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Applications of Autonomous Vehicles

[1]Matthew N. O. Sadiku and [2]Janet O. Sadiku,
[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Juliana King University, Houston, TX, USA

Abstract: Autonomous vehicles (AVs) are vehicles that can achieve a set of goals in a changing environment without human control or intervention. These vehicles can sense the environment, keep track of their current state and location, and act in a safe manner to avoid risks to human safety, property, or the vehicle itself. The autonomous vehicles are fully equipped with sensors and computing capacities, and they assist the autonomous shuttles in perceiving their environment and correcting themselves when facing any driving emergencies. This is to ensure the safety of the passengers. Autonomous vehicles have attracted great attention from both industries and academic sectors during the past decades. The purpose of this paper is to explore some applications of autonomous vehicles.

Keywords: *Autonomous Vehicles, Self-Driving Vehicles, Connected Vehicles, Applications*

I. INTRODUCTION

Self-driving cars are used for enhancing safety, accessibility, and efficiency in transportation, by automating driving to reduce human error, provide mobility for the elderly and disabled, and free up commute time for work or leisure. Driver behavior constitutes a significant part of road accidents and reduces the efficiency of the global supply chain. That is why industries are leveraging autonomous vehicles to ensure better throughput. Self-driving cars change the way we live and work directly and indirectly. The autonomous vehicles comprise no driver seats, steering wheel, or accelerating or brake pad pedals. They are programmed to adhere to an already existing route while associating with other vehicles and pedestrians in their immediate driving environment.

Autonomous vehicles, once a futuristic concept, are now a reality transforming the landscape of urban transportation. The ability to sense its surroundings enables an autonomous vehicle, also known as a driverless vehicle, to drive itself and carry out essential tasks without the assistance of a human. Autonomous vehicles (AVs) are anticipated to disrupt business operations, costs, and economic models, whether on land, sea, or air. These independent "ecosystems" will be similar to the development of traditional vehicles such as cars and planes [1]. Examples of autonomous vehicles are shown in Figure 1 [2].

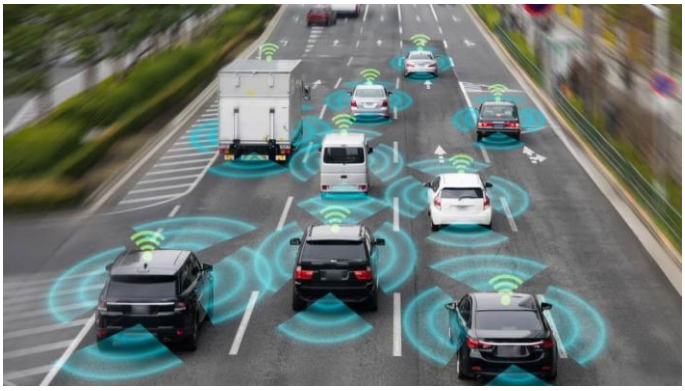

Figure 1: Examples of autonomous vehicles [2].

II. CONCEPT OF AUTOMOUS VEHICLES

Autonomous vehicles constitute one of the most spectacular recent developments of AI. As opposed to human-driven vehicles, autonomous vehicles essentially refer to self-driving vehicles. They are smart vehicles that are able to perceive their environment and to move on accordingly without human intervention. They operate with the capability to have automatic motions and navigate themselves depending on the environments and scheduled tasks. Figure 2 shows the architecture of autonomous car [3].

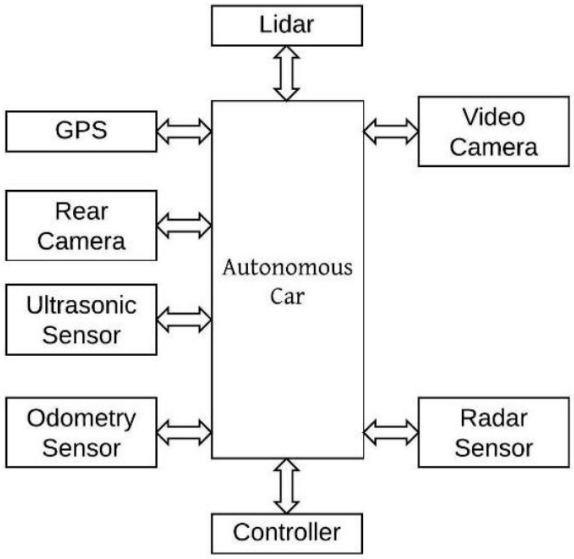

Figure 2: Architecture of Autonomous Car [3].

