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Section 02 – Team 5

EMDP Final Report

# Safety Implications of Self-Driving Cars in the UAE:

# Engineering Challenges and Opportunities

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**Submitted To:** Prof. Liane Jeschull

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April  23, 2023

Prof. Leiane Jeschull
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Dear Prof. Jeschull,

Please find the attached report entitled "Safety Implications of Self-Driving Cars in the UAE: Engineering Challenges and Opportunities." This report was written to fulfill the Engineering Multi-Disciplinary Project (EMDP) requirement for the ENG207 course. In this report, we explore various technical and engineering challenges pertaining to the wide adoption of self-driving cars in the United Arab Emirates, and the safety concerns necessary to be addressed. Through this report, we propose various technical solutions to solve these problems.

Our team was composed of students from different engineering disciplines, each bringing their expertise to the project. Hamza Abushahla and Yousef Elmadani, a computer engineer and a computer scientist, explored the various issues about the software aspect of autonomous vehicle operation, such as the use of AI, and deep neural networks, and researching ways to resolve software complications. On the other hand, Ahmed Hassan and Fares Brake, who both are mechanical engineers, focused on the issues of the cameras and LiDAR sensors used in autonomous vehicles, such as the effect of climate on their functionality, and explored ways to address such issues.

We would like to thank several people for their support during our research. Firstly, we would like to express our gratitude to the AUS Librarians for their help in locating academic sources such as IEEE, WorldCat, JSTOR, and Google Scholar. We would also like to thank the tutors in the AUS writing center for their support and guidance regarding the use of IEEE referencing, as well as their insightful comments on the report.

We hope that our report meets all the criteria for the Engineering Multi-disciplinary Project (EMDP) and that you find our findings insightful. We believe that our report highlights the importance of addressing the engineering challenges associated with self-driving cars and provides a roadmap for future research. We thank you for your time and consideration, and we remain at your disposal should you have any questions or comments.

Yours Sincerely,
Ahmed Hassan, Fares Barake, Hamza Abushahla, and Youssef Elmadany
Encl.: EMDP Report "Safety Implications of Self-Driving Cars in the UAE: Engineering Challenges and Opportunities"

# EXECUTIVE SUMMARY

The development of self-driving UAE cars can address some significant transportation concerns. By removing human error from the equation, self-driving cars can help reduce accidents and traffic congestion. In this report, we proposed three solutions to address multiple problems affecting the safety of vehicles in the UAE.

This report identifies two technical challenges in achieving widespread adoption of self-driving cars in the UAE. These challenges include the adverse weather conditions in the country, such as dust, heavy fog, and extreme heat, and the software complications found in the current technologies. First, weather conditions may cause systems and sensors to malfunction, which seriously threatens the safety of autonomous vehicles. Secondly, software complications occur due to perception errors, when inputs from the sensors do not present the actual driving situation, or volatile driving environments due to limitations of machine learning AI models that have limited situation generalization.

After conducting substantial research, we present a few solutions to the problems at hand. First, sensor fusion can solve common visibility problems caused by dust and fog. Sensor fusion combines data from multiple sensors, filtering out these particles to ensure reliable autonomous vehicle operation. To counteract extreme heat during summer, thermally conductive interface materials (TIMs) dissipate heat from processors and sensors into the environment. Deep neural networks (DNNs) improve autonomous vehicle perception and decision-making processes, outperforming traditional algorithms. DNNs use complex algorithms to process and analyze data, learning from diverse and complex data sources.

While the solutions presented above may successfully address several issues, it is crucial to acknowledge their limitations. To start, sensor fusion effectively improves safety under adverse weather conditions but requires expensive hardware and frequent calibration. Moreover, TIMs are cheaper and more practical than liquid cooling systems, but the latter is more widely used for thermal management. Finally, the black-box problem, which refers to the need for more transparency in decision-making, is a significant challenge associated with DNNs and may hinder the widespread adoption of autonomous vehicles.

The primary methodology used in this project was secondary research, which involved analyzing a wide range of journal articles and books to build strong arguments. The team searched for relevant sources in databases to gather reliable statistics and insights on the current state and emerging trends in autonomous vehicles. We also integrated primary research, where our team conducted a survey. Daily efforts were made to collect information and generate the report.

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# GLOSSARY

**AI (Artificial Intelligence):** the simulation of human intelligence processes by machines, especially computer systems.

**Algorithms:** a set of well-defined sequences of instructions to carry out a specific task or solve a particular problem.

**AV (Autonomous Vehicle):** a vehicle that is able to operate itself and perform necessary functions without any human intervention, through the ability to sense its surroundings.

**DNNs (Deep Neural Networks):** a type of artificial neural network that consists of multiple layers of interconnected nodes; they are designed to recognize patterns and extract information from complex data sets.

**Deep Learning:** a powerful set of techniques for learning in neural networks

**LiDAR (Light Detection and Ranging):** a remote sensing method that uses light in the form of pulsed laser beams to calculate an object's variable distances from the earth’s surface.

**ML (Machine Learning):** a subfield of artificial intelligence that gives computers the ability to learn without explicitly being programmed.

**Occlusion:** a situation where an object or part of the environment is partially or completely hidden from the sensors of an autonomous vehicle.

