

# Advancements and Challenges in Automated Guided Vehicles for Smart Industrial Automation

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## Abstract

*Automated Guided Vehicles (AGVs) are increasingly central to modern industrial automation, enhancing operational efficiency in manufacturing, warehousing, and logistics. Traditionally reliant on fixed paths using magnetic tapes or wired tracks, AGVs were limited in flexibility. However, recent technological advances have enabled the development of autonomous AGVs equipped with sensor fusion, LiDAR, computer vision, and artificial intelligence (AI). These features support real-time obstacle detection, dynamic path planning, and robust performance in complex environments. Integration with Industry 4.0 technologies—particularly the Internet of Things (IoT) and cloud computing has further expanded AGV capabilities, enabling predictive maintenance and remote monitoring through real-time data. Current research is exploring the use of reinforcement learning and swarm intelligence to enhance multi-AGV coordination, energy efficiency, and adaptive task allocation. Despite these advancements, widespread adoption still faces barriers. High implementation and maintenance costs remain a hurdle for small and medium enterprises (SMEs). AGVs also face challenges in adapting to dynamic environments and ensuring secure, reliable connectivity with cloud-based and legacy systems. Additionally, the shortage of skilled personnel to operate and maintain AGVs continues to limit deployment in various industries. Furthermore, ongoing developments focus on improving navigation accuracy through advanced simultaneous localization and mapping (SLAM) techniques and enhanced sensor integration frameworks. The incorporation of edge computing is reducing latency in decision-making processes, enabling faster response times and improved operational safety. Energy optimization strategies, including intelligent battery management systems and automated charging solutions, are also being investigated to extend operational uptime and reduce overall lifecycle costs. In addition, cybersecurity frameworks are being strengthened to protect AGV networks from potential threats and unauthorized access. As industries move toward fully autonomous smart factories, AGVs are expected to play a pivotal role in enabling flexible manufacturing systems, just-in-time delivery, and seamless human-machine collaboration. Continued research and strategic investment will be essential to overcome existing limitations and unlock the full potential of AGVs in next-generation industrial ecosystems.*

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Received Date: January 13, 2026  
Accepted Date: February 25, 2026  
Published Date: March 11, 2026

**Citation:** Mayur Divate, Siddhi Dhulgand, Aditya Lokhande, Niranjan Labhade, Daisy Mudiar, R.A. Advancements and Challenges in Automated Guided Vehicles for Smart Industrial Automation. International Journal of Advanced Robotics and Automation Technology. 2026; 4(1): 1–5p.

**Keywords:** Automated guided vehicles (AGVs), industrial automation, autonomous navigation, sensor fusion, LiDAR, artificial intelligence, Industry 4.0, Internet of Things (IoT), predictive maintenance, swarm intelligence, deep reinforcement learning

## INTRODUCTION

Automated Guided Vehicles also known as AGVs. AGVs are machines that are made to move materials or Objects automatically from one place to another without human help. AGVs helps reduce

human errors and Labour, warehouses, and can be used in Industries like hospitals and Restaurants (Figure 1).

As the Industry 4.0 is being used in many industries with the technologies like automation and Internet of Things (IoT) AGVs are becoming more important in improving industrial processes [1]. AGVs have changed from simple machines that followed fixed paths to systems that can make decisions based on data and instructions with the time [1].

In early Development Phase AGVs were Controlled magnetic tape path, on the floor to guide them. These AGVs helped move goods but required a lot of changes to the factory setup [2–5][7–10]. Over time, AGVs have become smarter and no longer need fixed paths to follow. They can now decide where to go based on sensors and algorithms [2].

Today's Modern AGVs use sensors like LiDAR (a laser-based sensor) and cameras to detect their surroundings. This allows them to move safely and avoid obstacles [2]. These AGVs doesn't need Manual interventions, they navigate following a path that they decide on their own using the data they gather in real time [2, 5,10].

One of the new amazing technologies is Digital Twin technology. This allows us to monitor AGVs from a distance, checking how they are doing and making sure everything is working as it should and we can also monitor the status of the hardware and can predict the maintenance time needed in future based on the "Run Time" This technology helps to avoid mistakes and improves the overall management of AGVs [2, 5, 10].

