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Autonomous Vehicles in Automotive Industry

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***Abstract*:** The automotive industry is one of the most important industries in the US and around the world. It is one of the strongest pillars of the manufacturing sector. It encompasses the design, development, manufacturing, marketing, selling, and maintenance of motor vehicles, including cars, trucks, and motorcycles. The industry is currently undergoing significant transformation towards electric vehicles (EVs) and new mobility solutions. The automotive industry stands on the brink of a transformative era with the rise of autonomous vehicles. Autonomous vehicles are set to revolutionize the industry with increased safety, improved efficiency, and reduced operational costs. The international market for automobiles is already highly competitive and the competition to develop the autonomous vehicle is essentially a competition of innovation. This paper explores the impact of autonomous vehicles on the automotive industry.

Keywords: *Autonomous Vehicles, Self-Driving Vehicles, Connected Vehicles, Automotive Industry*

I. INTRODUCTION

Automotive industry comprises of all those companies and activities involved in the manufacture of motor vehicles, including most components, such as engines and bodies, but excluding tires, batteries, and fuel. The industry's principal products are passenger automobiles and light trucks, including pickups, vans, and sport utility vehicles. Commercial vehicles, though important to the industry, are secondary. The automotive industry has become a vital element in the economy of the industrialized nations [1].

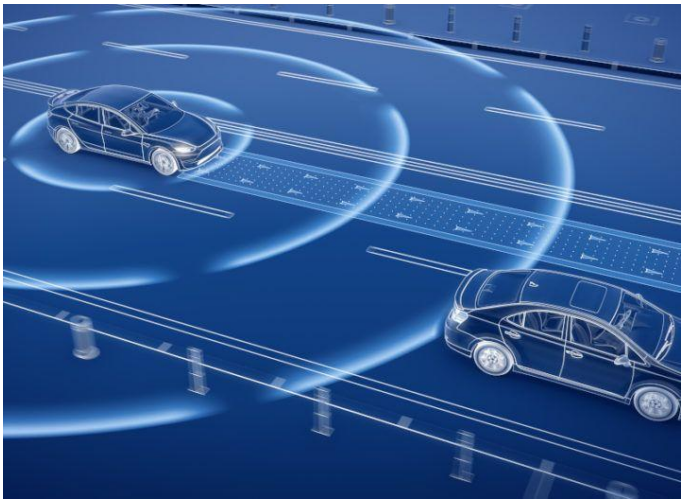

Figure 1: Examples of autonomous vehicles [2].

Autonomous vehicles (AVs) are one of the big trends in the automotive industry. They are transforming the automotive industry by using sensors, AI, and software for self-driving, promising enhanced safety, efficiency, and mobility. The notion of autonomous vehicles, once a sci-fi dream, is rapidly becoming a reality. Technological advancements have paved the way for this revolution, with leading auto manufacturers and tech companies investing heavily in developing these vehicles. Examples of autonomous vehicles are shown in Figure 1 [2].

II. CONCEPT OF AUTOMOUS VEHICLES

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

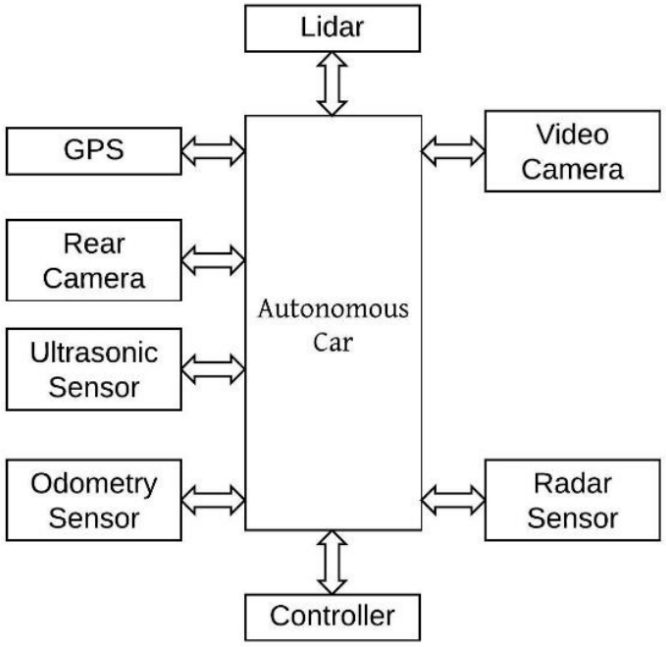

Figure 2: Architecture of Autonomous Car [3].

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

Connected and autonomous vehicles (Avs) are now becoming a cornerstone of the increasingly connected world.

