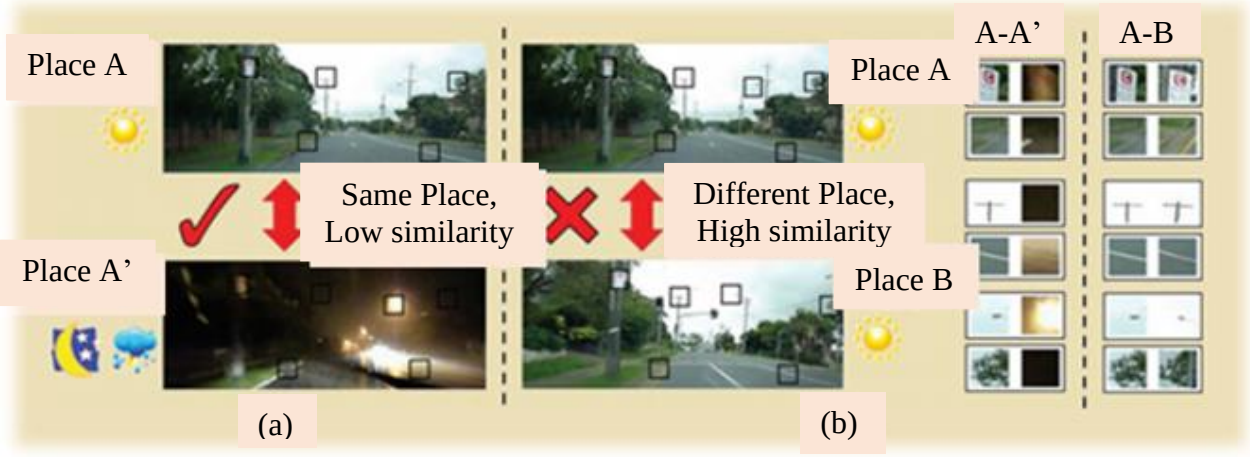

Figure 1: AVs' sensitivity to environmental changes

IV. SOLUTIONS AND FINDINGS

Considerable research has been conducted recently to overcome and provide solutions to the current challenges facing AVs. One solution to eliminate the communication system problem is a vehicle to vehicle (autonomous or manual) and vehicle to infrastructure communication system. According to [6], the term "connected vehicles" is used to demonstrate technologies that ensure communication between all contributing agents on the road, as shown in [2, Fig. 2]. Furthermore, to handle this massive amount of data provided to the vehicle, emerging technologies such as 5G networks, software-defined networking (SDN), and network function virtualization (NFV) can be used [4]. All of the mentioned technologies have many benefits, such as having high capacity, low latency, flexibility, and

affordability. Thus, to fully develop an efficient communication system, new technologies must be implemented [4].

