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Master's Thesis of Public Administration

Do Autonomous Vehicles Reduce Traffic Related Deaths?

A systematic literature review on the relationship between autonomous vehicle technology and traffic-related mortality.

자율주행자동차가 교통사고 사망자를 감소시키는가?

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Abstract

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The society is anticipated to gain a lot from Autonomous Vehicles (AV), such as improved traffic flow and a decrease in accidents. They heavily rely on improvements in various Artificial Intelligence (AI) processes and strategies. Though some researchers in this field believe AV is the key to enhancing safety, others believe AV creates new challenges when it comes to ensuring the security of these new technology/systems and applications. The article conducts a systematic literature review on the relationship

between autonomous vehicle technology and traffic-related mortality. According to inclusion and exclusion criteria, articles from EBSCO, ProQuest, IEEE Explorer, Web of Science were chosen, and they were then sorted. The findings reveal that the most of these publications have been published in advanced transport-related journals. Future improvements in the automobile industry and the development of intelligent transportation systems could help reduce the number of fatal traffic accidents. Technologies for autonomous cars provide effective ways to enhance the driving experience and reduce the number of traffic accidents. A multitude of driving-related problems, such as crashes, traffic, energy usage, and environmental pollution, will be helped by autonomous driving technology. More research is needed for the significant majority of the studies that were assessed. They need to be expanded so that they can be tested in real-world or computer-simulated scenarios, in better and more realistic scenarios, with better and more data, and in experimental designs where the results of the proposed strategy are compared to those of industry standards and competing strategies. Therefore, additional study with improved methods is needed. Another major area that requires additional research is the moral and ethical choices made by AVs. Government, policy makers, manufacturers, and designers all need to do many actions in order to deploy autonomous vehicles on the road effectively. The government should develop laws, rules, and an action plan in particular. It is important to create more effective programs that might encourage the adoption of emerging technology in transportation systems, such as driverless vehicles. In this regard, user perception becomes essential since it may inform designers about current issues and observations made by people. The perceptions of autonomous car users in developing countries like Azerbaijan haven't been thoroughly studied up to this point. The manufacturer has to fix the system flaw and needs a good data set for efficient operation. In the not-too-distant future, the widespread use of highly automated vehicles (AVs) may open up intriguing new possibilities for resolving persistent issues in current safety-related research. Further research is required to better understand and quantify the significant policy implications of Avs, taking into consideration factors like penetration rate, public adoption, technological advancements, traffic patterns, and business models. It only needs to take into account peer-reviewed, full-text journal papers for the investigation, but it's clear that a larger database and more documents would provide more results and a more thorough analysis.

Keywords: Autonomous Vehicle, Self-driving Vehicle, Traffic Death, Traffic Accident, Self-driving cars, Mortality

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Chapter 1: Introduction

1.1 Background

In modern day, many intelligent systems are being used all over the world to improve important industries. Countries are taking advantage of using intelligence systems to save costs, promote efficiency and save lives. Most countries are still yet to implement these technologies however they are on the rise and plan to follow in the footsteps of more advanced countries.

Traffic deaths are one of the main killers around the world. According to the World Health Organization (2022), a road traffic accident results in the premature death of about 1.3 million persons each year. Between twenty million and fifty million additional people have non-fatal injuries, with several of them becoming disabled as a result. On World Roads, A Death Occurs Every 24 Seconds. By 2030, this is expected to be the seventh leading cause of death around the world. The National Highway Transportation Safety Administration (NHTSA) found in a 2016 study that between 94% and 96% of all automobile accidents are caused by human error. Numerous other studies have produced comparable findings, and every one that we are aware of indicates that at least 90% of automobile accidents are the result of human error (NHTSA, 2017). Due to human limits, it is hard for drivers to act rationally and rapidly in an emergency situation. Many implementations have been put in place to reduce traffic deaths such as to improve traffic infrastructure, improve vehicle mechanics and eliminate all distraction when operating a motor vehicle. In the EU, there will be 44 road fatalities per million people on average in 2021, up 5% from 2020 but down 13% from the previous year, before the pandemic. (European Commission (2021). The number of fatalities for 2021 in the Western Balkans region are higher than they were for 2020 (Transport Community (2021).

According to PwC there are top 3 risk factors for Traffic Collisions Worldwide: speeding, drink-driving, distracted driving. (Morley, *et al.* (2017). Successful strategies, according to Morley et al. in 2017, should concentrate on the following six key themes: National Programmes and Target Setting, Safer Driving Behavior, Safer Vehicles and Roads, Safer Pedestrians and other Vulnerable Road Users, Education, Training, and Publicity (ETP), Data systems. In 45% of fatal crashes in the USA, the drivers of passenger cars engaged in at least one risky behavior, such as speeding, driving while intoxicated, or failing to buckle up. (NHTSA 2022). According to Marquis (2022), the most common causes of death in car accidents can be eliminated with readily available technology, provided that we don't hate the solutions. According to the Korean Road Traffic Authority, the following contribute to vehicle mishaps: unsafe factors, unsafe road environments, insufficient driver knowledge, failure to recognize the danger, and improper thinking. (KoRoad, 2020).

The latest research from the Insurance Institute for Highway Safety (IIHS) stated that thirty percent of all fatal car accidents each year over the past decade involved drunk driving. Alcohol-related fatalities increased by 5% in 2021. They also suggested that installing ignition interlock devices that detect if a driver has been drinking could prevent as many as 10,000 annual deaths on American roads (IIHS, 2020).

Traffic fatalities could be drastically reduced with the introduction of autonomous vehicles. This belief stems from the idea that the presence of autonomous vehicles would reduce the likelihood of traffic accidents by removing the human element (Petrovic, *et al.* 2020).

A report published in The Atlantic examined the effect of driverless cars on the number of fatal traffic accidents and concluded that lives lost on the road could be cut in half if humans were removed from the equation. Almost 300,000 lives could be saved every decade in the United States, along with an annual savings of $190 billion in healthcare costs attributable to accidents. (LaFrance, 2015).

It's arguable that AVs are more beneficial than human drivers in some respects, such as the ability to more effectively acquire and maintain situational awareness. It never tires or gets worn out and can keep working even after a few drinks. With these benefits in mind, it's reasonable to hope that AVs will reduce collision rates. They may help reduce accidents, and we'll reap social and economic gains, as well as the rewards of reduced pollution and other positive environmental effects (Filiz, 2020).

In certain sectors, autonomous vehicles are finally becoming a feasible possibility. The military, transportation, and agriculture are just a few applications. The widespread availability of autonomous vehicles to the general public is rapidly approaching. Vehicles rely heavily on data collected by sensors and processed by artificial intelligence algorithms to carry out a wide variety of tasks. A vehicle's mission entails three main steps: data collection, trajectory planning, and mission execution. The third and fourth items on that list necessitate the use of AI's machine learning techniques and thus call for novel approaches to programming (Hristozov, 2020). When it comes to developing fully autonomous vehicles, AI has been the single most influential factor. While the first demonstration of an autonomous vehicle occurred in the 1980s, it was AI that paved the way for the development of fully autonomous vehicles at levels 4 and 5 (Mahendra, 2022). Self-driving cars rely on AI systems that can plot out their moves and carry them out without any input from a human operator. The AI has all the tools a human driver would have. It can process information, make decisions, use its senses, and model information using deep learning techniques. Using these advancements, the AI-enabled car can operate independently to use full autonomy yet as not enough evidence and data is present knowing a full autonomous vehicle will keep the drive and surroundings safe.

An advanced version of AI needs to be implemented for road traffic, however before this technology is installed on modern vehicles, the system needs to be tested thoroughly hence why it is not safe to use full autonomy yet as not enough evidence and data is present knowing a full autonomous vehicle will keep the drive and surroundings safe.

There has been a steady increase in the prevalence of accident-avoidance technologies in the American car fleet, all of which serve to increase overall safety on the roads. Some of these systems only alert the driver and expect them to make the necessary adjustments; others are programmed to actively apply the brakes or the steering to try to avoid a collision. An increase in traffic safety is expected to result from the widespread use of these systems and the enhancement of their features and performance (Benson, *et al.* 2018).

The goal of autonomous vehicle technology is to minimize traffic deaths, and it may very well achieve this goal. Most modern automobiles use computer programs that make things like lane keeping, automatic emergency stopping, better visibility, and communication between cars possible (Vehicle to Vehicle-V2V). And yet, self-driving car data shows that even as AVs advance, new security worries crop up periodically. Numerous businesses have made an effort to claim a piece of the action, including Uber, Tesla, and even Google. Traditional automakers like Volvo, Ford, and General Motors have also entered the race in growing numbers. The market for driverless vehicles is currently valued at $54 billion, according to estimates. In the following five to seven years, many anticipate a tenfold growth (Kopestinsky, *et al.* 2022).

Both quantitative and qualitative social benefits are anticipated for autonomous vehicles (AVs) and many other AI technologies. For instance, a lot of specialists think AVs will lower rates of deaths (Litman, 2017), pollutants (Fagnant and Kockelman, 2014; Greenblatt and Saxena, 2015), traffic (Talebpour, and Mahmassani, 2016), and parking congestion (Zhang *et al.* 2015).

1.2 Purpose of research

Autonomous cars are a relatively new transportation alternative that is currently making inroads in several advanced economies. Autonomous vehicle testing is currently possible in the majority of developed countries. However, no plans or regulations using autonomous technology have been developed in underdeveloped nations, particularly in Africa (Ackaah, *et al.* 2021). However, those in developed nations with higher rates of motorization and lower rates of traffic fatalities are more pessimistic about the existing and future levels of AV safety (Moody *et al.*, 2020). Many developed countries have their own research on how they have benefited from Autonomous vehicle. Given this significant human cost, AVs have a very high potential for safety. Under normal circumstances, autonomous cars wouldn't speed, consume alcohol, or become sidetracked. In reality, studies claim that AVs might save over 30,000 lives annually in the US "by moving the focus from minimizing of post-crash harm to collision avoidance” (Fleetwood, 2017).

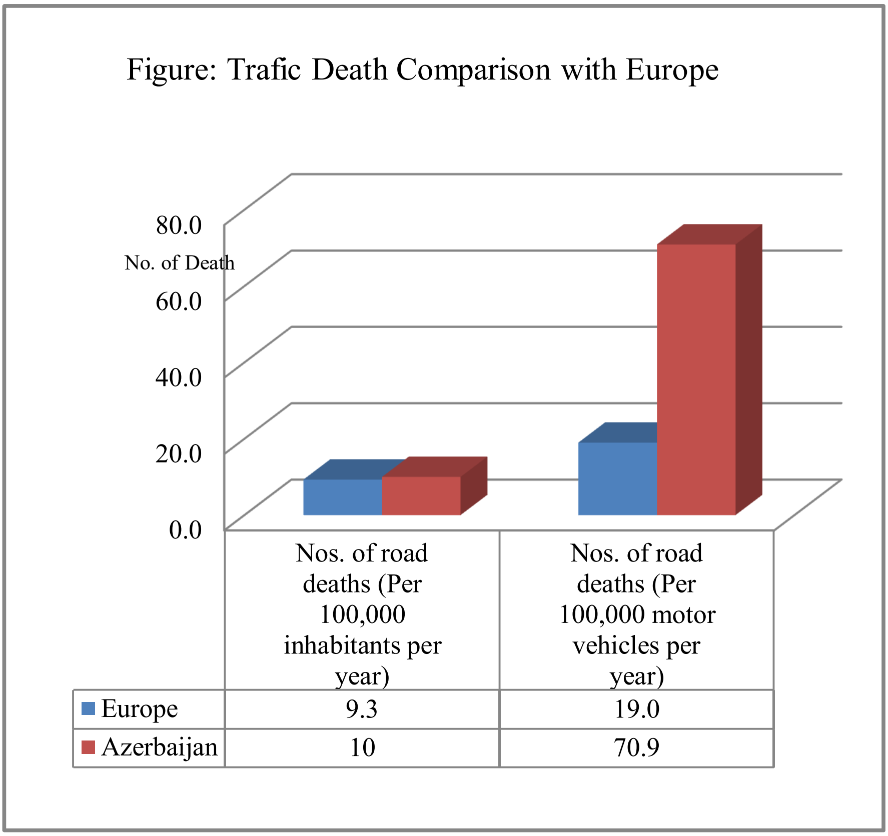
Artificial intelligence is the next technology in demand in solving issue. Many countries have adopted the use of AI in traffic systems and vehicles. The theory of this technology is to assist road users of potential accidents and save lives. Using AI is measured by data, the more data you have, the more the system can make accurate decisions. Many countries have been trialing Autonomous Traffic Systems for over 10 years however the data which is present today can act as a solid base to put this technology into play confidently rather than causing more traffic issues.

In developed countries Autonomous Traffic Systems are used to monitor traffic to keep it flowing and reduce accidents. The use of smart motorways ensure that drivers follow the speed limit at all times, otherwise a fine is charged to the driver if exceeded the speed displayed. This Autonomous System is always tracking the vehicle registration and how fast they are going when they pass each sensor and camera. The way this technology works is by inputting data and finding out how long it takes to reach the next camera (ITS International 2019). When the vehicle passes the first point, the vehicle registration is scanned, this is done by image recognition, once this data is inputted, the time starts and will end when the drive passes the next point. From analyzing this data, an algorithm is used to calculate the speed, and time taken to judge if the vehicle was speeding or not. This system cannot get vehicles mixed up as image recognition will only match up the registration from point A to point B. This system will force drivers to follow the rules which will result in a better flow of traffic. Combining the smart motorways with the traffic light system can help to control the flow of traffic and ensure that the traffic is moving at a rate where drivers are more likely to be safe rather than speed (RAC, 2022). Technology will continue to grow and has become increasingly advanced, however gathering the data now and studying how improvements can be made will be beneficial for future development.

According to government statistics, 821 deaths occurred in traffic accidents in Azerbaijan in 2019 while a significantly higher number of people suffered serious injuries. Road deaths in Azerbaijan are far higher than in the majority of European nations, despite expenditures in road network and greater enforcement of traffic laws (World Bank, 2022).

Global Status Report on Road Safety 2018 which was published by WHO, shown that number of road death is 70.9 per 100,000 motor vehicle per year, which is very higher than average rate in Europe (WHO, 2018)

Figure 1: Traffic Death Comparison with Europe



State Program of Azerbaijan Republic on Road Safety for 2019-2023 mentioned that In Azerbaijan, there were over 116,000 car accidents reported between 2013 and 2017. There were 4691 fatalities and 11611 injuries as a result of these accidents; 399 were children under the age of 18 and 1219 were children under the age of 14. In the previous five years, pedestrians made up 40.0% of those injured or killed in traffic accidents. Between 2013 and 2017, 16,302 persons perished or suffered serious or moderate injuries as a direct result of motor vehicle collisions. In the Republic of Azerbaijan, between 2013 and 2017, the population aged 25 to

64, or specifically those of active labor age, accounted for 68.6% of fatalities in traffic accidents and 68.7% of those who had severe or less severe health injuries. People aged 18 to 24 made up 12.3% of the deceased and 16.4% of those with severe or less severe health injuries (Republic of Azerbaijan, 2018).

According to the study, which was carried out by the World Bank Project (2022), the socioeconomic cost of traffic accidents in Azerbaijan in 2019 will be 1.6 billion AZN, or 2.0% of GDP. It was determined that the costs associated with people (65%) and the damage to automobiles (20%) make up the majority of the total costs. The other major expenses were administrative expenses (3%), medical expenditures for road casualties (4%), and output losses from workers being unable to work (9%).

With the ambitious goal of significantly improving the nation's road safety conditions and lowering the number of casualties, injuries, and accidents by 30%, the Government of Azerbaijan announced the State Road Safety Program in 2018. Its implementation will take place from 2019 to 2023 (Republic of Azerbaijan, 2018). The goal of the twinning project is to strengthen the legal, institutional, and human resources of relevant government agencies and other stakeholders in Azerbaijan in order to better manage and coordinate road safety issues and reduce road traffic accidents that result in death or serious injury and socio-economic damage (Mincom, 2022).

