

Artificial Intelligence Technology in Smart Logistics: Application Scenarios, Challenges, and Countermeasures

Mingyuan Zhang

(Jiangxi Vocational College of Transportation, Nanchang 330013, China)

Abstract: China is a major manufacturing country, and its logistics industry plays a prominent role as the link between “production and sales.” Against this background, China has increasingly emphasized the development of smart logistics and has successively issued policies such as the Action Plan for Large-Scale Equipment Renewal in Transportation and the Opinions on Accelerating the Construction of Smart Ports and Smart Waterways. Artificial intelligence is the core technology of smart logistics, and its application is crucial for enhancing the intelligence level of smart logistics. Taking the basic functions of the logistics industry as the starting point, this paper discusses the application scenarios of artificial intelligence technology in various logistics functions, including intelligent warehousing, logistics distribution, and intelligent decision-making. Based on the current status of smart logistics and artificial intelligence technology, it analyzes the challenges faced by the application of artificial intelligence technology and corresponding strategies, aiming to fully leverage the application value of artificial intelligence technology and promote the development of the logistics industry toward intelligence and refinement.

Keywords: artificial intelligence; smart logistics, machine learning; logistics sorting; technical challenges

1 Introduction

Smart logistics refers to a modern logistics model that relies on digital and intelligent technical means to carry out refined, dynamic, and intelligent management of all logistics links, so as to enhance the automated operation and intelligent analysis and decision-making capabilities of the logistics system. Data from the China Federation of Logistics & Purchasing shows that in 2024, the total value of social logistics in China reached 360.6 trillion yuan, a year-on-year increase of 5.8%. The rapid development of the logistics industry has imposed requirements on smart logistics. The application of artificial intelligence technology in smart logistics has significantly improved the intelligence level of the logistics system and is of outstanding significance for improving the quality and efficiency of system operation. This paper first elaborates on the specific application scenarios of artificial intelligence technology in smart logistics, and then analyzes the challenges faced in practical application and the countermeasures, for reference.

2 Application Scenarios of Artificial Intelligence Technology in Smart Logistics

The basic functions of the logistics industry can be roughly divided into three categories. The first is the main logistics functions, mainly including transportation, warehousing, and distribution, which constitute the basic framework for the circulation and operation of the logistics industry. The second is auxiliary functions, mainly including packaging, loading and unloading, and circulation processing, whose essence lies in assisting the completion of the main functions. The third is the logistics information management function, which penetrates every link of logistics to build an information integration model for the logistics industry. With the gradual development of smart logistics, the essential functions of the logistics industry have not changed. The application of artificial intelligence technology aims to promote the transformation of the entire logistics function toward automation, intelligence, and high efficiency, and its application can penetrate into the various basic functions of the logistics industry.

2.1 Application of Artificial Intelligence Technology in Main Logistics Functions

2.1.1 Intelligent Warehousing

Intelligent warehousing is the most important application scenario of artificial intelligence technology in the smart logistics industry. According to the China Intelligent Warehousing Market Research Report (2025) released by the AIoT Star Map Research Institute, the logistics warehousing industry has gone through five stages: manual, mechanized, informatized, automated, and intelligent. Under the integrated application of multiple technologies, intelligent warehousing has achieved automation and intelligence in major processes of the warehousing link. Intelligent warehousing includes a large number of hardware and software products. Hardware mainly includes automated warehousing equipment such as stereoscopic warehouses, conveyors, and warehousing robots, while software includes navigation technology, intelligent algorithms, and so on. Among them, the application of artificial intelligence technology penetrates into the underlying logic of intelligent warehousing, realizing the overall upgrade of the warehouse technical architecture and effectively solving the pain points of the logistics warehousing industry, such as high human costs, low picking efficiency, and low space utilization.

First, artificial intelligence improves the intelligence level of hardware equipment. In the automation stage, most links of logistics warehouses had already achieved automation and mechanization, for example, using conveyor belts and robotic arms to complete picking work. In the context of intelligent warehousing, picking, handling, and other work in the warehouse are mainly completed by AGV handling robots. Compared with traditional automated machinery, the outstanding advantage of AGV robots lies in their intelligent operation, guidance, and control systems, which give them path planning capabilities. The planned path is the optimal solution under efficiency requirements, collaboration requirements, and risk avoidance requirements [1]. Path planning includes a number of artificial intelligence algorithms, such as ant colony algorithms and genetic algorithms, to achieve efficient and accurate path planning.

