

How Effective is the science of Industrial Robotics in the Automobile Industry

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Abstract

This paper looks into the use of robotics in the automobile industry and its impact on manufacturing efficiency, quality, worker safety, and production costs. Specifically it examines efficiency: robotics has accelerated production speeds while maintaining near-perfect precision; Assessing safety: robots have reduced workplace injuries, exposure to toxic fumes, and ergonomic strains; and evaluating production cost: robots reduce costs through various means, such as minimizing material scrap and operating expenses. The study explores various types and applications of robotic systems used in vehicle production. We look into how robots have transformed the industry and some of the crucial roles they play in the industry. This study takes on a qualitative literature review supported by industrial performance data to evaluate the impact of robotics on productivity, manufacturing quality, worker safety, and production cost. The findings indicate that robotics has become a strategic competitive advantage in modern automobile manufacturing.

Keywords : Robotics, Automobiles, Safety, workplace, vehicles, performance,

1. Introduction

The automobile industry has been one of the largest adopters of industrial robots since the 1960s. Modern automotive factories rely mainly on robotic systems to manufacture vehicles with high precision and consistency. Robotics has helped manufacturers to increase productivity while reducing errors and hazards.

The automotive industry is globally valued at approximately USD 2.75 trillion. The companies in the industry have a list of processes that they follow: design, development, manufacturing, and sales of the vehicle. Everything from the design to the large-scale manufacturing of the vehicle has been made by humans. The development of robots and cobots has changed the labor-intensive manufacturing of vehicles. With more development in robotics, it continues to take over more processes. Building vehicles involves parts manufacturing, body/frame assembly, interior and exterior assembly, mechanical and electrical assembly, and finally inspection along with testing. Most of these steps involve complex and hazardous processes like lifting heavy objects and painting with harmful chemicals.

While it is really hard and time-consuming for humans, robots can complete all the processes faster and more accurately. Lifting heavy objects and working with harmful chemicals don't pose a threat to robots. Since the robots are programmed to follow a set of instructions, they don't miss any process or detail.

2. Research Question and Objective

Research Question

The increasing use of industrial robotics has transformed the automobile manufacturing industry by automating complex production processes such as welding, painting, assembly, material handling, and quality inspection. Although robotics has been widely implemented across automotive manufacturing, there

remains a need to understand the extent to which robotic systems contribute to manufacturing efficiency and other advantages. This study therefore seeks to answer the following research question:

How has the adoption of industrial robotics improved manufacturing efficiency, product quality, worker safety, and cost in the automobile industry, and what role will new technologies play in shaping the future of automotive manufacturing?

Research Objective

To answer the research question, this paper has the following objectives:

1. To examine the evolution of industrial robotics within the automobile manufacturing industry.
2. To identify the different types of industrial robots used throughout various stages of vehicle production.
3. To evaluate the impact of robotics on manufacturing productivity, operational efficiency, product quality, worker safety, and production costs.
4. To compare traditional manufacturing methods with robotic manufacturing using measurable industrial performance indicators.
5. To analyze recent technological developments, including artificial intelligence, collaborative robots, autonomous mobile robots, and additive manufacturing.
6. To discuss the future opportunities and challenges associated with increasing robotic automation in the automotive industry.

3.Research Methodology

This study looks at how robotics is used in the automobile industry and how it has affected vehicle manufacturing. Instead of conducting experiments, the study collects information from academic papers, industry reports, and real-world examples to understand how robotics has improved manufacturing efficiency, product quality, worker safety, and production costs.

The information for this study was collected from reviewed journals, reports published by engineering organizations, and technical documents from robotics companies such as ABB, FANUC, KUKA, Universal Robots, and Kawasaki Robotics. It also uses examples from automobile manufacturers including BMW, Nissan, Ford, Mercedes-Benz, Tesla, and General Motors to understand how robotics is applied in real manufacturing environments.

The collected information was analyzed using four main areas:

- Manufacturing efficiency, including production speed, cycle time, machine availability, and overall factory performance.
- Product quality, including manufacturing precision, consistency, repeatability, and defect reduction.
- Worker safety, including the reduction of hazardous tasks, improvements in workplace safety, and better working conditions for employees.
- Production cost, including labor requirements, maintenance costs, material savings, and the long-term financial benefits of robotic manufacturing.

