Autonomous Vehicles in Manufacturing

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Abstract: With advancements in AI, sensor technology, and connectivity, autonomous vehicles are transitioning from concept to reality, promising to revolutionize the automotive sector by improving safety, efficiency, and the overall driving experience. These vehicles rely on a combination of custom high-definition maps, artificial intelligence, on-board sensors, cameras, and connectivity modules to interpret the external environment and make driving decisions in real time. The combined power of AI and robotics is revolutionizing manufacturing. AV manufacturing relies on a global, technology-centric supply chain, blending traditional auto suppliers with new technology players. This paper will examine the impact of autonomous vehicles on manufacturing processes.

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

I. INTRODUCTION

Autonomous vehicles (AVs) rely on a complex mix of sensors, computing power, and AI to navigate their environment. In manufacturing, AVs are revolutionizing factories by automating material handling, reducing labor dependency, improving safety, and creating seamless, data-driven workflows for logistics and last-mile delivery. Revolutionizing transportation for customers while improving safety on roads is the goal of autonomous vehicle technology. Examples of autonomous vehicles are shown in Figure 1 [1].

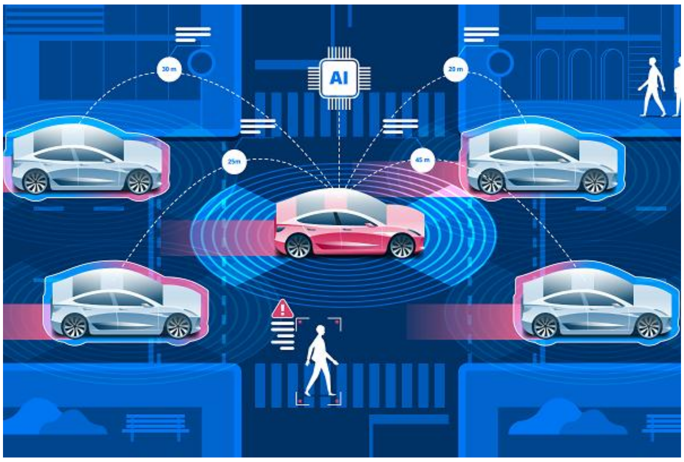

Figure 1: Examples of autonomous vehicles [1].

Automotive manufacturing is a massive global industry focused on designing, building, and selling motor vehicles, encompassing everything from passenger cars and trucks to components, using complex assembly lines, advanced robotics, and evolving technologies. Autonomous cars have been the driving force in modernizing automotive manufacturing. The next generation of manufacturing will not just take place on the plant floor. It will happen on computers and in the cloud. This introduces some additional challenges. Figure 2 shows a typical manufacturing environment [2].

Figure 2: A typical manufacturing environment [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 3 shows the architecture of autonomous car [3].

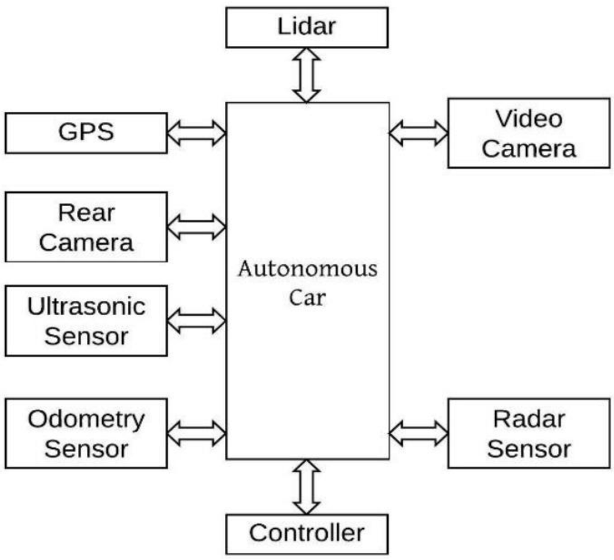

Figure 3: Architecture of Autonomous Car [3].

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 4 shows how autonomous vehicles work [6].