Second, artificial intelligence improves the management level of warehousing space. Intelligent warehousing management covers multiple contents, such as warehousing space optimization and multi-machine coordination. Intelligent management is built on digital twin technology. Relying on digital twins, three-dimensional geographic information, and other technical means, an intelligent and visual twin warehouse system can be constructed to realize comprehensive control and business integration of various warehouse elements. Digital twin technology constructs a real-scene twin scenario of the warehouse in virtual space and relies on the IoT perception layer deployed in the intelligent warehouse to perceive all details, linking with the intelligent control system to achieve remote control and intelligent control.

2.1.2 Logistics Transportation

In the logistics transportation link, the core role of artificial intelligence is to provide more efficient and accurate data and computing power support for the transportation link, and to provide data-driven scientific decision-making for route planning, equipment utilization, and risk avoidance.

Taking intelligent scheduling as an example, in the process of logistics transportation, the high empty-loading rate of trucks and low utilization efficiency are prominent problems. Traditional scheduling systems mainly rely on human subjective experience, which not only makes it difficult to propose optimal solutions, but also makes it difficult to quickly propose reliable solutions in the event of emergencies. The intelligent scheduling system built by artificial intelligence can rely on data analysis to match supply sources with returning empty trucks in real time, thereby improving truck utilization. At the same time, in emergencies such as extreme weather or major traffic accidents, artificial intelligence can achieve dynamic optimization of decision-making. After obtaining climate information and traffic data, it can quickly adjust truck transportation routes and coordinate backup warehouses, thereby improving the response speed of the logistics transportation system to emergencies and effectively ensuring the reliability, efficiency, and safety of logistics transportation.

At present, with the rapid development of the automobile industry, the progress of autonomous driving technology

is remarkable. In the autonomous driving link, artificial intelligence can also play a key role. Relying on various types of data perceived and obtained by the vehicle body and road traffic, intelligent algorithms can efficiently and accurately analyze and predict them, thereby completing intelligent decisions such as route planning and risk avoidance, and transmitting them to the control system to complete intelligent control of the vehicle.

2.1.3 Logistics Distribution

Traditional logistics distribution is highly dependent on manpower, which not only causes high human costs, but also makes distribution efficiency difficult to meet expectations. Unmanned distribution is the main development direction of the logistics industry in this link. Since Starship Technologies launched the first delivery robot in 2016, the unmanned distribution industry has developed faster and faster. At present, tools such as unmanned vehicles and drones are widely used in the terminal unmanned distribution link and have achieved good results. According to estimates by Zhiyan Industry Research Institute, by 2025, the market size of China's unmanned distribution will reach 17 billion yuan.

The development of artificial intelligence technology is an important technical support for making unmanned distribution a reality. In unmanned delivery vehicles, the value of artificial intelligence technology is reflected in path planning, intelligent decision-making, and intelligent scheduling. Taking path planning as an example, the unmanned distribution system needs to comprehensively consider multiple factors in path planning, including traffic conditions, driving speed, weather conditions, environmental factors, and so on. Technologies such as the Dijkstra algorithm, A* algorithm, and genetic algorithm can be used to calculate the most reasonable driving path. For example, the Dijkstra algorithm essentially applies the principle of the greedy algorithm, aiming to find the shortest path to the destination. Considering the complexity of unmanned distribution in practical applications, dynamic programming, multi-objective optimization, and dynamic environmental factors can be further considered on the premise of the basic algorithm [2]. The advantage of dynamic programming is that it takes into account the variability in the distribution process, so the path is divided into multiple stages, and a local optimal solution is selected in each stage. The core of multi-objective optimization is that unmanned distribution must not only consider efficiency, but also factors such as energy consumption and cargo safety. These objectives are integrated into the path planning algorithm to obtain a balanced optimization scheme. Dynamic environmental factors mainly consider changes in environmental conditions during distribution, such as sudden weather changes and sudden traffic control. At this time, the path and distribution strategy can be dynamically adjusted according to real-time environmental data.

2.2 Application of Artificial Intelligence Technology in Auxiliary Logistics Functions

2.2.1 Automatic Packaging

Logistics packaging is a seemingly simple but highly demanding task. Its core requirements are mainly reflected in economy, reliability, and stability. Economy means that on the premise of ensuring the safety and reliability of goods, the amount of packaging raw materials used should be reduced as much as possible. Reliability means that after packaging, the goods should be able to withstand external forces such as collision and extrusion caused by handling, stacking, and transportation throughout the logistics process without serious damage that affects the quality of the goods themselves. Stability requires that the packaging of goods should have good adaptability and be able to meet the requirements of space saving and stable placement in links such as transportation and stacking.