**Object-Scaling Issue**: a problem in autonomous driving where the perception system of the vehicle misjudges the size of an object, leading to incorrect distance and speed estimations.

**Radar (Radio Detection and Ranging):** It is a system that uses radio waves to detect and locate objects.

**Reinforcement learning**: a subfield of machine learning that involves training an artificial intelligence system to make decisions in a dynamic and uncertain environment.

**TIMS (Thermal Interface Materials):** materials with high thermal diffusivity which enhances heat transfer by decreasing the contact resistance.

**Ultrasonic Sensors:** An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal.

# I. INTRODUCTION AND ANALYSIS OF SITUATION

The adoption of autonomous vehicles, especially self-driving cars, has gained significant traction around the world in recent years, and the United Arab Emirates (UAE) is no exception. That is because self-driving cars address the primary cause of car accidents: human error. According to the World Health Organization (WHO), human error is responsible for approximately 90% of all car accidents worldwide [1]. By eliminating the need for human drivers, autonomous vehicles have the potential to significantly reduce the number of accidents caused by distracted, impaired, or reckless driving. Self-driving cars provide several other advantages, such as increased mobility for people with disabilities and reduced traffic congestion, which can help reduce travel time, fuel consumption, and air pollution, making transportation more efficient and environmentally friendly.

Autonomous vehicles may be seen as the next revolution in the transportation industry, as well as the natural progression of automotive technologies. In recent years, major automakers, researchers, and technology companies such as Google, Uber, Tesla, and General Motors have led the development of self-driving technologies [2]. These companies have made significant investments in developing and testing self-driving cars that can navigate roads safely and efficiently without human intervention. To make decisions and operate safely, these self-driving cars rely on a combination of advanced sensors such as LiDAR, radar, and cameras, as well as sophisticated software that analyzes the environment in real-time to make safe driving decisions. The software that powers these technologies employs a combination of AI, machine learning, computer vision, and obstacle avoidance algorithms, to comprehend the vehicle's surroundings, predict how other vehicles or pedestrians will behave, and plan the vehicle's trajectory accordingly [2]. For example, Uber's self-driving prototypes construct their internal map using sixty-four laser beams in conjunction with other sensors [3]. Google's prototypes, on the other hand, have used a combination of lasers, radar, high-powered cameras, and sonar at various stages of development [3].

Dubai, a major city in the UAE, has been at the forefront of adopting self-driving vehicles. Sheikh Mohammed bin Rashid, Vice President of the UAE and Ruler of Dubai, announced the self-driving transportation strategy in April 2017, with the goal of making 25% of all transportation trips in the city smart and driverless by 2030 [4]. This strategy is already being implemented, with Dubai expecting to launch its first fleet of self-driving taxis on the roads by the end of 2023 and aiming to deploy a total of 4,000 self-driving taxis by 2030 [5].

Moreover, in a partnership with the Cruise Company, an autonomous vehicle subsidiary of General Motors, the Emirate of Dubai has taken the lead in operating Cruise AVs outside of the US by using them to offer taxi and e-Hail services in the city [5]. The Cruise AVs are equipped with five LiDAR sensors, 16 cameras, and 21 radars, which collect data and feed it into the AV’s computer. This data is then used to construct a three-dimensional model of the vehicle's surroundings, keeping track of important objects and even predicting their future motion and trajectory [6].

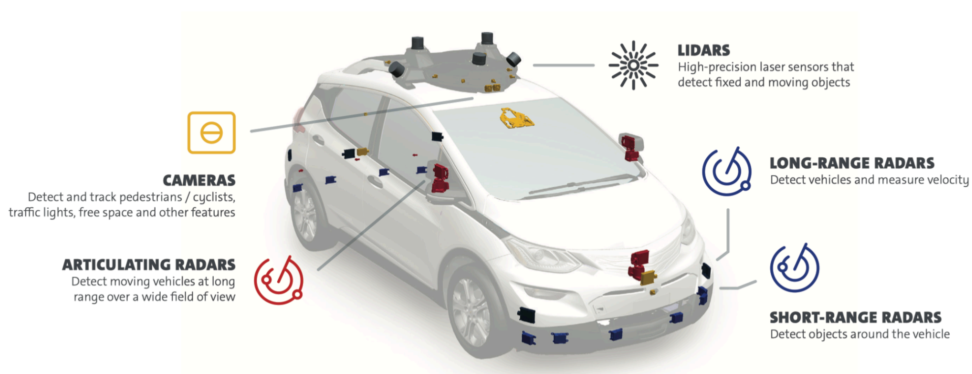


Fig. 1: Sensors and cameras on a Cruise AV [6]

The development and adoption of self-driving cars pose significant challenges that must be overcome before they can be widely adopted. The safety of self-driving cars is one of the primary concerns. Despite the fact that self-driving cars have the potential to reduce accidents caused by human error, they are not fully immune to accidents. For example, in 2018, an Uber-owned autonomous vehicle struck and killed a pedestrian in Arizona, USA [7]. Similarly, in June of 2022, a Cruise AV taxi carrying three backseat passengers was involved in an accident with another car after making an unprotected left turn [8]. Moreover, while self-driving cars have sensors and software that can detect obstacles and avoid collisions, they still make decisions based on inputs from their environment, which can be unpredictable at times. For example, in the UAE, road construction and maintenance activities are frequently carried out, resulting in changes in road conditions and traffic patterns. Self-driving cars may be unable to detect such changes or may find it difficult to navigate through construction sites, potentially resulting in accidents.

