

Intelligent Last-Mile Delivery Route Optimization in Smart Logistics: Application Value and Development Pathways

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Abstract: As smart logistics continues its digital transformation, last-mile delivery has become the final and most critical link in the logistics service chain. Its operational effectiveness directly affects enterprises' cost-control outcomes and customer service experience. Urban last-mile delivery today is marked by fragmented orders, scattered delivery points, and rigid time requirements. The traditional model, which relies on experience-based route scheduling, suffers from low resource utilization, high delivery costs, and weak dynamic adaptability. It struggles to meet the demands of high-quality modern logistics. To tackle these operational pain points, this paper centers on intelligent optimization of last-mile delivery routes. Drawing on the current state of smart logistics, it examines the diverse application value of intelligent route optimization models, analyzes the practical dilemmas that arise as the industry moves toward intelligentization, and proposes viable long-term development pathways in light of digitalization trends. The goal is to offer practical references for small and medium-sized logistics enterprises as they pursue intelligent upgrading of last-mile delivery, improve route scheduling systems, and enhance both quality and efficiency. In doing so, the study contributes to the standardized, refined, and sustainable development of smart last-mile logistics systems.

Keywords: Smart Logistics; Last-Mile Delivery; Route Optimization; Intelligent Upgrading; Logistics Quality and Efficiency Enhancement

1. Introduction

E-commerce, instant retail, and community delivery have all expanded steadily, pushing China's last-mile logistics delivery industry into

a stage of rapid development. Logistics service scenarios are extending to lower-tier markets, and end customers now expect more in terms of delivery timeliness, service quality, and flexibility. Compared with line-haul transportation and regional distribution, last-mile delivery has its own characteristics: small batch sizes, high frequency, broad coverage, and strong dynamism. It operates in complex road network environments, faces frequent order fluctuations, and must satisfy diverse constraints. As a result, it ranks among the links in the current logistics system with the highest cost proportion, the greatest management difficulty, and the most prominent resource waste [1]. For years, most small and medium-sized logistics enterprises in China have relied on manual experience for last-mile delivery route scheduling. This extensive operational management model has led to frequent problems such as route redundancy, idle capacity, and delivery delays. These problems not only compress profit margins but also constrain the overall digital transformation of smart logistics. The widespread application of digital and intelligent technologies has opened up entirely new solutions for last-mile delivery route optimization. Intelligent route planning and dynamic scheduling—enabled by artificial intelligence, big data, dynamic sensing, and other technologies—have become a core trend in the transformation and upgrading of the logistics industry [2]. Unlike the experience-based model of traditional manual scheduling, intelligent route optimization can leverage data coordination and intelligent iteration to achieve refined route arrangement under multiple constraints. This effectively compensates for the shortcomings of traditional delivery models. At the current stage, technical research on intelligent route optimization within the industry has become relatively mature, but practical implementation varies considerably. Most

enterprises face the problem of "understanding the technology but struggling to implement it," and intelligent equipment and scheduling systems have yet to fully realize their application value [3].

This paper therefore moves beyond the traditional research perspective of algorithm modeling and technical optimization. It focuses instead on the application level of intelligent optimization of last-mile delivery routes. It explores in depth the diverse value of such optimization in enterprise operations, industry development, and service upgrading, systematically examines the practical dilemmas in the current promotion and implementation of intelligentization, and proposes targeted optimization and development pathways in light of industry development trends. The findings can enrich the applied research framework for smart last-mile logistics and provide practical guidance for small and medium-sized logistics enterprises to implement intelligent route scheduling models, achieve cost reduction and efficiency improvement, and refine their operational management systems.

2. Core Application Value of Intelligent Optimization of Last-Mile Delivery Routes under Smart Logistics

2.1 Operational Value: Streamlining Redundant Resources and Reducing Enterprise Delivery Costs

Last-mile delivery costs form a core component of the overall operating costs of logistics enterprises, and unreasonable route planning is a key driver of resource waste and inflated costs. Traditional manual route planning is constrained by subjective experience, information barriers, and limited computational capacity. It cannot achieve coordinated arrangement of delivery nodes across the entire network. This easily leads to repeated detours, reverse deliveries, and imbalanced capacity allocation, resulting in multiple forms of waste in fuel consumption, vehicle wear and tear, and labor hours [4]. Intelligent route optimization, by contrast, leverages big data integration and intelligent scheduling logic. It can comprehensively coordinate diverse constraints including delivery points, road network conditions, vehicle capacity, and order timeliness. On this basis, it selects the most adaptable delivery routes, minimizes ineffective mileage to the greatest

extent, and reduces redundant resource consumption. Intelligent scheduling systems can also evenly distribute vehicle delivery tasks, avoiding localized capacity overload and overall capacity idleness. This substantially improves vehicle turnover rates and labor efficiency. Refined cost control is thus achieved across multiple dimensions—routes, capacity, and manpower—effectively enhancing the profitability of small and medium-sized logistics enterprises.