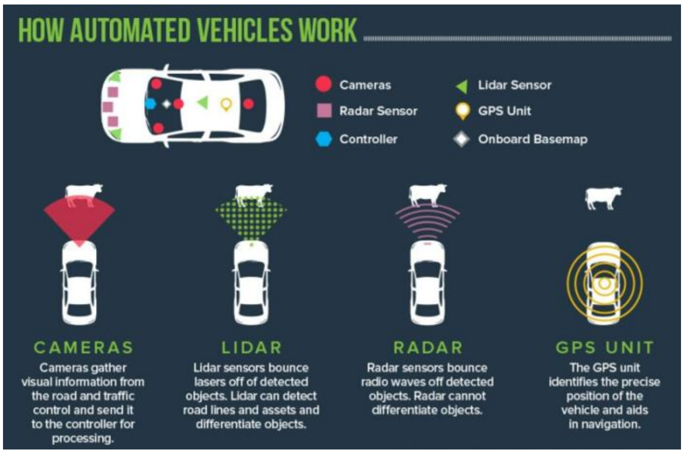

Figure 4: How autonomous vehicles work [6].

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 5 [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?

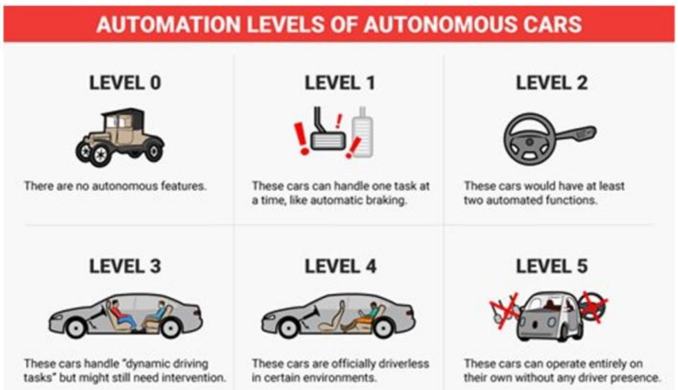

Figure 5: The six levels of autonomy [9].

IV. AUTONOMOUS VEHICLES IN MANUFACTURING

Nowadays, industries have to deal with a high competitive market. Therefore, any process optimization devoted to improve the production efficiency has a crucial role. Accordingly, current industrial systems move toward a more and more increasingly involvement of automation for enhancing challenging logistics issues. Autonomous vehicles are a radical innovation that could efficiently assist the management of production lines. They move raw materials, finished parts, and even finished vehicles within facilities, integrating with IoT and AI for real-time tracking and self-adjustment of production [10]. Figure 6 shows autonomous vehicles delivering parts around the factory [11].

Figure 6: Autonomous vehicles delivering parts around the factory [11].

Figure 7: A fully autonomous electric taxi vans by VW [12].

Automakers are heavily investing in manufacturing the first commercially available, fully autonomous cars. Autonomous vehicles (AVs) (also known as driverless vehicles, self-driving vehicles, and robotic vehicles) use sensors, radar, cameras, artificial intelligence (AI), and machine learning (ML) to operate without human input. They are being developed for safer driving. Occupants act only as passengers, so they do no need to be engaged or even awake. However, full AVs are not yet available in the US for consumer purchase. Audi, BMW, Ford, Tesla, General Motors, VW, and Volvo are among the automakers developing and testing self-driving cars. Vehicles that offer the highest levels of automation currently available to consumers include the Cadillac Escalade, the Genesis G90, the Ford F-150, and the BMW X5. Other companies are carrying out extensive testing on vehicle fleets, which often have higher levels of automation. Volkswagen has manufactured a fully autonomous electric taxi vans, shown in Figure 7 [12]. The US automotive industry remains one of the most dynamic manufacturing sectors in the world. Figure 8 shows the geographic distribution of US manufacturers [13].