In addition, public acceptance of self-driving cars is critical to their successful implementation because they may face opposition from those who are concerned about their safety. To gain more insights into public perceptions of self-driving cars, we conducted a survey on the topic. The survey aimed at exploring people's opinions on the safety and effectiveness of autonomous vehicles, as well as their concerns about their adoption. Roughly 50% of the respondents believe self-driving cars are unsafe, with technical issues being the most frequently cited reason. Similarly, a study conducted by Continental AG in Germany, China, Japan, and the United States found that 31% of people were concerned about the progress of automated vehicles, and 54% did not fully trust that such vehicles would operate reliably and safely [9].

These concerns about technical issues and safety highlight the need for continued research and development to address these challenges and enhance public trust in self-driving cars.

## II. IDENTIFICATION AND DISCUSSION OF PROBLEMS

When it comes to the safety of self-driving cars, the technical and engineering challenges currently facing their development are major obstacles to achieving widespread adoption in the UAE. Such challenges encompass both the hardware and software aspects of autonomous car technology and need to be addressed separately. In light of these challenges, it is important to ask: what are the engineering challenges facing the adoption of self-driving cars in the UAE, and how can they be tackled?

### *A. Adverse Weather Conditions*

To begin with, the adverse weather conditions in the UAE, such as dust, heavy fog, and extreme heat, can cause the systems and sensors used to operate the cars to malfunction, posing a serious challenge in the face of adopting fully autonomous cars. For example, the UAE gets around 24 fog days per year, with an average temperature of 33 degrees Celsius, and can reach up to 50 degrees Celsius [10]. As stated previously, autonomous cars mainly operate using three sensors, namely cameras, radars, and LiDAR sensors. Cameras can see bodies ahead of them such as traffic lights, road signs, and lane markings within a certain range, and capture images of these objects. They can detect and measure the distance between the car and objects which aids in avoiding pedestrians or any other body on the road. However, under adverse weather conditions, fog and dust particles create foggy images which drastically reduces the visibility of autonomous cars [11]. If the camera is exposed to a considerable amount of moisture due to heavy fog, its lens can get severely damaged which obscures the images captured by the sensor and reduces the color saturation [12].

Additionally, LiDAR sensors function by emitting laser beams that hit objects on the road and return to the sensor which creates a signal in the system. With this signal, LiDAR sensors generate a 3D map of the environment surrounding the driverless car [13]. However, heavy fog causes LiDAR sensors to not operate properly as their visibility will be reduced, leading to them incorrectly identifying the fog particles as objects to be avoided, which may in turn lead to an accident [14]. The presence of water droplets in heavy fog decreases the sensor's range as the light waves would eventually be intercepted by those droplets. In this case, the fog hinders the movement of the laser beams, stopping them from reaching the intended target. As a result, the pulsed light waves scatter around and reflect off the water droplets, causing the LiDAR sensors to detect false objects such as fog particles or even miss real ones [15].

Finally, extreme heat is a major problem affecting autonomous cars in the UAE, as it can cause certain sensors to overheat. As seen in Fig. 1, the LiDAR sensors are placed in a position such that they are directly exposed to the sunlight. Additionally, sensors such as radars and LiDAR sensors release a lot of heat when they operate. For example, LiDAR sensors emit laser beams as they function. When the laser diode that detects the returning light waves becomes too hot, it overheats and can eventually malfunction due to major damage. Its output power and range decrease considerably with very high temperatures [16]. Furthermore, extreme heat can reduce the processing power of the processors and sensors in autonomous cars and negatively impact their performance [17]. Therefore, with high temperatures, the crucial sensors of an autonomous car get affected to a degree in which they may fail and stop working completely.

### *B. Software Complications*

Autonomous car systems face significant software complications that impede their widespread adoption as a reliable transportation option. Current autonomous car systems, such as

Waymo, rely on a combination of sensors, such as cameras, radar, LiDAR, and ultrasonic sensors, to perceive their environment [3]. The sensors provide inputs to a central computer that processes the information to make decisions based on the situation [3]. However, if the central computer does not effectively utilize the sensor information, the car may frequently be the subject of many accidents. To ensure effective utilization of the sensor information, current autonomous vehicles utilize machine learning AI models, implementing both categorical and continuous learning algorithms [18]. These models enable the car to learn how to act in specific situations with specific sensor inputs. However, machine learning AI models have limitations. They do not allow for situation generalization, meaning they can only act upon exact situations they have learned before [18]. When an autonomous car is subjected to a unique unlearnt situation, the car will fail to make the right decision leading to unnecessary complications. The limitations of machine learning AI models result from two major software complications: problems with perception and volatile driving environments.