Modern AGVs are built with object detection systems that are used to detect obstacles in their way. This helps avoid accidents and ensures safety, especially in busy environments with people around [2, 5, 6]. AGVs are becoming more connected with other automated systems with help of IoT (Internet of Things). This means they can share information with other machines, such as robots or conveyor belts, to work better together. It became a lot easier to control and monitor AGVs using Cloud Computing. By using cloud systems, we can track multiple AGVs from one place, making sure everything runs smoothly [2, 5].

## CHANLLENGES

### Technical Challenges:

AGVs need to know exactly where they are now and where the need to go with how to move around safely. They use sensors like cameras, LIDAR, and GPS for this, but these sensors don't always work perfectly [6, 8].



**Figure 1.** AGVs.

For example, if there is poor lighting, dirt, or obstacles in the way, the AGV might get confused and not be able to find its correct path [6]. AGVs can make mistakes, like getting stuck, colliding with objects, or going the wrong way [6, 7, 8]. AGVs have to avoid obstacles like other vehicles, people, or equipment while moving. Detecting obstacles in real-time is challenging, especially in crowded environments [6, 8]. If an AGV can't detect a person walking in its path, it might crash into them. This may cause serious accidents, product damage, or even harm to workers [6].

AGVs run on batteries, and the battery life is limited. They need to be recharged regularly, which can cause delays in operations or we may need more AGVs to operate continuously [8, 9]. If the AGV runs out of battery before completing its task, it will need to go back to the charging station, causing delays. To avoid this if we add more AGVs it becomes very Costly [8]. This can lead to interruptions in work and reduce the AGV's overall efficiency or may affect profits [9].

When there are many AGVs working together, it becomes very hard to make sure they don't crash into each other or cause traffic jams in the workspace [9][6]. AGVs need to know when to stop, go, or change direction to avoid accidents and stay organized [6]. AGVs can block each other, slow down the production, or may cause accidents Because of lack of coordination [11]

### **Cybersecurity Challenges**

AGVs need to collect a lot of data, like their location, tasks, and environment. If this data got leaked, hackers could steal it [11]. A hacker stole data about the AGV's task and inventory, and used it for illegal purpose [11]. This is a serious issue about the companies' safety of important information, financial losses, and can lead to the company's reputation. AGVs depends on wireless communication like Wi-Fi, Bluetooth to Communicate with other machines. These communications are prone to be hacked and hackers could disrupt or change the commands sent to the AGV, causing it to behave unpredictably [11]. If hackers got control of AGVs, they could disrupt operations or cause accidents.

AGVs run on software and firmware that can have bugs or security weaknesses. If hackers find these weaknesses, they can misuse them. An attacker might find a bug in the AGV's software that allows them to control the vehicle or cause it to malfunction [11]. This can lead to AGVs getting hijacked, stopped in the middle of tasks, or causing accidents.