The effectiveness of the "human-transport-road" system determines the level of road safety. The majority of traffic accidents in the Republic of Azerbaijan are caused by drivers disobeying traffic laws and using their vehicles improperly. Due to this circumstance, the driver training procedure has to be improved. Over the course of the past decade, there has been a 67.5 percent growth in the number of mechanical transport vehicles. There are numerous instances in which individuals in the country use automobiles that are out of date and have low levels of technical and security indicators.

The risk of injury or death due to traffic congestion is unacceptable. Each citizen of the Republic of Azerbaijan has the constitutionally guaranteed right to life, limb, and health. One of such privileges is the right to travel in a safe manner on the road. Protecting the welfare of its citizens on the roads is a top priority for the state's economy, population, and other sectors (Republic of Azerbaijan 1995). The method of ensuring motorists' safety on the road is complicated. Users of the roads are one element of this system, while those who establish its legal, social, and economic framework are another. There has to be a clear allocation of duties now that providers and users are constantly exchanging information and working together. The "safe traffic system" strategy, which is used in many nations, is predicated on this division of labor, with the overarching goal of reducing the number of fatal and injury-causing car accidents. The United Nations General Assembly declared the Decade of Action for Road Safety 2021-2030 in

September 2020 under the theme "Improving global road safety," with the lofty goal of reducing road traffic fatalities and injuries by at least half by 2030 (UN, 2020). The Republic of Azerbaijan actively supports international efforts in this field, and it has adopted the United Nations' "Decade of Action for Road Safety 2021-2030" as its national road safety policy. Overall traffic intensity and the number of vehicles per capita in the Republic of Azerbaijan have been rising in recent years. This calls for a methodical strategy to improve road safety perceptions, boost car use and road culture, and organize adequate, safe, and sustainable traffic.

According to “State Program of Azerbaijan Republic on Road Safety for 2019-2023”, the Government already made an action plan under the safe vehicles (point 7.3). The plan is “Identification of pilot areas for autonomous (unmanned) vehicles, as well as for passenger transportation and entertainment purposes, and preparing suggestions on improvement of legislation and other organizational-legal issues for the purpose of organizing the movement of these vehicles” (Republic of Azerbaijan, 2018).

Based on the Action Plan, the goal of my research is to find out how successfully using autonomous vehicles can help to reduce traffic related death. The goal of this literature review is to comprehend benefits, challenges and risk of using Autonomous Vehicles for reducing traffic related fatalities in a Developing country.

The following research questions were formulated in order to achieve success in it:

1. Do autonomous vehicles reduce traffic-related deaths?

2. Are there any challenges to using autonomous vehicles?

3. As a developing country, how effective is the use of autonomous vehicles for reducing traffic mortality?

Chapter 2: Literature review

2.1. Intelligent Traffic Systems

In modern day society, everyone owns a smartphone. In terms of transport, this is very important as apps such as ‘google maps’ and ‘waze’ use data to determine how quickly a person can travel or display the estimated time of travel. This technology mainly works well with satellite navigation and Global Positioning Systems (GPS) (KentCamEye (2019). In the west, many people use an app called ‘waze’, the benefit of this app is that you get live updates in real time. You can see traffic updates such as road works, traffic jams, police vehicles and speed cameras. This all works by retrieving data from smartphones to provide a connected service. When users search for their destination, the system will use the data from other smartphones to calculate the best route. We suppose the shortest distance is always the best; however, this app will also take traffic flow into consideration. If the shortest route has an accident involved, it will calculate the route to avoid that area but use the next shortest distance it can find. Travel apps are used to get people to their destination as fast as possible. This will cause less congestion and traffic by using the relevant apps that avoid busy areas. Similar to the traffic light system, this system works the same way by using real life data from sensors and cameras (Tusker, 2019).

Unfortunately, around 1.35 million people die each year due to traffic related deaths (WHO, 2022). One of the most obvious benefits of automated driving is the potential for increased traffic safety given the high number of annual traffic fatalities and human error as a major cause of accidents. Many governments around the world encourage the development and adoption of autonomous driving technologies because they acknowledge the economic significance of automated driving. The interest in these technologies is sparked by the anticipated improvements to safety, accessibility of transportation, and traffic flow. With the arise of computer technology, scientist and engineers have been working on providing assistance.

2.2 System Architecture for Autonomous Vehicles

Most countries are not on the stage of full autonomy in cars however car manufacturers are providing driving aids in most common vehicles. For this technology to work, autonomous vehicles are fitted with encoders, ultrasonic sensors, inertial sensors, LiDAR, cameras, and Global Navigation Satellite Systems (GNSS) are the most frequently used sensors in autonomous driving systems. Based on their intended function, these sensors can be further divided into two categories. A perceptual sensor known as an external sensor controls a vehicle's external state by detecting its surrounding environment. The internal sensor processes the information the car receives and is more analytical, primarily containing internal states. The following section discusses how each sensor works:

2.2.1 LiDAR

Roadside objects can be found and their distances can be calculated using the Light Detection and Ranging (LiDAR) technology. It works on the premise that laser light pulses are emitted and reflect off of a target object. The distance is calculated using the elapsed time between the light pulse's emission and reception at the sensor (Lin *et al*, 2021). Higher measurement accuracy and spatial resolution can be attained by using laser light with a shorter wavelength. At a clocking rate of 150 kHz, the distance was estimated, and LiDAR provided instantaneous navigational environment mapping. Using a point cloud to represent the scene in three dimensions (3D), LiDAR scans its surroundings. To ensure accurate perception in any lighting condition, 3D spinning LiDARs are now used more frequently (Yeong *et al*, 2021). High manufacturing costs and susceptibility to cyberattacks are some of the disadvantages of LiDAR technology, but recently created optical phased array LiDAR technology (Lin *et al*, 2021) has proven successful in satisfying the performance and price demands of the AV market. LiDAR sensors, unlike cameras, also don't record color images of their surroundings, necessitating the synthesis of data from other sensors in order to make decisions.

2.2.2 Camera

Cameras are the most commonly used sensor technology for autonomous driving systems because they can distinguish between different environments and targets. They are even being widely used in manually operated vehicles. Sensory technology has been incorporated into a number of cameras, including optical flow, depth-of-field and Dynamic Vision

Sensor (DVS). Both stationary and moving obstacles, such as traffic lights, emergency vehicles, road signs, pedestrians, and other visually distinguishable stimuli, can be detected by cameras and software built into the vehicle. The landing light that objects emit when they touch a photosensitive surface is what drives Connected Autonomous Vehicles (CAV) cameras to work (Shahian Jahromi, 2019). There are numerous different types of cameras, each with a unique lens type or range of wavelengths they can capture, such as Night Vision (NV) or specialized chips like High Dynamic Range (HDR), which are extremely light-sensitive. As a result of their ability to distinguish particular wavelengths in the 0.9–1.7-micron spectral range, high-resolution cameras, such as infrared cameras, perform better than human eyes. Cameras are required in autonomous vehicles. Still, weather conditions with low light have a big impact on them, and the data extraction process is computationally intensive.

2.2.3 Ultrasonic

Ultrasonic sensors produce sound waves, much like some living things that use echolocation to measure their distance from nearby objects. Together with other sensors like radar, cameras, and LiDAR, interior sensors known as ultrasonic sensors build a comprehensive picture of any other vehicles in the vicinity. These sensors frequently function most effectively when detecting slow motion and close proximity. However, they also perform well in adverse weather, fog, and low light conditions.

Compared to the other sensor types we've talked about so far; these ones are typically the least expensive. But unlike LiDAR, they lack the resolution to detect numerous or small moving objects. These sensors work best for identifying solid hazards like barriers and traffic cones (Sharma *et al*, 2022).

2.2.4 RADAR

RADAR, also known as radio detection and ranging, is used to identify distant objects and determine their characteristics, including speed. It uses a transmitter, receiver, receiving antenna, processor, and radio-wave transmission and reflection techniques to calculate how far away the target object is. Similar to LiDAR, the distance between the source of the radio waves and the target object that reflects the radio waves determines how long it takes for a radio wave to move forward and backward. Although there are some differences, the main one is that while LiDAR uses specialized optics and lasers for receiving and transmitting, radar uses radio waves with an antenna. Second, unlike the LiDAR, which can identify and locate a target object, the radar can only provide an estimate of an object's distance rather than its exact appearance. Finally, while cameras and LiDAR cannot independently provide these features, radar can operate in both cloudy and dark environments (Sharma *et al*, 2022).

2.2.5 Inertia Measurement Units

An Inertia Measurement Unit (IMU) sensor measures angular rate, force, and magnetic field to determine inertia. It has two sensors: an accelerometer for measuring linear acceleration and a gyroscope for measuring rotational acceleration. The sensor provides real-time data from each of the six axes of motion simultaneously and is independent of visual or radio spectrum data. It is mounted in a protected container inside the vehicle's chassis, making it completely resistant to weather and other environmental factors. Additionally, this navigation sensor will assist self-stabilizing vehicles in determining whether any preventative safety measures are required (Sharma *et al,* 2022).

2.2.6 Global Navigation Satellite Units

Vehicles can navigate from point A to point B thanks to the Global Navigation Satellite Systems (GNSS) sensors. Using satellite transmissions, this sensor works with the CAVs' GPS to determine a location's latitude and longitude. Since the vehicle handles the rest, the user interface can mimic current GPS systems and require little input from the user. In terms of technology, a GPS tracking system communicates with satellites through a GNSS network. In contrast, GNSS uses microwave signals to deliver location, speed, time, and direction data to GPS devices that are then used to enable practical, automated driving (Sharma *et al*, 2022).

2.2.7 Wheel Encoder

In order to measure the car's acceleration and speed, a wheel encoder was fastened to its wheels. The angle of the turn is measured by an internal sensor mounted to the steering wheel of a vehicle

The actuator is yet another essential component of the Autonomous Driving System technology incorporated into CAVs. The Electronic

Control Unit (ECU) of the vehicle determines whether to activate the actuator after receiving data from the environment via sensors. To transform energy into reality, actuators work quietly in the background of vehicles. Back-up cameras, blind spot monitoring, lane assistance, emergency braking, and adaptive cruise control are some of the practical features they carry out (Dewesoft, 2021). The actuators needed for autonomous vehicles are already present in the majority of currently operating vehicles (see description below).

Throttle Actuator - using an electronic speed control system by depressing or releasing the gas pedal.

Steering Actuator - using power steering with electrical assistance to steer the vehicle.

Braking Actuator - deciding when to stop a moving vehicle using electronic stability control.

2.3 Key components in AV classification

Using sensors, an autonomous driving system was created that can operate independently of human intervention. The system creates an autonomy stack that enables data gathering, decision-making, and action by connecting the vehicle's sensors, actuators, and other parts of the vehicle. Sensors gather data about their surroundings, including data about object distance, and process it. After gathering sensor data, the autonomy stack decides what to do. By defining instructions to alter the physical behavior of the vehicle, the actuators (brake, throttle, and steering) also make executive decisions. According to Society of Automotive Engineers (SAE) J3016, there are different levels of autonomous driving systems, and in the real world, we are only at the beginning of this technology (SAE, 2021). From no automation to full automation, there are now six levels of driving automation. Figure 1 shows how automated a system is:

1. **Level 0 - No Automation:** the car is entirely under the driver's control.
2. **Level 1 - Driver Assistance:** Simple driving chores, like using adaptive cruise control, are handled by automation.
3. **Level 2 - Partial Automation:** The driver should be able to control the steering, acceleration, and braking in certain driving circumstances. The Advanced Driving System requires the driver to monitor and actively participate in the driving.
4. **Level 3 - Conditional Automation:** The driver is free to engage in other activities; they are not required to be fully alert and in control of the driving task. But in an emergency, the driver must be prepared to use manual control. At this level of automation, there are technologies like traffic jam assistance.
5. **Level 4 - High Automation:** In some use cases, drivers are unnecessary. In these scenarios, the car might not have a steering wheel or pedals, but geofencing technology would restrict its use to a specific area. The operation of the vehicle may be temporarily restricted or canceled due to certain circumstances, such as severe

weather. This level of automation, for instance, is present in driverless taxis and public transportation.

6. **Level 5 - Full Automation:** The greatest example of automated driving, where a car can drive itself anywhere and under any conditions with no assistance from a human.

Table 1. The 6 Levels of Autonomous Vehicles

	L0 No Automation	L1 Driver Assistance	L2 Partial Automation	L3 Conditional Automation	L4 High Automation	L5 Full Automation
Driver	In charge of all the driving	Must do all the driving, but with some basic help in some situations	Must stay fully alert even when vehicle assumes some basic driving tasks	Must be always ready to take over within a specified period of time when the self-driving systems are unable to continue	Can be a passenger who, with notice, can take over driving when the self-driving systems are unable to continue	No human driver required-steering wheel optional-everyone can be a passenger in an L5 vehicle
Vehicle	Responds only to inputs from the driver, but can provide warnings about the environment	Can provide basic help, such as automatic emergency braking or lane keep support	Can automatically steer, accelerate, and brake in limited situations	Can take full control over steering, acceleration, and braking under certain conditions	Can assume all driving tasks under nearly all conditions without any driver attention	In charge of all the driving and can operate in all environments without need for human intervention

Source: Society of Automotive Engineers (SAE); National Highway and Traffic Safety Administration (NHTSA)

At the moment, level 2 to 3 autonomy is used in vehicles as many countries have not given permission to use full autonomy yet. According Forbes, advanced driver assistance systems are increasingly popular. By the year of 2030 the global market for these systems will increase to 83 billion dollars (Forbes Advisor, 2020). Forbes claim that advanced driver aid systems have a big impact on driver experience and is beneficial for the driver, passengers and the environment. Research complied by LexisNexis Risk solutions show a reduction in bodily injury claim by 27% and a reduction in property damage by 19%. Another study was done to test if autonomous systems/driver assistance are actually helping to reduce accidents. A study done by the insurance institute for highway for vehicles showed that vehicles fitted with blind spot monitoring are 14% less involved in accidents rather than vehicles not fitted with this system. From this research, driver aid is helping (Forbes Advisor, 2020). This research is based on one form of driving assist, a vehicle fitted with multiple aids will reduce the chances of an accident even further. The main driving aid are as listed below:

- Adaptive cruise control
- Blind spot detection
- Road sign recognition
- Automatic emergency braking
- Lane departure warning
- Forward and rear collision warning

- Pedestrian detection system
- Collision warning
- Cross-traffic alert

These driving aids are beneficial as humans tend to get tired due to certain circumstances for example, long distance driving, lack of sleep or even distractions from a mobile device can cause the driver to become less focused whilst driving. Driving aids will warn the driver pre-collisions however the driver should not rely on this technology as it should only be considered as a safety net. Vehicle manufacturers state that the driver must have both hands on the steering wheel and should be in full control on the vehicle even if the vehicle is fitted with driving aids.

The advantages of using autonomous systems are primarily used to increase safety in most industries, this is because machines are used to carry out dangerous tasks to replace humans. Machines do not have feelings unlike humans hence they do not need regular breaks. They would also not feel overwhelmed in tense situations, this is the reason that factories have implemented AI machines as they are more accurate and efficient. Using this technology for operating a vehicle autonomously is not as simple to implement as the surroundings change drastically and quickly for AI vehicles to follow. This is why full Autonomy Vehicles are not issued in many areas in the world as they are not considered safe yet. However, on the other hand when more autonomous systems are implemented, people's skillsets will decrease, this is due to humans putting all of their trust into machines because the job will be done quicker, accurately and efferently, however over time the skill level of the human will decrease as they will not have done that particular job as much as they used to. We are not living in an era that humans will trust full autonomous vehicles, this will happen overtime when the system proves to be useful. The same concept is similar to seat belts. A Volvo engineer by the name of Nils Bohlin invented the seat belt in 1959 (Volvo, 2019), back then many drivers and passengers were unhappy with the seatbelt however now it is the law and everyone in the vehicle is required to fasten their seat belt.

