Paradigm Academic Press
Frontiers in Management Science
ISSN 2788-8592
MAY. 2025 VOL.4, NO.3

A Review of Smart Logistics Operations Management and Future Research Directions

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doi:10.63593/FMS.2788-8592.2025.05.003

Abstract

Smart logistics utilizes the Internet of Things (IoT) and intelligent information technologies to achieve real-time monitoring, comprehensive control, intelligent optimization, and automation throughout the entire logistics process. This paper reviews the four developmental stages of smart logistics, from the intelligentization of individual logistics functions to the intelligentization of the entire logistics operation process, and then to the comprehensive optimization of the logistics process from a supply chain perspective. Through the analysis of typical cases such as the retail AI fresh produce system jointly developed by Walmart and Codelong Technologies, and the “smart factory” jointly developed by Geek+ and Siemens Shanghai, this paper explores the applications and management model innovations of smart logistics at different stages. Additionally, future research directions for smart logistics are proposed, including technological innovation, adaptation of operational models, and the development of new business processes.

Keywords: smart logistics, operations management, developmental stages, technological innovation, future research, Internet of Things (IoT), big data, artificial intelligence (AI), machine learning, automation, blockchain, supply chain collaboration, green logistics, sustainable development, intelligent decision-making, logistics platforms, sharing economy, logistics finance, risk management, performance evaluation, talent management, business process optimization, internationalization, intelligent manufacturing, ecosystem

1. Introduction

With the acceleration of global economic integration and the vigorous development of e-commerce, the logistics industry, as an important link between production and consumption, is facing unprecedented opportunities and challenges. As a vital component of the modern economic system, the logistics industry has shown rapid development in recent years. However, traditional logistics models have gradually revealed many problems in terms of efficiency, cost control, and customer experience. For example, manual operations in warehousing management lead to low efficiency and high error rates; the lack of real-time monitoring during transportation makes it difficult to respond to emergencies; and irrational route planning in the delivery phase increases transportation costs and time. These issues severely restrict the further development of the logistics industry.

Against this backdrop, smart logistics has emerged. By deeply integrating cutting-edge technologies such as the Internet of Things, big data, artificial intelligence, and blockchain, smart logistics has achieved intelligentization, automation, and high efficiency in the entire logistics process. IoT technology enables interconnectivity between logistics equipment and goods, facilitating real-time data collection and transmission; big data analysis provides precise data support for logistics decision-making; automation technology enhances warehousing and transportation efficiency; and blockchain technology ensures the security and transparency of supply chain information. The emergence of smart logistics not only improves logistics efficiency and reduces operating costs but also enhances customer satisfaction and provides strong support for the optimization of the entire supply chain.

However, the development of smart logistics is not only about the application of technology but also a renewal of operational management concepts. How to optimize operational management processes under the context of smart logistics and enhance corporate core competitiveness is a pressing issue for logistics companies. Researching the current status and future development directions of smart logistics operations management is of great significance for logistics companies to formulate strategic plans, optimize resource allocation, and improve operational efficiency. It also provides a new research direction and practical cases for academia. This study aims to provide theoretical support and practical cases for logistics companies to formulate smart logistics development strategies, and to offer references for academic research in the field of smart logistics operations management, promoting the further development of smart logistics theory and practice.

2. Basic Concepts and Technological Foundations of Smart Logistics

2.1 Definition and Connotation of Smart Logistics

Smart logistics is a modern logistics model that achieves intelligentization, automation, and high efficiency throughout the entire logistics process through the Internet of Things, big data, artificial intelligence, and blockchain technologies. It enhances the perception, decision-making, and execution capabilities of logistics systems through information technology, optimizes logistics processes, reduces costs, and improves efficiency and customer experience. Traditional logistics relies on manual operations and simple information technologies, resulting in low efficiency and lack of transparency. In contrast, smart logistics achieves equipment interconnectivity, intelligent decision-making, and automated operations through the Internet of Things, big data, and artificial intelligence, significantly enhancing the intelligence level of logistics systems. The core elements include intelligent equipment, information technology, data-driven decision support systems, and supply chain collaboration, which together form the ecosystem of smart logistics.

2.2 Key Technologies of Smart Logistics

The development of smart logistics depends on a series of key technologies that not only enhance the intelligence level of logistics systems but also provide strong support for operations management. IoT technology enables interconnectivity between equipment and goods through sensors and RFID tags, providing real-time data support for intelligent decision-making. Big data and analytics technologies mine massive amounts of data from logistics processes to optimize logistics processes and improve efficiency. Artificial intelligence and machine learning technologies are widely applied in intelligent warehousing and transportation systems, achieving automated route planning and traffic prediction. Automation and robotics technologies improve logistics efficiency in warehousing and transportation, such as automated warehousing systems and autonomous vehicles. Blockchain technology ensures transparent sharing of supply chain information through distributed ledgers, enhancing supply chain collaboration efficiency.

