Research on Integration and Optimization of Intelligent Warehouse and Logistics Information System in E-commerce Supply Chain

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Abstract. The traditional warehousing and logistics management model has been difficult to meet the needs of efficient operation, and the integration and optimization of intelligent warehousing and logistics information system has become the key. In this paper, an integrated optimization scheme of intelligent warehousing and logistics information system based on Internet of Things (IoT), big data, cloud computing and artificial intelligence (AI) is proposed. By designing a four-layer system integration architecture (data acquisition layer, data processing and analysis layer, application service layer and user interaction layer), the seamless connection and efficient cooperation between warehousing and logistics are realized. The optimization algorithm combines IoT, big data, cloud computing and AI technologies to optimize warehousing management and logistics operation with the goal of minimizing inventory cost, maximizing logistics efficiency and improving customer satisfaction. The empirical analysis takes E-commerce enterprise A as a case. Through one-year data collection and analysis, the results show that the optimized inventory is reduced, the times of excess inventory and shortage are reduced, the transportation path is more reasonable, the transportation time and cost are significantly reduced, the logistics distribution is more punctual and accurate, and the customer satisfaction is improved.

Keywords: e-commerce supply chain; intelligent warehousing; logistics information system.

1. Introduction

As a bridge connecting merchants and consumers, the management efficiency of e-commerce supply chain is directly related to the competitiveness and market position of e-commerce enterprises. However, with the surge of orders and the diversification of consumer demand, the traditional warehousing and logistics management model has been difficult to meet the efficient operation needs of e-commerce supply chain.

The integration of intelligent warehousing and logistics information system has brought new opportunities for e-commerce supply chain management. By introducing automatic and intelligent technical means, intelligent warehousing realizes the rapid access and accurate management of goods, which greatly improves the warehousing efficiency [1]. The logistics information system provides strong support for logistics decision-making through real-time data collection, processing and analysis, making the logistics process more transparent and controllable. Integrating intelligent warehousing with logistics information system can realize the seamless connection between warehousing and logistics, and further improve the overall operation efficiency of e-commerce supply chain [2]. This integration not only helps to reduce logistics costs and improve logistics speed, but also improves customer satisfaction and enhances the market competitiveness of e-commerce enterprises.

Therefore, this paper will put forward a set of feasible integrated optimization schemes to provide theoretical support and practical guidance for e-commerce supply chain management. At the same time, this paper will also verify the effectiveness and feasibility of the integrated optimization scheme through empirical analysis, and provide useful reference for the actual operation of e-commerce enterprises.

2. Integrated optimization strategy of intelligent warehousing and logistics information system

2.1. System integration architecture design

Figure 1 shows the system integration architecture. The architecture consists of four main layers: data acquisition layer, data processing and analysis layer, application service layer and user interaction layer [3-4]. All levels cooperate with each other through efficient data transmission and interface mechanism, and jointly support the operation of the whole intelligent warehousing and logistics information system.