2.2 Service Value: Stabilizing Delivery Timeliness and Improving Customer Service Experience

In the context of the rapid development of instant retail, delivery timeliness and service stability have become key indicators for measuring the core competitiveness of logistics enterprises. Traditional manual static route planning cannot adapt to dynamic scenarios such as traffic congestion, last-minute order additions, and customer address changes. Delivery timeliness fluctuates considerably, and problems such as order delays and delivery confusion occur frequently, resulting in inconsistent customer service experiences [5]. Intelligent route optimization systems, however, possess real-time data updating and dynamic iteration capabilities. They can capture information on road network changes, order fluctuations, and delivery progress in real time, rapidly complete secondary route planning and task adjustments, and effectively respond to various emergencies in last-mile delivery. This ensures the continuity and timeliness of the delivery process. Stable delivery timeliness can effectively reduce customer complaint rates, enhance customer satisfaction and repurchase intention, help enterprises build a favorable market reputation, and strengthen their competitive advantages.

2.3 Industry Value: Promoting Business Format Upgrading and Facilitating Smart Logistics Transformation

Last-mile delivery is the core focal point in building a smart logistics system, and the intelligent upgrading of route scheduling is an important marker of the digital and refined transformation of the logistics industry. The traditional last-mile delivery model is extensive, low in standardization, and weak in management efficiency, making it difficult to meet the demands of large-scale, high-quality modern

logistics development. Intelligent route optimization breaks away from the traditional operating model dominated by manual experience. It establishes a modern scheduling system driven by data, supported by algorithms, and regulated dynamically, driving the transformation of last-mile delivery from "experience-based operations" to "digital operations" [6]. Intelligent route scheduling can also interface with new business formats such as unmanned delivery devices, smart parcel lockers, and new energy delivery vehicles. This allows it to adapt to diverse last-mile delivery scenarios, helping to build an efficient, green, and intelligent modern last-mile logistics system and promoting the intelligent upgrading and high-quality development of the entire logistics industry.

2.4 Social Value: Practicing Green Logistics and Reducing Urban Traffic Pressure

The disorderly driving and repeated detours of last-mile delivery vehicles not only cause resource waste for enterprises but also exacerbate urban road traffic congestion and exhaust emissions, contradicting the concept of green logistics development. By streamlining redundant delivery routes, intelligent route optimization can effectively reduce ineffective mileage of delivery vehicles, lower fuel consumption and exhaust emissions, and alleviate urban traffic flow pressure [7]. This is particularly true in densely distributed delivery areas such as core urban commercial districts and residential communities. There, intelligent scheduling can rationally plan driving routes and arrange delivery operations during off-peak hours, alleviating localized traffic congestion. It thereby contributes to the development of urban green transportation systems and aligns with the overall trend of green and low-carbon development in the logistics industry under the dual carbon goals. It thus possesses considerable social and ecological value.

3. Practical Dilemmas in Implementing Intelligent Optimization of Last-Mile Delivery Routes

3.1 Weak Digital Foundation of SMEs and Insufficient Implementation Adaptability

The current market entities in China's logistics industry are predominantly micro, small, and medium-sized enterprises. Most small and

medium-sized logistics enterprises have insufficient investment in digitalization and relatively weak infrastructure, which constrains the implementation and application of intelligent route optimization technologies. On the one hand, some enterprises lack a comprehensive data collection system. Basic data such as customer locations, delivery road conditions, and vehicle information are not collected comprehensively or updated in a timely manner, and data quality varies considerably. This makes it impossible to provide accurate data support for intelligent algorithm iteration and route planning, leading to a disconnect between intelligent scheduling solutions and actual delivery scenarios [8]. On the other hand, some enterprises still rely on traditional manual management models. Business processes are low in standardization, and the linkages among order entry, delivery control, and data statistics are chaotic, making it difficult to adapt to the operational requirements of intelligent scheduling systems. As a result, technological implementation adaptability is poor.

