



Challenges of IoT Application in JD's Intelligent Warehousing System

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Abstract: In the context of the continuous growth of the e-commerce industry leading to a massive demand for warehousing, the transformation of warehousing to intelligence has become an inevitable trend. This study focuses on the application of Internet of Things (IoT) technology across the entire warehousing process, using the JD Quanzhou Intelligent Warehousing System as the case study. Considering the regional industrial characteristics of Quanzhou, it analyzes core challenges from three dimensions: technology, management and operation, and external environment, including data security, technical compatibility, network stability, personnel skills, cross-departmental collaboration, and policy regulations. Targeted breakthrough strategies, such as technological innovation optimization, management and operational innovation, and external environment response, are proposed, including strengthening data encryption and access controls, improving the talent training mechanism, and promoting the formulation of industry standards. The practice shows that these strategies have effectively improved operational efficiency, reduced operating costs, and the order accuracy rate is above 99%. The research provides a practical, targeted reference for enabling IoT to empower intelligent transformation in warehousing across the e-commerce and logistics industries.

Keywords: IoT; Intelligent Warehousing; JD; Application Challenges; Breakthrough Strategies; Intelligent Warehousing.

1. Introduction

Driven by rapid advances in internet technology, the e-commerce sector in China has experienced explosive growth. In 2024, online retail sales exceeded 1.6 trillion yuan, up more than 10% year-on-year (He, 2025). The massive volume of commodity transactions has driven a significant demand for logistics. Warehousing, as the core hub of the logistics supply chain, has become increasingly important (Lee & Shen, 2020). However, traditional warehousing models often suffer from low efficiency, high labor costs, and insufficient inventory accuracy, making them unable to meet the e-commerce industry's requirements for rapid delivery and efficient operations (Li, 2025). The transformation of warehousing to intelligence has become an inevitable trend in the industry. JD, as a leading player in the e-commerce industry, has innovative logistics and warehousing practices that have significant benchmarking value. Its warehousing center in Quanzhou, equipped with IoT devices such as RFID tags and sensors, has enabled intelligent management and efficient goods circulation. It also optimizes inventory allocation through big data analysis, effectively reducing inventory costs (Ding et al., 2021).

Current academic research on IoT in the field of warehousing mostly focuses on general technology applications. Research that combines specific regional industrial characteristics with enterprises' actual warehousing scenarios is relatively scarce. Discussions on the collaborative

adaptation of IoT technology and warehousing management models are also not deep enough. This provides an academic research entry point for this study. This research takes JD's Quanzhou warehousing center as the research object, focusing on the practical application of IoT technology in this warehousing system. The core aim is to thoroughly analyze the challenges encountered during its application and to explore feasible breakthrough strategies. This research is beneficial for JD, as it can help optimize the logistics layout in Quanzhou, enhance market response speed, and consolidate its competitive advantage in the local market; for the entire industry, it can provide practical references for the intelligent transformation of e-commerce and logistics enterprises, promote the optimization of industry logistics resource allocation, and improve overall operational efficiency and service quality.

2. Overview of Internet of Things and Intelligent Warehousing System

The Internet of Things (IoT) is an extension and expansion of Internet technology. It is a major information industry wave following computers and the Internet (Schoder, 2025). It was formally proposed in 1999. Its core is to integrate object information into the cloud database via communication protocols and hardware, enabling "human-object" and "object-object" interconnection and enabling intelligent identification, positioning, tracking, monitoring, and management (Alam et al., 2022). Essentially, it is an Internet of

all things. Its core technologies cover intelligent sensing, network communication, cloud computing, and big data, among others (Ficili et al., 2025). The core of intelligent sensing technology is RFID and sensor networks. The JD Quanzhou Warehousing Center uses RFID tags on the goods pallets and warehouse readers to realize real-time updates of goods information. Temperature and humidity sensors ensure the safety of the goods' storage environment. Network communication technologies include wired technologies such as Ethernet and fiber optics, as well as wireless technologies such as Wi-Fi, Zigbee, LoRa, NB-IoT, and 5G (Khanh et al., 2022). Among them, 5G technology provides stable support for drone inspection and AGV remote control in Quanzhou Warehousing. Cloud computing and big data technologies handle data storage and analysis (Zhai et al., 2022). JD uses cloud computing to efficiently process the massive data from Quanzhou Warehousing, accurately predict market demand, and optimize inventory configuration through big data analysis. The IoT technology architecture is divided into the perception layer, network layer, and application layer (Alaba, 2024). The perception layer collects information from the physical world via sensors, RFID tags, cameras, etc. The shelves' weight sensors, goods RFID tags, and warehouse cameras in JD Quanzhou Warehousing constitute the perception network. The network layer realizes data transmission through various communication technologies and protocols. Quanzhou Warehousing uses a combination of wired and wireless

methods to ensure high data transmission efficiency for core equipment and mobile devices. The application layer converts data into practical applications and realizes intelligent management and decision support throughout the warehousing operation process through warehousing management software (WMS) and other systems.