The numerical data used throughout this paper were collected from published industry reports, manufacturer specifications, and technical documents. Comparison tables were created to show the differences between traditional manufacturing and robotic manufacturing using measurable performance indicators.

This methodology provides an overall understanding of how robotics is currently used throughout the automobile industry and allows comparisons between different manufacturing stages and robotic applications. By combining information from academic research, industrial reports, and real-world examples, this study evaluates how robotics has transformed modern automobile manufacturing.

4. Literature Review

Industrial robotics has evolved and become one of the most highly researched technologies in modern manufacturing due to their ability to improve efficiency, quality, and safety. Many studies and reports have examined the growth robotics automation within the automobile industry.

The International Federation of Robotics (IFR) has stated that the automotive industry continues to be the world's largest adopter of industrial robots. It accounts for approximately one-third of global industrial robot installations. The increasing labor shortages, rising electric vehicle production, and the demand for higher manufacturing quality have accelerated robotic adoption across automotive manufacturing plants.

ABB Robotics has published research which shows that robotic painting systems significantly improve coating consistency while reducing overspray and material waste through electrostatic spraying technologies. These improvements contribute to lower production costs and reduced environmental impact.

Similarly, studies by FANUC and KUKA Robotics have shown that robotic welding systems can achieve higher positioning accuracy and repeatability than manual welding operations. Higher precision reduces defect rates, minimizes rework, and improves overall vehicle quality while increasing production throughput.

Recent studies have also focused on Artificial Intelligence (AI) and Machine Learning (ML) within industrial robotics. AI-powered computer vision systems enable robots to perform automated inspection, detect manufacturing defects, and make production processes better in real time. Manufacturers such as Nissan have successfully integrated AI-assisted inspection systems to improve paint defect detection and overall manufacturing quality.

The development of collaborative robots (cobots) has further expanded the role of robotics beyond fully automated production lines. Unlike widely used industrial robots, cobots are designed to safely work alongside human operators, allowing manufacturers to automate repetitive tasks while maintaining flexibility in final vehicle assembly.

5. Robotics in the automobile industry

Robots have increased efficiency in automobile production drastically by working 24/7, speeding the production a lot. Robots have the benefit of achieving extreme precision and ensure uniform product quality. Antonia Davison, an IBM writer, has mentioned "The auto-industry is going all-in on robotics." According to a 2024 study, the automotive sector has become the number one adopter of industrial robots, making up 33% of all installations in the US last year. The sales in the automotive segment rose by 1% with a record number of 14,678 robots installed in 2023 which came after installations in 2022 which skyrocketed by 47% reaching 14,472 units. "Automotive manufacturers currently invest in robotics mainly to drive the electric vehicle transition and respond to labor shortages," says Marina Bill from IFR(International Federation of Robotics). These numbers show that robotics adoption is driven not only by automation but also by increasing labor shortages, growing electric vehicle production, and the need for higher manufacturing precision. Therefore robotics has become a strategic investment rather than merely a production tool.

6. Types of robots used and their application in the automobile industry.

The use of robotics in the industry has been divided into four main phases: (1) the body shop, (2) the paint shop, (3) the precise component assembly, (4) the final assembly. The phases are worked out in an order where each stage contains a set of processes to be completed. Across the phases a 6-axis articulated robot is used like the M-20iD by FANUC Corporation. This is an industrial robotic arm having six rotary joints that mimic the range of a human arm. This design allows six degrees of freedom (DOF), allowing the robot's end effectors to reach any position and angle within its workspace. An end effector also called End of Arm Tooling (EOAT), is the customizable device attached to the wrist of a 6-axis articulated robot which allows the robot to interact with the environment and to perform any actual work.

2.1 Body shop

In this phase robots cut, weld, and join strong metals. For cutting metal parts, companies like Nissan have replaced the traditional heavy stamping process with a new technology called dual-sided dieless forming to shape and cut complex metal parts. In this technology two synchronized robots work on opposite sides of a steel sheet, molding the metal using diamond coated tools guided by computer programs.