Some forms of autonomy work differently, reactive autonomy is a system where using data it can make correct decisions to achieve the goal. For example, IBM's chess playing super computer called Deep Blue, beat an international chess grandmaster Garry Kasparov in 1996 (IMB, 1997). This system uses algorithms to work out the quickest outcome, which allows the computer to always have the upper hand in the game. However, this system does not have any records of the past, therefore the opponent can learn movements from the system to make a prediction for future games. We can eventually overcome systems that do not learn from the past, such as in games, the player can retry and learn from their mistakes, they can also learn the limitations of the game. In a more realistic environment, reactive autonomy systems can be easily fooled because they have no imagination or sense of a real-world situation.

Design autonomy is very similar to reactive autonomy and can be used in conjunction to it. It can create its own process method and when combined with reactive autonomy, the system can create the process and always find the correct beneficial outcome. However, this can become complicated when troubleshooting problems due to difficulty locating the error.

Both types of autonomy are used in autonomous vehicle as all these vehicles are learning continuously whilst all data is stored. For example, Tesla's are prompted to update their system when an update is available. These updates are downloaded onto the vehicles computer and the aim is to enhance the capabilities of autonomous driving.

With the help of a graphic hardware and software company, Robots are being trained for the real-world using graphics by Nvidia (NVIDIA, 2022). In order to simulate the real world when designing a robotic arm that inserts objects into a compartment, for instance, engineers would build a 3D model. In an augmented reality, the robot would then learn the proper motions. The robot would then have the simulated version's artificial intelligence embedded into it by engineers. The robot would then be fully conscious and aware of the actions that must be taken. In accordance with the same theory, augmented reality is used to conduct research on autonomous vehicles in order to predict how they will behave. Testing for an autonomous vehicle versus a home robot would be very different. Both would require safety testing; however, the vehicle must undergo the most thorough testing because it has a much greater potential for harming the passenger and other pedestrians. This would entail testing in a variety of weather conditions, traffic patterns, and emergency braking situations. Nvidia developed the GTC graphics processing unit, and software is used to simulate different types of roads in order to test the autonomous vehicle (NVIDIA, 2022). In order for the system to take over and become fully autonomous, data from previously driven vehicles is processed so that when the driver repeats the same route, the system is aware of the layout of the road and any obstacles. However, once the AI has been trained on the computer, it will need to be properly tested in reality as it will depend on the possibilities of the moves of other road users.

There are thousands of AVs on the roads nowadays. Additionally, that figure is likely to rise, and in 2035, AVs are anticipated to account for 25% of all automobiles globally (Coren, 2017). Whether AVs reduce road accidents is an issue that Filiz, (2020), attempted to tackle. The advantages, disadvantages, and moral aspects of AVs have been discussed after information regarding their history, basic description, and operational procedure has been provided. He argued that AVs are superior to human drivers in some situations because they are better at learning and keeping situational awareness. It never gets exhausted, feels sleepy, or stops functioning when it's under the influence of alcohol. We could anticipate that the usage of AVs will cause less accidents as a result of these benefits.

Chapter 3: Methodology and data collection procedure

In this study was used Systematic Literature Review (SLR). The use of SLR is encouraged for the following reasons:

It has a long history as a tool for comprehending cutting-edge research in fields related to technology (Scornavacca, 2006); it assists in determining previous studies and encourages readers to identify new research directions (Jones, 2014); it assists in establishing the foundation for knowledge advancement (Webster, 2002).

The purpose of this study is to understand the relationship between autonomous vehicle technology and traffic-related mortality.

The primary goals served as the basis for the search term. Table 2 shows the search's key words:

Autonomous Vehicle, Self-driving Vehicle, Traffic Death, Traffic Accident, Self-driving cars, Mortality.

Searches for articles were conducted in electronic databases like **EBSCO, ProQuest, IEEE Explorer, Web of Science.**

Table 2. Search strings

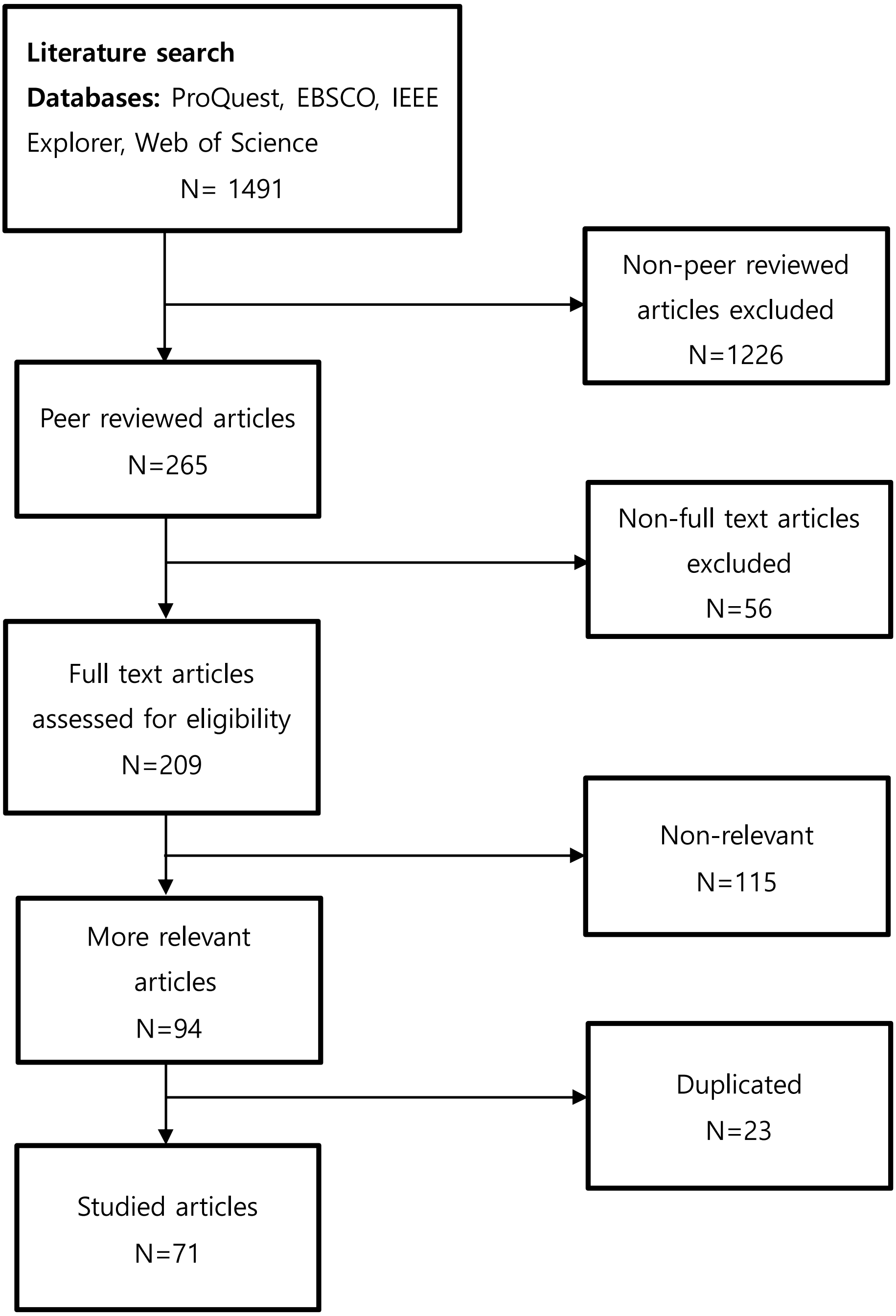
ab(("autonomous cars” OR "autonomous vehicles” OR "self-driving cars” OR "self-driving vehicles” OR “driverless cars” OR “driverless vehicles” OR “robotic cars” OR “robotic vehicles”) AND ("traffic deaths” OR "traffic accidents” OR “mortality”))

Then, published articles and journal papers were searched using the title, abstract, and keywords. As of November 2022, there were 1491 articles found in the literature search. The inclusion criteria are shown in Table 3. It is based on the following elements: studies with a focus on the research topic, articles written in English and peer-reviewed journal publications from 2012 to 2022, studies using both qualitative and quantitative methods.

Table 3. Inclusion and exclusion criteria

Inclusion Criteria	**Exclusion Criteria**
Peer-reviewed	Not Peer-reviewed
Publication: 2012 to 2022	Publications before 2011
Publication in English Language	Non-English language
Journal Articles	Duplicated articles (other source)
Qualitative and quantitative studies	Not having any of the search terms

Figure 2: Research strategy and study selection process



Based on my study 1491 articles was found from different databases. The papers were reduced to 265 articles after screening, due to the peer-reviewed articles. To determine whether the articles were pertinent to the topic of the literature review, it was found 209 full text articles. The abstracts of each of the 209 eligible publications, 94 articles were found more relevant to the research questions. Due to avoidance of duplicate articles, overall, 71 articles were selected as the full text studies. After that, articles were divided into the following criteria: author(s) and year of publication, title of paper, purpose of research, methodology. The full list of the selected articles is presented in Appendix 1.

Although we consider the years 2012 to 2022, the majority of the 71 articles are from the last three years (from 2022-17, from 2021-16 and from 2020-20, total 53). It shows that the study regarding Autonomous Vehicles very recent phenomena. Out of 71 articles, 10 are systematic review, which demonstrate familiarity with the topic and its scholarly context. On the other hand, most of the authors used the experimental analysis (total number 38), it indicates that the study regarding AV still in experimental level and the researchers tried to find out the conclusion through their scientific experiments. Besides this, most of the articles discussed about engineering and electronics dimension (31).

Chapter 4: Findings and Discussion

Seventy-one (71) papers in all were examined and evaluated. This research shows that with the successful introduction and testing of fully autonomous cars and the announcements by manufacturers that they would deploy their own AVs on the market by 2022, the number of studies on road safety with AVs began to expand at a quicker rate in 2012. Additionally, it is abundantly clear from the volume of papers that academics, governments, and politicians have begun to think about and focus on enhancing road safety and decreasing traffic deaths. However, contemporary AV literature seems to realize the seriousness of the issue before widespread AV adoption.

Based on this analysis, it can be concluded that there has been extensive research on relationship between autonomous vehicle technology and traffic-related mortality subject areas, and that researchers from a variety of disciplines have shown an interest in the subject. The most frequently cited articles in later research were those published in 2012 and later, indicating that current studies prioritize research done after 2012.

Quantitative and qualitative studies were included, with a focus on topics related to road safety. These included sustainable transportation, cost-effectiveness, data privacy, licensing configurations for AVs, reductions in travel time, crashes, and fuel efficiency accountability. Other topics covered included road anomalies, autonomous vehicle safety, an autonomous driving testing scenario, and understanding interactions between autonomous vehicles and other road users. The following methodologies were applied to these articles: systematic literature review, an international comparison, a comparison study, an empirical study, experimental and scenarios methods.

The majority of these studies focused on the technical elements of AVs that are linked to technology manufacturers rather than to governmental bodies, as well as the implications of liability on those manufacturers. In situations where accidents cannot be avoided, as well as the preferences of pedestrians and passengers in morally complex situations involving autonomous vehicles, AVs should be ready and pre-programmed. According to these articles, automakers should alter their systems to make self-driving cars secure, dependable, and safe. The study of self-driving vehicles is the closest to life, the biggest benefit is to make transportation more convenient (Lin *et al*, 2021).

4.1. RQ1: Do autonomous vehicles reduce traffic-related deaths?

Based on the articles (Yuan *et al*, 2019), I have tried to figure out this question that are AVs really reduce the traffic-related deaths. Most of the researchers talk about benefit from AVs, however, they also mentioned some conditions regarding uses of AV.

More and more advanced and technically feasible autonomous systems are becoming available for installation in commercial vehicles (Barabas *et al,* 2017). Many automakers have already confirmed they have begun manufacturing highly automated vehicles, so it's reasonable to expect to see driverless cars in industrialized nations soon. By 2030, we might expect to see a large number of fully autonomous automobiles on the road (Barabas *et al,* 2017). Autonomous technologies are expected to minimize traffic accidents, since human mistake and omission are the leading causes of vehicular collisions. Just now, there isn't enough evidence in the form of statistics to back up this claim. It's plausible to anticipate that fully autonomous vehicles will outperform their conventional counterparts in every conceivable way. Also, Dixit *et al.* (2016) pointed out that accidents can be greatly reduced if AVs are able to interact with their environment. According to Chuprov *et al*. (2019), the future of the automotive industry and the creation of intelligent transport systems would help alleviate traffic congestion and cut down on the number of lives lost in traffic accidents. Autonomous vehicle technologies give effective chances to enhance the driving environment and minimize the incidence of traffic incidents, as was also highlighted by Huang *et al.* (2019). Accidents, congestion, energy use, and pollution are just some of the issues that autonomous driving technology can help alleviate (Li *et al*, 2022). Autonomous vehicles (AV) are predicted to deliver significant benefits to society, such as traffic optimization and accident reduction, as was noted by Nascimento *et al.* (2020), who made a similar sort of statement. They rely significantly on recent developments in various Artificial Intelligence (AI) methods and processes. Some experts in the industry argue that artificial intelligence is crucial to improving security, while others point out the additional difficulties inherent in using AI to guarantee the integrity of newly developed AI-based systems and applications.

By transferring responsibility for driving safely from humans to technology, autonomous vehicles (AVs) have the potential to drastically cut down on traffic fatalities (Moody *et al,* 2020). According to Yao *et al.* (2020), the goal of autonomous vehicle technology is to decrease the number of traffic accidents, increase driver comfort and fuel efficiency. Route tracking, as the foundation of the autonomous vehicle's motion control module, works to precisely follow the reference path, guarantee the vehicle's stability, and fulfill the control system's robust performance requirements.

The autonomous vehicle's main goal is to reduce the number of people killed or injured in traffic collisions. Improper vehicle speed, particularly on road bends, is a contributor to traffic accidents. Accidents on the road can be avoided if drivers learn to anticipate turns in the road. For the automated vehicle, Dorj *et al.* (2020) provided a state-of-the-art Kalman filter-based curve lane detecting system. In order to estimate the parameters of a curve lane, it employs models based on the parabola equation and the circle equation within the Kalman filter. The curve lane identification algorithm has a good success rate, as demonstrated by the experiments (Dorj *et al*, 2020). Additionally, decreasing traffic accidents is a big goal, therefore the system that the autonomous vehicle is equipped with will play a very vital role, and the vehicle will be equipped with numerous sensor elements. Primarily, it serves as the "eyes" of autonomous cars, gathering and compiling data about their surroundings. Using the collected data, the system may ascertain the presence or absence of potential dangers in the vehicle's immediate vicinity and take the necessary precautions (Lin *et al.* 2021).

One of the leading causes of accidents in heavy traffic is drivers who weave in and out of lanes without signaling. The impacts of switching lanes are distinct when autonomous cars share the road with human-driven vehicles. Vehicle lane-changing behaviors are more proficient overall in traffic if human drivers are present. The volume of traffic and the frequency with which drivers switch lanes both rise when autonomous cars are operating in congested areas (Xie *et al,* 2022).

Because changing lanes in traffic is difficult and dangerous, a Lane Markings Detection System plays a crucial role in ensuring the safety of drivers on the road. Technique for driving assistance of AVs is crucial to preventing a vehicle from driving out of its lane. A comparison of the edge detection methods of canny, sobel, roberts, and prewitt led to the development of a new Hough Transform methodology presented by Talib *et al.* (2015) for lane recognition on roads. The system performed well in identifying highway lanes that were both straight and smoothly curved, even when those lanes were partially obscured by trees or buildings. As a result, AVs are better able to recognize lane markings and help cut down on accidents.