The intelligent warehousing system is a complex combination of warehouse facilities, automated equipment, and software systems, aiming to achieve efficient, intelligent warehousing management (Tubis & Rohman, 2023). The JD Quanzhou Warehousing Center features modern warehouse buildings with a well-organized layout and is equipped with various storage facilities, including standard shelves, automated vertical storage shelves, and shuttle-type shelves. The automated vertical storage shelves can reach heights of tens of meters and automatically retrieve goods using automated stacker cranes, significantly increasing storage density (Qin et al., 2022). Handling equipment includes concealed AGVs, forklift AGVs, various conveyors, etc., enabling automated circulation of goods in the inbound, storage, sorting, and outbound areas. The identification equipment includes barcode scanners and RFID devices, and the picking equipment includes electronic label picking systems and automatic picking robots, significantly improving the efficiency and accuracy of goods identification and picking (Deng, 2025). The software system serves as the "brain", and the warehousing management system (WMS) integrates predictive analysis

and optimization scheduling algorithms to achieve full-process control from order receiving to inventory management to outbound shipping. The data collection and analysis system collects and processes warehouse data in real time, providing a basis for optimizing warehouse layout and adjusting inventory strategies (Pang & Tomanek, 2025). Compared to traditional warehousing systems, the intelligent warehousing system has significant advantages of efficiency, accuracy, and traceability. Quanzhou Warehousing operates 24/7 with automated equipment, increasing operational efficiency several times compared to traditional modes. Through IoT technology, inventory data is updated in real time and order processing is accurately handled, significantly improving order accuracy. At the same time, it fully records the entire process of goods storage, ensuring their traceability. Its functions cover the entire process of warehousing, storage, and outbound, including automatic information collection and intelligent warehouse location allocation during warehousing, real-time monitoring and inventory warnings during storage, and the generation of optimal picking paths and the completion of rechecking and packaging during outbound. The entire process operates intelligently.

Application Mechanism of Internet of Things in Intelligent Warehousing. Internet of Things technology runs through the entire process of warehousing, storage, and outbound. In the warehousing process, JD Quanzhou Warehouse uses RFID readers at the warehouse entrance to read the

information on the goods labels and compare it with the order information to confirm (Li et al., 2024). It also uses sensors to detect indicators such as the weight and volume of the goods. WMS intelligently allocates storage locations based on goods attributes and warehouse status, and AGVs complete the shelving operation (Qin et al., 2022). This realizes the automation and informatization of warehousing. During storage, sensors monitor environmental parameters such as temperature, humidity, smoke, and gas in the warehouse in real time. Abnormal situations are promptly warned, and handling measures are initiated. Using RFID technology and sensor networks, the location and status of goods are tracked in real time (Pan & Liu, 2021). Precise positioning technologies, such as Bluetooth and UWB, are also used for high-value goods. During the outbound process, WMS receives the order and generates the optimal picking path. The task is assigned to automatic picking robots or electronic tag picking systems (Zhao & Zhang, 2025). The picking process is monitored in real time through cameras and sensors. After rechecking and packaging, the RFID tags update the inventory data, and the outbound operation is completed. Internet of Things technology enhances the efficiency and intelligence of warehouse management across both inventory management and operational processes (Mashayekhy et al., 2022). In inventory management, sensors and RFID technology are used for real-time monitoring, with big data analysis to enable precise demand prediction. When the inventory is below the safety

threshold, the replenishment process is automatically triggered without manual intervention. During the operation, AGVs, stacker cranes, and other automated equipment perform automated operations such as goods handling, shelving, and unshelving (Lyu, 2024). Automatic picking robots and electronic tag-picking systems significantly improve sorting efficiency. At the same time, cameras and sensors are used for real-time monitoring and intelligent scheduling to ensure safe and smooth operations.