For welding companies like Ford, Mercedes-Benz and Tesla rely on Magna International manufactures. This company joins automotive metal parts like chassis, frames, and body panels. They use advanced automated techniques like laser welding for highly precise welding tasks and cold metal transfer to join lightweight metals. Magna uses robots like KR CYBERTECH nano ARC by KUKA Robotics in its body and chassis plant. For instance, at Magna Presstec in Austria, the facility operates a fully automated production line driven by 45 KUKA robots to weld ladder frames for the Mercedes-Benz G-class. Magna also uses robots like M-710iC/12L by Fanuc across its North American facilities to execute MIG (Gas Metal Arc Welding) and spot welding. Some companies who paint their cars by themselves like Nissan which uses an army of 1,200 synchronized robotic arms to handle up to 95% of the welding. They achieve up to 3,000 welds per vehicle with extreme precision often down to 0.05mm.

2.2 Paint shop

In this phase there are two main stages: applying pre-painting/after-painting coats and the main painting. Car companies like General Motors partner with robotic companies like ABB, Fanuc and Kawasaki to fulfill painting requirements for their vehicles. Robots like the IRB 5500 FlexPainter, designed by ABB, use highly specialized robotic arms equipped with precision atomizers-RB 1000i-S atomizer-that utilizes electrostatic charges and digital path-planning to apply an even, waste-free coat. A switch to robotic painting has been a huge improvement—unlike humans, robots don't phase fatigue, which is common while working with chemicals for long hours, like while painting. Robots result in uniformity and precise material control, avoiding the overspray waste and reducing the cost due to material waste. Industrial paints are highly flammable, so painting robots are built with specialized explosion-proof designs and are operated in pressurized environments to prevent fire.

Robotic painting improves paint transfer efficiency while reducing overspray and worker exposure to hazardous chemicals. These improvements lower material consumption and improve environmental sustainability.

2.3 Precise component assembly

Precise component assembly involves assembling small circuits and parts like the communication network, which requires a lot of microdetailed work. SCARA robots (Selective Compliance Articulated Robot arms) are used for ultra-fast, highly repeatable assembly of small parts. FANUC has a series of SCARA robots (SR-3ia to -20iA), which are designed for high-speed, horizontal assembly, pick-and-place, and packaging. It has payload capacities from 3kg to 20kg and extends from 400mm to 1,100mm. The robots use 2D and 3D vision to identify and align parts and perform precision tasks.

2.4 Final assembly

Robots in the final car assembly handle tasks like installing windshields, windows, seats, etc. Collaborative robots (cobots), autonomous mobile robots (AMRs), and advanced humanoids work alongside human workers for the final assembly.

Cobots use computer vision to install fragile components like windshields and dashboards. They are manufactured by Universal Robots (UR) like the UR3e and UR16e are used widely by many car brands. Ford uses UR10 cobots at their European engine plant to grease camshafts, fill and install engines with oil, and to perform quality inspections. Nissan uses UR10 cobots at their Yokohama plant to assist workers with loosening bolts and installing engine intake manifolds. Bajaj Auto has integrated more than 100 UR cobots to automate their assembly process.

Autonomous Mobile Robots (AMRs) transport seats, doors, and battery packs from the warehouse to the production station. They use advanced sensors, cameras, and AI navigation to transport parts like tools and car components throughout the factories without any human guidance. Conveyor AMRs are docked with stationary assembly lines to pass cars between different production zones. It speeds up the autonomous car manufacturing process.

Although collaborative robots have lower payload capacities than industrial robots, they improve ergonomics and allow flexible human-robot collaboration.

7. Comparative Assembly

Robotics has changed the way vehicles are manufactured. Before robots were widely used, most manufacturing processes depended on human workers. Although skilled workers could produce high-quality vehicles, the work was slower, more physically demanding, and more likely to have small errors. The comparison tables shown in the previous sections highlight the differences between traditional manufacturing and robotic manufacturing. In welding, robots achieve much higher accuracy, lower defect rates, and faster production speeds than manual welding. Their ability to repeat the same movement thousands of times without losing accuracy improves both production quality and efficiency.