The first significant software complication facing autonomous cars is perception errors. Perception errors are one of the most significant challenges facing the development of autonomous vehicles. These errors commonly occur as, sometimes, inputs from the sensors may present only a partial picture of the driving situation. The car may be placed in driving situations with cases of occlusion, low-light environments, or object-scaling issues that hinder the sensors' ability to provide meaningful information to the central computer [19]. One example is when an autonomous vehicle is driving in an area with low visibility, such as during heavy rain or fog. In such a condition, the vehicle's sensors may not accurately identify objects on the road, such as other vehicles or pedestrians. In such cases, the autonomous vehicle may be unable to make the right decision, leading to dangerous outcomes [19]. Furthermore, the misidentification of objects can be a major issue, as the autonomous vehicle may not recognize or misidentify specific objects, leading to hazardous situations [20]. For example, an autonomous vehicle may misidentify a plastic bag on the road as an obstacle, causing the car to brake suddenly, which could result in a collision with the vehicle behind it. These perception errors are particularly challenging for autonomous vehicles, as they rely heavily on sensor data to make decisions, and any errors or inaccuracies in this data can have significant consequences [20].

The second major software complication in autonomous cars is the unpredictability and volatility of driving environments. This unpredictability arises from the inconsistency of other human drivers, changes in road infrastructure, accidents, and erratic pedestrian behavior. Although current autonomous car systems employ machine learning AI models to predict and respond to specific situations [3], these models cannot adapt quickly to new situations [19]. As a result, autonomous cars have difficulty surviving in volatile driving environments where unpredictable events occur frequently. Furthermore, a significant concern with autonomous cars is that they may need to break traffic laws to achieve the best outcome in certain situations [21]. This creates an issue of legality, particularly in situations where everything has been hard-coded [21]. For instance, an autonomous car may need to exceed the speed limit to avoid a collision with another vehicle or to reach a destination more quickly. However, doing so may violate traffic laws and raise questions about the responsibility of the car, the manufacturer, and the operator in the event of an accident [21].

# III. SOLUTIONS AND FINDINGS

## *A. Solution to Adverse Weather Conditions*

As mentioned earlier, autonomous cars operating in the UAE are subject to a variety of weather conditions including heavy fog and dust. Those conditions interfere with crucial measurements taken by the sensors making the cars prone to accidents. In order to increase the reliability of the measurements taken under those conditions we decided to adopt a technique called sensor fusion. Sensor fusion involves combining input data from multiple sensors and using them to allow autonomous vehicles to gain a clearer vision of their surroundings. In the case of fog and dust, low visibility obstructs the view of camera sensors. In addition, small dust and water particles cause laser beams emitted from LiDAR sensors to be scattered. This phenomenon affects the range of LiDARs and reduces their ability to detect objects [22]. On the other hand, radar sensors are not as affected under these conditions. This is because radars use radio waves that have longer wavelengths allowing them to be transmitted through dust and fog particles [23]. This characteristic of radar sensors is the basis of the success of sensor fusion under those conditions. As seen below in Fig. 2, data will be collected from multiple sensors and then will be processed before combining them together [24]. When the data are fused powerful algorithms will detect the dust and fog particles as they are missing from the radar measurements. With that being said, sensor fusion can be best described as filtering out the effect of foreign particles allowing autonomous cars to be more safe and reliable.

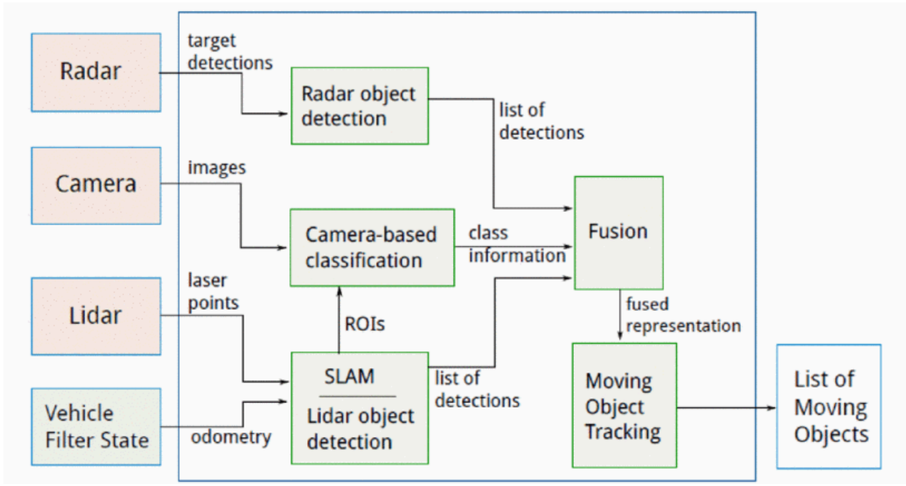


Fig. 2: Sensor fusion [25]

Another problem mentioned earlier was the extreme heat waves that occur during the summer. Those heat waves affect the operation of the sensors and processors in autonomous cars by making them more prone to overheating. The effect of heat can be in the form of increased response times which considerably decreases the safety of the car. In order to overcome this problem we decided on utilizing TIMs. These materials with high thermal diffusivity are used to improve the process of heat dissipation between two surfaces by decreasing the contact thermal contact resistance between the sensors/processors and the heat sinks [26]. As seen below in Fig. 3, the processors and sensors are usually grouped together where we plan to place the TIMs between them. As the components are in close proximity, a significant amount of heat will be generated making the use of TIMs crucial in this case. TIMs operate by absorbing heat from sources and transferring the heat into heat sinks by dissipating it into the environment. These materials help to manage the heat generated by the various components of the vehicle, ensuring safe and reliable operation. The efficient transfer of heat through TIMs improves the performance of the components, increases their lifespan, and reduces the risk of overheating, making autonomous vehicles safer and more reliable [27].