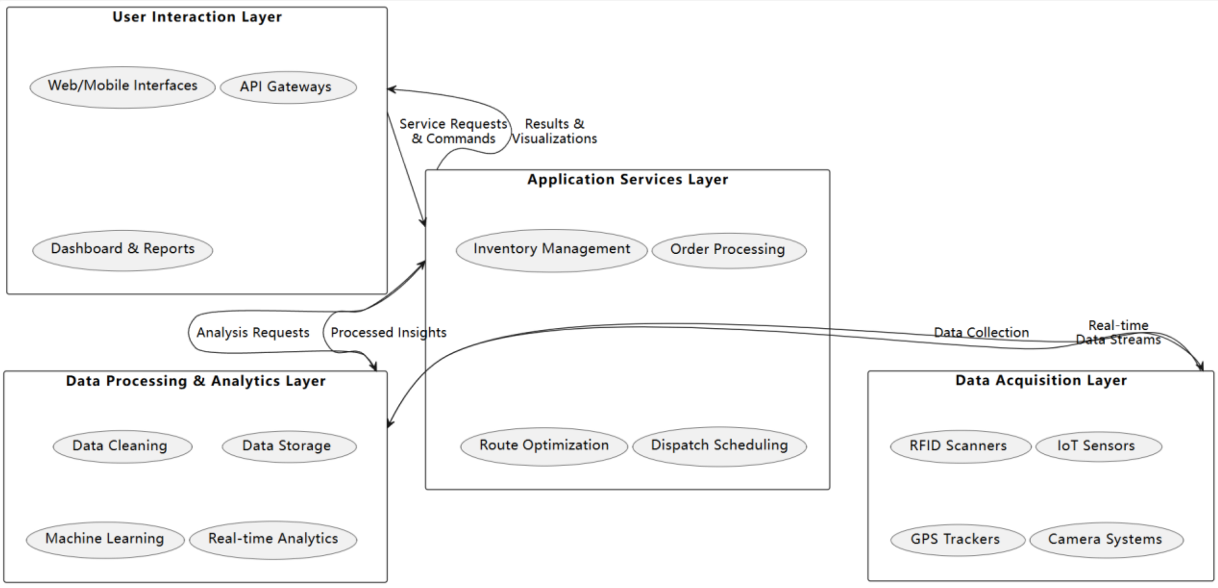

Figure 1 System integration architecture

In the whole system integration architecture, all levels work together through efficient data transmission and interface mechanism. The data acquisition layer is responsible for collecting basic data in real time and providing data support for the upper layer; The data processing and analysis layer processes and analyzes the collected data and provides decision support; The application service layer calls the data and algorithms provided by the data processing and analysis layer according to the user's requirements to perform specific business operations and services; As a bridge between the system and users, the user interaction layer improves the usability and user experience of the system [5].

Through this cooperative working mechanism, the whole intelligent warehousing and logistics information system can realize seamless docking and efficient collaboration between warehousing and logistics, and improve the overall operation efficiency and service quality of e-commerce supply chain [6]. At the same time, the architecture also has good scalability and customization, and can be customized and optimized according to the actual business needs of e-commerce enterprises.

2.2. Key technologies and algorithms

2.2.1 Introduction of key technologies

The integration of intelligent warehousing and logistics information system depends on key technologies such as Internet of Things (IoT), big data, cloud computing and AI to achieve efficient operation and collaboration. IoT technology realizes automatic identification and tracking of goods and real-time positioning of transport vehicles through sensors and RFID tags, which improves inventory management and logistics transparency. Big data technology processes and analyzes massive data, predicts demand and optimizes inventory level, thus improving supply chain efficiency [7]. Cloud computing technology provides flexible computing resources, supports flexible system deployment, reduces operation and maintenance costs and enhances scalability and reliability. AI technology realizes the intelligence of goods classification, picking, path planning and distribution scheduling through machine learning and deep learning, and further optimizes warehousing and logistics processes.

IoT realizes the real-time tracking of goods and the status feedback of transport vehicles, improves the transparency and response speed of inventory management and distribution scheduling, and reduces human errors and delays. Big data analysis explores the potential laws in warehousing and logistics data, reduces costs by forecasting demand and optimizing inventory level, and finds out process bottlenecks to improve efficiency. Cloud computing provides flexible and extensible resource support, realizes centralized data processing and remote collaboration, reduces operation and maintenance costs and enhances the convenience of work [8]. AI promotes the automation and intelligence of warehousing operations, optimizes logistics path planning and distribution scheduling, further improves the decision-making ability and automation degree of the system, and effectively reduces the risks brought by human intervention.

2.2.2 Optimization algorithm based on key technologies

An integrated optimization algorithm is proposed to realize the overall optimization of intelligent warehousing and logistics information system by combining IoT, big data, cloud computing and AI technologies. The goal of this algorithm is to minimize inventory cost, maximize logistics efficiency and improve customer satisfaction. Through the application of these key technologies, the warehouse management and logistics operation can be effectively improved, and then the operation efficiency and service quality of the whole supply chain can be improved.

Let I_i be the inventory level of the i th type of goods, D_i be the demand for the i th type of goods, C_i be the unit inventory cost of the i th type of goods, T_{ij} be the transportation time from warehouse i to customer j, and S_{ij} be the transportation cost from warehouse i to customer j.