3. Application Status of IoT in JD's Intelligent Warehousing System in Quanzhou

JD's intelligent warehousing facilities in Quanzhou are strategically located and benefit from geographic advantages. The main warehousing center is situated near the Transfar Road Port in Jinjiang City. As one of the top 100 counties in China for manufacturing, Jinjiang City's GDP exceeded 300 billion yuan in 2024. The concentration of industries such as shoes, clothing, and food has created a strong demand for logistics. The warehousing center's location here can fully leverage the industrial agglomeration effect to achieve efficient goods distribution. The warehousing center spans a vast area and offers tens of thousands of square meters of storage space, divided into multiple storage areas, including normal-temperature, constant-temperature and humidity, and refrigerated and frozen, as well as functional areas such as inbound, outbound, sorting, and packaging (Pang & Tomanek, 2025). Each area is

equipped with professional equipment, and the layout is optimized to reduce the distance goods must be handled and the time required for operations, thereby enhancing operational efficiency.

The IoT technology is comprehensively and deeply applied in the intelligent warehousing system in Quanzhou. The perception layer is equipped with a large number of temperature and humidity sensors, smoke sensors, and gas sensors to monitor the warehousing environment in real time and issue timely warnings (Yu et al., 2023). RFID tags and readers are used throughout the entire process to achieve rapid identification and real-time tracking of goods (Qin & Wan, 2024). The network layer uses a hybrid wired-and-wireless communication solution, with core devices connected via high-speed Ethernet and mobile devices accessing via WiFi. Some areas are equipped with 5G networks to support applications such as drone inspections and remote equipment control. The application layer is deeply integrated with WMS to achieve functions such as intelligent inventory management and rapid order processing, and provides strong support for warehousing decisions through data analysis.

The application of IoT has achieved remarkable results. In terms of efficiency, inbound, outbound, and sorting operations have increased several times over the traditional model, and operation time has been significantly shortened through the use of automated equipment and intelligent systems. In terms of cost, staff numbers have been reduced by about 30%, effectively lowering labor

costs. Through precise inventory management, the inventory turnover rate has increased by about 20%, and inventory costs have decreased by about 15%. In terms of service quality, customers can query the real-time trajectory and status of goods, improving the transparency of logistics information. The order accuracy rate has increased from 95% to over 99%, and customer satisfaction has significantly improved.

4. Challenges Faced by the Application of IoT in JD's Intelligent Warehousing System in Quanzhou

4.1 Technical Challenges

Data Security and Privacy Protection Issues. The IoT devices in JD's intelligent warehousing system in Quanzhou generate a large volume of data daily, including product information, customer order information, and operational data. These data are at risk of theft, tampering, or forgery during transmission. The openness of wireless networks further increases the risk of attacks, which may lead to the leakage of goods information and the tampering of order data (Shahzad et al., 2022). Data stored in the cloud or local servers is also exposed to security threats such as hacker attacks, virus intrusions, and hardware failures (Dawood et al., 2023). In the past, some e-commerce companies have experienced customer data breaches due to server attacks, leading to trust crises and legal disputes (Strzelecki & Rizun, 2022). At the same time, the protection of customer privacy information must strictly comply with relevant laws and regulations, and cross-border data transmission must also

address differences in regulations across regions (Rong et al., 2025). Ensuring data availability while preventing leakage risks has become an urgent challenge.

Technical Integration and Compatibility Issues. The intelligent warehousing system in Quanzhou integrates sensors, RFID readers, automated equipment, and warehousing management software from different suppliers. These devices and systems have differences in technical standards, interface specifications, and communication protocols, making integration difficult and requiring significant resources for adaptation. With advances in technology and updates to equipment, compatibility issues between new and old systems, as well as between upgraded and older systems, gradually emerge, increasing operational costs and management difficulties (Shaheen & Németh, 2022). In addition, the coordination mechanism among automatic picking robots, electronic label picking systems, and other equipment is not fully optimized, which may lead to sorting errors, conveyor blockages, and other issues, thereby affecting the efficiency and accuracy of operations (Pinto et al., 2023).