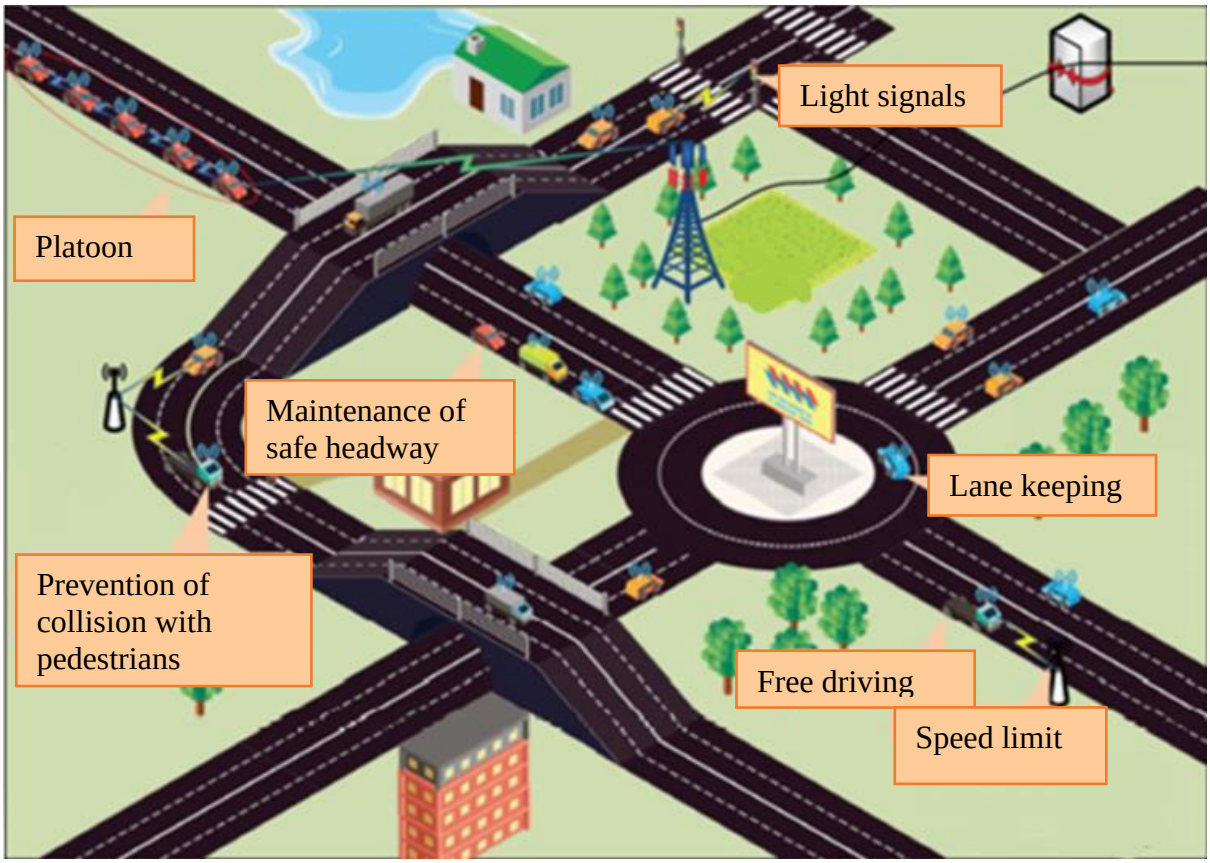

Figure 2: A representation of vehicle to vehicle and vehicle to infrastructure communication system

To avoid unauthorized access from hackers into the vehicle's system, there are two main solutions. First, blockchain solutions can be introduced into the software since they are usually used for crucial data and information systems. Blockchains use advanced algorithms and cryptography to ensure that the system becomes "hack proof" [8]. These blockchains are a chain of immutable blocks, where each block contains information about itself and previous blocks [9]. Every block includes a hash, which is a unique value given to each block, and the hash of the previous blocks. These blocks are chained together into what is called a

blockchain that can be either public, private, or consortium. The advantage of using blockchains is that if anyone tries to modify information, the hash will change making the whole system invalid since each block has a unique hash, much like fingerprints [9]. Therefore, any cyber-attack can be easily detected if the hacker attempts to change any block containing information. Another solution provided by ethical hacking is when AV companies hire ethical hackers to break into the car's system to highlight and detect any flaws in the software [8]. After the potential flaws in the operating system are identified, corrections to the system's security are made to boost its safety.

To address the privacy concerns in AVs, most governments should enact legislation to manage privacy risks associated with autonomous vehicles. For instance, some countries such as the UK and Germany have introduced to AVs manufacturers non-mandatory privacy guidelines that they must follow [2]. Similarly, most states in the US also introduced some specific privacy guidelines to follow [2]. These guidelines include restricting personal data usage unless the user consents to use his/her private information. Furthermore, there must be transparency from network operators about the purpose and usage of the collected data. However, privacy concerns for AVs may be avoided at the expense of data sharing. As mentioned previously, AVs rely on data sharing between other vehicles and infrastructures to navigate optimally. For example, AVs use shared data from other vehicles to request changing lanes on the road or entering an intersection, as shown in Fig. 3 below. Therefore, scholars have emphasized the importance of balancing privacy concerns and data sharing in order to avoid disturbing the vehicle's operation by not providing enough data [2].

