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Autonomous Vehicle in Transportation

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ABSTRACT

Mobility is a basic necessity of contemporary society and it is ensured by a three-component system: vehicle, driver and transport infrastructure. Autonomous vehicles (AVs) are one technology that has captivated the interest of both inventors and customers. Connected and autonomous vehicles are now becoming a cornerstone of the increasingly connected world. The main goal of autonomous vehicles is to build a self-driving system that can perceive the road better than the best human driver. They are incredible innovation that will likely transform transportation, especially in urban environments, in the near future. Although autonomous vehicles can improve performance and safety, there are a myriad of serious technology, regulatory, and security challenges to consider in preparation for full vehicle autonomy. The aim of this paper is to highlight the roles and challenges of emerging autonomous vehicle technologies in transportation.

KEYWORDS: *autonomous vehicles, self-driving vehicles, connected vehicles, transportation, transportation industry*

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INTRODUCTION

As opposed to human-driven vehicles, autonomous vehicles essentially refer to self-driving vehicles. They are vehicles that can drive themselves, using sensors and technology to navigate roads and respond to traffic. They are smart vehicles that are able to perceive their environment and to move on accordingly without human intervention. They operate with the capability to have automatic motions and navigate themselves depending on the environments and scheduled tasks. Examples of autonomous vehicle are shown in Figure 1 [1].

Autonomous vehicles combine artificial intelligence (AI) and robotics. They are regarded as a promising answer to traffic jams, accidents, and environmental pollution. They will constitute the backbone of future next-generation intelligent transportation systems (ITS) providing travel comfort and road safety along with a number of value-added services. They are used in search and rescue, urban reconnaissance, mine detonation, supply convoys, etc. [2]. They can help save lives on the battlefield.

Autonomous vehicles (AV) are also described as "driverless," "robotic," or "self-driving." They are the future of automobiles. The race to develop autonomous vehicles has heated up with many major automotive manufacturers such as Tesla, Audi, General Motors, Mercedes Benz, Uber, Google, and Amazon.

CONCEPT OF AUTOMOUS VEHICLES

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

Autonomous vehicle or driverless car is an ambitious project which requires the fusion of many technologies like electronics, communications,

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

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

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

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

LEVELS OF AUTONOMY

SAE International (formerly the Society of Automotive Engineers) classifies autonomous vehicles on a scale of 0 to 5. The six levels are presented as follows [6,7]:

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

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

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

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

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

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

The six levels are shown in Figure 3 [8] and are summarized as follows: No Automation, Driver Assistance, Partial Automation, Conditional Automation, High Automation, and Complete Automation. The classification has been adopted by DOT. Vehicles sold today are in levels 1 and 2. Levels 4 and 5 will probably increase vehicle prices significantly. But how do we get to Level 5?

ENABLING TECHNOLOGIES

AV is regarded as a multidisciplinary technology. The enabling technologies in support of connected autonomous vehicles include:

- *Camera:* This is located at the top of the windshield. It detects on the ground the lines to follow. It also identifies the cars, pedestrians, and animals on the road.
- *GPS & GNSS:* Autonomous vehicles use GPS (Global Positioning System) and GNSS (Global Navigation Satellite System) to navigate to desired locations.
- *Sensors:* Autonomous vehicles are being equipped with many sensors such as cameras, RADAR, LIDAR, and mechanical control units. The sensors gather data from around the

environment and the GPS. Since no sensor is perfect, autonomous vehicles will require a variety of sensors to properly see the world around them.

- *Computer Vision:* This is a critical technology that allows AVs to interpret and understand visual information from the environment. Using cameras and sophisticated image recognition algorithms, autonomous vehicles can identify and classify objects such as other vehicles, pedestrians, traffic signs, road markings, and obstacles. This visual understanding is crucial for safe and efficient navigation.

Figure 4 illustrates some of these technologies [9].