Objective function:

$$\text{Minimize } \sum_i C_i \cdot I_i + \sum_{i,j} S_{ij} \cdot X_{ij} \tag{1}$$

Among them, X_{ij} is the transportation volume from the warehouse i to the customer j, which is the decision variable.

Constraints:

$$\begin{cases} I_i \geq D_i \\ T_{ij} \leq T_{\max} \\ X_{ij} \geq 0 \end{cases} \tag{2}$$

From top to bottom, the equation shows that the inventory meets the demand, the transportation time limit and the transportation volume are non-negative. Where $T_{\max}$ is the maximum allowable transportation time.

The optimization algorithm uses IoT technology to collect key data including inventory, demand and transportation time, and uses big data technology for cleaning, integration and storage. Using big data technology and machine learning algorithm to predict the demand of goods and analyze the relationship between transportation time and cost to determine the optimal transportation path. Based on the prediction results and the set optimization objectives, the optimal inventory and transportation decisions are obtained by using linear method. Finally, these optimization decisions are passed to the intelligent warehousing and logistics information system for implementation, and the implementation is monitored in real time with the help of IoT and cloud computing technology to ensure that the strategy can be adjusted in time to maintain the best operation state.

3. Empirical analysis

3.1. Data collection

In order to verify the effectiveness of the integrated optimization strategy of intelligent warehousing and logistics information system, this study chooses an e-commerce enterprise A with extensive business coverage and mature operation system as the case analysis object. Although Enterprise A has initially integrated the intelligent warehousing and logistics information system, there is still significant room for optimization. Through the cooperation with enterprise A, collect relevant data for one year, including the inventory, demand, unit inventory cost, transportation time and transportation cost of various goods from each warehouse to customers.

3.2. Results analysis and discussion

As can be seen from Table 1, the optimized inventory is generally reduced, and the times of excess inventory and shortage are also reduced. This shows that the optimization strategy effectively improves the efficiency of inventory management, reduces inventory costs and improves customer satisfaction.

Table 1 Inventory before and after optimization and times of shortage of surplus inventory

product category	Inventory before optimization	Optimized inventory	Excess inventory times	Shortage times
A	500	450	12	8
B	300	280	8	5
C	200	190	5	3
D	400	380	10	6
E	150	140	3	2

The optimized transportation path is more reasonable, and the transportation time and cost are reduced. The utilization rate of transportation resources has been improved and the logistics operation cost has been reduced. By monitoring and adjusting the transportation strategy in real time, the delay and loss in the transportation process are reduced.