Since AVs eliminate the risk of human mistake, they have the potential to significantly cut down on road accidents, as stated by Szusc *et al.* (2022). However, further development is still required in several areas, including computer vision and detection and cyber security. The introduction of driverless technology has the potential to greatly enhance road safety (Wang *et al,* 2022). According to Xiao *et al*. (2022), the question of culpability is crucial to the settlement of the incident and the preservation of human rights since it is directly tied to the economic interests, personal safety, and rights protection of the persons involved in vehicle traffic accidents. Nyholm *et al*. (2016) also mentioned that autonomous vehicles have the potential to be safer than conventional vehicles. A large percentage of accidents, as stated by Chen *et al.* (2022), are caused by human mistake. Solutions can be found in the form of disruptive technology, such as autonomous vehicles (AVs), which can reduce the incidence of accidents by, among other things, eliminating the potential for human mistake.

Human involvement, in the form of the legal and moral responsibilities of imperfect operators, is assumed by the current transportation system. Setting design standards for autonomous cars or refusing to do so may have far-reaching effects on how people see their moral and legal obligations in relation to these vehicles (Riegler Carolyn, 2019). To what extent a "driver" is held responsible for a deadly collision depends on the specifics of the technology used in autonomous cars. There may be a happy medium between passenger safety and pedestrian security in self-driving vehicles, according to the variety of design possibilities available when it comes to the algorithms that control them. The number of people killed and property damaged in accidents may be reduced if autonomous cars utilize data ethically and make decisions in accordance with such data, as can the rank of pedestrians and passengers (Riegler Carolyn, 2019). It has been shown that AVs provide a safer environment for passengers and reduce the mental strain on drivers (Dixit *et al,* 2016).

The dangers of drivers who multitask while behind the wheel are increasing. In the near future, a wide variety of intelligent vehicles will be commonplace thanks to developments in autonomous driving and linked vehicle technology, while new potential sources of driver cognitive distraction are developing (Hua *et al,* 2021). Distraction alarms and autonomous driving assistance systems, both of which might benefit from the 'Bi-LSTM' model (a unique approach of diagnosing cognitive distraction based on bidirectional long short-term memory), could help keep drivers safe on the road. The Bi-LSTM with attention mechanism model was trained and tested using data on driving performance and eye movements. Its identification accuracy rate is 94.33%, which is 3.83% higher than that of the support vector machine (SVM) model in the overall event, suggesting that it may be useful for distraction recognition in a busy traffic setting (Hua *et al,* 2021).

One of the most crucial technologies for ensuring the security of autonomous vehicles is their ability to perceive and respond to traffic lights

(Zhang *et al,* 2021). For the advancement of intelligent cars, the detection and identification of traffic signals is of utmost importance since it provides a safety assurance for auxiliary driving system and self-driving system.

Pek *et al*. (2020) made sure that self-driving cars wouldn't crash into each other. They offered a formal verification method to ensure legal compliance in diverse urban traffic scenarios. For autonomous cars to be considered legally safe, they must be able to operate without ever causing an accident, even if other road users are free to violate the law in any way they see fit. The method they developed adds an extra layer of protection to pre-existing motion planning frameworks that plot routes for autonomous cars. They checked to see if the planned paths were legally safe and if there were any backup plans in case of emergency. Benefits of their verification method are illustrated in high-stakes urban situations captured from actual traffic. Even when employing an intended trajectory planner that lacked awareness of other traffic participants, the autonomous vehicle only carried out safe paths. Their findings suggest that AV's online verification approach can significantly cut down on road accidents (Pek *et al,* 2020).

Wang *et al.* (2020) indicated in the discussion section the implication of the derived results, showing that either these formulae reveal the optimum safe efficiencies and give the least requirements on velocity constraints of the traffic configurations, or that the AVs require the least amount of response time possible. In conclusion, our finding suggests that, on the one hand, AVs should travel as quickly as feasible and as near to other AVs as possible to enhance safe transit efficiency. The responsibility settings determine the minimum distance that AVs must maintain from one another for safe driving (Wang *et al,* 2020). The capacity and throughput of AVs are evaluated in accordance with safe driving regulations that exclude compliant AVs from legal responsibility in the event of an accident.

A monitoring system is required to identify the tiredness of drivers because it is one of the major causes of traffic accidents. Biometric data, vehicle behavior, and driver-generated graphics are the primary data points picked up by most driver monitoring systems. The sleepiness detection and estimating system will serve as a comfort system while driving, allowing the driver to avoid the weariness that comes with driving and to do tasks without feeling drowsy after they have arrived at their destination. Future applications of the sleepiness detection and estimate system for level 4 and level 5 autonomous driving include not just cars, but also areas and businesses connected to sleep, with the goal of detecting tiredness and putting people at ease (Toshiya Arakawa, 2021).

Successfully monitoring tired drivers on real-world road segments is a significant obstacle. Thankfully, autonomous cars, which heavily rely on reducing vehicle GPS and communication systems, can collect vast data on vehicle trajectories. The driving times from origins to any given road stretch are particularly useful for monitoring the effects of driver tiredness on the road. To cash in on this potential, researchers have developed a data-driven method that enables for the real-time tracking of driver weariness over different stretches of road (Chang *et al,* 2020). To effectively poll drivers who have become exhausted on a certain stretch of road, all that is needed is information on how long it took them to get there from their points of origin. An indicator for drowsy drivers was shown to have a high explanatory power over the car accident rate, with a correlation coefficient of 0.90. Based on these results, it appears that the suggested approach will be an effective way to track driver tiredness in the near future. As an added bonus, the approach may be put into quick use provided data on vehicle trajectories is readily accessible.

Reduced computational burden and enhanced real-time processing capabilities are further benefits of AVs that are essential for decreasing the number of traffic incidents (Ye *et al,* 2022). In his article, Ye *et al.* (2022) explained how Stackelberg game theory is used to represent the behavior decision algorithm, which is then used to inform real-time path planning and motion control while also providing feedback on vehicle states and path parameters to the decision-making module. Thus, we develop a decision-making framework for lane changes that is closed-loop and accounts for both vehicle contact and aggression. The study by Lin *et al.* (2020) presented a vision-based driving assistance system for use on the highway, in urban areas, and in city settings. The effective and robust methods for detecting lane changes, warning of impending collisions, and identifying vehicles being passed by have greatly decreased traffic accidents, he said.

Vehicle lateral active collision avoidance control method research, collision avoidance decision-making, path planning, and collision avoidance transverse vehicle longitudinal motion control are analyzed, and tests are conducted using automated driving simulation to verify the designed control strategy in order to further improve vehicle safety and ethical algorithm design points. Results from experiments validated that the suggested approach not only effectively avoids collisions in automated driving but also satisfies ethical standards for such systems. This study can serve as a roadmap for future investigations into algorithmic ethics in the field of autonomous driving, which has the potential to significantly lessen the number of road incidents (Yineng Xiao, 2022).

Lin *et al.* (2021) states that Light Detection and Ranging (LiDAR) is crucial to the operation of autonomous vehicles. In order to gather information about the world around the vehicle, it projects a beam of optical laser into the area and reads the reflected light from various objects.

In the case of autonomous cars, Santhakumar *et al.* (2021) demonstrated that radar sensing is a more reliable technique than camera or LiDAR. Because of this, they can function normally despite extreme climates, such as dense fog, intense sunlight, etc. By minimizing the likelihood of crashes and traffic accidents, the 77-81GHz frequency band for short-range radar provides a universal foundation for automobile radar. Impedance matching is improved by strategically placing the feed line and the Meta material structure. The antenna design is suitable for array deployment in vehicle radar systems. Preventing fatalities by speeding up the transmission of accident data to authorities is an important goal of autonomous vehicle safety systems. The word "accident" is often used to describe one of the leading causes of human mortality (Roohullah *et al,* 2022).

In research conducted with the help of the simulation program PC-Crash, (Choi *et al,* 2021) demonstrated that the use of AEBS on AV can lessen the likelihood of traffic accidents. Therefore, it is important to apply the real traffic accident database (ACCC) to different AEBS applications, sensor types, and radar detection angles to increase confidence in the system's capacity to reduce traffic accidents.

Analytical investigations showed that decreased visibility has a similar effect on traffic as lowered average speed and capacity. In addition, the free-flow density range is drastically reduced compared to when there is no fog present. Commercial autonomous vehicles (CAVs) will improve traffic flow (e.g., average vehicle speed and traffic capacity). The critical density also rises when the proportion of CAVs on the road grows; this is especially noticeable when visibility is low (Gong *et al,* 2022). Accident rates and severity might be reduced with a deeper comprehension of the peculiarities of mixed traffic in foggy conditions.

Fuzzy algorithm used to make decisions for human avoidance system depending on human position and distance. The system's success rate in avoiding humans at distances greater than 2 meters is 85.71%. However, the technologies are predicted to minimize traffic accidents caused by human mistake. Nizar *et al.* (2020) indicated that the implemented prototype of an autonomous vehicle may be implemented in the actual car with minor tweaks in the sensor and hardware system). When compared to the human decision-making process, the algorithm is remarkably logical since it does not factor in any emotional responses to individual issues but rather draws conclusions and forms assessments based on a set of assumptions. Algorithms, in contrast to humans, can apply total rationality with tight discipline, eliminating the errors caused by humans' inherent limits and irrationality. The advancement of algorithms marks a new phase in mankind's quest to decipher the mysteries of the universe. These algorithms may help individuals gain insight into who they are, synthesize the lessons they've learned through making decisions, and broaden their perspective on humanity and logic (Yineng Xiao, 2022).

Injuries and deaths from traffic accidents typically occur near crossroads. When it comes to these types of collisions, right-turning vehicles are typically at fault in Japan (despite the country's left-hand driving culture). Because of this, we've based the design of our ADAS for right-hand turns on it. The intersection problem is simple for autonomous vehicles with an ADAS system to solve (Yineng Xiao, 2022). As the population of Korea continues to grow, so does the number of traffic accidents and the number of lives lost as a result of them. The South Korean National Police Agency found that there were 45,921 pedestrian traffic incidents registered in 2019, resulting in 1,487 fatalities and 46,400 injuries. The notion of an Advanced Driver Assistance System (ADAS) is fast evolving as a result of the growing concern for the prevention of traffic accidents and is playing an important role in responding to events that the driver may not be aware of (Kim *et al,* 2020). One example of an ADAS is the Autonomous Emergency Braking (AEB) system, which helps avoid or lessen the severity of accidents by applying the brakes automatically in the case of an emergency.

Lee et al. (2021) developed a deep learning-based algorithm to identify roadside anomalies and deployed an app to alert drivers whenever something out of the ordinary was seen by surveillance cameras. Testing of this service was conducted virtually with CCTVs in Daegu, Busan, and Gwangju, South Korea, utilizing application notification simulations and virtual trials. The purpose is to increase traffic safety and foster the growth of the autonomous vehicle industry through the provision of related services. Lee *et al.* (2021) recommended developing a reliable CCTV control system for the transportation sector as a potential area for further study.

To create a hazardous scenario prediction model of AVs at intersections, Li *et al*. (2020) uses a Gaussian mixture model and analyzes the elements that impact the scene, picking relevant variables (such PET) in the process (GMM). We use simulated experiments to train and validate the model. Predicting potentially hazardous situations at intersections using AV's GMM-based prediction model is technically achievable. Using the

VRUCW (Vulnerable Road User Collision Warning) application in AV, Miao *et al.* (2022) demonstrated that it is feasible and may improve autonomous driving road safety.

Due to its complexity and high rate of traffic accidents, intersections have garnered a lot of attention. Problems with autonomous driving judgments and control at intersections must be addressed during the process of creating (Xiao *et al.* 2022) and above autonomous-driving solutions. By constructing a road-geometry model, the important role of collision avoidance in the convergence process is identified, and the predicted speed of the straight vehicle that guarantees passing safety is computed. Next, the decision-control issue of the straight vehicle is solved using a reinforcement-learning method, with the agent's predicted speed adjusted to guide its learning and eventual convergence on the desired option. Through simulations, we were able to validate the effectiveness of the suggested technique, finding that it can make optimal selections for the straight car to go through the junction, with a high priority on both safety and efficiency (Liu *et al*, 2022). In his research, Liu *et al.* (2022) suggests a decision-and-control approach utilizing reinforcement learning and speed prediction to handle the commingling of straight and turning cars at two-way single-lane un-signalized junctions.

Bigman *et al.* (2020) states that results from the Moral Machine Experiment (MME) indicate that the general public wants autonomous vehicles (AVs) to prioritize the lives of certain demographics (such as men, the elderly, and the impoverished) over others when it comes to taking human life (for example, women, the young and the rich). Given that the MME's approach is highly indifferent to desires for equality, it concludes that people prefer disparity across lives. The MME uses trolley dilemmas, in which participants must decide whether to murder one individual (or group of people) or another (or set of people). Their research disproves this theory by showing that the MME's 'trolley-type' paradigm is actually the driving force behind the observed predilection for inequity. Multiple studies using a new paradigm found that the vast majority of people want autonomous cars to disregard factors like a person's gender, age, or social standing when deciding whether or not to save a life. There is a need for caution when interpreting MME data, but we still believe in its use. Like any other approach, the MME has its drawbacks, but it does indicate universal preferences for avoiding harm to others and basic moral cognition processes. The MME also draws attention to broader ethical concerns raised by AVs, which will eventually need to be addressed by society. Similarly, in The Moral Machine experiment (MME), Awad *et al.* (2020) argued that policymakers would benefit from knowing citizens' preferences regarding the behavior of autonomous vehicles in emergency situations, such as when an autonomous vehicle cannot save everyone but must still choose to save one group of road users over another.

Driving at night, in fog, or during heavy rains is a risky endeavor that increases the risk of collisions and injuries. It is a solar-powered, intelligent road marking system that uses wirelessly networked signaling devices to increase driving safety in low visibility and on dangerous roads. Nails, sometimes called signaling devices, are self-sufficient nodes that can store energy, communicate wirelessly, identify nearby cars, and shine a light to alert others. In this paper, we offer a unique distributed network topology discovery technique that combines sensor and wireless communication features, and in which nodes act independently of one another (Samardzija *et al,* 2012). This is one manner in which AV helps to create a safer and more tranquil atmosphere.

Mistakes made when steering might lead to collisions. The ease with which the steering may be operated has a major impact on drivers' concentration and relaxation when behind the wheel. Accordingly, long-distance driving-related shoulder stiffness and arm fatigue can be mitigated using an ergonomic steering operation. This is accelerating progress toward a day when vehicles can drive themselves, which is great news given that avoiding collisions is one of the trickiest driving tasks in the field of intelligent vehicles (Kajiwara *et al*, 2018). A number of active safety technologies, such as collision avoidance systems, have recently entered the market in an effort to increase motorists' peace of mind while behind the wheel. While these systems have proven effective in reducing accidents, they have primarily been used to warn drivers of impending collisions rather than prevent them (Yineng Xiao, 2022).

Due to a variety of variables, drivers may not always have complete visibility of crossing sites (e.g., poor road maintenance, occlusion of vertical signs, and adverse weather conditions). In 2015, the United States government reported that there were 70,000 pedestrian-vehicle incidents, 5,376 of which were fatal. When people cross the street, vehicles may see a visual warning barrier generated by a network of autonomous, intelligent, and low-cost wireless devices from a safe distance. That way, motorists may slow down and come to a halt without risk. The system's brain is a fuzzy controller, which fuses data from a wide range of low- and high-level sensors attached to nearby devices to create the basis of the system's intelligence. In accordance with a ROC analysis, the results of the tests showed that the average success rate was 94.64% and the accuracy was 100%. Therefore, the suggested system has been granted a patent and submitted to the worldwide PCT (Dominguez *et al,* 2018).