3.2 High Costs of Intelligentization and Insufficient Willingness to Invest

Building an intelligent route scheduling system requires supporting software systems, hardware equipment, technical operations and maintenance, and personnel training, with relatively high upfront investment costs. For small and medium-sized logistics enterprises with thin profit margins, this creates certain financial pressure. Most SMEs focus more on short-term operating returns and have insufficient awareness of the long-term value of intelligent upgrading. They worry that investment costs cannot be recovered quickly, exhibiting a wait-and-see attitude of "unwilling to invest and afraid to invest" [9]. At the same time, the operations and maintenance costs of some intelligent scheduling systems are high, and lightweight, low-cost intelligent scheduling products suitable for SMEs are relatively scarce. This further constrains the widespread implementation of intelligent technologies in small and medium-sized logistics enterprises, resulting in a polarized pattern of intelligentization development across the industry.

3.3 Scarcity of Professional Talent Reserves and Insufficient Intelligent Operations

Capability

The implementation and operation of intelligent optimization of last-mile delivery routes require interdisciplinary talent who possess both logistics operations management knowledge and digital technology capabilities. However, the overall educational level and digital literacy of practitioners in the current logistics industry are relatively low. Frontline scheduling personnel and delivery personnel have long relied on traditional operating models and have insufficient understanding of the operation, maintenance, and optimization logic of intelligent scheduling systems. They therefore cannot fully leverage the scheduling advantages of intelligent systems. At the same time, most small and medium-sized logistics enterprises lack professional digital operations and maintenance teams, making it difficult to efficiently carry out system troubleshooting, parameter optimization, and data updating. As a result, intelligent scheduling systems become mere formalities and cannot achieve normalized, refined operations, severely constraining the realization of intelligent optimization outcomes.

3.4 Absence of Industry Standard Systems and Weak Collaborative Scheduling Capability

At present, China's last-mile logistics intelligent delivery industry has yet to develop unified technical standards, data standards, and operational specifications. Data interfaces of intelligent scheduling systems across different enterprises and platforms are not interoperable, and algorithm logic is not unified, making the industry's data silo problem prominent. Logistics enterprises independently carry out intelligent route planning without cross-enterprise, cross-platform collaborative scheduling mechanisms. This makes it impossible to achieve delivery resource sharing, route complementarity, and capacity coordination. It easily leads to the clustering of delivery resources in certain localized areas and capacity gaps in others, making it difficult to leverage the scale advantages of intelligent scheduling. At the same time, industry regulation and incentive mechanisms remain inadequate, enterprise intelligent upgrading lacks effective guidance, and the overall pace of intelligent upgrading across the industry is slow.

4. Long-Term Development Pathways for**Intelligent Optimization of Last-Mile Routes under the Smart Logistics Context****4.1 Consolidating the Digital Foundation and Enhancing Scenario Adaptability**

In response to the weak digital foundation of SMEs, enterprises need to advance digital infrastructure construction in a gradual and orderly manner and establish a comprehensive data collection and management system. By leveraging big data technologies to integrate multidimensional data—including customer addresses, order timeliness, vehicle parameters, and road network information—enterprises can build a dynamically updated delivery database, thereby ensuring the data accuracy and timeliness of intelligent route planning. They should also optimize their internal business processes to achieve standardized, digitalized linkages across the entire workflow—from order entry and task allocation to delivery execution and after-sales feedback—so as to meet the operational requirements of intelligent scheduling systems. In light of the last-mile delivery characteristics of different regions and scenarios, intelligent scheduling parameters should be flexibly adjusted to balance static route planning with dynamic scenario regulation. This enhances the adaptability of intelligent optimization solutions to actual delivery scenarios and effectively realizes the value of technological application.