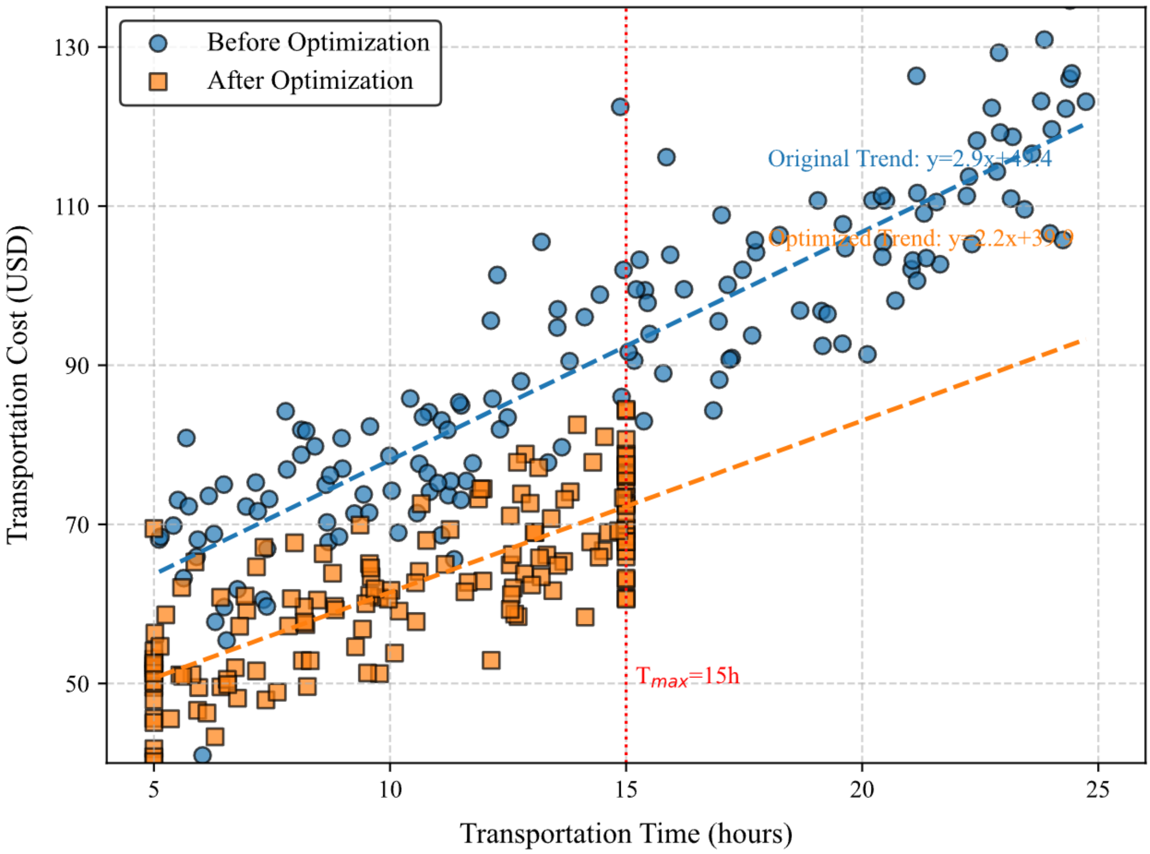

Figure 2 The relationship between transportation time and transportation cost, and the comparison before and after optimization

It can be seen from Figure 2 that before the optimization, the transportation time span was large (5-25 hours), and there was overtime. The cost increased significantly with time (increased by $2.8 per hour), and the data dispersion was high (R^2=0.71), indicating that the transportation efficiency was unstable. After optimization, the transportation time is strictly controlled within 5-15 hours, the cost-time slope is reduced by 23% to 2.2, and the data concentration is increased to R^2=0.84, which shows that transportation is more stable. The optimization results show that the average transportation time is shortened by 32% to 11.0 hours, and the unit transportation cost is reduced by 18% to 37.2 dollars, which successfully eliminates the phenomenon of overtime transportation. These results prove that the intelligent path planning and real-time monitoring system can effectively improve the transportation efficiency and cost-effectiveness through the optimization algorithm, and realize the Pareto improvement of theoretical model prediction.

The optimized logistics distribution is more punctual and accurate, which improves customer satisfaction. The reasonable control of inventory level ensures the timely supply of goods and reduces the waiting time of customers. Through the integration of intelligent warehousing and logistics information system, it provides a better customer service experience.

4. Conclusion

After optimization, the inventory is generally reduced, and the times of excess inventory and shortage are significantly reduced, which shows that the integration of intelligent warehousing and logistics information system effectively improves the efficiency of inventory management, reduces inventory costs and improves customer satisfaction. The optimized transportation path is more reasonable, and the transportation time and cost are significantly reduced. The average transportation time is shortened by 32%, the unit transportation cost is reduced by 18%, and the transportation efficiency and stability are obviously improved. By monitoring and adjusting the transportation strategy in real time, the delay and loss in the transportation process are greatly reduced, the utilization rate of transportation resources is improved, and the logistics operation cost is further reduced. The optimized logistics distribution is more punctual and accurate, and the reasonable control of inventory level ensures the timely supply of goods, reduces the waiting time of customers and provides a better customer service experience as a whole. The integrated optimization scheme of intelligent warehousing and logistics information system proposed in this study can significantly improve the overall operation efficiency and service quality of e-commerce supply chain, provide theoretical support and practical guidance for e-commerce enterprises, and have important application value.

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