It is recommended that the elimination edge of the road feature in sensor information be considered a visible mobility obstacle, and the concept of PTA be used to enhance the active safety performance of autonomous vehicles in complex road environments such as bends and crossroads. The 'driver' response time will be minimized thanks to the usage of a Convolution neural network (CNN) to recognize and categorize PTA regions (obscured areas). As a result, autonomous vehicles' active safety performance will increase significantly (Yuan *et al,* 2019). The edge movement trend analysis led to the development of SDM-PTA for the shadowed regions. SDM-primary PTA's components—reduced safe distance and ahead-of-time control—enable intelligent vehicles to move swiftly through obfuscated regions while maintaining a high level of safety. This demonstrates the robust security and usability of the SDM-PTA. A study reveals that the SDM-PTA outperforms standard SDM at intersections with pedestrian and vehicle traffic. Evidence from experiments demonstrates that our SDM-PTA approach is useful for locating potentially hazardous situations, such as corners and crossroads, that are otherwise difficult to see.

PTA is a concept designed to boost the active safety of autonomous vehicles in challenging situations on the road, such as turns and intersections. Autonomous road vehicle navigation systems rely heavily on pedestrian detection technology because it informs the vehicle of potential dangers in its immediate vicinity and directs it to take action to prevent crashes that might cause injury to pedestrians (Mounsey *et al,* 2021).

Although there have been significant technological advancements in the area of autonomous driving, traffic accidents still need to be addressed in the transportation sector. Unsafe driving contributes to more than half of all traffic accidents. Furthermore, aggressive driving might cause traffic backups (Kwon *et al*, 2021). Using time-series data as an input to model temporal variations, Kwon *et al*. (2021) proposes a 4-layer CNN-2 stack LSTM-based driving behavior categorization and V2X sharing system. Using just the vehicle's 3-axis acceleration, the proposed system classifies driving behavior into defensive, normal, and aggressive driving and broadcasts this information to the surrounding area. Both ACC simulations and real-world settings have verified the effectiveness of the suggested solution. The results of the trial showed that the driving behavior categorization performance was 97% or higher in the real-world test, and 98% or higher in the simulation test. It was also established that the average latency in V2X transmission via the prototype was 4.8 mc. The suggested approach has the potential to increase transportation safety by facilitating the dissemination of driver behavior data (Kwon *et al,* 2021).

Panadero *et al.* (2021) emphasized the need of "agile" optimization in the context of data-driven smart cities, where autonomous and unmanned vehicles may need difficult issues to be solved in real time (less than a second). Thinking about the problem's ever-changing context might help them do even more. The travel times and benefits in this setting are always shifting. As a result, the predetermined paths may need to be adjusted midway through the process of carrying them out. When a deviation is recognized by sensors, en route cars, video cameras, etc., the created routes and judgments are reevaluated.

Pure pursuit algorithm, Stanley, PID, model-free data-driven control, the Lyapulov technique, feed forward feedback control, LQR, and MPC are only some of the methods that have been investigated for autonomous vehicle route tracking and obstacle avoidance control. The properties of the vehicle's powertrain and steering system, however, have a more significant effect on the vehicle's maneuverability. Yao *et al.* (2020) is rarely thought of while analyzing the vehicle's steering system. Existing path tracking control methods use a hierarchical control framework to account for vehicle stability, fuel economy, passenger comfort, and other performance indicators in order to arrive at an optimal solution (suboptimal solution), which is then used to derive the final control input at a lower control level. Since the best solution is found for each layer independently, this style of control may not be able to optimize performance globally (Yao *et al,* 2020).

Street parking is one of the most time-consuming and difficult jobs a human motorist must complete. Parking maneuvers, despite the low speeds involved, are a leading cause of minor and occasionally serious traffic accidents, particularly in metropolitan areas with a scarcity of parking spots. Further, the time spent driving around in search of a parking spot adds to traffic congestion and pollution. The system is built around a communication protocol for automated cars, parking facilities, and motorists. For effective system communication and status monitoring, several user-friendly HMI ideas have been created (Plihal *et al,* 2022).

An unsafe interaction between humans and autonomous systems is a realistic possibility. By examining how risk sensitivity and emotions underlie safety judgment in AVs, Tan *et al.* (2020) sought to identify the linkages between these two concepts. It was discovered that the notion of risk sensitivity might help explain why people have different opinions on whether AVs are safe to use. Worry influences one's sense of safety more than fear does. One's lack of understanding and expertise with AVs leads them to conclude that the two concepts are unrelated. That paved the way for more research into how people view and anticipate the safety of AVs.

When evaluating the security of AVs, critical-scenario simulations are frequently employed. This research demonstrated an innovative method for creating practical, logical, and tangible testing situations for autonomous driving (Wang *et al,* 2022).

We may also develop a smarter control system to cut down on traffic accidents as vehicle communication and self-driving technologies advance. To enhance the effectiveness and security of the traffic environment, Karthikeyan *et al.* (2022) suggests implementing autonomous intersection management (DRLAIM), which is influenced by deep reinforcement learning.

An accident rate and risk of hazards on poor roads might be reduced with the use of road pictures recorded by camera and the deployment of the trained model for road anomaly identification in a vehicle. Intelligent Transportation Systems (ITS) developed the concept of the vehicular network called vehicular ad hoc network (VANET) for the purpose of establishing security and safety in a traffic flow by resolving accident concerns and exchanging emergency information (Bibi *et al,* 2021).

Mayer *et al.* (2021) showed that there are substantial disparities in the chosen course of action in critical circumstances among passengers, pedestrians, and spectators. As a result, it's crucial that autonomous cars' behaviors not only cater to the demands of their passengers but also consider those of pedestrians, cyclists, and motorists. The utilitarian choice to save multiple other lives above one's own is one such moral preference that seems to be shared by most participants regardless of their perspective, even if utilitarian reasons cannot fully reconcile the competing interests of passengers and pedestrians (Mayer *et al,* 2021).

4.1.1. Additional benefits for using AV:

Some articles mentioned that AVs not only reduce the traffic accident, but also give the other benefits:

1. Reduce CO2 and emissions:

According to Szucs *et al.* (2022), developing AVs will receive even more attention in the future because of the huge potential they have for reducing fuel usage, CO2 emissions, and pollutant emissions. Just as Li *et al.* (2022) has said, autonomous driving technology will help alleviate a number of issues related to transportation, including but not limited to, resource depletion and air pollution.

2. Reduce Environmental Noise:

LiDAR is a system used by AVs that consists of an optical radar and a processing module, and it is capable of decreasing environmental noise (Lin *et al,* 2021).

3. Reduce Traffic jams:

As technology in the automobile sector improves and smarter transportation solutions are implemented, traffic congestion may one day be a feature of the past (Chuprov *et al,* 2019).

4. Effective Traffic management:

All things considered, we are of the opinion that autonomous cars can significantly alleviate congestion in urban areas with a high concentration of both types of vehicles. Multivariate linear model fitting degrees are more than 0.7 and model parameter value intervals in the same lane under different operating ratios of autonomous cars are close as the number of autonomous vehicles on the road rises. Everything points to the model's stability. Mixed-traffic management and control may benefit from proposed multivariate linear model (Xie *et al,* 2022).

5. Identify the cause of accident:

Investigations into recent traffic accidents have increasingly relied on in-vehicle data like video recordings and driving logs to determine what exactly went wrong. Many times, the reason of an accident can't be determined since investigators can only rely on the words of the alleged offender and the alleged victim when just a video record, only a driving record, or neither is available (Yoon *et al,* 2021). The moment has come to begin Level 3 operations of autonomous driving cars and to initiate corresponding vehicle digital forensics. Simultaneously, digital forensic accident investigation on cars, particularly autonomous driving vehicles, necessitates study of traffic accident sensor data. In example, digital data forensics based on block chain may be used actively to data collected from cars.

6. Workers' compensation:

According to Donald G. Gifford (2018) analysis, it's likely that the liability system controlling autonomous cars would be similar to the workers' compensation system, in which the victim is not responsible for establishing who was at fault for an accident.

7. Social utility:

Using autonomous cars as the primary form of transportation has been shown to significantly enhance net social benefit, as discussed by Donald G. Gifford (2018).

4.2. RQ2: Are there any challenges to using autonomous vehicles?

Most of the experts surveyed highlighted various difficulties or cautions associated with widespread AV deployment. There is much hope that autonomous vehicles can help decrease road fatalities, improve people's daily lives, and advance more secure and effective transportation networks. However, there are still numerous obstacles to overcome in the realm of forensics, security, and privacy in Connected Autonomous Vehicles (CAV) technologies (Sharma *et al,* 2022). It is not yet obvious how well these technologies will cope with highly unusual or rare situations, based on current research and development. The proliferation of technology raises concerns about the incompatibility and incomprehensibility of the resulting goods. While certain developments can proceed entirely on data gathered by in-vehicle sensors, others will benefit from changes to the underlying infrastructure (Barabas *et al,* 2017). It would appear, however, that the present restrictions do not keep up with the advancement of technology and can occasionally impede the development and testing of autonomous technologies.

1. System failure:

Drivers of fully autonomous vehicles would not be able to use their car's built-in information system to be driven while they did anything else. In the event of a system failure, however, drivers must take control once again, and they must do it quickly because AV cannot react in such a short window of time (Dixit *et al,* 2016).

Due to the importance of object detection in autonomous driving, it is unacceptable that state-of-the-art object detectors have failed in numerous driving conditions (Yang *et al,* 2021). Real-world traffic situations are too complicated to ensure 100% detection success; thus, online failure prediction is essential for reducing the likelihood of traffic accidents. False Negative (FN) items have the highest potential for catastrophic outcomes among all failure scenarios; nonetheless, online FN prediction has received very little study.

2. The moral and ethical issues:

Future work will also need to be done to address the moral and ethical concerns raised by autonomous vehicles (AVs), which remain a highly charged and contentious issue (Szucs *et al,* 2022). Similarly, Pugnetti *et al,* (2018) pointed out that self-driving cars will have to deal with thorny ethical dilemmas. In the event that an accident cannot be prevented, the algorithms controlling their behavior will need to determine how to direct them. Sometimes they'll have to pick and choose among numerous possible victims. Most studies on AV adoption have relied on questionnaires or video-based demonstrations rather than actual hands-on experience, which means that psychological elements like trust, safety, and advantages may not be quantified effectively (Chen *et al,* 2022).

3. Path planning and motion control algorithm:

There are still some gaps in the path planning and motion control algorithm that require filling out (Wang *et al,* 2022). Wang *et al*. (2022) also recommended that we should investigate the correlation between barrier danger and collision probability dispersion in order to humanize the path planning algorithm and use it in more intricate scenarios.

One of the most active study areas in autonomous vehicles is the control of their movement along a predetermined course. Academics have investigated route tracking control for autonomous vehicles by utilizing data including vehicle dynamics, kinematics, tire dynamics, deviation of position and heading, and road curvature (Yao *et al,* 2020).

4. Laws and regulations:

The development and widespread use of autonomous vehicles represents not just a technological accomplishment, but also a threat to the social order maintained by our legal and regulatory systems. The road traffic rules and regulations must be updated so that legal responsibility for future traffic incidents involving self-driving cars may be established (Xiao *et al,* 2022). The advent of autonomous cars promises to radically alter our daily lives in the not-too-distant future, but the exact timing of these changes is not always evident. Moreover, the future is sometimes seen as too far off to warrant any immediate policy considerations or implementations (Mark Ryan, 2019).

5. Tort Liabilities:

In this article, we'll look at how the tort liability laws for motor vehicle accidents differ from those for pedestrian and bicycle accidents so that readers may form their own conclusions on how to handle autonomous vehicles safely and responsibly (Yang Menglu, 2021). The widespread use of autonomous cars on public roads will inevitably lead to accidents where tough choices will need to be made about who should bear the brunt of the damage (Mayer *et al,* 2021).

6. Bad or Foggy Weather:

LiDAR is being utilized in a variety of settings, including in driverless cars; nevertheless, they cannot function in adverse weather conditions (Lin *et al,* 2021). Increasing research is being done to find ways to enhance LiDAR data in challenging conditions, such as bad weather. We can increase the efficiency of human transportation and boost the efficiency of self-driving cars if we can reduce the negative effects of adverse weather on LiDAR. The absence of widespread experimental data for connected vehicles in smog means that we have no way of knowing whether or not the model holds true in the real world.

The importance of data from previous cars on traffic and road conditions increases in the absence of line-of-sight (NLOS). Information dissemination issues, such as the broadcast storm or message congestion, arise under these situations (Eom *et al,* 2020).

Autonomous vehicles, even ones with high-tech sensors, are involved in accidents on a regular basis, according to Miao *et al.* (2022) reporting. Inclement weather, inadequate illumination, and obstructions to the driver's field of sight are common factors in vehicular mishaps.

7. Effective Database:

AV makes choices using information pre-loaded into the system. However, there has been a dearth of research examining scenarios that take into account accidents that are difficult to forecast since most studies have concentrated on common accident types or typical accident circumstances. Due to the unpredictability of road accidents, even those with lower probabilities of happening require adequate planning (Chae *et al,* 2022). Therefore, it is crucial to have a robust and efficient database for AVs to function properly. Even highly automated or assisted cars on the road might benefit from knowing the status of other vehicles around in order to avoid potential collisions (Eom *et al,* 2020).

Chuprov *et al,* 2019 has proposed a system based on reputation and trust mechanisms that can identify autonomous vehicles (AVs) relaying false information at intersections and prevent them from interacting with other AVs in the future. Both software and physical models were used to validate the method's efficacy and suitability, with findings that suggest the approach might be put into practice.

8. Proper Simulations:

To analyze and validate the proposed scenarios, either real-world vehicle testing or simulation experiments must be carried out. Unstructured data doesn't always provide the requisite numerical data to reliably assume certain states of affairs. Specific risk accident circumstances reflecting numerical data and scenarios containing sensor data may be developed through simulations of the resulting risk-situation scenarios (Chae *et al,* 2022). Ye *et al*. (2022) covered the very essential analogous simulation test for AVs. In his work, he explains how he used a simulation test to verify his approach by simulating two common roadway scenarios. He demonstrated that the closed-loop decision making model can handle interactive behavior in complicated traffic conditions and make intelligent lane-changing judgments. Prospects for using the algorithm are promising. When the car makes a turn, the overtaking detection method becomes less effective. For proper feature matching during overtaking vehicle recognition, ego-motion estimation can be performed (Lin *et al.* 2020).

Current implementations of SDM-PTA have some restrictions, particularly with regards to dynamic impediments and specific kinds of roads. Further study is required to loosen these constraints and examine additional PTA area features in order to account for a wider variety of traffic situations (Yuan *et al,* 2019).

9. Communication delay:

The AVs need to take into account things like the time it takes for messages to be sent and the amount of friction the roads have. However, although the lane-changing model currently only takes into account communication between the subject CAV and its neighboring vehicles, taking into account communication with other vehicles might improve fleet formation and ultimately boost road capacity.

10. Cost effectiveness:

The AV price is crucial for the community. If it's too expensive, people won't even think about it. While this will help reduce accidents, it is still important to keep inflation stable. Compared to current options, the new mobility model might be more cost-effective. What has been achieved is a paradigm of safe, sustainable, and efficient mobility at a more desired cost; this is what the revolution has been about (Alonso *et al,* 2020).

11. Cyber-attacks:

With more and more electronics being built into automobiles, both conventional and autonomous, cyber threats are bound to increase (Riegler Carolyn, 2019). Cybersecurity threats to CAVs were classified by Sharma *et al.* (2022) analysis of their sensor, communication, and actuator networks. Rogue attacks, in which the attacker poses as a trusted user or access point (AP), are another issue with AV. By settling on a reasonable threshold value, the false alarm rate (FAR) and the misdetection rate (MDR) can be drastically reduced. (Waqas *et al,* 2020).

12. Understanding of AV acceptance by the public:

Citizens do not yet know the advantages of driverless vehicles. As a result, it is extremely challenging to get people to adopt a new technological development (Yuen *et al,* 2020). People's sensitivity to the price or cost associated in using AVs compared to conventional cars can also be examined and considered as the top priority, given that the price or cost of using AVs would be a key concern for individuals in their decision to use AVs (Yuen *et al,* 2020). There is still work to be done to increase public acceptance and acknowledgement of autonomous driving due to technological limits and social ethics concerns (Huang *et al*, 2019).