APPLICATIONS OF AUTONOMOUS VEHICLES

The advent of autonomous vehicles (AVs) represents one of the most significant technological advancements in the transportation sector. Common areas of applications of autonomous vehicles include the following [10]:

- *Autonomous Driving:* AI enables vehicles to navigate roads, avoid obstacles, follow traffic rules, and respond to dynamic changes in the environment. This includes highway driving, urban navigation, and parking. Autonomous vehicles can maintain lane positions, adjust speeds, and overtake slower vehicles on highways using AI-driven systems like adaptive cruise control and lane-keeping assistance.
- *Electric Vehicles:* Environmental concerns, together with higher oil prices in the last decade have been the driving forces behind the emergence of electric vehicle (EV) technology. The EV suffers from some operational drawbacks including a distance-traveling capacity limited to the size and durability of the batteries. It limits the EV to short-range travel and can make the process of finding charging stations a matter of constant anxiety.
- *Transportation:* AVs could transform how people and goods are transported. Public autonomous vehicles (AVs) have a high potential to solve traffic related problems and environmental challenges. Transport as a Service (TaaS) allows you to transport goods and material on demand, while only paying for the capacity you use. Figure 5 shows a diversified public transport system [11].
- *Smart Mobility:* Autonomous vehicles are an essential part of smart mobility in smart cities. They can be integrated into shared mobility services like ride-hailing and car-sharing platforms. They will increase the mobility of individuals who do not drive as a result of age or disability. AI promotes advanced driving so that people can experience easy navigation. AI can help provide customized entertainment while the vehicle is traveling.
- *Trucking:* Autonomous trucks and vehicles promise significant benefits for an industry that struggles with a growing labor shortage and the demand for shorter delivery times. The American Trucking Association estimates a shortage of as many as 174,500 drivers by 2024, due to an aging workforce and the difficulty of attracting younger drivers. Although there has been much progress made toward developing autonomous vehicles to transport people, many believe that integrating autonomous trucks into the freight transportation supply chain is still a decade or more away. However, the thought of large trucks driving themselves on highways or in busy urban areas give rise to a number of concerns. Before commercial freight trucks run freely on the roads with no drivers at the wheel, there are many questions that need to be answered and issues to be addressed related to government regulations, legal risks, liability concerns, ongoing maintenance, and the need for employees and infrastructure to support it all. An autonomous Volvo truck is shown in Figure 6 [12].
- *Rail:* Autonomous trucks (ATs) will have an impact on the rail industry. To keep up with ever-changing technology, railroads are increasingly embracing digitization and thinking about rail transport as a part of a comprehensive supply chain solution. Railroads will need to understand how ATs may impact their intermodal business, as well as first- and last-mile deliveries. It will be key to be prepared for this change and embrace it as advances in technology continue. Although trains may not be running themselves any time soon, the industry is working through some automation initiatives of its own. If you are a business that relies on truck and rail to deliver your goods across the country, it might be time to consider how ATs could impact your production pipeline and schedule.
- *Taxi:* AV technologies can be conducive to driverless taxis or similar car-sharing schemes in which the cost of compensating cabdrivers' time and talent is excluded. As a result, driverless cabs are expected to become cheaper and which eventually may discourage car ownership. The concept of driverless taxis is analogous to car-

sharing which is a thriving business model. AVs can boost car and ride sharing schemes as they can cater to multiple persons on demand.

- *Drones:* Advanced driver-assistance systems (ADAS) and autonomous technologies are used in drones to improve safety, reliability, and performance. ADAS technologies such as LiDAR (Light Detection and Ranging) create a 3D map of the environment, helping the drone navigate and land safely.
- *Predictive Maintenance:* Predictive analytics is one of the strongest capabilities of AI and machine learning. The essence of predictive maintenance is that the system analyzes the equipment, compares its specs with industry and safety standards. The essence of reactive maintenance is to replace a critical part before it crashes the production system. By monitoring vehicle health and performance data, AI can predict when maintenance is needed, reducing downtime and extending vehicle lifespan.

GLOBAL AI IN AUTONOMOUS VEHICLES

Third world countries struggle with a lack of transportation infrastructure, such as roads, bridges, and public transport, which is impeding their economic development. AVs by these developing countries may spare them the costs associated with expanding capital-intensive infrastructure. Autonomous vehicles are becoming a real possibility in some sectors such as agriculture, transportation, and military. Here we consider the adoption of autonomous vehicles in different nations.