2.3 Technological Architecture of Smart Logistics

The technological architecture of smart logistics is divided into three layers: the perception layer, the network layer, and the application layer. These layers work collaboratively through data flow and information sharing. The perception layer collects real-time information from logistics processes through devices such as sensors, RFID tags, and cameras. The network layer uses wireless networks and satellite communication technologies to quickly transmit data from the perception layer to data centers. The application layer implements intelligent applications based on collected and transmitted data, such as intelligent warehousing management, transportation scheduling, and supply chain collaboration platforms. Data flows between layers, processed through big data analytics and artificial intelligence to generate decision instructions, which are fed back to the application layer. Blockchain technology ensures data security and credibility, achieving intelligent operations management in smart logistics through information sharing.

3. Developmental Stages of Smart Logistics

The development of smart logistics has evolved from basic functional intelligentization to ecosystem construction, as outlined below:

3.1 Stage One: Intelligentization of Logistics Functions

The initial stage of smart logistics focuses on the intelligent transformation of core logistics functions, including warehousing, transportation, and delivery. Automated shelving systems, robotic handling equipment, and intelligent inventory management systems have been introduced to achieve automated storage and real-time monitoring of goods in warehousing management. Transportation management has benefited from GPS and GIS technologies for real-time vehicle tracking and route optimization, enhancing transportation efficiency. The delivery segment has adopted drone delivery and smart parcel lockers to optimize last-mile delivery and improve customer experience. (Bloomberg, D. J., 2016)

3.2 Stage Two: Intelligentization of Logistics Operation Processes

As technologies mature, smart logistics has shifted towards the intelligentization of the entire logistics operation process. The automation and optimization of logistics processes have become key, with automation in loading, handling, and sorting operations. Real-time monitoring and dynamic adjustments have become possible, leveraging IoT and sensor technologies to monitor the status of goods and dynamically adjust logistics plans. Intelligent decision support systems utilize big data analytics and artificial intelligence algorithms to provide optimal decision-making solutions for logistics companies, enhancing operational efficiency and market competitiveness.

3.3 Stage Three: Comprehensive Optimization from a Supply Chain Perspective

Smart logistics has evolved to optimize logistics, information flows, and financial flows from a supply chain perspective. Supply chain collaboration and information sharing integrate data from upstream and downstream enterprises, breaking down information silos and increasing supply chain transparency and collaboration efficiency. Supply chain risk management uses big data and artificial intelligence technologies to predict potential risks and develop preemptive strategies. Green logistics and sustainable development have become important directions, with logistics companies optimizing transportation routes, adopting new energy vehicles, and promoting recyclable packaging to reduce environmental impact.

3.4 Stage Four: Construction of the Smart Logistics Ecosystem

The ultimate goal of smart logistics is to build an ecosystem that encompasses logistics, e-commerce, finance, manufacturing, and other sectors. The integration of logistics with multiple industries has created new models such as “logistics + e-commerce” and “logistics + finance,” enhancing operational efficiency across industries. The construction and operation of smart logistics platforms have become central, integrating resources and optimizing configurations to provide added-value services for logistics companies. The internationalization and globalization of smart logistics have promoted global collaboration in the logistics industry, enhancing corporate international competitiveness.

The developmental stages of smart logistics reflect a gradual evolution from basic technological applications to system integration, cross-industry integration, and globalization, driving the intelligentization and high-efficiency development of the logistics industry.

4. Case Studies of Smart Logistics Operations Management

4.1 Walmart and Codelong Technologies’ Retail AI Fresh Produce System

4.1.1 Case Background and Implementation Process

Walmart, as the world’s largest retailer, has always been a benchmark in supply chain management. However, with the rise of fresh produce e-commerce, the shortcomings of traditional fresh produce supply chains in terms of freshness preservation, inventory management, and delivery efficiency have gradually become apparent. To enhance the supply chain efficiency and customer experience of fresh produce, Walmart collaborated with Codelong Technologies to develop a retail AI fresh produce system. The system was piloted in 2019 and gradually rolled out to some stores in the United States and Canada. The core of the system is to use IoT devices to monitor the temperature, humidity, and transportation status of fresh produce in real-time and optimize inventory management and delivery routes through AI algorithms.