Autonomous vehicle or driverless car is an ambitious project which requires the fusion of many technologies like electronics, communications, mechatronics, software engineering, artificial intelligence, GPS, and industrial IoT. It is a vehicle that uses a combination of sensors, cameras, radar, and artificial intelligence (AI) to travel between destinations without a human operator. It is designed to be able to detect objects on the road, maneuver through the traffic without human intervention, and get to the destination safely. It is fitted with AI-based functional systems such as voice and speech recognition, gesture controls, eye tracking, and other driving monitoring systems. Several companies have announced their plan to get involved in autonomous or driverless and electric vehicle technology

Connected and autonomous vehicles (Avs) are now becoming a cornerstone of the increasingly connected world. They are receiving a lot of attention from manufacturers, service providers, governments, universities, consumers, and other stakeholders. The main goal of autonomous vehicles is to build a self-driving system that can perceive the road better than the best human driver. They are incredible innovation that will likely transform transportation, especially in urban environments, in the near future. Although autonomous vehicles can improve performance and safety, there are a

myriad of serious technology, regulatory, and security challenges to consider in preparation for full vehicle autonomy.

Autonomous vehicles combine artificial intelligence (AI) and robotics. They are regarded as a promising answer to traffic jams, accidents, and environmental pollution. They will constitute the backbone of future next-generation intelligent transportation systems (ITS) providing travel comfort and road safety along with a number of value-added services. They are used in search and rescue, urban reconnaissance, mine detonation, supply convoys, etc. [4]. They can help save lives on the battlefield.

Autonomous vehicle (AV) is also described as "driverless," "robotic," or "self-driving." AV is regarded as a multidisciplinary technology. The enabling technologies in support of connected autonomous vehicles include camera, GPS & GNSS, and sensors, radar , LiDAR (Light Detection and Ranging), and Internet of things. The race to develop autonomous vehicles has heated up with many major automotive manufacturers such as Tesla, Audi, General Motors, Mercedes Benz, Uber, Google, and Amazon [5]. Figure 3 shows how autonomous vehicles work [6].

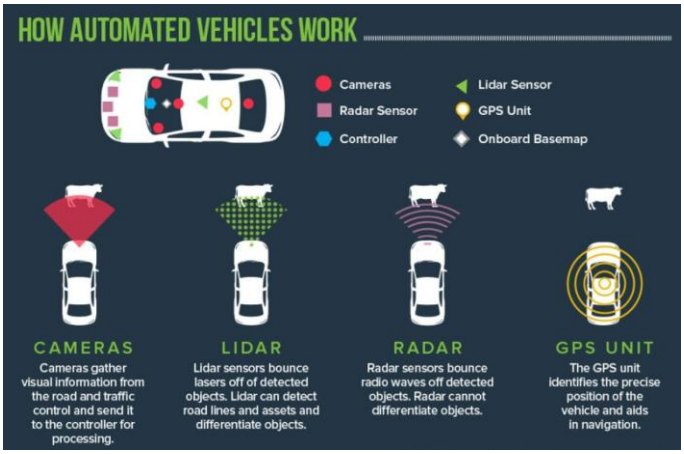

Figure 3: How autonomous vehicles work [6].

III. LEVELS OF AUTONOMY

SAE International (formerly the Society of Automotive Engineers) classifies autonomous vehicles on a scale of 0 to 5. The six levels are presented as follows [7,8]:

Level 0: No automation: All driving tasks and major systems are controlled by a human driver. The automated system has no vehicle control but can issue warnings.

Level 1: Function-specific automation: Provides limited driver assistance. The driver must be ready to take control at any time.

Level 2: Partial driving automation: At least two primary functions are combined to perform an action. The driver is obliged to detect objects and events and react if the automated system does not respond correctly.