- *United States:* Americans spend over 290 hours per year driving, making it one of the most common (and dangerous) points of human-machine interaction. The National Highway Traffic Safety Administration (NHTSA) contends that automated vehicles can reduce injuries. In early 2015, Ford announced its "Smart Mobility Plan" to push the company forward in innovative areas including vehicle connectivity and autonomous cars. As part of its 10-year autonomous vehicle plan, Ford is steadily increasing its fleet and currently has around 100 autonomous test vehicles. It has pioneered the testing of self-driving cars in environments including snowy weather and complete darkness. The Covid-19 pandemics has forced Ford to delay the launch of its self-driving service to 2022. GM planned to deploy thousands of self-driving electric vehicles beginning in 2018. A full commercial self-driving operation is taking longer to materialize than GM initially hoped, partly due to Covid-19 crisis. Microsoft is focusing its autonomous vehicle efforts [13].
- *The Netherlands*: Dutch traffic law poses some challenges for fully autonomous self-driving cars. One challenge is making the behavior of autonomous vehicles (AV) conform to the traffic laws. The safety and efficiency purposes of traffic law require it to be precise. Dutch traffic law that are easy for humans seem very hard for the current autonomous vehicles. For example, while the Google car may avoid colliding with a police officer, it may fail to obey the officer's directions [14].
- *China:* The expansion into China is a major strategic move for Aptiv, a self-driving software company. China is expected to account for more than two-thirds of autonomous miles driven worldwide by 2040. FAW Group, a China-based manufacturer of trucks, buses, and cars, is moving forward with several self-driving initiatives.
- *Israel:* Israel is evolving into a major hub for self-driving technology, with Intel, Continental, Samsung, Daimler, and General Motors also making investments or setting up shop in the country.
- *European Union:* In 2019, the European Union's Commissioner for Transport at said she expected fully autonomous driving capabilities to arrive by 2030. The European Telecommunications Standards Institute (ETSI) has developed a set of technical specifications to define an Intelligent Transport System (ITS) security architecture . French president responded sharply to rising pressure from the industrial sector and plans to grant driving licenses for level 3 cars, country-wide, from 2020. Fully autonomous vehicles are to be tested in France very soon [15].

BENEFITS

Autonomous vehicles have been receiving a lot of attention recently largely due to the technological boom of artificial intelligence. They promise to reduce traffic congestion and collisions, reduce accident and pollution problems, improve traffic flow, mobility, relieve individuals from driving, decrease fuel consumption, and facilitate transportation and businesses operations. Based on the data collected over time, AI can speculate and provide preferences such as seat position adjustment, screen adjustment, controls air input, and songs to be played. Other benefits include [16]:

- *Safety and Privacy:* Safety is at the core of everything we do. Security and privacy are always being the major issue associated with the

electronic systems. The main benefit of autonomous vehicle is safety. Autonomous vehicles are fully capable of sensing the surrounding environment to enhance roadway safety. AVs are designed to choose the course of action that causes the less damage to everybody. Autonomous cars can remove risk factors from the equation and significantly reduce the number of accidents or crashes. AI techniques are also being implemented in vehicles to provide more safety by simply removing the need of a human driver, the most common cause of traffic accidents. To ensure safety, automakers are introducing many exciting features such as automatic emergency braking, lane crossing alerts, driver and passenger monitoring, blind spot elimination, side collision warning, and optional self-driving capabilities. Risk of cyberattack will increase since the Avs are a moving computer.