13. Lack of Trust by the driver:

Dixit *et al.* (2016) also discovered evidence that a lack of trust might slow response times and make people more likely to assume physical control of a car. One school of thought would see this as evidence that drivers are becoming more comfortable with AV systems, while the other would be concerned about safety and the "driver-in-the-loop" problem.

14. Trolley problem:

Some recent discussions have drawn parallels between the trolley problem and the potential accident situations that might arise with self-driving automobiles. However, the primary literature on the trolley problem often does not examine the important difficulties we have distinguished as being of considerable relevance for the ethics of accident-algorithms for self-driving cars. As an illustration, the dangers and moral obligations of driving are not discussed in this literature. While we have highlighted several important ethical concerns about accident-algorithms for autonomous vehicles, the literature on the trolley dilemma mostly addresses distinct concerns. As we've seen, this body of work covers topics like the distinctions between positive and negative responsibilities, the ethics of murdering vs letting someone die, and psychological and neuroscientific views on how we form moral judgements. With these factors in mind, we conclude that the literature on the trolley issue is not the best, and possibly not even especially excellent, location to go for source materials and precedents directly applicable for the ethics of accident-algorithms for self-driving cars (Nyholm *et al,* 2016).

15. Mean mileage before a crash:

According to a calculation of accident rates across all manufacturers, conventional cars travel over 500,000 miles before experiencing a mishap, whereas AVs travel just 42,017 miles on average before encountering one (Favaro *et al,* 2017).

16. Huge Investment:

Significant time and money are being put into the research and development of autonomous cars. However, widespread implementation is not soon to come due of the high cost involved (Pugnetti *et al,* 2018).

17. Control of Autonomous Vehicle:

The use of Model Predictive Control (MPC) to manage autonomous vehicles is increasingly common. On the other hand, it is still difficult to perform stability analysis on an MPC-based route tracking system (Yao *et al,* 2020). The absence of factor response characteristics analysis motivates the investigation of a strong control strategy predicated on the response relationship of a single unknown component. For instance, a robust control method is investigated after the reaction characteristics of the load change and the vehicle mass, center of mass, and rotational inertia have been assessed (Yao *et al,* 2020).

4.3. RQ3: As a developing country, how effective is the use of autonomous vehicles for reducing traffic mortality?

The last stages of research and development of autonomous cars are underway, and their commercial release is rapidly approaching. The purpose of this paper is to examine the effects of this phenomena on the Azerbaijani economy from a comparative perspective. Since the database at the California Department of Motor Vehicles is open to the public, there is a need for the government to consolidate the scattered information that is now available in this format (Favaro *et al,* 2017). A similar database is yet unavailable in Azerbaijan.

Finding out what makes a difference in how people in underdeveloped countries feel about and react to autonomous driving approaches is crucial. Most of the acceptance and satisfaction criteria are affected by the level of education, while the other fundamental circumstances, such as the availability of a driver's license, are related to acceptance and contentment to varying degrees. Total Acceptance and Total Satisfaction Scores are Heavily Influenced by the Secondary Criteria (Huang *et al,* 2019). Autonomous cars will play a significant role in the future of transportation, but they cannot become mainstream without the proper direction and policy backing from the government and the confidence of local citizens. While researching autonomous driving methods, it's important to keep these aspects in mind and work to coordinate them so that autonomous driving technology advances.

Since the introduction of autonomous vehicles has the potential to increase energy efficiency thanks to the platoon effect and free up space for human activities by reducing the need for parking, it is important to understand the public's perspective in developing countries regarding its adoption in order to craft effective strategies and policies to take advantage of this technology's advantages (Chen *et al,* 2022).

Data obtained from e-call systems and the mandatory data content of accident data recorders under the current standard are insufficient to reconstruct the vehicle's movement prior to and following the accident at a level sufficient for analyzing the accident process and investigating liability issues. When an autonomous vehicle is involved in an accident, more research is done into questions of fault than in traditionally operated cars. In order to comprehend how Autonomous cars might reduce traffic fatalities while protecting a greater variety of people and places, it is required to expand the data richness of accident data recorders.

Moody *et al*. (2020) predicted that young, risk-taking males, especially in developing countries, would be the first to adopt AV technology because of the public's positive impressions and projections of its safety. AVs have the potential to enhance road safety in nations with the most severe road safety problems if the legal, economic, and political impediments to AV adoption are speedily removed and the technology is safer than the human drivers it replaces. As a result, Moody *et al.* (2020) suggests that public perception may accelerate the adoption of AVs among the most risk-taking drivers in developing countries, which might assist to reduce the current worldwide road safety discrepancy.

The advancement of the underlying technologies that underlie the development of AVs allows for higher automation levels. Immersive technologies are gaining importance as a tool since it is risky to create, test, and build fully autonomous machines until they are perfected and properly taught. According to all research articles, most of the studies are based on Developed countries. Because developing countries are still behind the technology. So, autonomous vehicles should be tested before riding in any developing country based on the database and other factors. Without consideration of local structure, autonomous vehicles are not applicable to developing countries at this stage.

Autonomous or self-driving vehicles will soon be on the highways of wealthy countries like the US and the UK. In this era of information technology, developments done in industrialized countries have an impact on not just the developing countries but also the lives and attitudes of those who live there. Therefore, it is necessary to create more efficient plans that can aid in the adoption of emerging technology in transportation systems, such as driverless vehicles. In this sense, user perception becomes extremely important because it can tell designers about current problems and human observations. There hasn't been much research done to date on how users in developing countries like Azerbaijan perceive autonomous vehicles.

Chapter 5: Conclusion

5.1 Summary

Future advancements in the automotive sector and the creation of intelligent transportation systems may contribute to the reduction of traffic accident fatalities. Technologies for autonomous vehicles offer efficient ways to enhance the driving experience and lower the frequency of accidents on the road. Autonomous driving technology will aid in resolving a number of driving-related issues, including collisions, gridlock, energy use, and environmental pollution. Path tracking, which is a fundamental component of the motion control module for autonomous vehicles, seeks to properly follow the reference path, assure vehicle stability, and meet the robust performance requirements of the control system.

As traffic grows, the likelihood of collisions and accidents is increasing. The improvement of traffic efficiency and driving dependability is the main goal of the development of autonomous and self-driving vehicles. These vehicles must be able to communicate clearly with other vehicles and their surroundings in order to accomplish this. The self-driving car uses a variety of sensors during the perception phase to gather information about its surroundings. The fusion process enables the AVs to synthesize this raw data and produce accurate results even though the sensor data may not be trustworthy. Once the AVs have evaluated their surroundings and made a decision to maintain traffic flow and road safety, the ad-hoc network topology allows them to communicate with one another and the network infrastructure.

As was already mentioned, in order to be able to drive autonomously, AVs and self-driving cars need to reach Level 5 automation. In order to communicate within the traditional transportation system and its surroundings, vehicles must be intelligent. To do this, there must be a period of adjustment during which existing non-autonomous vehicles must coexist with the AVs. Implementation therefore necessitates careful and gradual planning at the infrastructure and vehicular levels.

For the majority of the studies was reviewed that more research is required. They must be expanded in order to be tested in real-world or computer-simulated scenarios, in better and more realistic scenarios, with better and more data, and in experimental designs where the proposed strategy's outcomes are compared to those of industry standards and competing strategies. Even though many AI techniques have achieved outstanding results, it is still uncertain whether the error rates are appropriate for actual AV deployments in the absence of a hazard analysis. As a result, more research utilizing better techniques is required. Finally, the field would benefit from a greater presence of safety engineering in the majority of the studies.

Future research at the system, component, and AI technique levels must take a serious safety agenda into consideration. In fact, there are some AV safety-related issues that are crucial to the development of the industry. The difficulties of validating machine-learning-based systems to the ultra-reliable standards necessary for AVs, more extensive and in-depth research on human-machine collaboration in the context of AVs, assurance of autonomy and trust in AVs, ethical and moral decisions in the context of AVs, and other topics are a few of the topics that have been suggested. Studies on the best way people and AVs can interact during routine operations and when facing dangerous situations are necessary in order for semi-autonomous vehicles to meet the necessary safety standards that they must possess. These studies must take into account hybrid systems for collective decision-making that allow humans and machines to collaborate and reach consensus as well as how to handle situations where there is disagreement.

However, this depends on the vehicle's ability to collect traffic data and assumes that the sensing of the environment is accurate. The next level of investigation needs to focus on the impact of mistakes made at the perceptual layer. With cars seen as agents, we must also learn more about their cooperation and competition. When evaluating the security of autonomous vehicles, critical-scenario simulations are often used.

Making moral and ethical decisions in AVs is another broad topic that needs more study. While some studies simply focus on moral questions, others carry out simple experiments with simulated settings and/or in-person interviews. However, they misinterpret fundamental concepts and bring up issues like moral and ethical considerations from a human perspective and the decisions AVs must make when there are life losses involved. They all omit crucial information, including statistical analysis and the impact on society. To put it another way, the discussions about whether an AV should strike a child or an elderly person are not sufficiently in-depth, whereas a real safe machine control system would weigh all the probabilities and select the option that reduces the risk of fatalities rather than just picking one. The system needs to take into account small signals like which potential victims are paying attention to the approaching AV and what their potential reaction might be, as well as the effectiveness of that reaction based on age and other metrics. It must also take into account various scenarios and how they are set up, such as the speed and location of the car that hit which region of each victim, as well as the potential damages and the seriousness of the damages while taking the estimate into account. The level of safety for society will increase as a result of this strategy.

Importantly, we must determine the ethical ideals, considerations, and principles that may most effectively be applied to this current ethical situation. In addition, we must explore how to describe and apply these values, concerns, and principles to the specific challenge of how autonomous vehicles should be designed to respond to accident situations. In other words, there is much work to be completed here.

For effective use of autonomous vehicle in road, Government, policy maker as well as manufacturer, designer have to do many things. Especially

Government should prepare the law and regulations as well as action plan. On the other hand, manufacturer needs to remove the system error and need an effective data set for smooth performance. Autonomous vehicles need huge investment for manufacturing and for research & development. Therefore, this sector needs an initiative from the government. Also important is for the government to support the study and creation of ITS network cyber security protection solutions. To enable safe and effective AV operation across the whole network, a sufficient roadway infrastructure must be established.

The widespread introduction of highly automated vehicles (AVs) in the not-too-distant future might provide exciting new avenues for addressing long-standing problems in contemporary safety-related study. Taking into account elements like penetration rate, public adoption, technical developments, traffic patterns, and commercial models, further study is needed to better comprehend and quantify the important policy consequences of AVs (private-owned or public-owned). Public opinion has a role in determining how quickly and how widely autonomous vehicles (AVs) are adopted. This has implications for the pace at which safety advantages may be realized on the ground.

5.2 Implications and Recommendations:

Most of the researchers mentioned some recommendation for the manufacturer, policy maker as well as for the governments. Based on the literature review, I have tried to make some recommendations based on my study.

5.2.1 Recommendations for manufacturer:

1. Passive accident prevention in the future is also crucial, as most AV incidents are not caused by the AV but by another party. The AV needs to be able to identify potentially harmful circumstances and act appropriately.

2. Producers and system designers should be incentivized to create autonomous vehicles with an open and proactive mindset. Since it is crucial to the driverless vehicle's safety, developing long- and short-range navigation systems is a top priority (Nizar *et al,* 2020).

3. Because of moral difficulties, automakers and software designers must pay special care to their advertising. Although it may be tempting to portray one's own car and steering algorithm as exceptionally safe for one's own consumers, doing so might have unintended consequences for the firm and its reputation. What is more, this communication may be utilized as evidence of intent in legal proceedings involving traffic-related fatalities. Because of the prominence of their brands, automakers in particular must pay close attention to the decisions being made and the messages being sent at the regional level.

4. Quantifying the effects of extreme weather requires the use of scientific tools to quantify things like raindrop size, smoke concentration, and smoke particle size. To the verification and testing of theories, please include other forms of extreme weather. Real-world testing of the road's performance in a variety of inclement weather scenarios. Recent research has demonstrated the feasibility of restoring data from signals recorded during extreme weather conditions. If you have access to raw data that compares good weather with terrible weather, you can apply the technique provided in this paper to improve your situation. In order to ensure the AVs' reliability in extreme climates, a safety evaluation must be conducted (Kim *et al,* 2020). Further, the APS needs to be verified in heavier and busier traffic under more complicated environmental circumstances before moving on to the next round of road testing (Plihal *et al,* 2022).

5. **The decision-making algorithm:** The game-theory based decision-making system still has room for development, particularly in the areas of dynamic detection of vehicle aggression kinds and adaptation to more complicated and varied traffic circumstances. To more precisely analyze and provide feedback on the performance of the method in this study, it may be helpful to combine several experiments, such as driver-in-the-loop (MIL) and real-world car verification.
6. The Electronic Control Unit (ECU) or trip computer of autonomous cars must integrate the mechanism for safer autonomous driving in future-manufactured automobiles.
7. The promise of autonomous vehicles is that they will be safer than automobiles piloted by humans. Yet there is no way they can guarantee

complete safety. Accidental bumping into one another does happen. This necessitates the programming of collision avoidance and avoidance strategies into the software of autonomous vehicles (Nyholm *et al,* 2021). Given that there may be age and gender-related variances in the amount of time it takes for someone to respond to a stimulus by, say, applying the brakes, it's important to collect data on a massive scale that takes these factors into account (S. Kajiwara *et al,* 2018).

8. As a result of segmenting the road surface, lane change detection may be made more accurate. Since lane lines are not always visible, the driving space must be taken into account while developing lane change aid (Lin *et al,* 2020).

9. It is believed that upgrading to a twin-lever steering system will improve steering performance (TLS).

10. As an alternative to relying solely on side-by-side vision, stereo vision may be used to better gauge the distance to the leading cars. Integration with other jobs, such as vehicle control, will benefit from the more accurate data it generates (Lin *et al,* 2020).

11. The AV methods will be tested for their real-time performance after being adapted for an embedded platform (Lin *et al,* 2020).

12. To counteract malicious interference in vehicle-to-vehicle, vehicle-to-RSU, and RSU-to-vehicle communications, manufacturers should use a reinforcement learning algorithm (RLA). In this context, AVs determines the best threshold value for identifying legitimate from malicious nodes.

13. **Software asymmetry:** In order to expand the model's usefulness, it will be applied to the detection and forecasting of potentially risky behaviors in a larger variety of junction settings involving AVs (Li *et al,* 2020). Manufacturers should explore software asymmetric encryption solutions for more secure C-V2X Side link communication. Those blind spots (bad weather, low lighting, and non-line-of-sight impediments) for autonomous driving can be greatly strengthened by cellular vehicle-to-everything (C-V2X) radio technology (Miao *et al,* 2022). As AV technology progresses at full speed, it is crucial to comprehend the factors that lead to disengagements and the ensuing driver reaction times.

14. The AV's maker is responsible for developing a system for diagnosing and fixing any problems that may arise inside the AV's own software or hardware (Chuprov *et al,* 2019). There has to be better introspection from manufacturers by factoring in FN prediction uncertainties and incorporating them into the object-wise decoder to boost FN prediction accuracy (Yang *et al,* 2021).

15. **Data set:** Checking the datasets with other deep learning models to predict their future performance. Validation of a model by applying it to data sets other than the one it was trained on. It's possible that our model's accuracy may suffer if we choose a larger picture size for our

data set. A possible improvement in accuracy might result from AV Manufacturer's plans to improve the training model and expand the sample size utilized for training (Roohullah *et al,* 2022). The vehicle's data will be recorded and synced with the mobile application and the MQTT server in real time (Plihal *et al,* 2022).