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

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

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

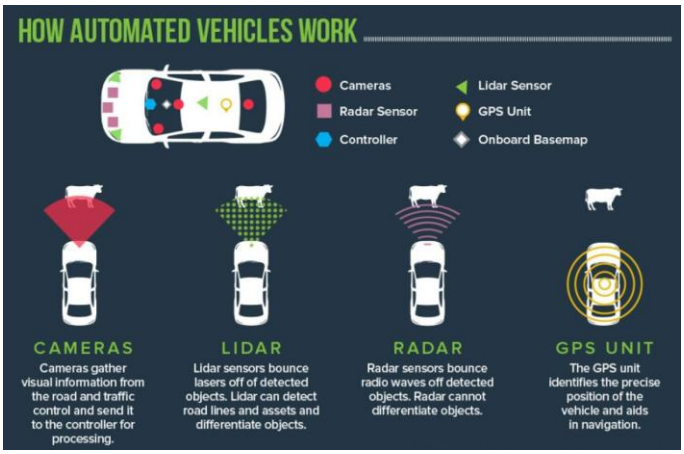

Figure 3: How autonomous vehicles work [6].

III. LEVELS OF AUTONOMY

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

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

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

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

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

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

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

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

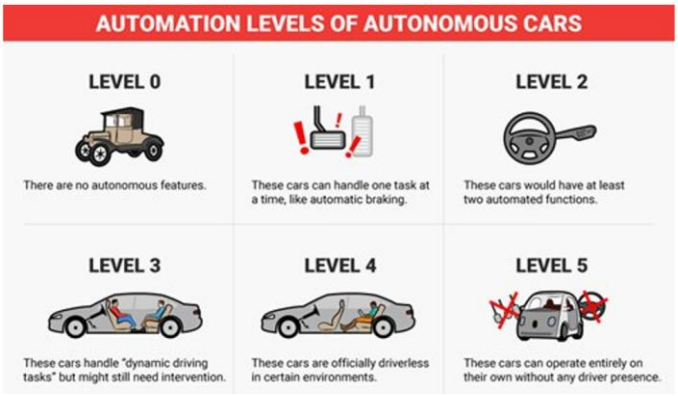

Figure 4: The six levels of autonomy [9].

IV. AUTOMOTIVE INDUSTRY

The automotive industry has been around for quite some time and it has evolved over time, but the major transformation that is happening now from vehicles driven by humans to vehicles driven by themselves will have a long term impact on society.

Figure 5: A typical automotive industry [10].

The automotive industry comprises a wide range of companies and organizations involved in the design, development, manufacturing, marketing, selling, repairing, and modification of motor vehicles. It involves automakers (like GM, Ford, Toyota, VW), parts suppliers, dealers, repair shops, and fuels related industries like oil, steel, and rubber, impacting jobs, trade, and economic growth worldwide. It relies heavily on other sectors (steel, plastics, rubber) and supports infrastructure like roads and fueling stations. Figure 5 shows a typical automotive industry [10].

The automotive industry began in the 1860s with hundreds of manufacturers pioneering the horseless carriage. The manufacturing process evolved from engineers working on a stationary car to a conveyor belt system where the car passed through multiple stations of more specialized engineers. The producers were assemblers who put together components and parts that were manufactured by separate firms. After the first success of the gasoline engine, there was widespread experimentation with steam and electricity. The outstanding contribution of the automotive industry to technological advance was the introduction of full-scale mass production (which was an American innovation), a process combining precision, standardization, interchangeability, synchronization, and continuity [1]. Due to the massive digitization of today's cars, vehicle manufacturing should be considered a process that takes place in the physical and digital world. From the advent of mass car production in the early 1900s to the rise of modern electric vehicles in the 2000s, the automotive industry has transformed dramatically over the last century.

For many decades, the United States led the world in total automobile production, with the US big three -- General Motors, Ford Motor Company, and Chrysler -- being the world's three largest auto manufacturers for a time. China increased its production drastically, and became the world's largest-producing country in 2009. In 2024, China produced the most passenger cars in the world, with Japan, India, Germany, and South Korea trailing [1].

Two fundamental technological developments currently have the potential to substantially transform the automobile market. The growth in "electric drive" technology and the digitalization of vehicles call for new technologies and skills, while also opening up opportunities for new business models and providers. This may challenge and threaten the existing business models and fortunes of established manufacturers.