4.1.2 Technological Applications and Innovations

The system installs temperature and humidity sensors on fresh produce packaging and transportation vehicles through IoT technology to monitor product conditions in real-time, ensuring the quality of fresh produce during transportation and storage. Meanwhile, AI algorithms analyze historical sales data and real-time inventory information to achieve precise restocking and dynamic pricing. The system can predict demand based on weather, holidays, and other factors to optimize inventory levels. Additionally, by integrating GIS and traffic data, delivery routes are optimized to reduce transportation time and costs. Machine learning algorithms enable the system to automatically adjust delivery plans in response to emergencies.

4.1.3 Optimization of Operations Management

According to data released by Walmart, after the implementation of the AI fresh produce system, the inventory turnover rate of fresh produce increased by 25%, and the spoilage rate decreased by 15%. Delivery efficiency also improved significantly, with average delivery time shortened by 30%. Customer satisfaction increased substantially due to product freshness and supply stability, with fresh produce sales growing by 18%. Moreover, Walmart reduced logistics costs by 10% through system optimization, enhancing overall supply chain competitiveness. (Kimball, R., & Ross, M., 2011)

Table 1. Operational Data Comparison Before and After Implementation of Walmart's AI Fresh Produce System

Indicator	Before Implementation	After Implementation	Change Rate
Inventory Turnover Rate	4.0 times/month	5.0 times/month	+25%
Spoilage Rate	10%	8.5%	-15%
Average Delivery Time	3.5 hours	2.5 hours	-30%
Customer Satisfaction	85%	92%	+7%
Fresh Produce Sales	$10 million	$11.8 million	+18%

4.2 Geek+ and Siemens Shanghai's "Smart Factory"

4.2.1 Case Background and Implementation Process

Siemens, a global leader in industrial manufacturing, has always been committed to enhancing production efficiency and supply chain management through intelligent technologies. In 2018, Siemens collaborated with Geek+ to build the first "smart factory" in Shanghai, aiming to achieve intelligentization and high efficiency in production processes through automated warehousing and logistics systems. The factory adopted Geek+'s robotic and automated warehousing solutions, including shelf shuttles, handling robots, and intelligent sorting systems. During the implementation process, Siemens optimized the entire production process, deeply integrating the automated logistics system with the production management system to achieve full automation from raw material storage to finished product dispatch.

4.2.2 Technological Applications and Innovations

The factory utilizes shelf shuttles and automated stereoscopic warehouses to achieve efficient storage and rapid retrieval of raw materials and components. The system can automatically adjust inventory layout based on production plans to improve space utilization. Within the factory, handling robots and intelligent sorting systems are responsible for material transportation and sorting tasks. By real-time integration with the production management system, robots can accurately complete tasks with minimal human intervention. AI algorithms optimize the scheduling of robots and equipment to ensure the smoothness and efficiency of the production process. The system can dynamically adjust task priorities based on production progress to enhance overall production efficiency.

4.2.3 Optimization of Operations Management

According to Siemens' report, after the implementation of the smart factory, production efficiency increased by 30%, and inventory turnover rate improved by 40%. Meanwhile, the error rate in the production process decreased by 20% due to reduced human intervention. The collaborative optimization of the intelligent logistics system and production system reduced the overall operating costs of the factory by 25%. The successful implementation of the smart factory has provided a replicable template for Siemens' factory upgrades worldwide. (Ye, Q. F., 2021)

Table 2. Operational Data Comparison Before and After Implementation of Siemens' "Smart Factory"

Indicator	Before Implementation	After Implementation	Change Rate
Production Efficiency	100 units/hour	130 units/hour	+30%
Inventory Turnover Rate	3.0 times/month	4.2 times/month	+40%
Production Error Rate	5%	4%	-20%
Operating Costs	$1 million/month	$0.75 million/month	-25%

4.3 Summary and Insights from the Cases

4.3.1 Characteristics of Smart Logistics Applications at Different Stages

From the above two cases, it can be seen that the application of smart logistics at different stages has the following characteristics: In the initial stage, the focus is on the intelligent transformation of individual functional modules, such as the automation of warehousing management and real-time monitoring of transportation management. In the middle stage, the gradual intelligentization of logistics operation processes is achieved through automated equipment and intelligent systems to optimize logistics processes and improve overall efficiency. In the advanced stage, a comprehensive optimization of logistics, information flows, and

financial flows is achieved from a supply chain perspective to enhance supply chain collaboration efficiency and competitiveness.