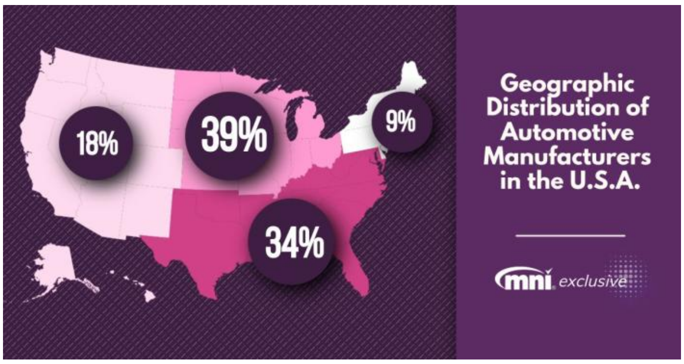

Figure 8: Geographic distribution of US manufacturers [13].

V. APPLICATIONS OF AUTONOMOUS VEHICLES IN MANUFACTURING

Robots and automation technologies, including robotic assembly and assembly line robots, are revolutionizing the manufacturing industry by enhancing efficiency, speeding up production, and lowering costs. Common applications of AVs in manufacturing include the following [14-16]:

- *Automotive Manufacturing:* This utilizes two main types of robots: traditional "hard" robotics for repetitive tasks and collaborative robots (cobots) that work alongside humans. These robots are deployed for a variety of tasks, including assembly, welding, material handling, and more, showcasing their versatility and the automotive industry's reliance on robotic technology for innovation and productivity. Robots with sophisticated vision systems may perform precise quality control, identifying even the smallest flaws and guaranteeing that every component satisfies exacting requirements. Major robotic innovations are transforming automotive manufacturing. Figure 9 shows robots used in manufacturing [1].
- *Robotic Automation:* One of the most significant automotive manufacturing trends is the growing reliance on AI and automation. Automotive industry was one of the first industries to adopt automation and to introduce advanced tools and equipment. The industry has undergone automation in almost all areas in the past few decades. Collaborative robots are being used to handle tasks that are, otherwise, complicated and risky tasks when performed manually. As illustrated in Figure 10, new technologies may lead to more automated robots on the floor next to human workers [17].
- *Autonomous Mobile Robots (AMRs):* These advanced robots are changing the landscape. The automotive industry is undergoing a significant transformation with the adoption of autonomous mobile robots (AMRs). These advanced robots are changing the landscape of car manufacturing by enhancing efficiency, reducing costs, and improving safety. They are transforming the automotive manufacturing industry by providing advanced, flexible solutions for a variety of tasks. These robots are designed to operate autonomously, using sophisticated navigation systems to move materials, parts, and tools within a factory setting. They have become indispensable, enhancing the efficiency and flexibility of production lines.
- *Electric Vehicles:* Electric vehicles used in autonomous vehicle solution helps customers transition to more cost-effective and environmentally-friendly fleets. Electric vehicle innovations have disrupted the transportation and transit space. Customers are able to accelerate the global deployment of autonomous vehicle fleet solutions across their gas-powered, diesel and electric passenger and cargo shuttles.
- *3D Printing:* 3D printing is being used in the manufacturing industry to create larger parts or components using different raw materials, including concrete and masonry, wood, etc. 3D printing is mainly preferred in auto manufacturing for the fact that objects are created layer by layer just like how the components are assembled in a vehicle.
- *Computer Vision:* Computer vision, AI, and edge tech are transforming assembly lines, boosting quality control, and increasing efficiency in smart

manufacturing. Manufacturing industry leaders now recognize computer vision as essential for achieving their business goals, highlighting the widespread adoption and strategic importance of this technology in modern production environments. With computer vision work, machines can see, understand digital images, and understand what is happening on the production line. These tools help machines handle specific tasks, like sorting parts or spotting defects. Figure 11 shows the use of computer vision in manufacturing [2].

Figure 9: Robots used in manufacturing [1].

Figure 10: New technologies may lead to more automated robots on the floor next to human workers [17].