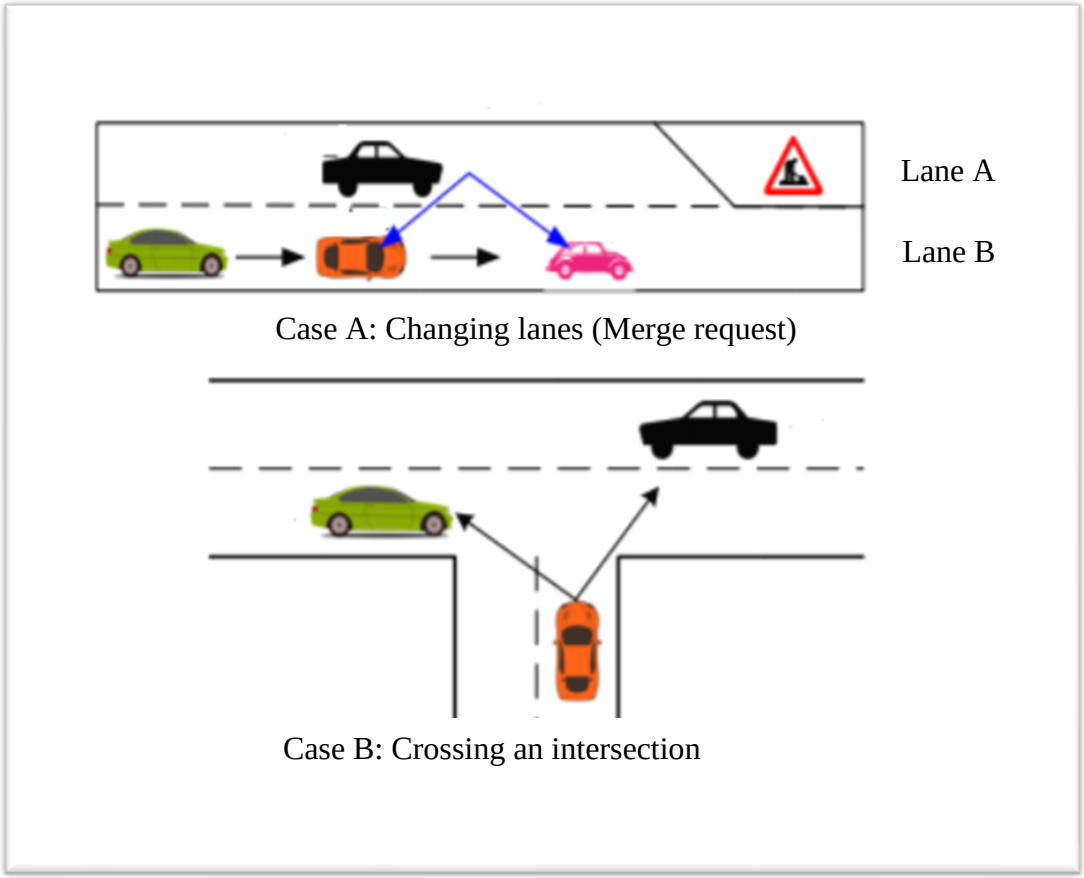

Figure 3: AVs using shared data to change lanes and enter intersection

To further improve AVs, two necessary steps must be taken to overcome the sensors' poor performance in adverse scenarios and weather conditions. First, to deal with unusual scenarios on the road, AVs must be provided with a larger amount of data [6]. Data can be collected by implementing cameras and sensors that store data from manual cars while driving. The quality and quantity of data provided are essential. The more variety sets of data present, the more corner cases are encountered by the sensors, as shown in Fig. 4. Thus, the sensors become trained to predict and act accurately in such adverse cases.