Intelligent packaging equipment developed relying on artificial intelligence technology can help the logistics packaging link meet the core work requirements. First, artificial intelligence can be used to optimize packaging design. With the assistance of machine learning algorithms, artificial intelligence can learn and train from a large amount of packaging data, including packaging material property data, structural data, pressure distribution data, and so on, extract the rules of goods packaging, and thereby optimize existing packaging methods to meet the requirements of economy and reliability. Second, artificial intelligence can be used to provide optimal solutions for cargo transportation and stacking. Artificial intelligence technology can simulate and test different transportation

modes and stacking methods, and analyze the reliability and adaptability of packaging schemes under different packaging methods and stacking methods, so as to achieve the purpose of saving truck/warehouse space and ensuring cargo stability [3]. Third, artificial intelligence can be used to realize monitoring and optimization of the packaging process. With the support of artificial intelligence technology, smart logistics can build a full-process compound operation mode of intelligent packaging, stacking, and handling of goods, and carry out all-factor monitoring of the entire process to identify and diagnose parameter setting problems and equipment failure problems in the packaging line production process, making packaging operations more flexible, efficient, and reliable.

2.2.2 Loading and Unloading

Loading and unloading is an important auxiliary task for goods entering and leaving the warehouse. Mechanized and intelligent loading and unloading equipment is the main path for smart logistics to handle loading and unloading problems. At present, the industry is promoting the research and development of intelligent loading and unloading robots to meet the needs of smart logistics. In the loading and unloading link, the main difficulties faced by intelligent loading and unloading robots lie in three aspects.

First, the operating objects are complex. Different types of goods differ greatly in material, packaging method, stacking method, and so on, which requires the robot to have good adaptability and flexibility to meet the processing needs of different types of goods. Second, operating standards are not unified. Limited by the diversity of truck types and cargo types, the existing loading and unloading operation processes for goods are not unified and standardized, which brings many difficulties to the work of intelligent loading and unloading robots and makes it difficult for them to adapt to changing environments and requirements in actual work. Third, the loading and unloading system occupies too much space. The loading and unloading process has high space requirements. For example, when depalletizing, the robotic arm needs a certain working space to complete depalletizing. However, excessive space occupation not only reduces warehouse utilization but also affects operational efficiency.

In response to the above problems, the solutions proposed by artificial intelligence technology are as follows. First, improve the recognition and dynamic decision-making capabilities of intelligent loading and unloading robots. Relying on image recognition technology, intelligent loading and unloading robots can accurately identify goods with different packaging forms and match them with different stacking methods. The core algorithm emphasizes flexibility of operation rather than following unified stacking rules and standards. Second, improve the environmental perception ability and dynamic adaptability of intelligent loading and unloading robots. Relying on environmental perception technology and recognition technology, artificial intelligence technology can improve the robot's environmental adaptability and meet loading and unloading needs in compact spaces. Combined with intelligent algorithms, the robot has efficient robotic arm cycle capability, making operations more flexible and efficient.

2.3 Application of Artificial Intelligence Technology in Information Management Functions

The value of artificial intelligence in logistics information management is mainly reflected in data-driven intelligent decision support. The construction of full-chain informatization and digitalization of the logistics industry chain has realized the extensive collection and collaboration of logistics information. Massive data resources provide reliable support for artificial intelligence to improve the decision-making ability of the logistics system. Decisions that smart logistics needs to make are happening all the time, from the path planning and business arrangement of a single robot to the scheduling of a logistics route and the order arrangement of a region. All of these can be optimized and upgraded with the support of artificial intelligence.

Artificial intelligence mainly relies on data and algorithm models to make decisions. Relying on the data integrated by the smart logistics system and the data shared after collaboration among upstream and downstream links, artificial intelligence can use algorithms and models to process data and then output the required decision results. Algorithm technology is used to process data. For example, machine learning algorithms can extract features from data and summarize rules; deep learning algorithms can automatically learn complex patterns; and optimization algorithms

can use objective functions to handle a specific goal. Models are used to describe the relationship between data and algorithms. For example, neural network models are used to simulate the neural operation mode of the human brain, thereby making intelligent decisions [4].

The outstanding advantages of artificial intelligence in decision-making are shown in two aspects. First, computing reasoning and prediction capabilities. The basic principle of artificial intelligence in making decisions is to mine the characteristics, internal correlations, and trends of data through data processing and computation, thereby carrying out complex data calculation and logical reasoning. Its algorithms and computing power are powerful and efficient. Artificial intelligence can not only analyze historical data, but also predict according to current fluctuation trends, such as predicting potential risks and possible failures. Second, learning and adaptability. Relying on machine learning and deep learning algorithms, artificial intelligence can complete self-optimization in continuous data training, thereby achieving continuous improvement in performance and accuracy.