- *Mobility:* AV provides new opportunities for millions of Americans with disabilities, allowing them to travel freely and easily without the need to operate a car themselves. Having access to a self-driving car could expand transportation options for people with physical disabilities, older adults, and people who are not licensed to drive. Illness, fatigue, or intoxication are also cases where AVs could provide a safer transportation option.
- *Consumer Behavior:* To be successful, Avs has to cope with individual idiosyncrasies and variation in needs. Deployment of autonomous vehicles on public roads requires understanding the intent of human drivers and adapting to their driving styles. Interacting with human drivers is a major challenge of autonomous driving. Changes in consumer behavior and technology are disrupting traditional modes of operation. AI and perception technologies promise to provide a safer and more deterministic behavior which will lead to benefits such as fuel efficiency, comfort, and convenience.
- *Ease of Claim*: Data from the vehicle can be used for faster processing of claims in case of accidents. This can contribute to decrease in prices for insurance, since the safety is more deterministic and guaranteed.
- *Less Equipment Failure*: If a machine fails unexpectedly on an automotive assembly line, the costs can be catastrophic. AI-based algorithms can digest masses of data from sources, detect anomalies, separate errors from background noise, diagnose the problem, and predict if a breakdown is likely or imminent.
- *Quality Control*: Once the parts are put into production, it is necessary to carefully control their quality. Sensor-based AI can assess the quality of every part on the production line and detect defects more accurately than humans.
- *Leaner Supply Chain:* Automotive supply chains are complex networks. AI-powered supply chains are being used to analyze a massive amount of data to be able to forecast accurately. AI-powered supply chains will allow fully automated self-adjusting systems to make supply-chain management decisions autonomously, adjusting routes and volumes to meet predicted demand spikes.
- *Improved Accessibility:* Self-driving automobiles have the potential to give mobility to people who cannot drive, such as the old, handicapped, or visually impaired. Transportation becomes more inclusive and accessible for all with autonomous technology.
- *Reliability:* Ensuring the safety and reliability of AVs is paramount. Unlike human drivers, autonomous delivery vehicles maintain consistent performance without the risk of fatigue or human error. This reliability ensures timely deliveries and enhances customer satisfaction. Equipped with advanced sensors and GPS technology, AVs can accurately navigate to delivery destinations, reducing the likelihood of misdeliveries and improving service accuracy.

CHALLENGES

There are risks and challenges autonomous vehicles face in reaching full autonomy. It is challenging to support security, stability, reliability, and security requirements. AVs pose numerous ergonomic, safety, regulatory, and political problems. Autonomous vehicles (AVs) are poised to improve roadway safety and lower transportation costs, yet policy barriers are delaying their adoption. Other challenges posed by autonomous vehicles include the following [17-20]:

- *Safety:* Ensuring the safety of the decisions made by the self-driving car is the hardest part of reaching level five autonomy. Ensuring safety is not something that can be solved with a single technological silver bullet. Rather it requires a multi-disciplinary approach covering hardware fault tolerance, resilient machine learning, cooperation with humans driving conventional vehicles. Autonomous vehicles are designed to avoid accidents caused by human errors. Although AVs allow all vehicle occupants to relax, read, work, and watch television, they are required to wear seatbelts for safety reasons.