Level 3: Conditional driving automation: Enables limited self-driving automation. Vehicles at this level can make informed decisions for themselves. In known environments (such as highways), the driver can safely divert his attention from driving tasks.

Level 4: High driving automation: An automated driving system performs all dynamic tasks of driving. The automated system can control the vehicle in almost any environment, such as extreme weather conditions. and fewer parking spaces.

Level 5: Self-driving automation: An automated driving system performs all dynamic functions of driving. No human intervention is required. A vehicle at this level requires no driver. It is on its own and must be able to react to all situations that might arise.

The six levels are shown in Figure 4 [9] and are summarized as follows: No Automation, Driver Assistance, Partial Automation, Conditional Automation, High Automation, and Complete Automation. The classification has been adopted by DOT. Vehicles sold today are in levels 1 and 2. Levels 4 and 5 will probably increase vehicle prices significantly. But how do we get to Level 5?

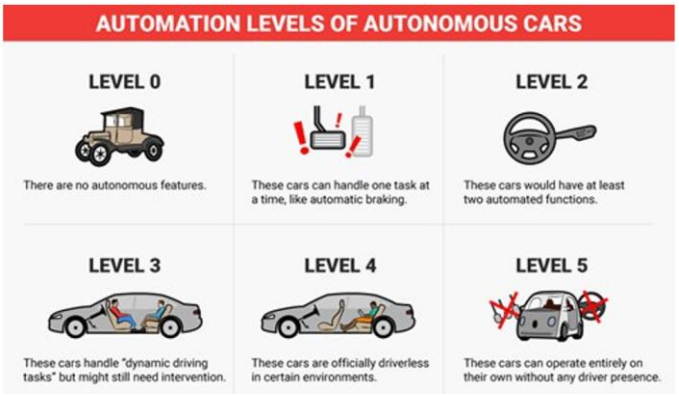

Figure 4: The six levels of autonomy [9].

IV. APPLICATIONS OF AUTONOMOUS VEHICLES

The technology transforming the automotive industry is being developed for practical applications that currently exist on our streets, in warehouses, on farms, and in the sky.

Common applications of autonomous vehicles across industries include the following [10,11]:

1. *Transportation:* Road transport system is significant in the transportation of goods and people from one place to another via the road network. The importance of introducing autonomous mobilities into the transportation of goods and services cannot be under-emphasized. Self-driving cars will provide more access to transportation for those who would have otherwise been unable to get around.

Figure 5: A typical driverless robotaxi on the streets [12].

Autonomous driving systems eliminate the ambiguity in driving decisions and minimize road accidents. They allow mobility companies to avoid capital-intensive in-house vehicle development and accelerate the time-to-market. As mobility companies reduce dependence on drivers, they are able to increase asset utilization rates and deliver a better customer experience, driving sales. The future of transportation will be changed significantly in the coming years as the freight industry enables self-driving trucks. To fully deploy autonomous vehicles in a road transportation system, the

existing road transportation infrastructure needs significant improvement. The driverless robotaxi use case is probably one of the first that comes to mind when thinking of AV implementations that are being currently deployed. Figure 5 shows a typical driverless robotaxi on the streets [12].

2. *Smart City*: The movement of people, goods, and services is crucial for transportation planning and smart cities' decision-making. Climate scientists, urban developers, citizen initiatives, as well as many local politicians, emphasize that traffic in and around cities must change. Smart cities focus on walking, cycling, and public transportation. They use autonomous vehicles to automate various aspects of city operations. These include public transportation, last-mile delivery, critical response, and waste logistics. They reduce traffic congestion and improve road safety. Intelligent mobility solutions are aiding in reducing traffic jams in urban areas and promoting the right to autonomous mobility in rural and disadvantaged areas. The city service providers can be government-owned or privately-owned companies. They offer them a more customer base coupled with the service flexibility needed to run day-to-day activities more cost-effectively. Cities are already planning for the eventual changes that AVs can potentially bring.