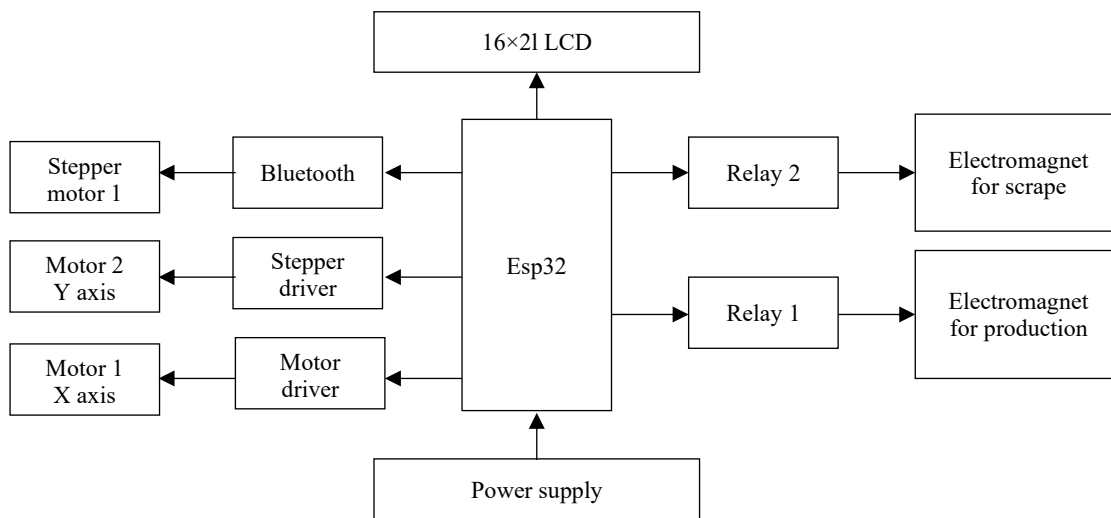
Many factories and warehouses still use older systems that are not designed to work with modern Machineries. That's why integration of these is difficult. Older warehouse management systems might face difficulty in communicating with AGVs, it requires extra software or hardware to make them work together. This can make it harder to manage AGVs and can lead to system failures or inefficiencies [2, 6, 11]. Older systems may have outdated communication protocols that AGVs can't easily connect with [7, 11]. If the AGV needs to send data to an older system using an old protocol like Modbus that doesn't support secure communication, hackers could intercept that data [6, 11]. There could be security risks, delays in information transfer, or errors in how AGVs operate due to poor communication.

Upgrading older systems to be compatible with AGVs is expensive and time-consuming. Many businesses can't afford to replace their old equipment just to accommodate AGVs [1, 8, 9]. To make the legacy system work with the AGVs, the company may need to buy new software, hire experts, and train employees [8]. The integration process can cause delays in getting AGVs up and running, leading to higher costs and lost productivity.

### **FUTURE SCOPE**

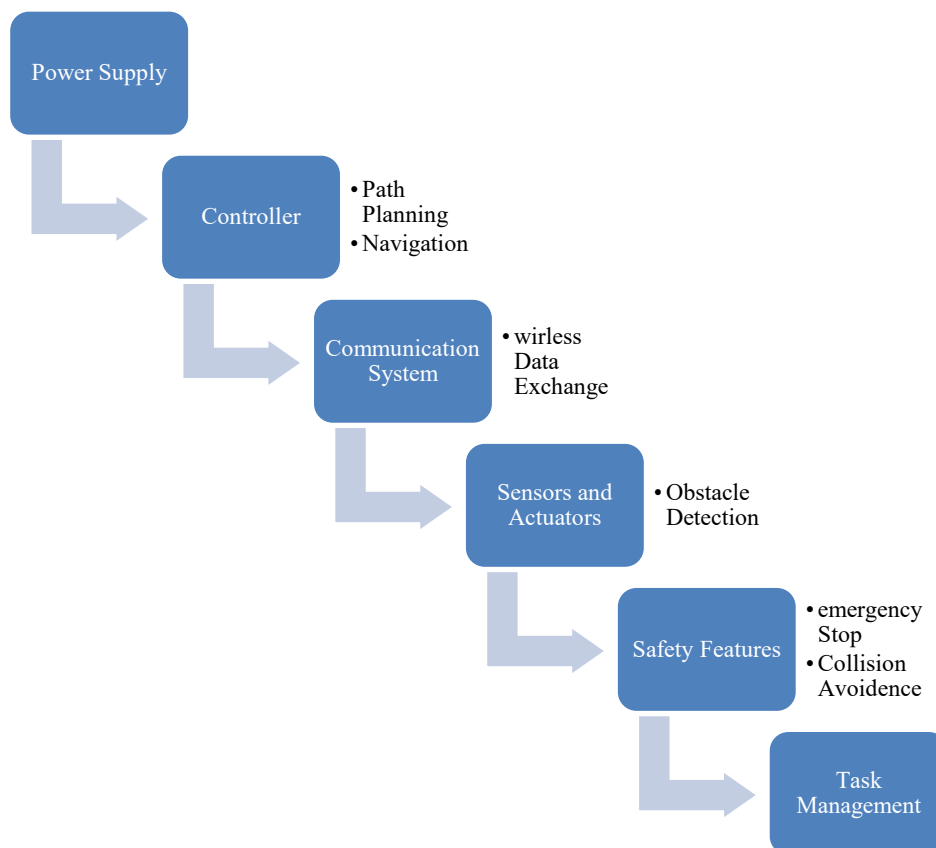
As technology is continuously improving, AGVs are expected to become even smarter. They will be able to handle more complex tasks and work in a variety of environments. Today, AGVs are used in industries like manufacturing and warehousing, but in the future, they may also be used in new areas, such as smart cities or delivery services.