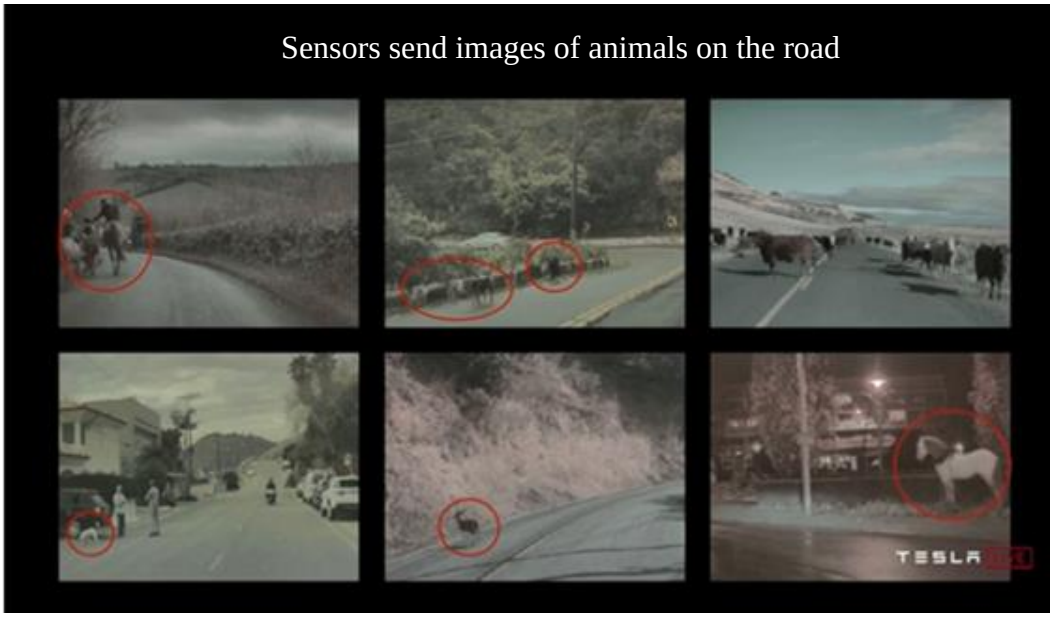

Figure 4: Different corner cases encountered by AVs' sensors

The second step to enhance the sensors' performance in adverse weather conditions is a little more challenging. Each different weather condition, such as rain, fog, snow, and sandstorms, require a unique and different solution. For instance, if one of the AVs' cameras has moisture below the freezing point, frost is formed on the camera's lens. Consequently, frost will block the vehicle from viewing anything but the crystalline patterns of snow. To solve the issue, a self-heating camera, which generates heat while operating, can be applied to evaporate any frozen moisture on the lens [7]. Furthermore, rain can cause sharp intensity fluctuations in the images collected by the vehicle's sensors. These fluctuations degrade the quality of the image by decreasing the image's intensity and blurring the edges of any object behind the sensors causing the object to be unrecognized [7]. To solve this problem, computer scientists and engineers can reduce and remove the effect of raindrops without considerably altering the appearance of the image [7]. This method is conducted during image acquisition, where the camera's parameters such as focus settings and exposure time are set to reduce the effect of raindrops [7]. Therefore, unique solutions for each different weather condition are important in improving the sensors' technology.

V. EVALUATION

The most glaring issue with AVs is public trust. According to a survey conducted by Partners for Automated Vehicle Education (PAVE), 48% of Americans said that they would never get in a car, whether taxi or ride-share, that is self-driving [10]. Similar trends can be observed all over the world in places like Europe, where 45% of German respondents agreed with a statement saying that self-driving vehicles will not be safe, and Asia where 47% of Japanese respondents, and 46% of Korean respondents agreed with the same statement [11]. These statistics would not be surprising if the surveys that report them were conducted in the early stages of the development of self-driving vehicles. However, all mentioned surveys were conducted in 2020, which is almost five years after the release of Tesla Autopilot. The issue of public trust is important to address because the regulation of traffic with communicating self-driving vehicles can only be possible if the majority, if not all, vehicles on the road are able to transmit signals and regulate themselves, which necessitates the use of self-driving vehicles.

Despite the public's lack of trust in AVs, it is not all bad news when it comes to the public reception of self-driving vehicles. In fact, in the same survey conducted by PAVE, 60% of Americans responded that they would trust AVs if they had a better understanding of how the technology works [10]. Similarly, 58% of Americans mentioned that they would further trust AVs if they could experience a test drive in one [10]. Based on these findings, it seems like the solutions to the matter of public trust are not out of reach. First, the manufacturers of self-driving cars need to be more transparent when it comes to the details of the inner workings of the technologies utilized by the vehicles. Second, there should be more public demonstrations of the capabilities of the vehicles so that people can have a chance to experience and become exposed to these seemingly foreign technologies. Lastly and most

importantly, the safety features of these vehicles should be highly emphasized, and this goal can be achieved in a variety of ways. One way could be through the development of a series of tests defining an international standard for the minimum acceptable performance of AVs [12]. All in all, the application of these proposed solutions is sure to help alleviate the issue of public trust, as these solutions are based on the concerns voiced by the public.

In addition to the issue of public trust, the matter of ethical concerns has been a detriment to the development of AVs. There was a study in which participants were shown pairs of hypothetical situations, which portrayed a self-driving vehicle about to collide with people [13]. The participants were then asked which of the two situations they thought was the right decision for a self-driving vehicle to make. The researchers also made sure to consider as many factors as possible by including different characteristics such as whether the people were women or men, young or old, rich or poor, and even entirely replacing the human victims with animals [13]. The study found that in countries with collectivistic cultures, like China and Japan, people were more likely to spare the old over the young. Whereas in countries with individualistic cultures, like France and the U.S., people were more likely to spare the young over the old [13].