3. *Automotive:* Automated and autonomous vehicle technology has already significantly transformed the automotive industry, and there is still more to be accomplished. There is a growing interest among customers for autonomous vehicles, especially after Tesla's autonomous cars were a success. Therefore, all automotive manufacturers are integrating self-driving solutions to stay competitive. This allows automotive manufacturers to mitigate in-house autonomous driving system development. As the automotive industry continues to evolve with connected cars, the need for reliable, scalable, and secure communication platforms is more critical than ever. Figure 6 shows automotive trends [13].

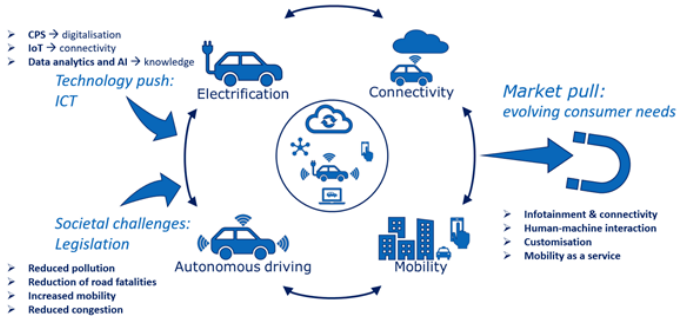

Figure 6: Automotive trends [13].

4. *Logistics:* Driver shortage and high fuel costs are the leading concerns among logistics companies. Autonomous vehicles enable the logistics industry to tackle these issues and automate supply chains. Autonomous delivery vehicles allow logistics companies to reduce operational and maintenance costs, increase lane capacity, as well as decrease traffic congestion and emissions. Order fulfillment and logistics are being automated in warehouses, storage, and shipping centers by leveraging perception technology. Companies in the supply chain industries can create an advantage by efficiently applying autonomous technologies to their daily logistics operations. For logistics and supply chain industries, introducing autonomous technologies in material handling of goods will minimize cost and save time concerning the production and delivery process.

5. *Manufacturing:* The manufacturing sector leverages autonomous vehicles to automate material handling and last-mile operations. This reduces the dependence on manual labor while improving worker safety in industrial environments.

6. *Healthcare*: The healthcare industry uses autonomous vehicles to deliver prescriptions and drugs to patients as well as improve medical care delivery. Autonomous vehicles further allow passengers to direct their vehicles automatically to hospitals for quicker emergency response. At the same time, these vehicles provide persons with disabilities with improved access to healthcare. Autonomous systems can assist in surgeries, monitor patients, and provide personalized healthcare.

7. *Aerospace:* Autopilot and other automated control systems are already a part of commercial aviation. Startups and large companies now integrate fully autonomous navigation systems to develop pilotless aircraft. This improves the safety of long-distance air travel and enhances the use of aircraft for defense applications.

8. *Construction:* Operating construction machinery requires worker expertise and comes with significant safety concerns. Autonomous vehicles remove human labor from hazardous environments to optimize various operations like excavation and demolition. Additionally, startups automate dozers, load carriers, and haul trucks to optimize asset fleets of construction companies. Figure 7 shows a construction site [14].

Figure 7: A construction site [14].

9. *Delivery:*

Figure 8: Coco remote-controlled delivery robot [12].

Delivery vehicles are often delayed due to traffic and the difficulty of parking in urban spaces. These issues may be resolved using mobile delivery hubs, lessening the necessity of bringing big trucks into crowded, busy cities. Autonomous vehicles are transforming the delivery industry by providing efficient last-mile solutions for ecommerce businesses. Automated delivery vehicles can also streamline the actual delivery process. The most generally recognized use for self-driving cars at this time is robotaxis, shuttles, and delivery

vehicles utilized for commercial use. Self-driving delivery vehicles allow companies to transport goods in new or more efficient ways. Figure 8 shows Coco remote-controlled delivery robot [12].

10. *Warehouse:* Automated stackers, forklifts, pallet trucks, and small carry rack robots are examples of autonomous vehicles used in warehouses. They train themselves to follow their chosen paths and engage in relevant warehousing activities using machine learning and deep learning.

Other areas of application include agriculture, energy management, environmental monitoring, Industry 4.0, the military, and smart homes.