**BASIC NAVIGATION FLOW**



**Figure 2.** Basic navigation flow of an AGV.

**SYSTEM ARCHITECTURE**



**Figure 3.** System architecture of an AGV.

In Autonomous Operation, AGVs will be able to make decisions on their own, with the help of sensors and smart algorithms [11].

Considering safety factor, AGVs will have features to detect obstacles, that helps them to move safely in busy spaces [8].

AGVs can be monitored remotely to improve management and Avoid problems through Digital Twin (Figure 2 and 3) [6].

AGVs can work together with other machines through connected technologies by using IoT [11]. AGVs can be managed easily with the help of cloud systems for better coordination [11].

## CONCLUSION

Automated Guided Vehicles are Upgrading industries by boosting efficiency, reducing labour costs, and improving safety. However, their development faces some challenges:

AGVs need to navigate complex environments, avoid obstacles, limited battery life. Advances in AIs and sensor technology, as well as improved battery solutions, are addressing these issues, making AGVs more efficient and reliable.

AGVs are vulnerable to hacking and data theft. However, stronger encryption, secure communication, and access control systems are being implemented, improving security significantly.

AGVs may face integration issues with some older systems. But new cloud-based solutions and flexible software are making it easier to connect AGVs with existing systems, reducing costs and improving operations.

Despite the challenges, AGVs are becoming smarter, more secure, and easier to integrate. Ongoing technological advancements can produce even greater benefits, making AGVs an essential part of future industrial operations.

## REFERENCES

1. E. A. Oyekanlu et al., "A review of recent advances in automated guided vehicle technologies: Integration challenges and research areas for 5G-based smart manufacturing applications," *IEEE Access*, vol. 8, pp. 202312–202353, 2020, doi: 10.1109/ACCESS.2020.3035729.
2. D. M. Nicolescu and M. J. Mataric, "Natural methods for robot task learning: Instructive demonstrations, generalization and practice," *Autonomous Robots*, vol. 23, pp. 191–205, 2007.
3. "Design and Methodology of Automated Guided Vehicle - A Review," *The International Journal of Robotics Research*, vol. 1, p. 25, 2022. [Online]. Available: ResearchGate.
4. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, e-ISSN: 2278-1684, p-ISSN: 2320-334X.
5. S. E. Sung, K. L. Ng, and Y. C. Yin, "Parallel linkage steering for an automated guided vehicle," *IEEE Control Systems Magazine*, pp. 3–8, Oct. 1989.
6. H.-B. Zhang, K. Yuan, S.-Q. Mei, and Q.-R. Zhou, "Visual navigation of an automated guided vehicle based on path recognition," in *Proc. 3rd Int. Conf. Machine Learning and Cybernetics*, Shanghai, China, Aug. 15–19, 2004, pp. 3877–3881.
7. S. Senoo, M. Mino, and S. Funabiki, "Steering control of automated guided vehicle for steering energy saving by fuzzy reasoning," *IEEE*, pp. 1712–1716, Oct. 1989.
8. R. J. Mentel and H. R. A. Landeweerd, "Design and operation control of an AGV system," *Int. J. Production Economics*, vol. 41, pp. 257–256, 1995.
9. P.-S. Liu and L.-C. Fu, "Planning and scheduling in a flexible manufacturing system using a dynamic routing method for automated guided vehicles," *IEEE*, pp. 1584–1589, 1989.
10. G. Ullrich, "The history of automated guided vehicle systems," in *Automated Guided Vehicle Systems—A Primer with Practical Applications*, Voerde, Germany: Springer, 2014, pp. 4–14.
11. "Cybersecurity challenges in vehicular communications," *Vehicular Communications*, doi: 10.1016/j.vehcom.2019.100214.