Similarly, robotic painting has improved the quality of vehicle finishes, while reducing paint waste and worker exposure to harmful chemicals. Robots apply paint evenly using computer-controlled movements and electrostatic spraying, resulting in better surface quality and lower material consumption. Since robots do not become tired, they can maintain the same level of accuracy throughout the production process.

The use of robotics has also improved worker safety. Dangerous tasks such as welding, painting, lifting heavy parts, and handling hazardous materials are replaced by robots. This has reduced the risk of workplace injuries while allowing workers to focus on supervision, maintenance, and quality control.

Although robotic systems require a large initial investment, they reduce long-term production costs by increasing productivity, reducing material waste, lowering defect rates, and minimizing rework. Their ability to operate continuously also allows manufacturers to produce more vehicles without increasing the size of their workforce.

Overall, the comparison shows that robotic manufacturing provides significant advantages over traditional manufacturing in terms of productivity, quality, safety, and long-term cost efficiency. These improvements have made robotics one of the most important technologies used in modern automobile manufacturing.

8. Future of robotics in the automobile industry

Robotics in the automotive industry are guaranteed to develop as the technology advances. Car brands invest a lot into developing new technology to increase production efficiency. BMW Group is a pioneer in the field of additive manufacturing, better known as 3D printing. 3D printers have been used from as early as 1991 to produce individual vehicle parts and components, initially for concept cars, prototypes and race cars, then later for production models. In BMW's 'Additive Manufacturing Campus' in Oberchleibheim, the central hub for production, 3D printed more than 300,000 parts in 2023 itself. Furthermore 100,00 printed parts were produced across other sites each year. Using 3D printing BMW has also developed a bionic robot gripper which could hold and move the entire floor assembly of the BMW i4. They continue to develop different 3D printing techniques to produce futuristic vehicle designs at a faster pace.

Nissan on the other hand is using AI to perfect its painting process. Nissan uses nearly two gallons of paint on each vehicle during the manufacturing. And with three coats (prime, base and clear), there can be opportunities for imperfection to form on the surface, sometimes even in the most sterile environment. To fix this issue, Nissan has invested in advanced artificial intelligence and machine learning to detect paint flaws faster than ever. Using the AUTIS Surface verification system, Nissan has improved its defect detection rate by nearly 7% at its Tennessee assembly plant. AUTIS uses high-resolution cameras to capture 15,000 pictures of each vehicle immediately after it is painted. "The human eye can spot 85%-95% of the flaws, but AUTIS identifies 98%," said Travis Fritsche, a paint process engineer at Nissan. Other companies are working on AI and ML models which can learn and program the robots by itself without much human programming. This would save a lot of time, since programming, training and testing robots with manually written codes is really time consuming and expensive. Therefore it is seen as an important futuristic goal in the use of robotics in the automobile industry.

9. Challenges and Limitations

Although robotics has changed the automobile industry in many positive ways, there are still few changes that companies have to deal with. Robots increase productivity and improve quality, but they are expensive to buy, install, and maintain. Companies also need skilled workers to program and repair robots, and there are concerns about cybersecurity and job changes. As robotics continues to develop, these challenges need to be solved to make automation more effective.

9.1 High Initial Cost

One of the biggest challenges of using robots is the high cost. Industrial robots, along with the equipment needed to run them, cost a lot of money. Companies also have to spend money on installation, programming, testing, and training workers. Larger manufacturers can usually afford these costs because robots help save money in the long run, but smaller manufacturers may find it difficult to invest in robotic systems.

9.2 Maintenance

Robots need regular maintenance to keep working properly. Parts such as motors, sensors, controllers, and robotic arms can wear out after long periods of use. If a robot suddenly stops working, the production line may also stop, causing delays and increasing production costs. Regular maintenance is needed to reduce these problems and keep the robots working efficiently.

9.3 Cybersecurity

Modern factories connect robots to computers and factory networks so they can share information and work together. While this makes manufacturing more efficient, it also creates cybersecurity risks. If someone gains unauthorized access to the system, they could interrupt production or steal important company data.