VI. BENEFITS

There are several benefits to deploying autonomous vehicles. Autonomous vehicles are supposed to reduce accidents on the road and make travelling times shorter, accident-free, and reduced excessive road maintenance. Using autonomous technologies to transport goods will revolutionize the logistics and supply chain industry and change the status of urban transportation to a more robust, intelligent, and innovative system. Other benefits include the following [1,15]:

- *Automation:* Similar to trucking, individuals operating large farming machinery are susceptible to exhaustion and risk. Self-driving vehicles in these spaces can operate longer hours than a person, allowing people to rest or eliminate the need to perform labor-intensive tasks such as tilling or harvesting. Efforts can then be directed to other crucial areas.
- *Reduced Costs:* Cost savings are another important advantage of autonomous vehicles. Business operations can be made more productive, and labor expenses can be reduced. Errors can be avoided, and work times streamlined when you rely less on human drivers. Owning an autonomous car could translate to substantial cost savings for individuals. Reduced accidents and optimized driving patterns contribute to lower maintenance and fuel costs, making autonomous vehicles an economically viable choice.
- *Public Perceptions:* Existing studies have examined people's attitudes towards autonomous vehicles technology and the level of willingness to buy, drive, and adopt autonomous technologies. Many researchers have indicated that adults and grown-up males are the two demographics that have more open and positive perceptions concerning autonomous vehicle technology. Research has shown that young adults, especially men and university educated adults and residents of metropolitan cities, have positive perceptions of autonomous vehicles, including the willingness to apply this technology. Investigations carried out by multiple nations have shown that people's perceptions about autonomous vehicles and the socio-demographics that predict autonomous vehicles operations are widely different among countries.
- *Safety:* The immediate benefit an autonomous future would provide is improved safety. The implementation of autonomous vehicles in developed countries has drastically reduced road accidents. More than 40% of fatal car crashes usually involve drinking alcohol, overdosing on marijuana, or fatigue. A self-driving vehicle will not be affected because it relies on little or no human interference in its navigation. It is rare for an autonomous vehicle to malfunction to the extent of causing an accident on the road. Enhanced safety features such as collision avoidance and pedestrian detection significantly lower liability and repair costs. Car makers and software security providers are forced to work together to prevent risks related to the safety of autonomous vehicles in the future.
- *Traffic Congestion:* Apart from making roads accident-free, transportation researchers have also come up with ways by which autonomous can safely reduce traffic congestion on highways and road intersections by developing an external sensor that can easily sense the lead car decision-making involving braking and acceleration. Another significant impact of autonomous vehicles in reducing traffic congestion is the advantage of vehicles travelling close together which lead to a significant upsurge in road capacity on existing road lanes.
- *Travel Behavior:* Autonomous vehicles will change the travel behavior of people. There will be a change in parking patterns in urban areas. There will be fewer illegal parking on-road lanes, which will lead to more road capacity for vehicles. The car ride-sharing programs will expand, leading to fewer vehicles on the road, reducing traffic congestion. According to recent studies, it has been shown that there is an increment in the miles of vehicles travelled because of autonomous vehicles.
- *Collision Avoidance:* Collision avoidance systems leverage computer vision to detect potential hazards and take corrective action to prevent accidents. These systems continuously monitor the vehicle's surroundings, identifying objects, vehicles, or pedestrians that could pose a risk. This application is critical for reducing errors that could lead to collisions. The technology can identify hazards in high-traffic areas, during lane changes, or when unexpected obstacles appear on the road.
- *Parking:* The application of driverless private vehicles of taxis will reduce the demand for parking spaces in malls and offices, making these spaces available for other economic activities. This may lead to an increase in urban migration.
- *Traffic Efficiency:* By streamlining routes and speeding up deliveries, autonomous cars can also contribute to the efficiency of logistics and transportation operations. Businesses can decrease the risk of late deliveries and shorten lead times by using real-time data to modify routes and avoid traffic. Predictive algorithms optimize routes, minimizing travel time, and enhancing overall traffic efficiency.
- *Environmental Impact:* The adoption of autonomous cars aligns with environmental sustainability goals. Efficient driving patterns, coupled with the potential for electric or hybrid autonomous vehicles, lead to a substantial decrease in carbon emissions, making them a green solution for urban mobility. Autonomous cars, with their ability to optimize traffic flow and reduce bottlenecks, have the potential to significantly alleviate urban traffic congestion. This not only enhances the efficiency of transportation but also improves the overall quality of urban life.