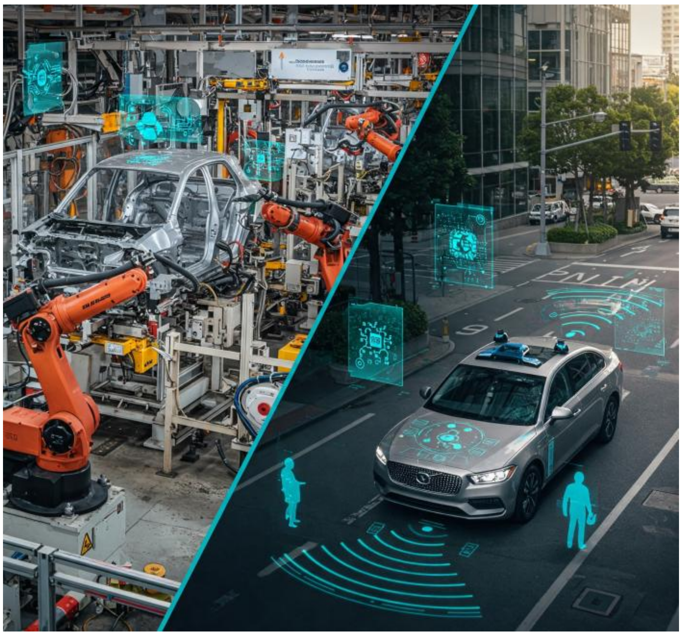

Figure 11: Use of computer vision in manufacturing [2].

VI. BENEFITS

Basic benefits include mobility and costs based on infrastructure. AV surely increases the safety level of driving. Customer satisfaction is the main priority here. Automotive manufacturers are utilizing data and innovative technologies for various purposes, including vehicle simulation testing, improving operational efficiencies, predictive maintenance, and the development of autonomous vehicles. Other benefits include the following [1,15]:

- *Automation:* Automotive and manufacturing industries have adapted to automation since many years. Automated systems are not only enhancing assembly lines but also optimizing quality control and predictive maintenance, leading to reduced downtime and lower operational costs. Automation has historically been pitched as a replacement for “dull, dirty and dangerous” jobs, and that continues to be the case. Removing humans from harm’s way in sectors are essential and varied as energy, commodities, and healthcare remains a worthy goal.
- *Cost Reduction:* The adoption of robots reduces the reliance on manual labor for repetitive and time-consuming tasks. This shift not only cuts labor costs but also minimizes errors and waste. Robots can work around the clock without the need for breaks, further enhancing productivity and operational efficiency. By streamlining logistics, robots free up your staff to focus on higher-value activities, ultimately driving down costs.
- *Sustainability:* Sustainability is becoming a major focus in automotive manufacturing, with companies adopting greener practices to reduce their environmental impact. Looking at the future of automotive industry trends, sustainability will continue to be a driving force in innovation. Manufacturers are implementing energy-efficient production processes, using recycled materials, and reducing waste. This shift not only helps automakers meet environmental goals but also improves overall cost efficiency. The push towards sustainable practices is evident in the adoption of green energy, recycling, and the use of sustainable materials in 3D printing processes.
- *Increased Efficiency:* AV reduces bottlenecks, streamlines workflows, and optimizes resource use. AMRs automate the transport of materials and components, ensuring a continuous supply to the assembly line. This automation eliminates bottlenecks and reduces downtime, allowing for smoother and faster production processes.
- *Enhanced Flexibility:* One of the key advantages of robots is their adaptability. Robots can be easily reprogrammed to handle different tasks or navigate new routes, making them highly flexible in response to changing production needs. Whether it is scaling up production or adjusting to new workflows, robots can seamlessly adapt without requiring significant infrastructure changes.
- *Improved Safety:* Safety is paramount in any manufacturing setting. Robots minimize human involvement in dangerous tasks and environments. They contribute to a safer work environment by taking over tasks that pose risks to human workers. Equipped with state-of-the-art sensors and safety features, robots can navigate through crowded factory

floors and avoid collisions, reducing the likelihood of workplace injuries.