16. **Autonomous Emergency Braking System (AEBS)**: The Autonomous Emergency Braking (AEB) system is a prototypical ADAS that helps avoid and mitigate collisions by automatically applying the brakes in dangerous situations (Kim *et al,* 2020). Since it may be hard to stop in time to avoid an accident, the Autonomous Emergency Braking System (AEBS) applies the brakes automatically in the event of an emergency. Given the limitations of physical friction, researchers are trying to create a risk-predictive right-turn assistance system to increase traffic safety. The technology anticipates obstacles in the path of the vehicle and slows it down accordingly. Blind spots can be detected by on-board sensors without any assistance from the surrounding environment (Fujinami *et al,* 2018).

17. **Uses of image augmentation:** When applied to data used for training, picture augmentation can produce inconsistent outcomes. We also present a pre-processing technique for preparing 3D spatial data collected using LiDAR sensors. Classification, whether it be 3D classification or a mix of 2D and 3D classifications via sensor fusion, can benefit from the results of this pre-processing system's ability to

identify suitable areas. For this problem, Mounsey *et al*. (2021) offered many models using transfer learning and convolutional neural networks, the most successful of which, the adaptive transfer learning model, obtained an accuracy of over 98%.

18. Adding the distance adjustment factor, the dynamic road repulsive field, the velocity repulsive field, and the acceleration repulsive field to Manufacturer's enhanced artificial potential field approach is crucial for the completion of the planning of automated driving trajectories (Li *et al,* 2022).

19. A better 'Bi-LSTM' model that can be used for real-time recognition can be developed by the manufacturer.

20. In order to evaluate DRLAIM's applicability to various sorts of crossings, the manufacturer may want to run simulations of intersections like roundabouts. Further, they can use an environment with several junctions to model how decisions made at one intersection might influence others. They may now plan an approach that will work for both autonomous cars and the addition of pedestrians and bicycles at a crossroads (Karthikeyan *et al,* 2022).

21. Better sensor data and an updated algorithm are needed to improve the movements' effectiveness (Plihal *et al,* 2022). Full vehicle autonomy in urban mobility infrastructures is a goal, therefore plans call for integrating with other autonomous driving features.

22. As autonomous cars become more commonplace on the road, it is inevitable that they will be engaged in accidents requiring equitable harm allocation choices.

23. It is recommended that autonomous vehicles use a framework based on Edge AI in order to detect road irregularities (Bibi *et al*, 2021).

24. More sorts of road abnormalities and roads with various flaws can be included to the manufacturer's study to increase its scope. Additionally, less complicated deep learning models may be used to include automatic control of vehicle action based on anomaly kind and prevention into an autonomous vehicle (Bibi *et al,* 2021).

25. Researchers and designers might also identify other ways to make AVs safer for passengers. As a result, looking into people's psyches can help improve AV safety from both an engineering and psychological standpoint.

26. The manufacturer of an autonomous vehicle must integrate 3D LiDAR point cloud data with depth maps.

5.2.2. Recommendations for Government/Policy Maker:

One method devised to assess these new AVs worries was the policy-focused scenario approach, which was presented in many studies (Mark Ryan, 2019). Scenarios present us with insightful glimpses of what the future may contain and how policymakers may either put actions in place for a good future or prepare for an undesirable one. This article presents a methodology that shows several barriers to and enablers of Self-driving vehicle (SDV) development by 2025, highlighting issues and strategies for policymakers to consider. Scenario planning is not an exact science, but it does provide policymakers more information about how their current decisions may affect the growth and adoption of new technologies like SDVs in the future.

1. **Transport Policy Formulation:**

The government must implement several transport policies including the promotion, advertising, subsidization, infrastructure building, training, and design of AVs (Yuen *et al,* 2020).

2. **Formulate legal norms:**

The government must revise the relevant laws in order to construct legal standards that are consistent with the progress of artificial intelligence technology, safeguard the legal rights and interests of consumers, and secure the personal and property safety of automobile users. Lack of full judgments of damages under common law necessitates an administrative regulation to ensure proper attention to safety (Donald G. Gifford, 2018).

3. **Determination of accident liability:**

We need to use graph convolutional neural networks to determine the mental health effects of autonomous driving systems and the culpability for accidents using them in the future. Lawmakers need to go to work right on figuring out how to allocate responsibility for AV-related incidents. The government has an incentive to encourage the use of AVs, but the release of such vehicles and the usage of such vehicles by the general public would need the establishment of a mechanism to deal with accidents. One possible course of action for lawmakers to explore is the establishment of a no-fault system paired with a National Car Insurance Fund (Carrie Schroll, 2015).

4. Autonomous Emergency Braking System (AEBS):

It is important to check if the criteria used in evaluating AEBS conform to national requirements for evaluating traffic safety and conditions.

5. Preparing an Action plan:

Governments should immediately begin planning on an economic, technological, and social level to enable businesses to get ready for the incorporation of autonomous cars. Moreover, it's important for both enterprises and governments to take the right steps from the get-go. While large expenditures would be required, any government that takes the time to plan ahead may position itself at the forefront of this transformation. As such, this strategy will be crucial for the continued success of all concerned industries as they work to adapt to new conditions, mitigate any resulting harm, and avert any ensuing societal upheaval. To achieve this goal, a comprehensive research project over an extended period of time is required, as studying the beginning of the shift reveals relatively little in the big picture.

6. Government Protection for business industries:

Finding a business or economic activity that is not touched by this shift, even if just little, is next to impossible (Uses of AV). On a global scale, this transformation has the greatest impact on the automobile and energy industries. The tides are changing for their business models, and they require government support. The government has a responsibility to take action. Obviously, people's well-being trumps business concerns, thus the government is also thinking about this (Alonso *et al,* 2020).

7. Resource allocation for improving public acceptance:

Public acceptance of AVs can be boosted through a more efficient distribution of society's scarce resources. In particular, efforts might be focused where they will have the most impact on increasing people's comfort with AVs. If we want to learn more about why people accept AVs, future studies can look at the appropriation of technology and the effects of vicarious reinforcement (Yuen *et al,* 2020).

8. Subsidy for developing the AV:

There is a widespread belief that reducing insurance premiums is necessary to fund the introduction of driverless cars into the transportation sector (Donald G. Gifford, 2018).

9. Database:

The government should compile the existing data into a single database that is open to the public.

10. Ensure Cyber security:

The government should prioritize funding initiatives to create cyber security protection solutions for ITS networks. Researchers in this area also benefit from the government's assistance by way of an overview of the present status of ITS and CAVs development (Sharma *et al,* 2022).

11. Provide an adequate roadway infrastructure:

The government should reevaluate its road construction and safety guidelines, which may still be using response time numbers derived experimentally from the operation of manually driven cars. The safe and effective functioning of AVs over the whole network requires a well-developed road network. The government must create, deploy, and test a prototype system for pedestrian crossings in an effort to lower the number of pedestrian fatalities and injuries that occur on public roadways (Dominguez *et al,* 2018). Given the upward trends in both population and vehicle numbers, the government must create a safer and more efficient system for controlling traffic at intersections (Karthikeyan *et al,* 2022).

12. Psychology training for the Drivers:

The effects of various human-machine interfaces on drivers' attention and involvement must also be investigated. Many accidents involving autonomous vehicles have their roots in journey duration, the interaction between drivers and their expectations of other motorists, and the lack of attention paid to road conditions (Dixit *et al,* 2016). Therefore, the government should provide more mental health services for the autonomous car operators (which is not yet fully automated).

5.3 Limitations of the study

This study may have some potential shortcomings. I investigated four databases, but I might have found more relevant issues and formed accurate conclusions if I had utilized additional databases. Additionally, I just look at the peer-reviewed, full-text journal articles, but if I count all publications (such as conference papers, seminar papers, etc.), I could find more information about autonomous cars. There are relatively few published publications because the topic is so recent. In addition to this, occasionally the Keyword I chose did not correspond to a quality journal. Maybe using additional keywords helped me get more hits. However, another constrained element for a systematic review is time. In this little amount of time, it is quite difficult to read the full text and grasp the stone.

Autonomous vehicles are the latest trend in technological advancement. Clearly, it has a significantly great influence on reducing road accidents, considering some challenges. Still, we must research and test more in order to get the desired outcome. In addition, this study is very new for Azerbaijan, and it is required further research in this area.

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Appendix 1: List of selected articles

Selected Articles	Author (s)	Research Purpose	Method	Type	Year
1. "Self-protective and self-sacrificing preferences of pedestrians and passengers in moral dilemmas involving autonomous vehicles"	Mayer et al.	The study suggests that there may be moral principles that transcend these self-protective biases, as both riders and pedestrians agreed on the utilitarian principle that the choice that protects the greatest number of lives should be chosen	Experiment	Journal (Plos One)	2021
2. "Edge AI-based automated detection and classification of road anomalies in VANET using deep learning"	Bibi et al.	This study examines the identification and categorization of road abnormalities for safe and efficient vehicle navigation	Experiment	Journal (Hindawi Computational Intelligence and Neuroscience)	2021
3. "How people perceive and expect safety in autonomous vehicles: An empirical study for risk sensitivity and risk-related feelings"	Tan et al.	This work gives a better knowledge of the mental causes of safety judgements in AVs by examining how risk sensitivity and emotions explain safety judgment in AVs and identify the linkages between them	An empirical study	Journal (Human–Computer Interaction)	2020
4. "A Systematic Literature Review About the Impact of Artificial Intelligence on	Nascimento et al.	This research delivers a thorough literature review to illustrate the current status of AI literature	Systematic Literature Review	Journal (IEEE Transactions on Intelligent Transportation	2020

Autonomous Vehicle Safety”		on AV safety		Systems)	
5. “State-of-the-Art of Factors Affecting the Adoption of Automated Vehicles”	Chen et al.	This study tries to summarize prior studies on the public's acceptance of Avs	Systematic Literature Review	Journal (Sustainability)	2022
6. “Road Capacity and Throughput for Safe Driving Autonomous Vehicles”	Wang et al.	This study introduces the concepts of safe driving capacity and safe driving throughput for measuring the safe effectiveness of traffic arrangements	Concept	Journal (IEEE Access)	2020
7. “Cybersecurity and Forensics in Connected Autonomous Vehicles: A Review of the State-of-the-Art”	Sharma et al.	This report presents a thorough analysis of cyberattacks and digital forensics pertaining to connected autonomous vehicles	A review	Journal (IEEE Access)	2022
8. “Control Strategies on Path Tracking for Autonomous Vehicle: State of the Art and Future Challenges”	Yao et al.	This article describes representative control techniques, robust control strategies, and parameter observation-based control strategies for autonomous vehicle route tracking	Control	Journal (IEEE Access)	2020
9. “3D Point Cloud Matching Technology Based on Depth Image Based Rendering”	Lin et al.	It is proposed in this study to merge 3D LiDAR point cloud data with depth maps	Experiment	Conference (IEEE International Conference on Consumer Electronics)	2021
10. “A new active safety distance model of autonomous vehicle based on sensor	Yuan et al.	This study analyzes the links between the relative speed and distance of	A comparison study	Journal (Modelling And Simulation)	2019

occluded scenes”		autonomous vehicles and PTA zones			
11. “Autonomous driving testing scenario generation based on in-depth vehicle-to-powered two-wheeler crash data in China”	Wang et al.	This research developed autonomous driving testing scenarios at the functional, logical, and practical levels	Scenarios	Journal (Accident Analysis and Prevention)	2022
12. “Public perceptions of autonomous vehicle safety: An international comparison”	Moody et al.	This paper explores differences in perceptions of AV safety across 33,958 individuals in 51 countries	An international comparison	Journal (Safety Science)	2020
13. “Road Safety Analysis of Autonomous Vehicles”	Szűcs et al.	This article analyzes variations in perceptions of AV safety among 33,958 persons in 51 countries	An Overview	Journal (Periodica Polytechnica Transportation Engineering)	2022
14. “Route Control and Behavior Decision of Intelligent Driverless Truck Based on Artificial Intelligence Technology”	Wang et al.	This work applies artificial intelligence technology to explore the route control and behavior decision-making of intelligent autonomous vehicles, and a better tracking control approach is proposed	Experiment	Journal (Wireless Communications and Mobile Computing)	2022

15. “Accident Liability Determination of Autonomous Driving Systems Based on Artificial Intelligence Technology and Its Impact on Public Mental Health”	Xiao et al.	This article analyzes the investigation of the influence of autonomous driving public on public psychological health, highlights the important elements impacting the public acceptance of autonomous driving, and dissects its impact on public psychological acceptance	Experiment	Journal (Environmental and Public Health)	2022
16. “Unmanned Driving Infringement Judgment Based on Wireless Sensor Network Data Mining”	Yang	This study focuses on the use of data mining and state machine technologies and creates and executes a set of effective and practical solutions	Data mining	Journal (Sensors)	2021
17. “Application of Kalman Filter to Improve 3D LiDAR Signals of Autonomous Vehicles in Adverse Weather”	Lin et al.	This study applied the Kalman filter to enhance the application of automobile LiDAR signals under extreme weather conditions	Experiment	Journal (Applied Science)	2021

18. “Research on the Method of Traffic Signal Image Detection and Recognition”	Zhang et al.	This research investigates the detection and recognition technique of traffic lights, uses the color information of traffic lights in conjunction with an image processing approach to locate the candidate region of traffic lights, and then employs a convolution neural network to recognize traffic lights	Experiment	Journal (Physics: Conference Series)	2021
19. “Development of Risk-Situation Scenario for Autonomous Vehicles on Expressway Using Topic Modeling”	Chae et al.	The study's objective was to introduce unexpected risk conditions in the scenarios by picking traffic incidents with a low frequency of occurrence	Scenarios	Journal (Advanced Transportation)	2022
20. “Research on Lane Changing Game and Behavioral Decision Making Based on Driving Styles and Micro-Interaction Behaviors”	Ye et al.	This research proposes a closed-loop lane-changing decision-making framework suited for AVs in fully autonomous driving conditions in order to achieve both safety and efficiency	Experiment	Journal (Sensors)	2022

21. “79GHz Substrate Integrated Waveguide antenna for short- range radar applications”	Santhakumar et al.	This work proposes a substrate-integrated waveguide cavity antenna operating at 79 GHz with desirable results of gain more than 8dB, VSWR of 1.04, and low-profile design	Experiment	Journal (Physics: Conference Series)	2021
22. “Simulation of AEBS Applicability by Changing Radar Detection Angle”	Choi et al.	This study examines the influence of AEBS and radar angle on collision avoidance using a PC-Crash simulation based on the National Police Agency's traffic accident database	Simulation	Journal (Applied Science)	2021
23. “Economic impact of autonomous vehicles in Spain”	Alonso et al.	This research examines the evolution of transportation in Spain as a result of the introduction of new technologies, which will lead to the development of a mobile park comprised of autonomous and electric cars	Scenarios	Journal (European Transport Research Review)	2020
24. “Modeling HDV and CAV Mixed Traffic Flow on a Foggy Two-Lane Highway with Cellular Automata and Game Theory Model”	Gong et al.	A thorough comprehension of the dynamics of mixed traffic in foggy conditions might reduce the frequency and severity of traffic accidents	Literature Review	Journal (Sustainability)	2022

25. "The Moral Decision-Making Capacity of Self-Driving Cars: Socially Responsible Technological Development, Algorithm- driven Sensing Devices, and Autonomous Vehicle Ethics"	Riegler Carolyn	This research empirically explores the potential of self-driving automobiles to make moral decisions	Literature Review	Journal (Contemporary Readings in Law and Social Justice)	2019
26. "AI and the Illusion of Human-Algorithm Complementarity"	Marie David	This article demonstrates how freshly built algorithmic systems have a common flaw	An Overview	Journal (Social Research)	2019
27. "Using online verification to prevent autonomous vehicles from causing accidents"	Pek et al.	This article describes a formal verification method for ensuring legal safety in random urban traffic conditions	Scenarios	Journal (Nature Machine Intelligence)	2020
28. "Topological Sequence Recognition Mechanism of Dynamic Connected Cars Using the Connected Mobile Virtual Fence (CMVF) System for Connected Car Technology"	Eom et al.	This study presents a topological sequence recognition technique for generating linked car-based subgroups and identifying the relative sequence and distance for each vehicle in subgroups according to the dynamic topology changes of preceding or following cars	Experiment	Journal (Applied Science)	2020