V. AUTONOMOUS VEHICLES IN AUTOMOTIVE INDUSTRY

The advent of autonomous vehicles (AVs) has marked a significant shift in the automotive industry. Autonomous vehicles have the potential to address three major challenges: traffic congestion, fuel consumption, and human-error accidents. By leveraging advanced technology and artificial intelligence, autonomous vehicles can offer various advantages. For the automotive industry, autonomous vehicles present both opportunities and challenges. On the one hand, they offer a chance to revolutionize transportation and create new business models. On the other hand, they require substantial investments in research and development and adaptation to new regulatory frameworks [11]. The traditional car manufacturers have been pushed to reconsider their business strategies and adopt new technologies to keep up with the changing trends.

The automobile industry transition to autonomous, connected, electrified, and shared (ACES) vehicles has the potential to boost technological development and economic activity in the traditional manufacturing cities of the United States, bridging the divide between high-tech innovation hubs and regions historically known for industrial economies. The AV revolution is tied to other sweeping changes to transit that will be disruptive opportunities for growth: electrification, connectivity, workforce modernization, and new technology-driven infrastructure requirements. Automakers expect that within five years, electric vehicles will cost the same amount to produce as internal combustion vehicles [12]. Figure 6 shows some components of advanced automotives [13].

Figure 6: Some components of advanced automotives [13].

VI. APPLICATIONS OF AUTONOMOUS VEHICLES IN AUTOMOTIVE INDUSTRY

Autonomous vehicles (AVs) are revolutionizing the automotive sector by using sensors, AI, and software to drive themselves, promising enhanced safety, mobility for all, and efficiency. Connected car technology will be a possibility, allowing for accurate, up-to-date driving maps as vehicles share information with each other about collisions or traffic jams en route. Common applications of AVs in automotive industry include the following [12,14,15]:

- *Traffic Management:* Improved traffic management, especially in conjunction with artificially intelligent transport system (ITS) infrastructure could significantly improve road safety by avoiding congestion. Many AVs will instantaneously communicate with transportation infrastructure, including "smart" traffic lights, which has already shown promise in reducing stoppages and wait times. Less advanced systems have also been proven to improve traffic management.
- *Incident Management:* Traffic congestion on busy roads and highways is often exacerbated by improper incident management. AVs would be able to reduce the duration of incident-caused congestion by instantaneously alerting ambulances and emergency services, and the volume of congestion by immediately alerting oncoming traffic of the incident and optimally rerouting.
- *Route Optimization:* AI allows for route optimization and optimized matching of drivers and riders, which is already being explored by Uber and Lyft. This technology includes predictions of upcoming delays and instantaneous rerouting.
- *Road Safety:* AVs would drastically reduce the potential for road accidents. Ninety-four percent of crashes are attributable to human error, which autonomous systems even below level five would

guard against. Sensors and computers cannot fall asleep, drive under the influence, or become distracted. Real-world data backs the safety theory.

- *Data Curation:* The ability to handle large amounts of data enables new digital business models, and this is also a form of competence that is well advanced in digital-based technology companies. Data generated during vehicle operation can also be collected, analyzed, and applied to improve technological components and develop new business models based on big data. Data curation is a crucial step for pretraining and continuous training of world models, especially when working with large-scale multimodal data. It involves processing steps like filtering, annotation, classification, and deduplication of image or video data to ensure high quality when training or post-training highly accurate models. The data is then organized and cleaned for training. Throughout this process, efficient data orchestration ensures a smooth data flow among the GPUs, enabling them to handle large-scale data and achieve high throughput. Figure 7 shows data curation process [14].
- *Electromobility*: Facing the perspective of a further gradual rise in electromobility, the automotive industry is already in a state of flux. This trend challenges the value and differentiating potential of the existing core competencies of established automotive companies. The combination of technological advancements in electromobility and autonomous vehicle technology increases the chances of both successful market entry and repositioning. Electrification will continue to gather pace over the next few years. Electric vehicles will grow in popularity as the electrification of heavier cars and trucks becomes more feasible.

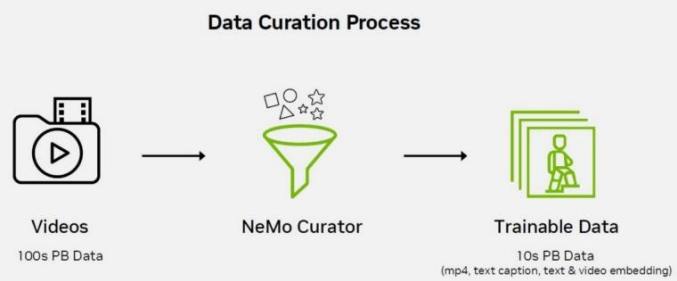

Figure 7: Data curation process [14].