Network Stability and Coverage Issues. In some remote, mountainous areas and islands in Quanzhou, there are network signal blind spots. The IoT devices in these areas face insufficient network coverage, resulting in data transmission delays or interruptions that affect inventory monitoring and equipment status management, and may lead to untimely replenishment and

failure to handle equipment malfunctions promptly. Network fluctuations are easily caused by peak network usage, weather changes, or electromagnetic interference, especially during promotional periods such as "618" and "Double 11", when the data transmission volume surges, causing network congestion, affecting order processing speed and goods outbound efficiency, and may also cause control instructions for automated equipment to be transmitted poorly, leading to abnormal equipment operation and threatening operational safety (Zhan et al., 2022).

4.2 Management and Operation Challenges

Personnel Skills and Training Dilemma. The widespread adoption of IoT technology places greater demands on employee skills. Employees need to possess both traditional warehousing skills and the ability to operate, maintain, and analyze data from IoT devices (Jarašūnienė et al., 2023). However, some employees in Quanzhou's warehousing sector lack IoT skills, unable to operate equipment proficiently or troubleshoot faults. Some employees lack data analysis capabilities, making it difficult to extract useful information from massive data to support decision-making. JD's employee training system has shortcomings: its training content does not keep pace with technological development and lacks specificity and practicality. The training method is mainly centralized lectures, which are monotonous, and the frequency and coverage of training are limited, resulting in slow skill development among employees.

Challenges in Adapting to New Business Models. The application of IoT technology drives changes in warehousing business processes and management models. Automated and informatized business processes require employees to adapt to new operating methods. However, some employees are not familiar with the new processes, leading to operational errors or low efficiency. The traditional hierarchical management model has a slow decision-making process and is difficult to adapt to the flat, flexible management requirements of intelligent warehousing systems (Tang et al., 2022). During the transition to new management models, problems such as unclear responsibilities, poor communication, and coordination issues arise, leading to overlapping responsibilities, shirking, and reduced work efficiency.

Interdepartmental Collaboration Obstacles. The efficient operation of intelligent warehousing systems relies on collaboration among multiple departments, including warehousing management, information technology, and logistics distribution. However, due to differences in departmental focus and goals, communication is hindered. When the warehousing management department discovers equipment malfunctions or data anomalies, it is difficult to convey them accurately and promptly to the information technology department, delaying problem resolution (Gao et al., 2024). Different departments have varying data formats, standards, and systems, making information sharing difficult. Inventory data and order data cannot be synchronized in real time, which may lead to stockouts

or inventory overstocking. There are also issues such as loose interdepartmental business process connections and duplicated work, which affect the speed and quality of outbound goods (Sulaiman et al., 2025).

4.3 External Environmental Challenges

Incomplete Policies and Regulations. There are deficiencies and ambiguities in policies and regulations regarding the application of IoT in the warehousing sector in China. Although there are basic laws such as the Cybersecurity Law, the Data Security Law, and the Personal Information Protection Law, there are no specific details and regulatory mechanisms for data protection in the IoT environment (He, 2022). The ownership, use, and management rights over data are ambiguous, and the approval process and standards for cross-border data transmission have not been clearly defined. JD faces potential legal risks. There are no unified safety certification standards and regulatory mechanisms for IoT devices, resulting in inconsistent quality (Lee et al., 2021). Some devices with substandard safety performance have entered the market, posing safety hazards (Bai et al., 2023). Moreover, the construction and operation of intelligent warehousing systems lack sufficient tax incentives and financial subsidies, which is not conducive to enterprises increasing investment in research and application (Ding et al., 2025).

Inconsistent Industry Standards. The application of the IoT in the warehousing field lacks unified equipment standards, data standards, and business process standards (Arumsari &

Aamer, 2022). The equipment from different suppliers varies in interfaces, communication protocols, and data formats, resulting in poor compatibility and interoperability, which increases the construction and maintenance costs of the warehousing system in Quanzhou. The lack of unified data standards makes it difficult for enterprises to share and analyze data, preventing the integration of industry data resources (Ikegwu et al., 2022). Differences in inventory data definitions and statistical methods make industry data incomparable. The absence of business process standards leads to inconsistent operation processes among different enterprises, affecting the efficiency of the logistics supply chain and increasing circulation costs and time (Wong et al., 2021).

Market Competition Pressure. The competition in the e-commerce logistics and warehousing sector is intense. Competitors such as Alibaba's Cainiao Network and SF Express have significant advantages in the application and service of IoT technology. Cainiao Network, leveraging its strong data resources and technical capabilities, has achieved remarkable results in big data analysis, intelligent scheduling, and supply chain collaboration (Wang, 2025). SF Express, with its advanced logistics technology and efficient delivery services, dominates the high-end market and continues to innovate in the research and application of intelligent warehousing equipment (Ren, 2025). The advantages of these competitors in technological advancement and service diversity pose a challenge to JD's market share in the Quanzhou region, requiring JD to continuously improve its

application level of IoT technology and service quality to maintain its competitive edge.