4.2 Promoting Lightweight Solutions and Lowering the Threshold for Enterprise Upgrading

To address the challenges of high intelligent upgrading costs and low willingness to invest among SMEs, the industry needs to vigorously promote lightweight, low-cost, and easy-to-operate intelligent route scheduling solutions. Technology companies can tailor their approach to the operational characteristics of small and medium-sized logistics enterprises. They can simplify redundant functions of intelligent scheduling systems and develop lightweight intelligent planning tools suitable for micro and small enterprises, thereby reducing costs for hardware procurement, system deployment, and subsequent operations and maintenance. At the same time, the government can introduce targeted support policies, providing financial subsidies, policy support, and technical guidance for the digital and intelligent upgrading of small

and medium-sized logistics enterprises. This alleviates their financial pressure and stimulates their enthusiasm for intelligent upgrading. Through a lightweight implementation model, low-cost, high-efficiency intelligent transformation can be achieved, promoting the widespread application of intelligent route optimization technologies among small and medium-sized logistics enterprises.

4.3 Strengthening Talent Cultivation and Enhancing Intelligent Operations Capability

Interdisciplinary talent is the core support for the intelligent upgrading of last-mile delivery, and enterprises and the industry need to collaboratively advance the development of a talent cultivation system. Enterprises should routinely conduct digital skills training for employees, offering specialized training in intelligent system operation, digital management, and intelligent scheduling logic for scheduling personnel, management personnel, and delivery personnel. This transforms employees' traditional operational mindset and enhances the digital literacy of the entire workforce. Enterprises should also strengthen university-enterprise cooperation with higher education institutions and vocational colleges to cultivate interdisciplinary talent in logistics management and digital technology through targeted programs, thereby reinforcing their intelligent operations teams. Professional operations and maintenance teams should be established to handle system optimization, data updating, and troubleshooting, ensuring the efficient and stable operation of intelligent route scheduling systems and maximizing the effectiveness of intelligent optimization.

4.4 Improving Industry Standards and Building a Collaborative Scheduling System

Industry regulatory authorities and industry associations need to accelerate the development of a standards system for intelligent last-mile delivery, unifying data interfaces, algorithm specifications, operational standards, and service specifications. This breaks down industry data silos and achieves cross-enterprise, cross-platform data interoperability and resource sharing [9]. A regional collaborative scheduling platform for last-mile delivery should be established to integrate the capacity resources and delivery point resources of logistics enterprises within the region. Such a platform

enables multi-enterprise collaborative route planning, capacity sharing, and route complementarity, reducing redundant deliveries and resource waste and enhancing overall regional last-mile delivery efficiency. At the same time, industry regulation and incentive mechanisms should be established and improved to guide enterprises in conducting intelligent upgrading in a standardized manner, driving the last-mile delivery industry toward high-quality development in the direction of standardization, intelligentization, collaboration, and greening [10-12].

5. Conclusions and Outlook

5.1 Research Conclusions

Against the backdrop of smart logistics transformation, intelligent optimization of last-mile delivery routes is an inevitable trend for logistics enterprises to enhance quality and efficiency and for the industry to transform and upgrade. This paper systematically examines the diverse application value of intelligent optimization of last-mile delivery routes in enterprise cost control, customer service upgrading, industry business format transformation, and green logistics development, clarifying the significance of intelligent optimization for the high-quality development of last-mile logistics. It also provides an in-depth analysis of the practical dilemmas currently encountered by small and medium-sized logistics enterprises in implementing intelligentization, including weak digital foundations, high upgrading costs, a shortage of professional talent, and the absence of industry standards. In response to these development challenges, this paper proposes long-term development pathways suited to industry development from four dimensions: infrastructure construction, cost control, talent cultivation, and industry standardization. The research demonstrates that only by continuously consolidating the digital foundation, lowering the threshold for enterprise upgrading, strengthening talent support, and improving the industry collaboration system can the application value of intelligent optimization of last-mile delivery routes be fully realized, thereby driving the refined, intelligent, and green upgrading of the last-mile logistics system.

5.2 Research Outlook

This paper conducts research on intelligent optimization of last-mile delivery primarily from the perspectives of application value and development pathways, with a focus on industry status analysis and countermeasure exploration. Future research can incorporate emerging business formats such as new energy delivery vehicles and unmanned delivery devices to further explore intelligent route optimization application models under multi-scenario integration. By combining multi-objective constraints such as low carbon, timeliness, and cost, a more comprehensive and adaptable intelligent development system can be constructed. Differentiated intelligent upgrading pathway research can also be conducted in light of the last-mile delivery characteristics of different cities and regions, providing more comprehensive theoretical support and practical references for the refined, high-quality development of smart last-mile logistics.

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