VII. CHALLENGES

Despite many benefits, several significant challenges remain. These include cybersecurity and data privacy concerns, driver and pedestrian safety, and lacking infrastructure. Many companies are not yet profitable, and their timelines for being in the black shift ever further into the future. A common misconception in the industry is that we are trying to replace human drivers with vehicles. That is simply not the case. Mass production here still requires a great deal of manual intervention for tool changeover, assembly, programming, and scheduling. Other challenges include [18-20]:

- *High Cost:* High initial investment and ongoing maintenance costs present significant barriers. Strategies to mitigate these include leveraging economies of scale, seeking governmental incentives, and investing in modular robotics systems that offer greater flexibility and lower long-term costs, a prudent approach in the context of robotic assembly.
- *Workforce Impact:* The adoption of robotics has led to job displacement in manufacturing and other sectors, with a significant need for re-skilling, a challenge that underscores the transformative impact of robotic assembly and assembly line robots. The shift towards automation necessitates a skilled workforce adept in robotics, software development, and AI. Employers must invest in comprehensive training programs, foster an environment where the workforce is not anxious that they are being replaced by robots.
- *Safety:* Self-driving vehicles and unmanned air systems have already been implicated in crashes and casualties. "Mixed" environments, featuring both human and autonomous agents, have been identified as posing novel safety challenges. Longer supply chains, along with more data and connectivity, introduce or accentuate safety and cyber risk. As the behavior of autonomous systems becomes more complex, safety models with a common framework and terminology and interoperable testing become necessities.
- *Trust:* Trust will be key for autonomous systems, both for consumers and regulators. Autonomous technology is revolutionizing mobility and manufacturing, but trust issues need to be addressed. Trust and assurance — from consumers, the public, and governments — will be critical issues for the AI and autonomous technology space in the years ahead. Yet, earning that trust will require fundamental innovations in the way autonomous systems are tested and evaluated. To increase public trust in driverless cars, automakers, and governments must be transparent, engaged, and informative.
- *Interoperability:* Interoperability and virtual testing will become an imperative. Different systems may need to interact effectively with one another and be tested together in virtual test environments.
- *Standardization:* Standards and common verification systems will offer credibility as emerging technologies scale. Without standards, a fragmented approach to safety may prove detrimental to the industry. Companies that take proactive approaches to shaping and complying with standards can reduce risks and build a competitive advantage.
- *Regulation:* The regulatory landscape is complex for several reasons, including conflicting government guidelines, public concern, rapidly advancing technology, new infrastructure, and concerns surrounding ethics. Governments will take a proactive role to both to regulate and develop standards. As the technology develops, governments will face additional pressure to pass legislation ensuring quality and safety while providing the space and infrastructure for companies to test and scale their designs.
- *Complexity:* The process of designing, building, testing, and scaling autonomous cars is complex and time-consuming. Autonomous vehicles rely on a complex mix of sensors, computing power, and AI to navigate their environment. The manufacturing complexity of AVs also varies by level, with higher autonomy requiring more sophisticated integration between hardware, software, and safety systems. Automakers must manage this complexity and ensure quality and reliability.
- *Skills Gap:* There is a big skills gap to be addressed. 42% of industrial companies are reporting they are already experiencing a shortage of labor. To reskill and upskill the workforce at scale, it is suggested that manufacturers develop effective technological learning methods, such as gamification and VR or AR learning.
- *Infrastructure:* Initial infrastructure changes are made to accommodate pilot testing, followed by the necessary changes to suit mixed traffic, before finally establishing the infrastructure to support a complete transition to AVs. It also stresses the importance of investing in infrastructure and prioritizing shared autonomous mobility.

CONCLUSION

Manufacturing systems and technologies are evolving in ways that can help minimize the time and effort required for vehicle changeover while helping manufacturers stay on top of changing consumer demand. No companies have so far reached the highest level of manufacturing autonomy. The future trends in automotive robotics, including the surge in artificial intelligence, the advent of autonomous vehicles, and the emphasis on sustainability, suggest a vibrant horizon for automotive manufacturing.