- *Security:* In addition to safety, autonomous vehicles will have to deal with security. Some security risks and vulnerabilities associated with AV have been identified. Autonomous vehicles pose a myriad of security concerns due to the risk of cybersecurity breaches. Cybersecurity protection is necessary to ensure vehicle optimal performance. Protecting autonomous vehicles from hackers is of a major concern to governments, manufacturers, and service providers. DOT mandated the incorporation of a thorough cybersecurity threat mitigation system in vehicle electronics. Encrypting communications between vehicles may help with the security of inter-vehicle coordination messaging. The future of security breaches will be revolutionized with advanced technologies such as artificial neural networks.
- *Privacy:* Before selling highly automated vehicles, it is required that manufacturers develop written privacy plans concerning the collection and storage of data generated by the vehicles. There should be a means of making that information transparent to vehicle owners and occupants.
- *Regulations*: Regulation will impact the adoption of AVs. In the US there are no national standards or guidelines for AVs, allowing states to determine their own. As of February 2020, 29 states and D.C. have enacted legislation regarding the definition of AVs, their use, and liability.
- *Social Acceptance:* The social acceptance of autonomous vehicles is evidently a complex process. Recent studies show that public skepticism about autonomous vehicles. This is may be due to lack of understanding about autonomous vehicles. It is DOT's concern that consumer should be educated and trained as vehicles are deployed. Consumers should know about the anticipated differences in the use and operation of AVs and conventional vehicles. For citizens to embrace the autonomous vehicles, auto manufacturers must demonstrate trust in the vehicle and improve its safety.
- *Adaptation:* It is impractical to validate all the possible adaptation states of an autonomy system using traditional safety design processes. The challenge is that influencing the autonomous vehicle's decisions requires a wide variety of parameters such as traffic conditions, pedestrian conditions, and weather condition.
- *Human Error:* Most of the crashed involving autonomous vehicles are due to human drivers sharing the road with autonomous vehicles. This may be due to distractions caused by pedestrians. Autonomous vehicles promise a future where drivers are freed from a tedious driving and traffic collisions are a relic of history.
- *Ethics:* AVs pose both technological and ethical challenges. Several ethical challenges of autonomous vehicles have been identified. Mundane traffic situations illustrate how the driving behavior of autonomous vehicles meshes with the rights and responsibilities of other traffic participants. The public has raised the question of how AV would behave when an accident is inevitable, how AV weighs decisions, and what such decisions mean in relation to others. What ethical considerations should constrain the behavior of AVs? Can we trust AVs to always make good decisions even in extreme emergency situations? AV is said to have "ethical limitations" because it is unlikely to have the capacity to make decisions which encompass human values, rights, societal norms, and ethics.
- *Education:* Education on autonomous vehicles plays an important role because many major automotive companies depend on it for building their workforce. One way of gaining knowledge of autonomous vehicles is by taking video-based online courses provided by various companies.

Some of these challenges are illustrated in Figure 7 [21]. These issues will become part of the public discussion. The anticipated merits of autonomous vehicles are more the perceived disadvantages. Automakers can only program their cars to act within some bounds. They are working to overcome these challenges on all fronts. Governments around the world should prepare for a wide range of technical, social, and regulatory issues in preparation for full vehicle autonomy.

THE FUTURE OF AI IN AUTONOMOUS VEHICLES

The autonomous vehicle is but one application of AI technologies which have a significant bearing on contemporary and future society [22]. Future autonomous (electric) vehicles are essentially software-driven compared to conventional vehicles. Cars are being manufactured all over the world, with each manufacturer in intense competition with one another to produce the best vehicle. Autonomous cars are the future smart cars which are expected to be driverless, efficient, crash avoiding, and ideal urban car of the future. Some are working tirelessly to create their very own self-driving vehicle from scratch. AI is a critical technology required for realizing autonomous driving. Car manufacturers

around the globe are using AI in just about every facet of the car manufacturing process. AI is changing the way cars are manufactured globally. Due to the various challenges of AI in autonomous vehicles, barriers to widespread adoption remain. In the near future, AI will enable autonomous vehicles to become mainstream. Technology companies are at the forefront, leveraging their AI experience to capture the autonomous vehicle market.

Connected and automated vehicle has become the focal point of current transportation studies (covering topics like automation, car visions systems, and AI) and has a crucial role to play in the future of transportation. The demand and the need for autonomous vehicle technology is almost there. As the autonomous vehicle technology matures, personal and public transportation will be greatly transformed. A day is fast approaching when you can commute to work with driverless car, without needing to watch the road [23]. Figure 8 shows seven trends shaping the automotive industry by 2030.

CONCLUSION

Artificial intelligence is making inroads in the automotive industry. It is the backbone of self-driving, autonomous or connected vehicles. It is being harnessed to bring autonomous driving from fantasy to reality. Autonomous cars are essentially the future smart cars anticipated to be driverless, efficient, crash avoiding, and ideal car of the future.

Currently, no fully autonomous vehicles are available for public use. However, autonomous vehicles may soon be mass produced and widely used for travel and logistics since they have potential to avoid most traffic accidents caused by human driver, improve transportation efficiency, and release people from driving. It is predicted that 4 in 10 vehicles will be autonomous by 2040. It is apparent that autonomous vehicle will soon have a positive effect on traffic congestion abatement. It is expected that autonomous vehicles will revolutionize the transportation industry.