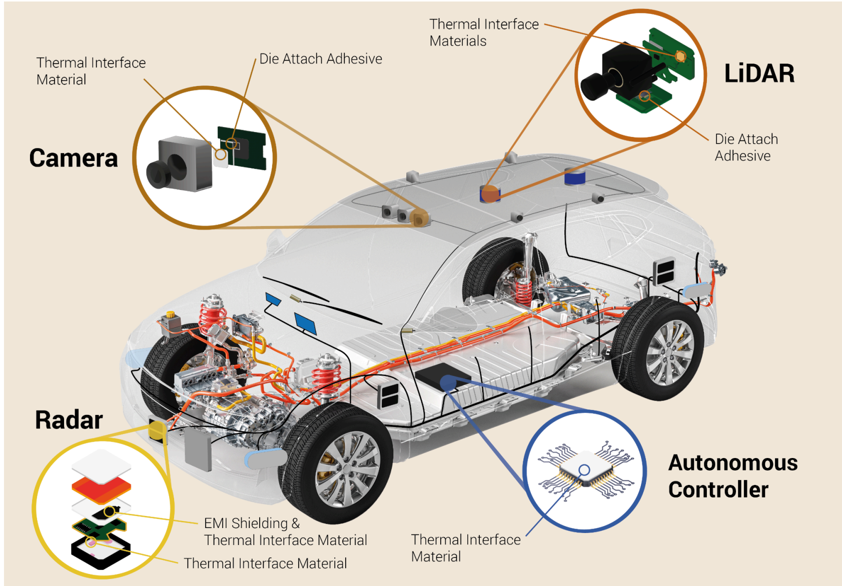


Fig. 3: Integration of TIMs in autonomous cars [28]

*B. Solution to Software Complications*

Deep neural networks (DNNs) are a promising solution to the limitations of traditional driverless car systems. DNNs can be trained on large amounts of data to improve the accuracy of perception, prediction, and decision-making [29]. DNNs can recognize and respond to driving scenarios with an accuracy of up to 95%, outperforming traditional algorithms [19]. Moreover, unlike traditional learning algorithms, DNNs can learn from new data and situations, enabling them to adapt to changing road conditions and scenarios [29]. DNNs use mathematical models inspired by the human brain's structure and function [29]. These networks consist of multiple layers of interconnected artificial neurons that process and analyze data [29]. The network processing data through these layers enables cars to learn and adapt like humans rather than simply reacting to pre-programmed scenarios.

The core of DNNs lies in their utilization of deep learning and reinforcement learning techniques to achieve their ability to learn and adapt like humans. Deep learning is a subfield of machine learning that allows neural networks to learn from vast amounts of data by using complex algorithms to process and analyze the data [30]. These algorithms improve DNNs' perception, prediction, and decision-making accuracy. Conversely, reinforcement learning is a technique that allows an autonomous system to learn through trial and error by receiving rewards or punishments for specific actions taken in a given situation [31]. This technique allows the system to adapt and respond to new situations more effectively. These two learning techniques are essential for successfully utilizing deep neural networks in autonomous cars.

Deep neural networks can be used to tackle the two major subproblems found in current autonomous technologies. Firstly, DNNs offer a significant advantage in improving perception and decision-making in autonomous vehicles. One of the key advantages of using deep neural networks (DNNs) for perception in autonomous cars is their ability to simultaneously handle complex and diverse data sources, such as LiDAR, cameras, and radar [32]. By processing and fusing data from multiple sources, DNNs can create a more comprehensive and accurate view of the environment around the vehicle. DNNs can also alleviate the challenges posed by variations in lighting, weather conditions, and other environmental factors that can affect traditional computer vision techniques [31]. Traditional techniques rely on handcrafted features often tuned to specific lighting conditions or environments, limiting their ability to adapt to new situations [32]. In contrast, DNNs can learn to recognize objects in different lighting and weather conditions through exposure to diverse data [32].

Secondly, deep neural networks can also help alleviate the uncertainty with other drivers on the road. Autonomous cars trained with reinforcement learning have been shown to perform maneuvers in complex driving scenarios with a success rate of over 90%, far outperforming traditionally trained autonomous cars [32]. By combining deep neural networks with reinforcement learning techniques, driverless cars can learn to adapt and respond to new situations more effectively [31]. Over time, the system learns which actions lead to the most rewards and which actions lead to punishments [32]. This learning enables the system to adapt and respond to new situations more effectively [32].

## IV. EVALUATION

### *A. Evaluation of Sensor Fusion*

The adoption of sensor fusion in autonomous cars helps improve their safety and reliability since it provides a more accurate view of the environment surrounding the car. This is the case for operation under ideal conditions as well as abnormal conditions. Our research focused on abnormal weather conditions, specifically dust and fog. Sensor fusion improves safety under those conditions by merging data from multiple sensors. Using data from multiple sensors, driverless cars can detect anomalies such as dust particles [22], meaning that sensor fusion helps autonomous cars navigate safely. In addition, in the event of one sensor failing, other sensors can still provide information reducing the likelihood of accidents.