Self-driving and autonomous vehicles have been in the news for a while now. It is almost becoming a reality in the next few years. Car manufacturers like VW and Tesla have advanced plans and prototypes for self-driving vehicles, and many other car manufacturers are not too far behind. Proactively planning for changes in your manufacturing facility can be the difference between a successful, fruitful transition into manufacturing new products and a total disaster. To stay on top of the developments in autonomous vehicles in manufacturing one should consult the following related journals:

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

References

[1] "Latest automation trends revolutionising auto manufacturing like never before,"

https://www.5pider.com/latest-automation-trends-revolutionising-auto-manufacturing-like-never-before/

[2] "Automating assembly lines with computer vision," https://www.technolynx.com/post/automating-assembly-lines-with-computer-vision

[3] T. Raviteja and R. Vedaraj, "An introduction of autonomous vehicles and a brief survey," *Journal of Critical Reviews,* vol 7, no. 13, 2020, pp. 196-202.

[4] J. Connelly et al., "Current challenges in autonomous vehicle development," *Proceedings of. SPIE,* May 2006.

[5] M. N. O. Sadiku, S. M. Musa, and A. Ajayi-Majebi, "Artificial intelligence in autonomous vehicles," *International Journal of Trend in Scientific Research and Development*, vol. 5, no. 2, Jan.-Feb. 2021, pp. 715-720.

[6] "Autonomous vehicles: Coming to a road near you (if they're not there already)," July/August 2018, https://www.govtech.com/transportation/autonomous-vehicles-coming-to-a-road-near-you.html

[7] S. Meryem and T. Mazri, "Security study and challenges of connected autonomous vehicles," *Proceedings of the 4th International Conference on Smart City Applications,* October 2019, pp. 1–4.

[8] A. Qayyum et al., "Securing connected & autonomous vehicles: Challenges posed by adversarial machine learning and the way forward," https://arxiv.org/pdf/1905.12762.pdf

[9] M. H. B. Abdullah, "Autonomous trucking in logistics transportation," September 2018, https://publication.sipmm.edu.sg/autonomous-trucking-in-logistics-transportation/

[10] D. Famularo et al., "An intelligent multi-layer control architecture for logistics operations of autonomous vehicles in manufacturing systems," *IEEE Transactions on Automation Science and Engineering*, vol. 22, August 2024, pp. 7296 – 7311.

[11] J. Marc and N. Lewis, "How BMW is trying to modernize manufacturing," January 2020, https://www.cnn.com/2020/01/23/business/bmw-regensburg-smart-factory

[12] "Volkswagen is manufacturing a fully autonomous electric taxi vans by 2025," May 2021, https://www.southernvolkswagengreenbrier.com/volkswagen-is-manufacturing-a-fully-autonomous-electric-taxi-vans-by-2025/

[13] "Top automotive manufacturers in the U.S.A.," August 2025, https://www.industryselect.com/blog/top-10-automotive-manufacturers-in-the-us

[14] J. Portley, "Driving change: The impact of car manufacturing robots," March 2024, https://knowhow.distrelec.com/automation/driving-change-the-impact-of-car-manufacturing-robots/

[15] "Revolutionizing automotive manufacturing with AMRs," https://mobile-industrial-robots.com/blog/revolutionizing-automotive-manufacturing-with-amrs

[16] "Perrone Robotics and Tropos team up to develop autonomous electric compact utility vehicles," https://www.perronerobotics.com/news/perrone-robotics-and-tropos-team-up-to-develop-autonomous-electric-compact-utility-vehicles

[17] "How self-driving vehicles can change manufacturing," https://allianceindustrial.jobs/employer-insights/self-driving-vehicles-manufacturing/

[18] S. Kimmel, "How autonomous technology is revolutionizing mobility and manufacturing," March 2023, https://www.ey.com/en_us/insights/strategy/how-autonomous-technology-is-revolutionizing-mobility-and-manufacturing

[19] "The road ahead: Autonomous vehicle manufacturing and adoption in the GCC," Spring 2025, https://www.deloitte.com/middle-east/en/our-thinking/mepov-magazine/next-generation-business/the-road-ahead-autonomous-vehicle-manufacturing-and-adoption-the-gcc.html

[20] L. Ross, "Challenges in autonomous driving in manufacturing," https://www.thomasnet.com/insights/challenges-in-autonomous-driving/

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