Autonomous vehicles have the potential to revolutionize transportation by improving safety, reducing congestion, and improving energy efficiency. The future of autonomous vehicles has significant implications for transportation. The future for AVs is bright. Driverless vehicle (cars and trucks) are certainly on the horizon. To stay on top of the developments in autonomous vehicles, one should consult the books in [24-30] and related journals:

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

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Figure 1 Examples of autonomous vehicles [1].

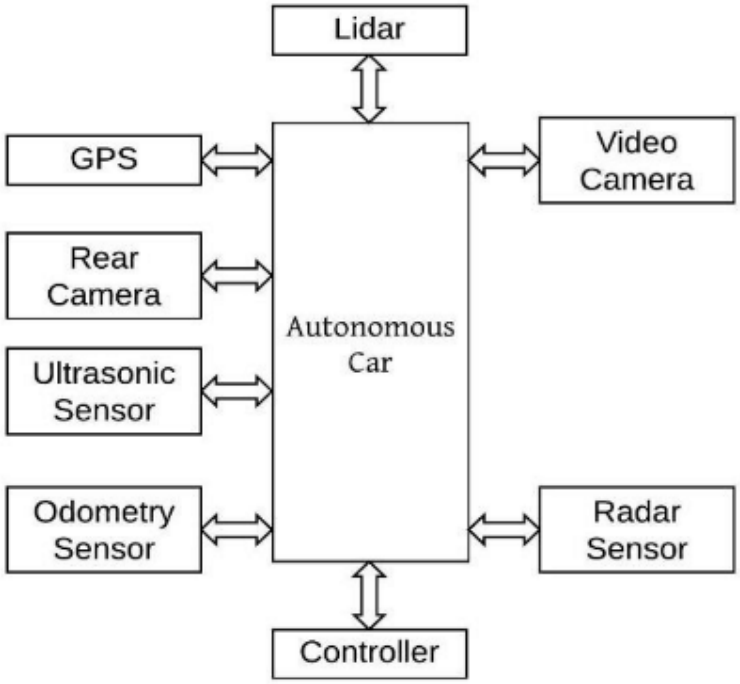

Figure 2 Architecture of Autonomous Car [3].

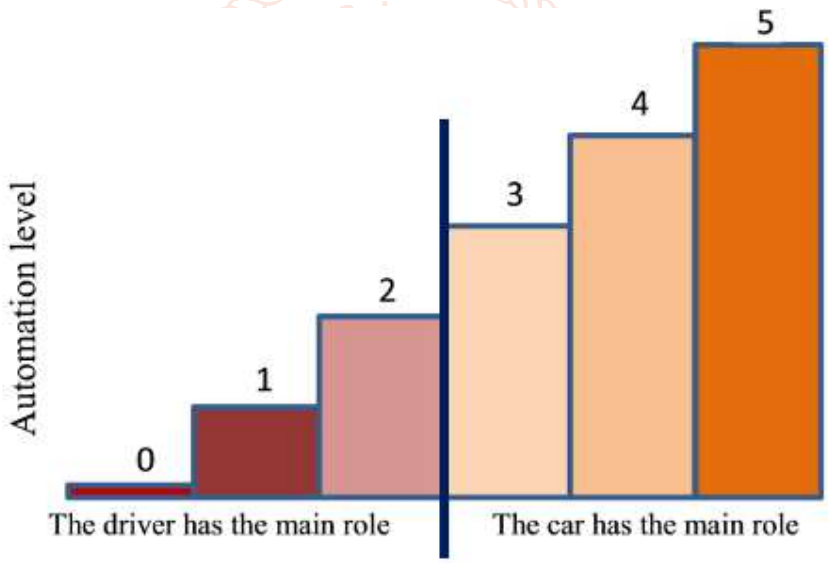

Figure 3 The six levels of autonomy [8].