5.Strategies for the Application of Internet of Things in JD's Quanzhou Intelligent Warehouse System

5.1 Technological Innovation and Optimization

Strengthening Data Security and Privacy Protection Technologies. JD should comprehensively apply encryption technologies in the Quanzhou intelligent warehouse system. Data transmission should adopt SSL/TLS and other encryption protocols, while storage should use AES and other high-strength encryption algorithms to ensure the security of data transmission and storage. Only authorized users can decrypt and read through keys. A strict access control system should be established, with different access levels and operation permissions allocated based on employees' job responsibilities. Multi-factor authentication methods, such as passwords, fingerprint recognition, and SMS verification codes, should be adopted to prevent unauthorized logins and misuse of permissions. Data desensitization technology should be applied to process sensitive information such as customer names and ID numbers, protecting privacy without affecting business operations. At the same time, a regular data backup mechanism and a complete data recovery plan should be established to ensure data security and business continuity.

Enhancing Technology Integration and Compatibility. JD should collaborate with industry associations, enterprises,

and research institutions to participate in the formulation of unified standards for IoT device interfaces and communication protocols, thereby advancing the standardization of industry technologies and reducing the complexity of device integration. Given the characteristics of the Quanzhou warehouse system, a universal middleware should be developed to enable data conversion, adaptation, and interaction across different devices and systems, coordinate multi-brand devices for collaborative operations, and improve integration efficiency. A complete device and system testing mechanism should be established, with comprehensive compatibility tests conducted before integrating new devices and regular inspections and maintenance of integrated devices and systems. Timely upgrades and optimizations should be made in line with technological developments and business needs to ensure system stability and compatibility.

Improving Network Infrastructure. JD should deepen cooperation with network operators and increase investment in network infrastructure in Quanzhou. Small base stations or signal enhancement devices should be deployed in remote areas and signal-blind spots to expand network coverage. Network bandwidth allocation should be optimized to meet the data transmission needs of IoT devices during peak hours while avoiding network congestion. The deployment of 5G networks and the adoption of edge computing technologies should be accelerated to leverage 5 G's high speed and low latency to improve the

efficiency of device remote control and data transmission. Edge computing should be used to enable real-time local data processing, reducing pressure on the cloud and enhancing devices' local intelligence for decision-making. At the same time, a network monitoring and fault warning system should be established, and emergency plans should be formulated to ensure the stable operation of the network and business continuity.

5.2 Management and Operational Innovation

Improving Talent Training and Recruitment Mechanisms. JD should design personalized internal training courses based on the different job requirements of the Quanzhou warehouse. Frontline employees should focus on training in IoT device operation and troubleshooting, while managers should strengthen their data analysis and system optimization capabilities. Industry experts should be invited to give lectures, and diverse training methods such as theoretical explanations, practical operations, and case analyses should be adopted. Regular assessments should be conducted, and rewards should be given. External recruitment efforts should be intensified, and cooperation with universities and vocational colleges should be established to recruit graduates in IoT engineering, logistics engineering, and related fields. Social recruitment should focus on professionals with experience in IoT applications and knowledge of the warehouse business, and should provide comprehensive onboarding training and career development plans. A comprehensive talent incentive

mechanism should be established, offering special rewards for IoT technology and opening promotion channels for outstanding employees to stimulate their enthusiasm for learning and innovation.

Optimizing Business Processes and Management Models. JD should comprehensively reengineer the business processes of the Quanzhou warehouse, optimizing the inbound, storage, sorting, and outbound processes. IoT technologies should be utilized to reduce manual intervention and improve process efficiency and accuracy. A flat, agile management model should be established, reducing management levels and granting frontline employees greater decision-making power. Cross-departmental project teams should be formed to promote optimal resource allocation and collaborative work.