These findings illustrate the core issue of the ethical concerns regarding AVs, which is that people have different opinions based on their nationalities, backgrounds, and experiences. Therefore, there cannot be a single ethical decision-making algorithm for all AVs to share, as people of different countries may disagree with their implementation. However, most people agree with the utilitarian position, which states that the decision should be made with the goal of minimizing the number of casualties, and that is likely the best solution for such a complicated issue.

In contrast to the issue of ethical concerns, cybersecurity is an issue that can be directly addressed and resolved. The previously proposed solution to ensure the security of the vehicle's data, ethical hacking, has proven its success in some car samples. For instance, researchers at Jeep demonstrated that they could control the car remotely by hacking into the car's multimedia system. The researchers were able to change the radio station and track the car's GPS location remotely [5]. Fortunately, because the flaw in the system was detected, Jeep producers corrected the software's vulnerabilities. Similarly, researchers in China exposed vulnerabilities in a Tesla X model. The researchers were able to control the vehicle's brake, trunk doors, and radio [5]. Therefore, detecting such flaws in the software is essential in ensuring the public's safety and trust.

Lastly, enabling an effective communication system in AVs affords an opportunity to lessen the congestion burden. For instance, Dresner and Stone [5] proposed a reservation-based system for lessening traffic congestion. The results indicate that the proposed communication system can perform two to three times better than traffic lights [6]. Therefore, as the number of "connected vehicles" increases, traffic delays decrease as well. Furthermore, AVs reduce traffic delays by reducing vehicle crashes caused by human error. AVs also allow efficient pathways and routes based on continuous traffic updates every minute. Consequently, AVs will have a significant contribution in mitigating traffic congestion.

VI. CONCLUSION AND RECOMMENDATIONS

Traffic congestion is a standard part of modern life. The human factor is the leading cause of traffic jams. Therefore, one of the apparent solutions in this situation is vehicle automation. Autonomous vehicles make it possible to rationally calculate paths by collecting data from traffic and as a result reduce congestion. The algorithms and software used in AVs may require significant improvement. However, the idea of AVs is particularly promising

because it offers the potential to improve the quality of life and safety of all road users. It will help reduce traffic and eliminate human error, which is the leading cause of fatal accidents on the road.

Like any other technology, AVs face some problems. One of the main problems in implementing these self-driving vehicles is that they do not interact with other systems and infrastructures such as traffic lights or parking spaces. The communication system needs to implement functions for processing large amounts of data from all transport-related systems. Another concern is security, the vehicle's software is still quite vulnerable to cyber-attacks, and since AVs are associated with the use of external systems, these systems can create a risk for drivers. On the same basis, there is a problem with protecting personal confidential data of users. Furthermore, AVs face a difficulty with corner cases that occur outside of the operating parameters of the system. It is not easy for AVs to adapt to these unusual scenarios because AVs depend on artificial intelligence, which has certain limitations to the variety of data sets it can react to. Lastly, the inability of the vehicle's sensors to cope with certain weather conditions can degrade the performance of the sensors. Thus, there is a need to improve AVs' technology before introducing the cars to the road.

Resistance to this research project by societies and government is expected. As mentioned in the evaluation, the biggest issue with AVs is public trust. Surveys were conducted on people from different countries, and most of the participants in the survey were hesitant to trust autonomous vehicles with their lives. Furthermore, some ethical concerns regarding the vehicle's ability to make certain decisions created much controversy among the public to whether use the vehicle's or not. Therefore, the lack of public trust and the ethical issues in these advanced vehicles could possibly push their potential in being released anytime soon.

In response to the findings of this report, we encourage others to conduct further research on autonomous vehicles in an attempt to show how such vehicles and technology can be implemented into our daily lives. This research may include studying the effects of AVs on the environment, handling different types of cyber-attacks, and solving more adverse weather problems. While such cars may already exist, having a fully equipped artificial intelligence based transportation system could possibly open doors to new technologies in the future. In addition, we hope to shed more light on this topic, and hopefully more advanced research is conducted to produce these vehicles for our community.

Lastly, having physical access to these technologies makes it easier to define more effectively and visually all aspects that require change. The recommendations provided in this report to further improve AVs centers on the need for technology development. Each of the presented ideas is innovative, unusual, and modern for the current society. Therefore, a society that may not be ready to innovate can oppose these ideas as it worries about the degree of safety artificial intelligence will provide. However, all of the concepts outlined aim only to improve the convenience and safety of people's lives. Thus, this paper could be a valuable resource for specialists involved in developing transport and information technologies.

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