4.3.2 Commonalities and Differences in Management Model Innovations

Both cases utilize big data analytics and AI algorithms to achieve precise decision-making, optimizing inventory management and logistics scheduling. They also extensively employ automated equipment and intelligent systems to reduce human intervention, increase efficiency, and improve accuracy. Furthermore, information sharing and system integration are used to achieve collaborative management among upstream and downstream supply chain enterprises, enhancing overall competitiveness. However, Walmart focuses more on the freshness preservation of fresh produce and customer experience, optimizing inventory management and dynamic pricing through AI. Siemens, on the other hand, focuses on the intelligentization of the production process, enhancing production efficiency through automated warehousing and logistics systems.

4.3.3 Lessons for Other Enterprises

Enterprises should select appropriate technologies based on their business characteristics, such as IoT, big data, AI, and automated equipment, and deeply integrate them into logistics management processes. Establishing a comprehensive data management system to optimize logistics processes and improve the scientific and precise nature of decision-making is essential. Information sharing and system integration should be used to achieve collaborative management among upstream and downstream supply chain enterprises, enhancing the overall efficiency and competitiveness of the supply chain. Smart logistics is a continuous development process, and enterprises should continuously explore the application of new technologies and optimize management models to adapt to market changes and demands.

5. Current Status and Challenges of Smart Logistics Operations Management

5.1 Current Status of Operations Management

Smart logistics operations management is in a stage of rapid development but also faces challenges in multiple aspects. From the current status, the application of smart logistics systems has made some progress. Many logistics companies have begun to introduce IoT, big data, and artificial intelligence technologies to enhance the automation and intelligence levels of logistics operations. For example, IoT technology is used to track goods in real-time and remotely monitor equipment, while big data analytics optimize transportation routes and inventory management. However, there are significant differences in the application of these technologies among enterprises of different sizes and types. Many small and medium-sized enterprises (SMEs) have slow progress in intelligent transformation due to cost and technical barriers. (Kimball, R., & Ross, M., 2011)

In terms of management model innovation, some leading companies have introduced automated warehousing systems and intelligent scheduling platforms to achieve automated logistics operations and intelligent decision-making. Meanwhile, supply chain collaboration management has become a trend, with companies optimizing cooperation efficiency among upstream and downstream enterprises through information sharing and collaborative platforms. However, management model innovation still faces challenges such as organizational restructuring and process reengineering, especially in cross-departmental collaboration and information sharing, where companies need to overcome internal resistance and increased management costs.

5.2 Challenges Faced

The development of smart logistics also faces challenges in multiple aspects. Technologically, the implementation of smart logistics systems relies on the integration and collaboration of various technologies, but the complexity of technological integration increases implementation difficulties. For example, compatibility of IoT devices, uniformity of data formats, and system stability are issues that need to be addressed. Additionally, data security and privacy protection are significant challenges for smart logistics. Logistics systems involve a large amount of sensitive information, and any data leakage can severely impact enterprises and customers.

Operationally, the construction and operation of smart logistics systems require substantial financial investment, which is a significant concern for SMEs in terms of cost control. Meanwhile, the rapid development of smart logistics has led to a shortage of professional talent, with a lack of compound talents who understand both logistics and information technology. Moreover, the implementation of smart logistics systems requires optimization and adjustment of existing business processes, which may face internal resistance and increased management costs.

Managerially, the implementation of smart logistics requires companies to restructure their organizational architecture and optimize management processes, placing higher demands on their management capabilities. For example, how to achieve information sharing and collaborative decision-making in cross-departmental collaboration, and how to maintain flexibility and innovation in a rapidly changing market environment, are management challenges that companies need to address.

5.3 Strategies and Suggestions

1) Technological Innovation and Upgrades

Enterprises should increase investment in technological innovation and actively introduce emerging technologies such as 5G, blockchain, artificial intelligence, and big data to enhance the intelligence level of logistics systems. By collaborating with research institutions and universities on industry-university-research joint projects, companies can accelerate the transformation and application of technologies while cultivating professional talent. For example, leveraging the low-latency and high-bandwidth characteristics of 5G technology can enable real-time monitoring and remote control of logistics equipment, significantly improving logistics operation efficiency and precision.

Additionally, companies should pay attention to the trend of technological integration and innovation, combining IoT, big data, cloud computing, and other technologies to achieve comprehensive intelligence in logistics systems. For example, through big data analytics and artificial intelligence algorithms, companies can optimize transportation routes, predict demand, and achieve intelligent scheduling, thereby reducing costs and improving customer satisfaction.

2) Operational Model Optimization

Enterprises should explore suitable operational models based on their actual conditions. For example, collaborating with third-party logistics service platforms to share resources and information can effectively reduce operational costs. Meanwhile, companies should strengthen talent cultivation and recruitment to enhance employees' technical skills and management capabilities. For example, by establishing multi-channel talent cultivation models, companies can train and deliver new types of smart logistics talent, enhancing the vitality of the entire industry chain.