Because of this, manufacturers must use secure computer systems and regularly update their software to protect their factories.

9.4 Worker Retraining

As robots take over more physically demanding jobs, workers need to learn new skills. Instead of performing manual tasks, many workers now operate, program, monitor, and maintain robotic systems. Companies must provide training so that workers can adapt to these new technologies. In many factories, collaborative robots (cobots) work together with humans instead of replacing them completely.

9.5 Small and Medium-Sized Companies

Large automobile manufacturers have the money and resources to invest in advanced robotic systems, but this is not always possible for smaller companies. High costs and the lack of trained workers make it difficult for small and medium-sized manufacturers to introduce robotics into their production lines. As robots become cheaper and easier to use, more companies are expected to adopt them in the future.

9.6 Future Challenges

As robots become more advanced with artificial intelligence and machine learning, they will also become more complex. Companies will need better software, stronger cybersecurity, and workers with higher technical skills to manage these systems. Solving these challenges will allow manufacturers to make better use of robotics while improving productivity, quality, and worker safety.

10. Conclusion

This study examined the role of robotics in transforming automobile manufacturing by evaluating their impact on productivity, manufacturing quality, worker safety, and production costs. Through the evidence gathered from industrial reports, manufacturing cases, and performance analysis, robotic systems significantly excels traditional manufacturing technologies when it comes to precision, repeatability, effectiveness and consistency of production.

Robots have transformed all stages of automotive manufacturing – from body production, welding and painting to parts assembly, material handling and quality control. High precision of their continuous operation resulted in higher production capabilities of car manufacturers and also with decrease in defective products, wastes of materials and workplace accidents. The comparison of traditional and robotic manufacturing discussed in the paper clearly demonstrates the positive results that were achieved through automation in industry.

The use of artificial intelligence, machine learning, computer vision, collaborative robots, autonomous mobile robots, additive manufacturing and digital manufacturing systems, which are among the newest technologies, can increase capabilities of automotive robotics.

Although there are many advantages, some problems remain. The high cost of implementation, cybersecurity issues, difficulties in maintenance, workforce training, and the use of robotics in small and medium-sized manufacturers remain the major challenges. Coping with the listed challenges will demand technological advancements, education of the workforce, and proper investments.

To sum up, the current review proves that robotics has gone beyond being only an automation technology and became a helpful asset in the field of automobile industry. The companies which will be able to combine robotics with other smart manufacturing technologies will have an advantage in becoming more productive,

making products of higher quality, ensuring the safety of workers, and succeeding in their business. As Industry 4.0 progresses toward Industry 5.0, robotics will continue to be a key driver of innovation and sustainable growth in automobile manufacturing.

Reference

Bogue, Robert. "The changing face of the automotive robotics industry." *Industrial Robot: the international journal of robotics research and application* 49.3 (2022): 386-390.

Bartoš, Michal, et al. "An overview of robot applications in automotive industry." *Transportation Research Procedia* 55 (2021): 837-844.

Benotsmane, Rabab, László Dudás, and György Kovács. "Survey on new trends of robotic tools in the automotive industry." *Vehicle and automotive engineering*. Singapore: Springer Singapore, 2020. 443-457.

Dassbach, Carl HA. "Industrial robots in the American automobile industry." *Insurgent Sociologist* 13.4 (1986): 53-61.

Devaraj, E., Ismail Kakaravada, and Naveen Kumar. "Robotics, Automation, and Artificial Intelligence's Future in the Automotive Sector." *Integrating Intelligent Control Systems With Sensor Technologies*. IGI Global Scientific Publishing, 2025. 281-310.

Karabegovic, Isak, and Ermin Husak. "Industrial Robot Application in Automobile Industry in Countries of Asia." *International Journal of Computer Science and Artificial Intelligence* 3.3 (2013): 95.

Deng, Yunxue, Xini Chen, and Xin Yong. "Robotics training and workers' attitudes toward robot adoption in China's automotive industry: the moderating roles of techno-insecurity and techno-uncertainty." *Cognition, Technology & Work*(2026): 1-14.

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