3 Challenges Faced by Artificial Intelligence Technology in Smart Logistics

Although the application of artificial intelligence technology in smart logistics is becoming increasingly extensive and in-depth, it still faces certain problems and challenges, prominently manifested as technical challenges, ethical challenges, and market challenges. How to effectively respond to these challenges and maximize the value and advantages of artificial intelligence is a question that must be deeply considered in the development of the smart logistics industry.

3.1 Technical Challenges: Data Bottleneck and Algorithm Defects

In recent years, although artificial intelligence technology has made considerable development and progress, in actual use, artificial intelligence technology has not yet reached public expectations, and the technical level still has considerable room for improvement. The current technical challenges facing artificial intelligence directly point to the core of artificial intelligence operation, namely data and algorithms.

3.1.1 Data Bottleneck

The intelligence level of artificial intelligence is closely related to the quantity and quality of data, but the “blood” of artificial intelligence is facing depletion. According to research predictions published by the research institution Epoch AI, by 2028, the scale of typical datasets used to train AI models will reach the estimated scale of the total amount of public online text. This means that in the near future, artificial intelligence will exhaust available high-quality data. The “data shortage” problem will largely curb the “intelligence” ceiling of artificial intelligence, making it unable to learn and make correct predictions and decisions.

3.1.2 Algorithm Defects

Existing artificial intelligence algorithms have deficiencies in robustness and generalization ability. Although algorithm models can be used to handle specific tasks, such as path planning within a fixed range, when encountering data or environmental changes, calculation deviations or even failures may occur. This greatly limits the flexibility and adaptability of artificial intelligence technology. Algorithm defects largely restrict the further expansion of application scope. For example, in the process of unmanned distribution, if unmanned vehicles or drones encounter complex environmental changes, the algorithm may find it difficult to solve the problem efficiently and accurately.

3.2 Ethical Challenges: Data Security and Algorithmic Bias

In fact, the development and application of artificial intelligence have always been accompanied by huge controversy. This is because artificial intelligence technology has some contradictions and conflicts at the ethical and moral level in operation and use, which makes smart logistics have certain problems and hidden dangers in technology application. Ethical challenges are prominently reflected in two aspects. First, data privacy and security. The operation of artificial intelligence is data-driven. The more data there is, the higher the intelligence level of artificial intelligence will be. However, data application may have privacy and security problems. On the one hand,

when artificial intelligence is trained and used, it may involve some private data. For example, data in the logistics industry includes customers' identity data and consumption data. If such data is used without authorization, it will infringe on customers' privacy rights. On the other hand, the data use process hides security threats. For example, during data storage and circulation, malicious attacks and network intrusions may occur, leading to the leakage and loss of logistics data. Once these private data and commercial data are leaked, they will inevitably cause losses and threats to consumers, enterprises, and others. Second, algorithmic bias and discrimination. In the process of making decisions, the data used for algorithm training by artificial intelligence is not necessarily objective and neutral data. This will cause bias in artificial intelligence algorithms and then output one-sided results that are inconsistent with objective facts. This may not only infringe on the interests of relevant groups, but also violate the basic principle of fairness and justice.

3.3 Market Challenges: Equipment Deployment and Cost Pressure

Although smart logistics is an important trend in the development of the logistics industry, deploying artificial intelligence and intelligent systems and equipment is not only a technical issue, but also needs to be considered from the perspectives of cost and market. At present, many logistics enterprises have a wait-and-see attitude toward smart logistics. The essential reasons are mainly two aspects. First, equipment deployment is difficult. A complete smart logistics system contains many software and hardware devices, such as IoT systems, automated robots, and data centers. The full deployment cycle is long, the investment is high, and subsequent maintenance is also very difficult. Only by carrying out systematic analysis and research and advancing gradually can enterprises realize the transformation of the existing logistics system toward smart logistics. Second, cost pressure is relatively high. The software and hardware costs of smart logistics are high. Taking AGV robots as an example, although the AGV robot market has developed rapidly in the past two years with fierce competition, and more than 180 enterprises in China launched AGV products in 2024, their prices have dropped sharply from 458,000 yuan in 2018. At present, the price has fallen below 200,000 yuan, and some product prices have even dropped to 50,000–60,000 yuan. However, from the perspective of layout scale, the cost of AGV robots alone may reach millions of yuan. At the same time, although the application of artificial intelligence technology can effectively improve the efficiency and quality of logistics system operation, the current return cycle is still relatively long, which does not match the efficiency pursuit of enterprises.