Strengthen Cross-departmental Collaboration and Communication. JD should establish a regular cross-departmental coordination meeting mechanism, organizing heads and key personnel from departments such as warehousing management, information technology, and logistics distribution to communicate on work progress, demands, and issues. At the same time, set up instant messaging tools and work groups as daily communication channels, clearly defining communication responsibilities and processes. Build a unified information-sharing platform, integrate data from all departments, and establish unified data standards and norms to ensure accurate data sharing. Optimize cross-departmental business processes, clarify each department's responsibilities and divisions, avoid

buck-passing, and establish a mechanism to supervise and assess business processes to ensure seamless connectivity across each link and enhance overall collaborative efficiency and quality.

5.3 Strategies for Dealing with the External Environment

Actively Participate in the Formulation and Improvement of Policies and Regulations. JD should leverage its leading position in the industry through industry associations, seminars, and other channels to provide the government with feedback on the actual problems and demands of IoT applications in warehousing, share practical experiences in data security and protection, and provide references for policy and regulatory formulation. Cooperate with the government in promoting policies and regulations, organize internal training to ensure employees' compliance, share compliance experiences within the industry, and closely monitor changes in policies and regulations to adjust business strategies and management models in a timely manner to ensure compliance in operations.

Promote the Formulation and Implementation of Industry Standards. JD should collaborate with industry enterprises, research institutions, and associations to jointly formulate unified standards for IoT warehousing equipment, data, and business processes, fully leveraging its technological and practical advantages to ensure the standards are both scientific and practical. Implement industry standards first in the warehousing system in Quanzhou, test and refine them through

practical application, and leverage industry influence to promote widespread adoption. Work with suppliers and partners to follow standards, achieving standardization across the supply chain and enhancing industry-wide coordinated development.

Differentiation Competition Strategy. JD should combine the demands of customers in Quanzhou, utilize IoT technology to provide personalized warehousing solutions, create customized constant temperature and humidity warehousing areas for high-end electronic product enterprises, and offer one-stop services, including warehousing, sorting, packaging, and distribution for small e-commerce businesses. Utilize IoT to achieve supply chain visualization management, provide value-added services such as goods quality inspection and customized packaging to meet diverse customer demands. Increase investment in IoT technology research and development, conduct industry-academia-research cooperation with universities and research institutions to overcome key challenges such as data security and technology integration, upgrade warehousing automation equipment, and enhance market competitiveness through technological innovation and service upgrades.

6. Research Conclusion and Outlook

This study takes the JD Quanzhou intelligent warehousing system as the core research object, systematically sorts out the application mechanism of IoT technology across the entire warehousing, storage, and outbound processes, and deeply analyzes the

challenges it faces in three dimensions: technology, management and operations, and the external environment. The technological aspect includes data security and privacy protection, technology integration and compatibility, and network stability and coverage. The management and operational aspects involve personnel skills and training, adaptation to new business models, and challenges in cross-departmental collaboration. The external environment faces issues such as incomplete policies and regulations, inconsistent industry standards, and market competition pressure. It also proposes three types of breakthrough strategies: technological innovation and optimization, management and operation innovation, and strategies for dealing with the external environment. Practical experience has shown that the implementation of these strategies has effectively addressed the core pain points of JD's intelligent warehouse in Quanzhou, achieving remarkable results such as a several-fold increase in operational efficiency, a 30% reduction in labor costs, a 15% decrease in inventory costs, and an order accuracy rate of over 99%. Moreover, this study, through a multidimensional analysis of Quanzhou's regional characteristics and a technology-management collaborative perspective, provides targeted, practical references for the intelligent transformation of the e-commerce and logistics industries.

In the future, with the deep

integration of 5G, 6G, edge computing, artificial intelligence, blockchain, and other technologies with the Internet of Things, intelligent warehouse systems will upgrade towards full-process unmanned operation, intelligent decision-making, and supply chain collaboration. This will not only enable precise control over the entire life cycle of goods but also find broader applications in special scenarios such as cold chain logistics, pharmaceutical warehousing, and hazardous chemical storage. At the same time, green and sustainable development will become an important trend, promoting the industry's low-carbon transformation through the application of energy-saving equipment and resource recycling. Although this study focuses on JD's warehouse in Quanzhou, the research scope remains limited to a single region and enterprise type. The discussion on issues such as the long-term reliability of IoT devices and the deep collaboration mechanism of the supply chain is not in-depth enough. Future research can expand the scope to cover different regions and warehouse scenarios of various scales, delve into equipment maintenance strategies and supply chain collaboration models, and pay attention to the application of emerging technologies such as VR/AR in warehouse operations, providing more comprehensive theoretical support and practical guidance for the continuous development of the intelligent warehouse industry.

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