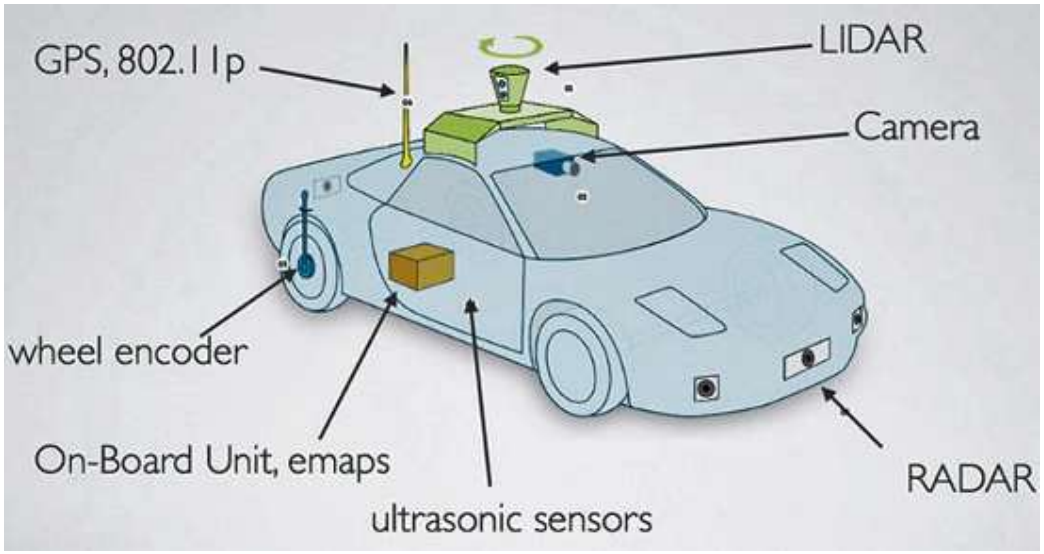

Figure 4 Autonomous vehicle technology [8].

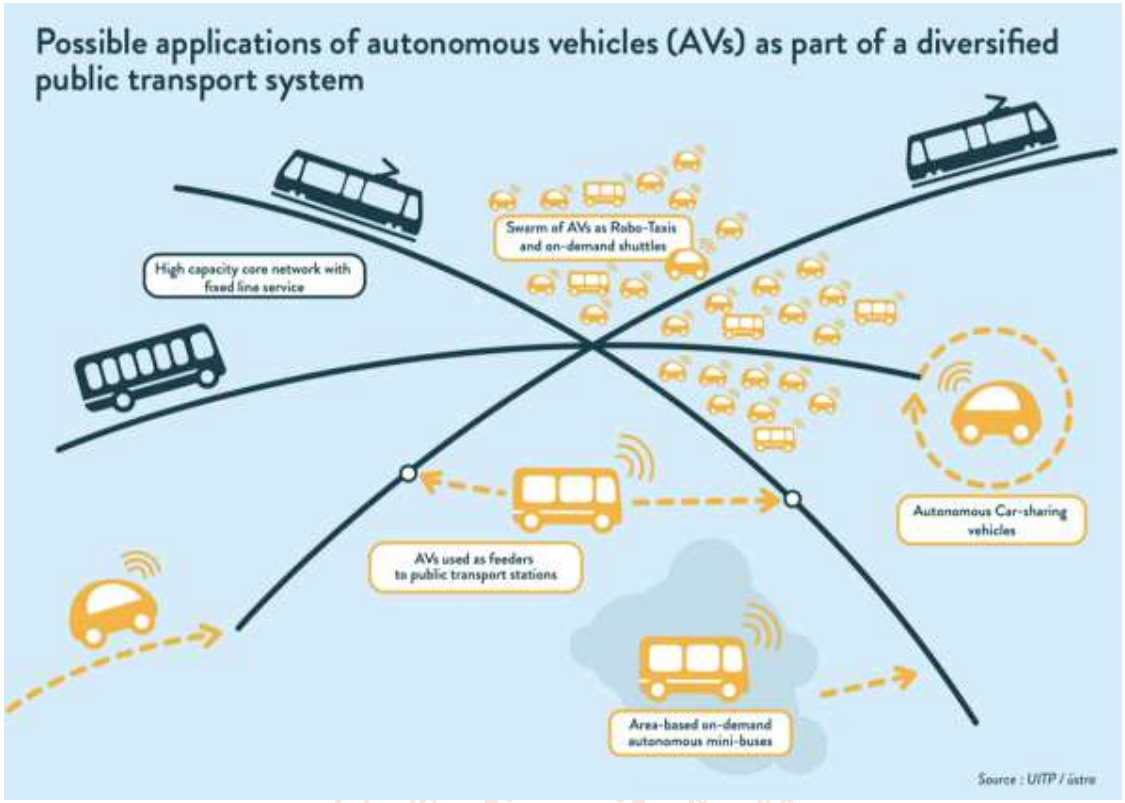

Figure 5 A diversified public transport system [11].