29. “Authentication of Vehicles and Road Side Units in Intelligent Transportation System”	Waqas et al.	Utilizing the channel state information of the communication connection, this work presents a reinforcement learning approach to identify rogue nodes	Experiment	Journal (Computers, Materials & Continua)	2020
30. “Understanding Public Acceptance of Autonomous Vehicles Using the Theory of Planned Behavior”	Yuen et al.	This research uses the theory of planned behavior to identify and analyze the factors influencing the public's acceptance of Avs	Survey	Journal (Environmental Research and Pubic Health)	2020
31. “Human Detection and Avoidance Control Systems of an Autonomous Vehicle”	Nizar et al.	This research creates a prototype autonomous vehicle equipped with a short-range navigation system that is designed to identify and avoid humans	Experiment	Journal (Conf. Series: Materials Science and Engineering)	2020

32. "A Vision-Based Driver Assistance System with Forward Collision and Overtaking Detection"	Lin et al.	This study aims to prevent future traffic accidents caused by forward collisions and vehicle overtaking, as well as aid drivers and autonomous vehicles in performing safe lane changes	Experiment	Journal (Sensors)	2020
33. "The Future of Transportation: Ethical, Legal, Social and Economic Impacts of Self-driving Vehicles in the Year 2025"	Mark Ryan	This article synthesizes the vast variety of ethical, legal, social, and economic effects that may come from the usage and implementation of SDV technologies by 2025, including concerns of autonomy, privacy, liability, security, data protection, and safety	Scenarios	Journal (Science and Engineering Ethics)	2019
34. "Current challenges in autonomous driving"	Barabas et al.	This article examines the various levels of driving automation, as well as the potential environmental and safety impacts of these new technology	An overview	Journal (Conf. Series: Materials Science and Engineering)	2017

35. "Dangerous Behavior Recognition of Autonomous Vehicles at Intersection Based on Gaussian Mixture Model"	Li et al.	This article examines the components that influence the junction scene and selects pertinent variables (such as PET) to develop an intersection risk scene prediction model based on a Gaussian mixture model	Scenarios	Journal (Physics: Conference Series)	2020
36. "How Does C-V2X Help Autonomous Driving to Avoid Accidents?"	Miao et al.	This document explains one of the C-V2X system solutions: Autonomous driving Vulnerable Road User Collision Warning (VRUCW)	Experiment	Journal (Sensors)	2022
37. "Accident Detection in Autonomous Vehicles Using Modified Restricted Boltzmann Machine"	Roohullah et al.	This research suggests a modified limited Boltzmann machine for accident detection	Experiment	Journal (Security and Communication Networks)	2022
38. "Road Accident Reconstruction Using On-board Data, Especially Focusing on the Applicability in Case of Autonomous Vehicles"	Pinter et al.	This article describes a method for defining a data package, including the description of data points and the frequency of measuring and recording	Simulation	Journal (Periodica Polytechnica Transportation Engineering)	2020

39. "Technological Triggers to Tort Revolutions: Steam Locomotives, Autonomous Vehicles, and Accident Compensation"	Donald G. Gifford	This article recounts how successive waves of technical progress in American culture influenced the evolution of the law controlling personal injury responsibility	An overview	Journal (Technological Triggers to Tort Revolutions)	2018
40. "Autonomous Vehicles: Disengagements, Accidents and Reaction Times"	Dixit et al.	This study uses actual field data from experiments being undertaken on public roadways in California, including freeways, highways, and urban streets	Literature review	Journal (Plos One)	2016
41. "Using online verification to prevent autonomous vehicles from causing accidents"	Pek et al.	This paper proposes a formal verification method for ensuring legal safety in all urban traffic circumstances	Scenario	Journal (Nature machine intelligence)	2020
42. "The Ethics of Accident-Algorithms for Self-Driving Cars: An Applied Trolley Problem?"	Nyholm et al.	This study investigates critically the comparison between the trolley problem and the problem of accident-algorithms for autonomous vehicles	Scenario	Journal (Ethical Theory and Moral Practice)	2016
43. "Splitting the bill: creating a national car insurance fund to pay for accidents in autonomous vehicles"	Carrie Schroll	This Note examines the potential accountable parties, including drivers, car-sharing providers, and manufacturers	Literature review	Northwestern University Law Review	2015

44. “Life and death decisions of autonomous vehicles”	Bigman et. al	Because its approach is generally insensitive to preferences for equality, the study implies that the MME discovers preferences for inequality across lives	Moral Machine experiment (MME)	Journal (Nature)	2020
45. “Examining accident reports involving autonomous vehicles in California”	Favaro et al.	This study provides a comprehensive review of the accident reports reported by several manufacturers testing autonomous vehicles in California	Literature review	Journal (Plos One)	2017
46. “Reply to: Life and death decisions of autonomous vehicles”	Awad et al.	It was stated in the study that politicians would benefit from being informed of citizens' preferences about the critical-situation conduct of autonomous cars	Literature review	Journal (Nature)	2020
47. “Customer Preferences and Implicit Tradeoffs in Accident Scenarios for Self-Driving Vehicle Algorithms”	Pugnetti et al.	This article examines the preferences of Swiss consumers for this decision by requiring them to choose between simplified scenarios in which a specific number of automobile passengers or pedestrians may be killed in an accident	Experiment	Journal Risk and Financial Management	2018

48. "Road Nail: Experimental Solar Powered Intelligent Road Marking System"	Samard ˇzija et al.	This research combines the most sophisticated sensor, wireless communication, and battery-powered technologies to build and deploy an innovative road-safety system	Experiment	Journal (Electrical Engineering)	2012
49. "Improvement in Steering Performance by Push-Pull Operation in Car Driving"	S. Kajiwara et al.	Utilizing an experimental racing kart and driving simulator, the superiority of the suggested TLS was validated in this study (DS)	Experiment	Journal (Automotive and Mechanical Engineering)	2018
50. "Design, Modelling, and Implementation of a Fuzzy Controller for an Intelligent Road Signaling System"	Domíng uez et al.	This study describes the design, implementation, and testing of a smart prototype system used at pedestrian crossings that are not governed by semaphores in an effort to lower the traffic accident rate	Experiment	Journal (Hindawi, Complexity)	2018
51. "Risk Predictive Driver Assistance System for Collision Avoidance in Intersection Right Turns"	Fujinami et al.	This research describes a right-turn assistance system that decelerates the ego vehicle to a safe speed in emergency situations to avoid collisions with the AEBS	Scenario	Journal (Robotics and Mechatronics)	2018

52. “A Study on the Evaluation Method of Autonomous Emergency Vehicle Braking for Pedestrians Test Using Monocular Cameras”	Kim et al.	This study aims to examine actual pedestrian collisions in order to assess the possible usefulness of AEB in pedestrian protection	Scenario	Journal (Applied Science)	2020
53. “Reputation and Trust Approach for Security and Safety Assurance in Intersection Management System”	Chuprov et al.	This study tackles the contextual data integrity problem that arises when an autonomous unmanned vehicle communicates wrong data owing to technical issues or malicious assaults	Experiment	Joournal (Energies)	2019
54. “Analyzing of Impact Factors of Residents' Choice of Autonomous Vehicle: A Network Questionnaire Survey in Nanchang, China”	Huang et al.	This study focuses on two dimensions of resident happiness and acceptance	Survey	Journal (Conf. Series: Materials Science and Engineering)	2019
55. “Highly Curved Lane Detection Algorithms Based on Kalman Filter”	Dorj et al.	This work provides an innovative curve lane recognition technique based on the Kalman filter for autonomous vehicles	Experiment	Journal (Applied Science)	2020
56. “Introspective False Negative Prediction for Black-Box Object Detectors in Autonomous Driving”	Yang et al.	This study presents a broad introspection framework for black-box object detectors that can make live predictions about FN items	Experiment	Journal (Sensors)	2021

57. "Deep and Transfer Learning Approaches for Pedestrian Identification and Classification in Autonomous Vehicles"	Mounsey et al.	This research indicates that the use of image enhancement to training data might produce variable outcomes	Scenarios	Journal (Electronics)	2021
58. "Research on Automatic Driving Trajectory Planning and Tracking Control Based on Improvement of the Artificial Potential Field Method"	Li et al.	This study focuses mostly on autonomous vehicle trajectory planning and tracking control	Simulation	Journal (Sustainability)	2022
59. "Trends and Future Prospects of the Drowsiness Detection and Estimation Technology"	Toshiya Arakawa	This article highlights the research and development trends of several approaches for sleepiness detection systems	Literature review	Journal (Sensors)	2021
60. "Cognitive Distraction State Recognition of Drivers at a Nonsignalized Intersection in a Mixed Traffic Environment"	Hua et al.	This research investigates cognitive distraction in three common conditions at an unsignalized crossroads with mixed traffic	Experiment	Journal (Hindawi Advances in Civil Engineering)	2021
61. "Reinforcement-Learning-Based Decision and Control for Autonomous Vehicle at Two-Way Single-Lane Unsignalized Intersection"	Liu et al.	Research was undertaken on the control of decision-making at junctions with several surrounding cars	Simulation	Journal (Electronics)	2022

62. "Application of Machine Learning in Ethical Design of Autonomous Driving Crash Algorithms"	Yineng Xiao	This paper examines the application of machine learning in the ethical design of autonomous driving crash algorithms by constructing collision warning and intelligent vehicle test scenarios for autonomous driving to improve the driving safety of intelligent vehicles in complex vehicle traffic environments	Experiment	Journal (Hindawi Computational Intelligence and Neuroscience)	2022
63. "Autonomous Intersection Management by Using Reinforcement Learning"	Karthikeyan et al.	In this article, we propose an autonomous intersection management system (DR- LAIM) that is motivated by deep reinforcement learning to create an intersection-crossing strategy	Experiment	Journal (Algorithms)	2022
64. "Transport Automation in Urban Mobility: A Case Study of an Autonomous Parking System"	Plihal et al.	This study is devoted to APS development and real-world, experimental street testing	A case study	Journal (Vehicles)	2022

65. "Driving Behavior Classification and Sharing System Using CNN-LSTM Approaches and V2X Communication"	Kwon et al.	This work aims to enhance traffic safety by anticipating aggressive driving behavior using just low-cost sensor data and sharing this information with adjacent cars to minimize the loop of negative consequences	Experiment	Journal (Applied Science)	2021
66. "A Review of Multiple Edge Detection in Road Lane Detection Using Improved Hough Transform"	Talib et al.	This work aims to determine the optimal selection of banks for a superior Hough transform methodology to detect lane highways using edge detection methods	Experiment	Journal (Trans Tech)	2015
67. "Potential of Highly Automated Vehicles for Monitoring Fatigued Drivers and Explaining Traffic Accidents on Motorway Sections"	Chang et al.	This study is based on large data on vehicle trajectories obtained through the operation of autonomous vehicles	A case study	Journal (Hindawi Advanced Transportation)	2020
68. "A Study on Building a "Real-Time Vehicle Accident and Road Obstacle Notification Model" Using AI CCTV"	Lee et al.	Based on deep learning, this study developed a model that can recognize anomalous road conditions and proposes a service that can prevent accidents caused by other vehicles and traffic congestion	Experiment	Journal (Applied Science)	2021

69. "Combining Parallel Computing and Biased Randomization for Solving the Team Orienteering Problem in Real-Time"	Panadero et al.	This article presents vehicle route planning as a team orienteering challenge	Experiment	Journal (Applied Science)	2021
70. "Analysis of the Relationship between Vehicle Behaviors of Changing Lane and Volume of Traffic under Different Operating Ratios of Autonomous Vehicles"	Xie et al.	This research examines a multiple linear regression model to characterize the impact of lane-changing behaviors on urban expressway traffic under varying autonomous vehicle operating ratios	Experiment	Journal (Hindawi Advanced Transportation)	2022
71. Study on DID Application Methods for Blockchain-Based Traffic Forensic Data	Yoon et al.	This research aims to present a digital framework for traffic analysis using digital data supplied by various devices and sensors	Simulation	Journal (Applied Science)	2021

Abstract in Korean

국문초록

자율주행자동차가 교통사고 사망자를 감소시키는가?

자율주행차 기술과 교통 관련 사망률의 관계에 관한 체계적 문헌 검토

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자율주행차(AV)를 통해 교통 흐름이 개선되고 사고가 줄어드는 등 사회가 얻는 것이 많을 것으로 예상된다. 그들은 다양한 인공지능(AI) 프로세스와 전략의 개선에 크게 의존한다. 이 분야의 일부 연구자들은 AV가 안전성을 향상시키는 열쇠라고 믿지만, 다른 연구자들은 AV가 이러한 새로운 기술/시스템 및 애플리케이션의 보안을 보장하는 것과 관련하여 새로운 문제를 야기한다고 믿는다. 이 논문은 자율주행차 기술과 교통 관련 사망률 사이의 관계에 대한 체계적인 문헌 검토를 수행한다. 포함 및 제외 기준에 따라 EBSCO, ProQuest, IEEE Explorer 및 Web of Science의 기사를 선택하고 분류했다. 연구 결과는 이러한 출판물의 대부분이 고급 운송 관련 저널에 게재되었음을 보여준다. 미래의 자동차 산업의 개선과 지능형 교통 시스템의 개발은 치명적인 교통 사고의 수를 줄이는 데 도움이 될 수 있다. 자율주행 자동차 기술은 운전 경험을 향상시키고 교통 사고의 수를 줄일 수 있는 효과적인 방법을 제공한다. 충돌, 교통, 에너지 사용, 환경 오염과 같은 수많은 운전 관련 문제들은 자율 주행 기술에 의해 도움을 받을 것이다. 평가된 대부분의 연구에 대해 더 많은 연구가 필요하다. 실제 또는 컴퓨터 시뮬레이션 시나리오, 더 좋고 현실적인 시나리오, 더 좋고 더 많은 데이터, 그리고 제안된 전략 결과가 산업 표준 및 경쟁 전략의 결과와 비교되는 실험 설계에서 테스트될 수 있도록 확장되어야 한다. 따라서 개선된 방법에 대한 추가 연구가 필요하다. 추가 연구가 필요한 또 다른 주요 분야는 AV의 도덕적, 윤리적 선택이다. 정부, 정책 입안자, 제조업체 및 설계자는 모두 자율 주행 차량을 효과적으로 도로에 배치하기 위해 많은 조치를 취해야 한다. 정부는 특히 법, 규칙, 실행 계획을 개발해야 한다. 운전자 없는 차량과 같은 운송 시스템에서 새로운 기술의

채택을 장려할 수 있는 보다 효과적인 프로그램을 만드는 것이 중요하다. 이와 관련하여, 설계자에게 현재 이슈와 사람에 의한 관찰을 알려줄 수 있기 때문에 사용자 인식이 필수적이 된다. 제조업체는 시스템 결함을 수정해야 하며 효율적인 작동을 위해 좋은 데이터 세트가 필요하다. 멀지 않은 미래에, 고도로 자동화된 차량(AV)의 광범위한 사용은 현재의 안전 관련 연구에서 지속적인 문제를 해결하기 위한 흥미로운 새로운 가능성을 열어줄 수 있다. 보급률, 공공 채택, 기술 발전, 교통 패턴 및 비즈니스 모델과 같은 요소를 고려하여 Avs의 중요한 정책 영향을 더 잘 이해하고 정량화하기 위한 추가 연구가 필요하다. 조사를 위해 동료 검토를 거친 전문 저널 논문만 고려하면 되지만, 데이터베이스가 커지고 문서가 많아지면 더 많은 결과와 더 철저한 분석이 제공될 것이 분명하다.

키워드: 자율주행자동차, 교통사고 사망, 교통사고, 사망률
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