4 Strategies for Responding to the Challenges of Artificial Intelligence Technology in Smart Logistics

4.1 Continuously Optimizing Core Artificial Intelligence Technologies

In response to the data bottleneck problem, the main solution currently proposed by experts and scholars is to explore the application ability of artificial intelligence on unstructured data. Unstructured data mainly refers to data that current artificial intelligence technology cannot directly use, such as unlabeled images, speech, and video. In fact, in addition to the structured data resources suitable for artificial intelligence training, there are still a large amount of unstructured data available for development and use. If artificial intelligence has the ability to use unstructured data, it will effectively solve the “data shortage” problem. In addition, in addition to structured data, annotated synthetic data generated by computer simulation or algorithms can also be used in artificial intelligence training to solve the problem of insufficient data [6].

In response to the algorithm defect problem, the fundamental reason affecting algorithm robustness is still the data problem, that is, the lack of high-quality data to train and optimize algorithms. In addition to enhancing data diversity, model regularization, ensemble learning, and other methods can also be used to improve algorithm performance. Model regularization refers to the use of regularization techniques to prevent model overfitting, thereby improving generalization ability. Ensemble learning refers to combining the prediction results of multiple algorithms to balance the error rate of the algorithm, so as to improve prediction accuracy.

4.2 Mobilizing All Parties to Respond to Ethical Issues

In response to the ethical challenges existing in artificial intelligence, the government, enterprises, and other relevant subjects should take effective measures to respond.

4.2.1 Strengthening the Effectiveness of Data Protection

Data protection requires the joint efforts of both the government and enterprises. On the one hand, the government should issue laws and regulations to constrain data collection and use behavior and effectively protect the public's privacy rights. The Data Security Law of the People's Republic of China and the Personal Information Protection Law of the People's Republic of China, implemented in 2021, have effectively regulated enterprises' data use behavior and safeguarded data privacy and security. On the other hand, enterprises should not only comply with legal and regulatory requirements and strictly constrain their own behavior, but also use technical means to improve data security performance and do a good job in data protection at all links, avoiding potential threats as much as possible.

4.2.2 Adopting Reasonable Means to Eliminate Bias and Discrimination

In response to the problem of algorithmic bias and discrimination, enterprises can focus on three key points to build a fair and transparent algorithm mechanism. First, ensure the quality and fairness of the data itself. The diversity and comprehensiveness of data can be improved through multi-source data collection to achieve balance of positions. Data screening and management can be carried out through data cleaning and processing technology to remove data that may contain bias and discrimination. Third-party data verification can also be introduced to provide stronger guarantees for data quality. Second, improve the transparency of algorithms and avoid using “black box” algorithms. Enterprises or developers can disclose algorithm principles so that the public understands the basic framework and logic of the algorithm and rely on public supervision to avoid bias. They can provide algorithm explanations and bases to increase public trust in the algorithm. They can also integrate rule engines so that users can check decision paths and rules. Third, mobilize other professional forces to jointly optimize artificial intelligence. Enterprises can strengthen cooperation with scientific research institutions and experts and scholars, and jointly participate in the design and development of algorithms and models, so as to consider the ethical issues existing in the practical application of artificial intelligence from multiple dimensions.

4.3 Strengthening Enterprise Cooperation to Explore Solutions

In response to the practical problem of market challenges, logistics enterprises should recognize that the development of smart logistics is the general trend, and gradually promoting technology deployment and equipment layout is a top priority related to the strategic development of enterprises. In this regard, enterprises can reasonably plan the deployment scheme of smart logistics according to their own actual conditions and gradually promote the application of artificial intelligence technology in the industry. At the same time, enterprises can strengthen cooperation with relevant artificial intelligence enterprises to jointly explore solutions that are feasible both technically and economically, realize the optimal allocation of resources, and accelerate the pace of smart logistics layout.

5 Conclusion

With its data processing, analysis, and prediction capabilities, artificial intelligence technology has effectively improved the intelligence level of the logistics industry and promoted the development of the logistics industry toward smart logistics. Artificial intelligence technology has outstanding application value in all links of logistics, but at the same time it also faces certain challenges and problems. The logistics industry should firmly grasp the development trend of artificial intelligence technology, explore artificial intelligence application scenarios, and solve current bottlenecks and problems, thereby promoting the high-quality development of the entire industry.

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