Figure 6 An autonomous Volvo truck [12].

Figure 7 Main challenges of the automated vehicles [21].

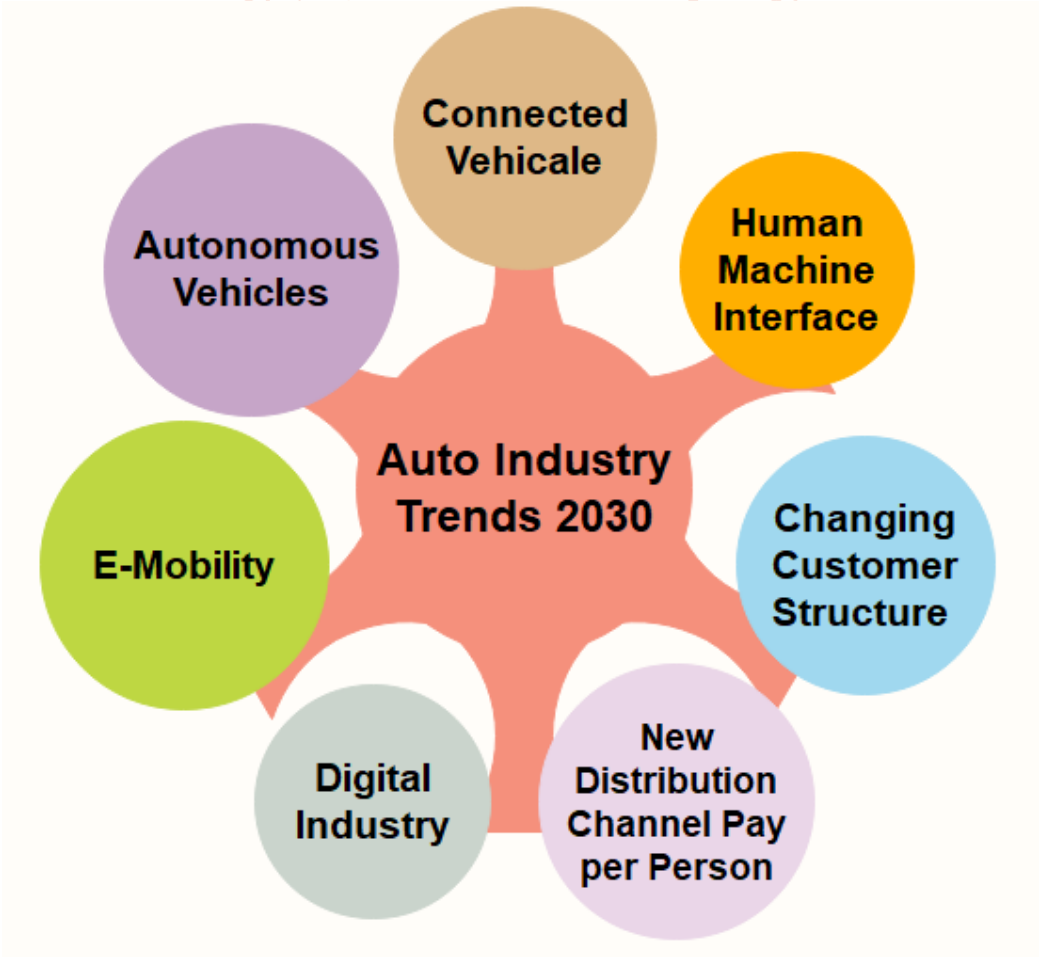

Figure 8 Seven trends shaping the automotive industry by 2030.