Some benefits of AVs are displayed in Figure 9 [15].

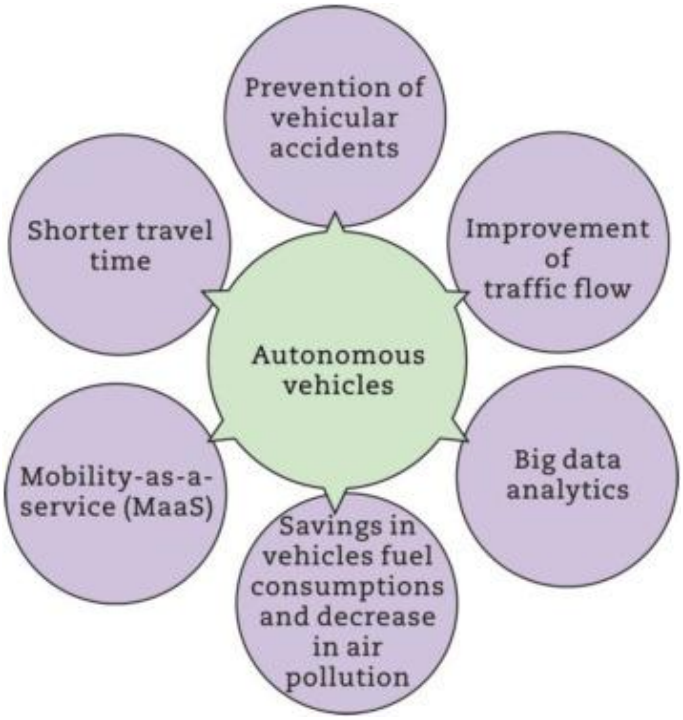

Figure 9: Some benefits of autonomous vehicles [15].

VII. CHALLENGES

There are risks and challenges autonomous vehicles face in reaching full autonomy. It is

challenging to support security, stability, reliability, and security requirements. AVs pose numerous ergonomic, safety, regulatory, and political problems. Widely known challenges of trucking include the long hours and risk involved in such a crucial position. Other challenges posed by autonomous vehicles include the following [16-21].

- *Safety:* Ensuring the safety of the decisions made by the self-driving car is the hardest part of reaching level five autonomy. Ensuring safety is not something that can be solved with a single technological silver bullet. Rather it requires a multi-disciplinary approach covering hardware fault tolerance, resilient machine learning, cooperation with humans driving conventional vehicles. Autonomous vehicles are designed to avoid accidents caused by human errors. Although AVs allow all vehicle occupants to relax, read, work, and watch television, they are required to wear seatbelts for safety reasons.
- *Security:* In addition to safety, autonomous vehicles will have to deal with security. Some security risks and vulnerabilities associated with AV have been identified. Autonomous vehicles pose a myriad of security concerns due to the risk of cybersecurity breaches. Cybersecurity protection is necessary to ensure vehicle optimal performance. Protecting autonomous vehicles from hackers is of a major concern to governments, manufacturers, and service providers. DOT mandated the incorporation of a thorough cybersecurity threat mitigation system in vehicle electronics. Encrypting communications between vehicles may help with the security of inter-vehicle coordination messaging. The future of security breaches will be revolutionized with advanced technologies such as artificial neural networks.
- *Data Privacy:* Data privacy and protection remain one of the most severe threats to the functionality of autonomous vehicles. Personal information is significant for the software servers of autonomous vehicles. This personal information may comprise sensitive information on the owner or driver of the vehicle, such as phone number, address, location, and gender. Before selling highly automated vehicles, it is required that manufacturers develop written privacy plans concerning the collection and storage of data generated by the vehicles. There should be a means of making that information transparent to vehicle owners and occupants.
- *Social Acceptance:* The social acceptance of autonomous vehicles is evidently a complex process. Recent studies show that public skepticism about autonomous vehicles. This is may be due to lack of understanding about autonomous vehicles. It is DOT's concern that consumer should be educated and trained as vehicles are deployed. Consumers should know about the anticipated differences in the use and operation of AVs and conventional vehicles. For citizens to embrace the autonomous vehicles, auto manufacturers must demonstrate trust in the vehicle and improve its safety.
- *Adaptation:* It is impractical to validate all the possible adaptation states of an autonomy system using traditional safety design processes. The challenge is that influencing the autonomous vehicle's decisions requires a wide variety of parameters such as traffic conditions, pedestrian conditions, and weather condition.
- *Human Error:* Most of the crashed involving autonomous vehicles are due to human drivers sharing the road with autonomous vehicles. This may be due to distractions caused by pedestrians. Autonomous vehicles promise a future where drivers are freed from a tedious driving and traffic collisions are a relic of history.
- *Ethics:* AVs pose both technological and ethical challenges. Several ethical challenges of autonomous vehicles have been identified. Mundane traffic situations illustrate how the driving behavior of autonomous vehicles meshes with the rights and responsibilities of other traffic participants. The public has raised the question of how AV would behave when an accident is inevitable, how AV weighs decisions, and what such decisions mean in relation to others. What ethical considerations should constrain the behavior of AVs? Can we trust AVs to always make good decisions even in extreme emergency situations? AV is said to have "ethical limitations" because it is unlikely to have the capacity to make decisions which encompass human values, rights, societal norms, and ethics [20].
- *Cybersecurity:* Another significant issue regarding AVs is the ease at which hackers can hack with ease any software. There is increase in vulnerability of these software to outside hackers. At present, it is possible that someone that hacks your car can have access to your biodata, and they can use this information to take over the control of your car even without you knowing it.