Although sensor fusion appears to be quite safe and reliable, there are major drawbacks to installing sensor fusion into autonomous cars. Using sensors such as LiDAR sensors is very costly due to their design, complex functionality, and high accuracy and resolution [33]. Moreover, sensor fusion requires very high processing power to operate so that they provide accurate results, which means that they require expensive hardware. Due to that, autonomous cars are relatively expensive, making them less accessible to the public.

Another major drawback to sensor fusion is that it requires frequent calibration before being publicly used in autonomous cars. Each sensor has its own functionality and calibration parameters, meaning that each sensor needs to be tested out so that the sensor fusion aligns the data accurately from different sensors. A large fleet of autonomous cars is required to be tested and analyzed based on how they deal with everyday encounters, which can be time-consuming [34]. Overall, sensor fusion is an excellent answer to sensor reliability under abnormal weather conditions. However, there are certain drawbacks that need to be considered before making sure that sensor fusion is suitable enough to solve the problems we have encountered.

### *B. Evaluation of Thermal Interface Materials*

When it comes to heat management in autonomous vehicles, TIMs and liquid cooling systems are two popular solutions. During our research, we were conflicted about which method to use as both have their advantages and disadvantages, where the choice of which one to use depends on various factors, such as the cost, size, and complexity of the system.

One advantage of TIMs over liquid cooling systems is that they are simpler and cheaper to implement. TIMs are applied directly between the components and the heat sink, requiring a small number of components. They also don't require any maintenance or replacement, which can be an advantage in terms of cost and reliability [33]. On the other hand, liquid cooling systems offer a higher level of thermal management than TIMs. They use a liquid coolant to transfer heat away from the components, which can be more efficient than TIMs. Liquid cooling systems can also handle higher heat loads than TIMs, making them more suitable for high-performance applications [35].

However, liquid cooling systems also have some disadvantages. They require complex hardware, which can increase the cost, complexity, and weight of the system. They also require regular maintenance, including the replacement of coolant and the cleaning of the system [36]. Therefore, it is more practical to use TIMs for their small form factor and also to drive down the cost of the vehicles, making them more accessible to the public.

### *C. Evaluation of Deep Neural Networks*

The use of deep neural networks (DNNs) in autonomous cars has several advantages and disadvantages. On the positive side, DNNs significantly improve perception and decision-making in autonomous vehicles [29]. With their ability to process and fuse data from multiple sources, DNNs can create a more accurate and comprehensive view of the environment around the vehicle [30]. This enables them to detect and classify objects in real time, making them more effective in handling dynamic and unpredictable situations on the road [19]. DNNs also can learn from new data and situations, enabling them to adapt to changing road conditions and scenarios [29]. In addition, DNNs offer a self-improvement mechanism that can improve the accuracy of perception, prediction, and decision-making [29]. With reinforced learning techniques, DNNs can learn through trial and error, improving their performance over time [32]. This advantage may reduce the need for maintenance and enhance overall efficiency. As such, compared to relying heavily on sensory data to respond to external stimuli, neural networks offer a more efficient way of programming an artificial intelligence system. This improved efficiency helps us reach our goal of lower error rates and safer driving operations. However, the self-improvement mechanism can also be a double-edged sword, leading to overfitting and the potential for making decisions based on partial or incomplete data [37]. Overfitting occurs when the model is trained too well on a specific data set, resulting in a loss of generalization and the model's inability to perform well on new data.

On the other hand, one of the major drawbacks of DNNs in autonomous vehicles is the black-box problem. DNNs are often seen as opaque, making it difficult to understand how they arrive at decisions [38]. This lack of transparency can be a significant obstacle to the widespread adoption of DNNs in autonomous vehicles [38]. For example, it can be difficult to determine the cause of an accident involving an autonomous vehicle that uses DNNs, potentially leading to legal and ethical issues. As such, there is a need for research to address the interpretability and transparency of DNNs in autonomous vehicles. Furthermore, DNNs require significant amounts of data and computational power to train and operate effectively, which can be expensive and time-consuming [29]. Additionally, DNNs are vulnerable to adversarial attacks, where attackers can manipulate inputs to deceive the system and cause it to make incorrect decisions [39]. To mitigate these security concerns, it is imperative to develop robust DNN architectures that can withstand such attacks. This development may be costly and lead to less overall technology adoption.

In conclusion, DNNs offer significant advantages for improving the accuracy of autonomous vehicle perception, prediction, and decision-making. However, they also pose challenges such as the black-box problem, the need for significant amounts of data and computational power, and vulnerability to adversarial attacks. Further research is needed to address these challenges and improve the transparency and interpretability of DNNs in autonomous vehicles.

# V. CONCLUSION AND RECOMMENDATIONS

Self-driving cars have gained significant attention worldwide as they have the potential to significantly reduce accidents caused by human error, which is responsible for most car accidents. Self-driving cars rely on a combination of advanced sensors and software to make safe driving decisions. Dubai, in the UAE, has taken the lead in adopting self-driving cars to make 25% of all transportation trips smart and driverless by 2030. However, the safety of self-driving cars is a primary concern, and they still make decisions based on inputs from their environment, which can be unpredictable at times. Public acceptance is also critical to their successful implementation, as many people are concerned about their safety and reliability.