VII. BENEFITS

Autonomous vehicles have generated significant interest with the promise of increased safety, improved efficiency, and potentially lower operational costs. The environmental impact of autonomous vehicles is significant, potentially reducing carbon emissions and improving air quality. The potential for enhanced safety, reduced carbon emissions, and improved transportation accessibility is within our reach. Other benefits include the following [11]:

- *Personal Costs*: Implementing AVs in ridesharing applications and taxis will likely lower the cost of these services, especially in more remote areas. Reduced costs for ridesharing services could incentivize their substitution for personal vehicles, decreasing individuals' average vehicle miles traveled and gasoline costs. More affordable, accessible, and efficient transportation options would unlock economic opportunities for individuals by expanding their ability to commute farther, faster, and cheaper.
- *Reducing Congestion:* Autonomous vehicles can communicate and coordinate with each other, optimizing traffic flow and minimizing congestion. With improved coordination and efficient routing, autonomous vehicles have the potential to alleviate traffic congestion in busy urban areas.
- *Less Fuel Consumption:* Autonomous vehicles are designed to operate with greater precision and efficiency. By reducing unnecessary braking and accelerating, autonomous vehicles can lower fuel consumption and contribute to a greener and more sustainable transportation system.
- *Eliminating Human-Error:* Human error is a significant factor in many road accidents. Autonomous vehicles have the potential to significantly reduce the occurrence of accidents by eliminating or minimizing human errors such as distracted driving, fatigue, or impaired judgment.
- *Environmental Impact:* One of the most promising aspects of autonomous vehicles is their potential environmental impact. AVs, especially with electric vehicle technology, could significantly reduce carbon emissions and improve air quality. The potential integration of AVs into shared mobility services could decrease the number of vehicles on the road, leading to less traffic congestion and lower emissions. AV-based public transport systems were found to be the most sustainable strategy in dense urban areas.

VIII. CHALLENGES

Autonomous vehicles face hurdles in regulatory frameworks, public trust, and scaling beyond limited deployments. Shifting from internal combustion engines to electric powertrains presents major R&D and manufacturing challenges. Insurance issues increase in complexity due to the need to share the responsibility between driver and manufacturer. Other challenges include [1,11,16]:

- *Safety*: Safety is a state that implies being protected from any risk, danger, damage, or cause of injury. In the automotive industry, safety means that users, operators, or manufacturers do not face any risk or danger coming from the motor vehicle or its spare parts. Safety in the automotive industry is particularly important and therefore highly regulated. AVs have the potential to reduce accidents by eliminating human error, fatigue, and impairment.
- *Regulatory Challenges:* Integrating autonomous vehicles into our daily lives also necessitates significant regulatory adaptations. Governments worldwide are grappling with how best to facilitate the development and deployment of AVs while ensuring public safety. Automotive companies must engage with policymakers and contribute to developing these regulations. The responsibility falls on manufacturers to address different regulations and policies.
- *Collaboration:* As the automotive industry is based on cooperation among different manufacturers and various suppliers of parts and specific technologies or services, complex international value chains have been developed. The cooperation of manufacturers and suppliers is important for innovation within the industry. To maintain and improve the workforce,

pipeline automakers, other industry actors, government stakeholders, and education and training institutions must continue to cooperate on curriculum development, internship and apprenticeship opportunities, and other paths to reskilling and upskilling.

- *Battery:* Major changes are taking place in the manufacture of integral car components, namely batteries. The European battery market is moving toward localized production and shoring up battery supply as demand soars, with the aim of attaining 100% electric mobility by 2035. The drive to keep battery production in-house and closer to home is partly due to pricing and partly due to control. An EV battery contains various critical minerals including nickel, copper, and lithium, and the majority of these are imported.

CONCLUSION

The autonomous vehicle market will grow rapidly during the 2020s and will transform many industries including consumer mobility, commercial transport, industrial automation, smart cities, and transportation systems as a whole. Automakers know the automotive industry is changing rapidly. They recognize that to stay competitive, they must offer smarter, including autonomous, vehicles. The era of autonomous vehicles is not just a dream; it is a transformative reality that promises to reshape the way we move and connect in our increasingly interconnected world. The transition towards AVs demands an industry-wide shift, requiring automotive companies to adapt their business strategies, manufacturing processes, and supply chains. Companies in the automotive industry must adapt their business strategies to capitalize on the potential of autonomous vehicles.

The journey towards fully autonomous vehicles is still underway, with many technical and regulatory hurdles to overcome. However, the potential benefits – improved safety, increased efficiency, reduced emissions, and new business opportunities – make it a compelling path. The view that the future of the automobile will be electric and ultimately autonomous is widely held. Automakers are responding to projections that electric vehicle demand will grow, and costs will decline. To stay on top of the developments in autonomous vehicles in the automotive industry one should consult the books in [17,18] and related journals:

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

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