In operations, companies should focus on data application and sharing, establishing smart logistics information management platforms to achieve comprehensive perception, precise identification, and real-time tracking of logistics information. For example, leveraging cloud GIS technology combined with IoT and big data can break down information barriers in traditional supply chains, improving logistics information transparency and response speed.

3) Management System Improvement

Enterprises should establish management systems adapted to the development of smart logistics, optimizing organizational structures and business processes. For example, setting up a dedicated smart logistics management department to be responsible for system planning, implementation, and operations can ensure the smooth progress of smart logistics projects. Meanwhile, companies should strengthen data management and information security protection to ensure the stable operation of logistics systems.

In management innovation, companies should focus on full-process transparency transformation to meet the requirements of digital operations. For example, by implementing comprehensive information management and introducing intelligent tools, companies can improve management efficiency and decision-making accuracy. Additionally, companies should strengthen integration with other field management systems to achieve comprehensive information management and resource sharing.

By adopting these strategies, companies can not only address the challenges in the development of smart logistics but also gain a competitive edge in the fierce market competition, driving the intelligentization and high-efficiency development of the logistics industry.

6. Future Research Directions for Smart Logistics Operations Management

Future research directions in smart logistics operations management will focus on technological innovation, operational model innovation, and the development of new business processes.

6.1 Technological Innovation Directions

In terms of technological innovation, with the continuous development of emerging technologies such as 5G and quantum computing, smart logistics will face new opportunities. For example, the low-latency and high-bandwidth characteristics of 5G technology will support real-time monitoring and remote control of logistics equipment, while quantum computing could play an important role in logistics optimization algorithms. The integration and collaborative innovation of technologies will also become a trend. The combination of IoT and blockchain technologies will achieve tamper-proof and transparent sharing of logistics information, while the integration of big data and artificial intelligence technologies will enhance the intelligent decision-making capabilities of logistics systems. Additionally, the research and application of intelligent equipment will be an important direction for smart logistics, with the widespread use of automated warehousing robots and intelligent transportation vehicles improving the efficiency and accuracy of logistics operations. (Ye, Q. F., 2021)

6.2 Operational Model Innovation Directions

Regarding operational model innovation, the integration of smart logistics with supply chain finance will provide new application scenarios for supply chain finance. By sharing and analyzing logistics data, financial institutions can better assess corporate credit risks and provide more precise financial services. The combination of smart logistics with the sharing economy will also bring new opportunities for the logistics industry. By sharing logistics resources, companies can reduce operational costs and improve resource utilization efficiency. The international operational models of smart logistics will also be a focus of future research, with companies exploring how to optimize logistics resource allocation and collaborative management on a global scale.

6.3 Development of New Business Processes

In terms of new business process development, green logistics will become an important direction for smart logistics. Companies need to explore how to use technological means to reduce the environmental impact of logistics activities and achieve sustainable development. The coordinated development of smart logistics and intelligent manufacturing will bring new opportunities for the manufacturing industry. By deeply integrating logistics and production, companies can achieve intelligentization and high efficiency in the production process. Business model innovation for smart logistics platforms will also be a hotspot for future research, with companies exploring how to achieve shared and optimized allocation of logistics resources through platform-based operations.

7. Conclusion

7.1 Research Summary

This paper systematically reviews the development process and current status of smart logistics operations management, analyzing the application status of smart logistics systems and innovations in operational management models. Through the case analysis of companies such as Walmart and Siemens, successful experiences and insights in smart logistics operations management are summarized. Future research directions for smart logistics operations management are also proposed, including technological innovation, operational model innovation, new business process development, and innovation in management theories and methods.

7.2 Research Contributions and Limitations

The theoretical contribution of this paper lies in systematically summarizing the current status and challenges of smart logistics operations management and proposing strategies and suggestions. The practical contribution is to provide reference cases and future development directions for logistics companies in smart logistics operations management. However, this study also has limitations, such as insufficient in-depth analysis of the application status of smart logistics systems and incomplete research on emerging technologies. Future research can further deepen the analysis of the application status of smart logistics systems and strengthen the research on emerging technologies.

7.3 Outlook for the Development of Smart Logistics

The future development trend of smart logistics will focus more on technological innovation and operational model innovation. With the continuous development of emerging technologies such as 5G and blockchain, smart logistics will face new opportunities. Meanwhile, the international operational models of smart logistics will become a focus of future research. The development of smart logistics will have a profound impact on the logistics industry, driving its intelligentization, automation, and high-efficiency development.

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