Like any new technology, the current self-driving systems face many technical and engineering challenges which pose major obstacles to any form of large-scale adoption. One of the main challenges that face self-driving cars, especially in the UAE, is adverse weather conditions. The UAE experiences harsh weather conditions such as dust, heavy fog, and extreme heat, which can cause the sensors and systems used in self-driving cars to malfunction, making it difficult to adopt autonomous vehicles.

In addition to adverse weather conditions, self-driving cars face significant software complications that impede their widespread adoption as a reliable transportation option. Perception errors and the unpredictability of driving environments are two major software complications. Perception errors occur when sensors provide incomplete or inaccurate information, leading to dangerous outcomes. Unpredictability arises from the inconsistency of other drivers, changes in road infrastructure, accidents, and erratic pedestrian behavior, making it difficult for autonomous cars to adapt quickly.

To improve the safety and reliability of autonomous cars in the UAE, solutions must be implemented to address adverse weather conditions and software complications. Sensor fusion can filter out the effects of foreign particles and make autonomous cars more reliable in heavy fog and dust. TIMs can manage the heat generated by various components and improve heat dissipation between two surfaces during extreme heat waves. DNNs can be trained on large amounts of data to improve perception, prediction, and decision-making accuracy, and can recognize and respond to driving scenarios with high accuracy. Combining DNNs with reinforcement learning techniques can enable driverless cars to learn to adapt and respond to new situations more effectively.

In conclusion, autonomous vehicles have the potential to revolutionize transportation in the UAE, but technical challenges must be addressed to achieve widespread adoption. This report highlights some possible solutions for adverse weather conditions and software complications, but more research is needed to refine these solutions and explore new avenues for improvement. As the technology and infrastructure for autonomous vehicles continue to evolve, it is essential to prioritize safety and efficiency to ensure their success.

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APPENDICES

*Appendix A: Survey results*

Have you ever ridden in a self-driving car before? This includes the autopilot mode on Tesla cars and the like.

66 responses

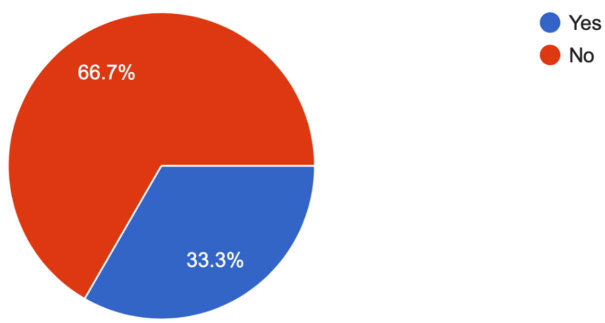


Fig. 4: Survey question 1

On a scale of 1 to 5, how comfortable are you with the idea of riding a driverless car?