Some of these challenges are illustrated in Figure 10 [23]. These issues will become part of the public discussion. The anticipated merits of autonomous vehicles are more the perceived disadvantages. Automakers can only program their cars to act within some bounds. They are working to overcome these challenges on all fronts. Governments around the world should prepare for a wide range of technical, social, and regulatory issues in preparation for full vehicle autonomy.

Figure 10: Main challenges of the automated vehicles [23].

VIII. THE FUTURE OF AUTONOMOUS VEHICLES

Autonomous vehicles is a growing industry with lots of development. It has been observed that autonomous vehicles are the future of road transportation and that the negative perception of humans is rapidly changing towards autonomous vehicles. The complete shift into a mass implementation of electric vehicles (EVs) forms the question of what the future of autonomous vehicles (AVs) looks like. Currently, an autonomous future would consist of augmenting the autonomous features already integrated into vehicles to the point of operating without human intervention. As AVs become more prominent, the way we design and think about urban spaces will radically change. Some believe that AVs will take away the need for individual car ownership and parking spaces. While the potential impacts of AVs are substantial, it will take time for them to be realized. AVs are still some years from being commercially available, let alone in widespread use. AVs will surely affect our economy and society in a variety of ways [14]. Autonomous driving will change how we spend time in the car.

CONCLUSION

Autonomous vehicles (AV) are vehicles that can operate with minimal to no human supervision. They have the necessary capability to travel from one place to another without human control. They are undoubtedly one of the most eagerly anticipated innovations that will radically change the lifestyles of millions of people around the world. Driverless cars are already very smart, but they need to become smarter. The technology is still in development and consumers remain wary of autonomous vehicles.

The field of AV is interdisciplinary, involving tools from computer science, artificial intelligence, mechanical and electrical engineering, mathematics, and more. Autonomous vehicles (AVs)— requiring little or no input from a human driver—may be a killer app that transforms our economy significantly. To stay on top of the developments in autonomous vehicles, one should consult the books in [24-32] and related journals:

- *Artificial Intelligence Review*
- *Applied Artificial Intelligence*
- *Artificial Intelligence and Law*
- *AI Magazine*

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ABOUT THE AUTHORS

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics, computer networks, engineering education, and marriage counseling. He is a Life Fellow of IEEE.

Janet O. Sadiku holds bachelor degree in Nursing Science in 1980 at the University of Ife, now known as Obafemi Awolowo University, Nigeria and doctoral degree from Juliana King University, Houston, TX in December 2023. She has worked as a nurse, educator, and church minister in Nigeria, United Kingdom, Canada, and United States. She is a co-author of some papers and books.