66 responses

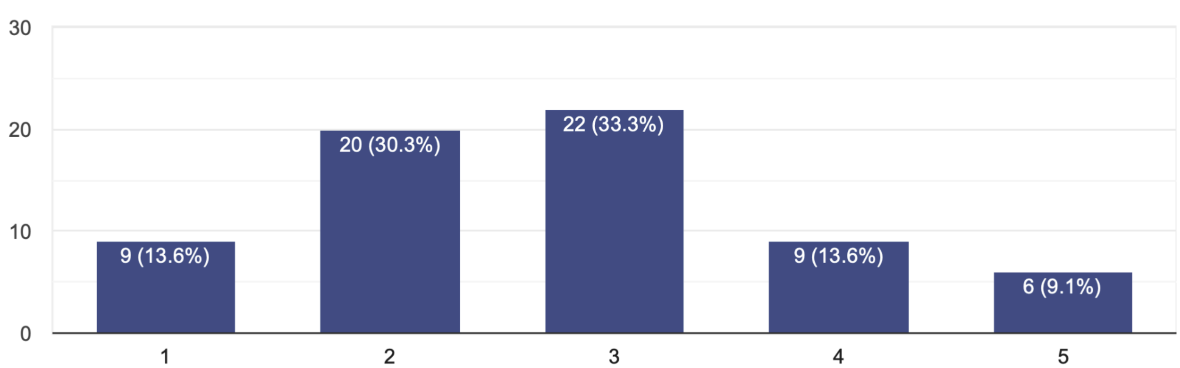


Fig. 5: Survey question 2

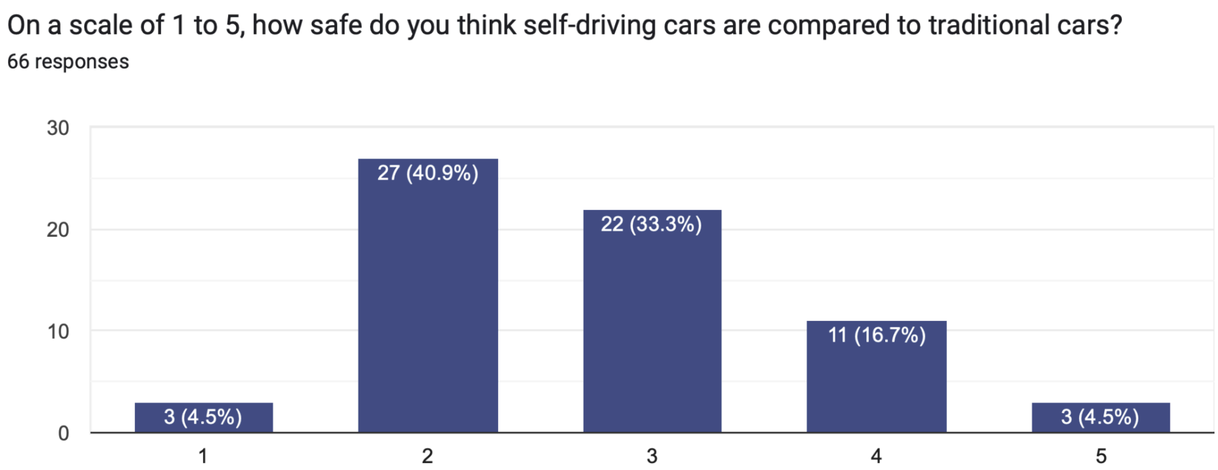


Fig. 6: Survey question 3

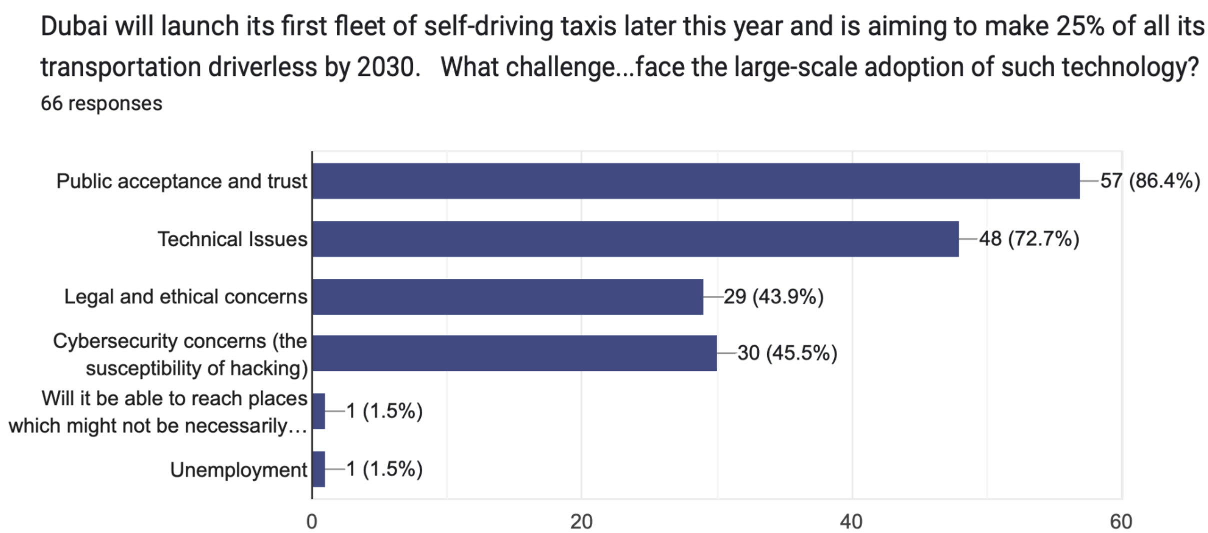


Fig. 7: Survey question 4

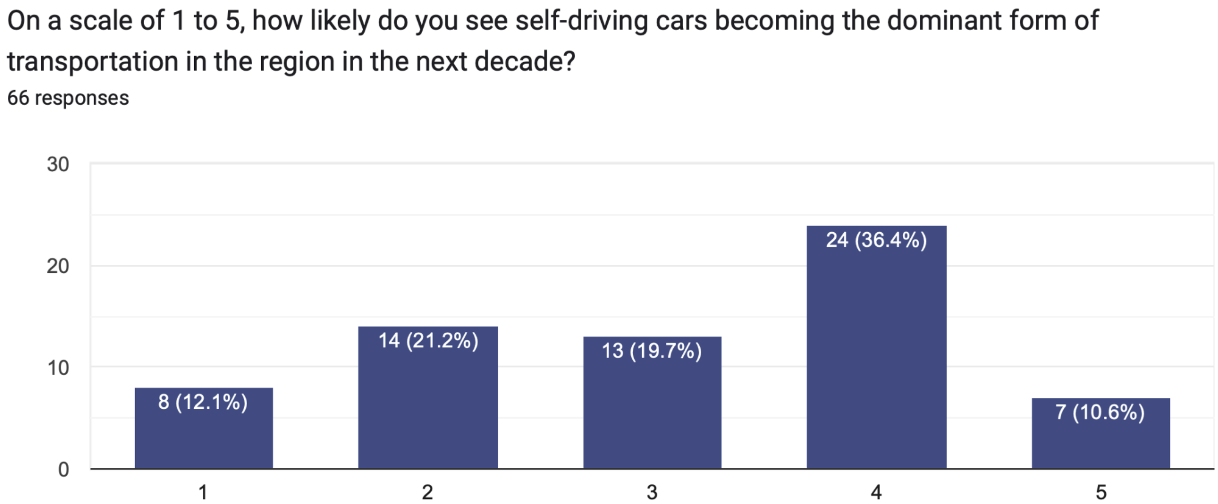


Fig. 8: Survey question 5