

Research on Logistics Distribution Route Optimization Based on Artificial Intelligence Technology

Qirou Lu, Guohua Cheng*

*School of Digital Economy and Management, Guangdong University of Science and Technology,
Dongguan, Guangdong, China*

**Corresponding Author*

Abstract: The vigorous development of the e-commerce industry has driven the rapid iteration of logistics last-mile distribution systems. Current logistics distribution exhibits characteristics of multiple delivery points, fragmentation, and high timeliness requirements. The drawbacks of traditional route planning models dominated by manual experience have become increasingly prominent, including insufficient planning scientificity, redundant routes, poor dynamic adaptability, and high operational costs, making it difficult to meet the demands of smart logistics development. To address these industry pain points, this paper takes artificial intelligence technology as its research vehicle, systematically analyzes the existing deficiencies in traditional logistics distribution route planning, and, by integrating the technical advantages of AI in data processing, global optimization, and dynamic iteration, constructs a route optimization system suitable for small and medium-sized logistics enterprises, proposing targeted intelligent optimization solutions. The research demonstrates that artificial intelligence technology can effectively compensate for the shortcomings of traditional manual scheduling, achieve standardized, refined, and dynamic distribution route planning, significantly improve logistics distribution efficiency, reduce enterprise operational costs, and provide theoretical reference and practical basis for the intelligent transformation of the logistics industry.

Keywords: Artificial Intelligence; Logistics Distribution; Route Optimization; Intelligent Scheduling; Smart Logistics

1. Introduction

In recent years, China's e-commerce,

community group buying, and instant express delivery industries have continued to grow at a high rate, with online consumption scenarios continuously expanding to lower-tier markets, driving the sustained expansion of last-mile logistics distribution business scale [1]. Compared with traditional trunk-line logistics transportation, urban last-mile logistics distribution at the current stage exhibits distinctive characteristics of small batch sizes, high frequency, broad coverage, and high timeliness requirements. Distribution customer points are scattered, order dynamics fluctuate significantly, and distribution constraints are numerous, imposing higher demands on the scientificity and precision of route planning [2]. Against the backdrop of industry transformation and upgrading, the traditional extensive manual distribution scheduling model can no longer adapt to the operational needs of modern logistics, and many small and medium-sized logistics enterprises commonly face operational challenges such as unreasonable distribution routes, wasted transportation resources, and relatively low overall operational efficiency [3]. At present, the last-mile distribution route planning of most small and medium-sized logistics enterprises in China still relies on the subjective experience of dispatchers, lacking systematic, standardized, and intelligent planning methods [4]. Manual planning is affected by factors such as personal experience, subjective judgment, and energy limitations. When facing complex distribution scenarios with multiple nodes and large coverage areas, it cannot comprehensively coordinate multiple factors such as road traffic conditions, point distribution, delivery sequence, and transportation costs, making various planning problems highly prone to occur [5]. Long-term unreasonable route arrangement not only increases invalid vehicle mileage and escalates fuel and labor costs but also leads to chain

problems such as delivery delays and degraded customer service experience, severely constraining the profitability and market competitiveness of logistics enterprises [6]. Therefore, introducing artificial intelligence technology to innovate traditional route planning models, resolve existing pain points in distribution routes, and achieve quality and efficiency improvement in logistics distribution systems carries important practical significance and application value.

Artificial intelligence technology, with its powerful data analysis, global coordination, intelligent iteration, and autonomous optimization capabilities, can efficiently handle complex optimization problems involving multiple variables and constraints, and can precisely adapt to the scenario requirements of logistics distribution route optimization. Based on this, this paper, grounded in the current development status of the logistics distribution industry, focuses on prominent problems in distribution route planning, relies on artificial intelligence technology to construct a novel route optimization scheme, elaborates on the application logic and implementation path of AI technology in logistics route optimization, and provides theoretical support and practical ideas for small and medium-sized logistics enterprises to achieve intelligent scheduling, optimize distribution systems, and reduce operational costs.

2. Main Problems in Current Logistics Distribution Route Planning

2.1 Strong Subjectivity and Insufficient Scientificity in Route Planning

Currently, the distribution route planning of small and medium-sized logistics enterprises is mostly completed independently by manual labor, without the support of a standardized planning system, resulting in strong subjectivity and arbitrariness. Dispatchers typically arrange delivery sequences based on familiar road segments and habitual driving routes, without conducting overall measurement and coordinated planning of the spatial distribution, road distances, and traffic efficiency of all delivery points. In simple scenarios with a small number of delivery points and concentrated distribution areas, the manual planning model can basically meet distribution needs. However, when facing complex distribution scenarios

involving large urban areas, multiple points, and cross-road segments, the shortcomings of manual planning are fully exposed, making problems such as chaotic delivery sequences, unreasonable arrangement of primary and secondary points, and route crossing and detours highly prone to occur, and the overall planning scheme lacks scientificity and rigor [7].

2.2 Severe Distribution Route Redundancy and Relatively High Operational Costs

The inability of the manual experience planning model to achieve global optimal route selection is the core reason for distribution route redundancy. Manual scheduling can often only consider the convenience of local road segments, making it difficult to coordinate the overall distribution network, and frequently resulting in invalid transportation such as repeated driving, long-distance detours, and reverse distribution. A large number of redundant road segments directly increases total vehicle mileage, which not only elevates hard transportation costs such as fuel consumption, vehicle wear, and road and bridge tolls but also increases the working hours and labor costs of distribution personnel [8]. For small and medium-sized logistics enterprises with already thin profit margins, long-term waste of invalid transportation resources greatly compresses their profit space, which is not conducive to their normal and stable operations.

2.3 Weak Dynamic Response Capability and Unstable Distribution Timeliness

Logistics last-mile distribution is highly dynamic, with sudden situations such as temporary order additions, customer address changes, road congestion, and temporary road segment control commonly occurring in daily operations. The traditional manual planning model is a static planning approach with extremely poor overall flexibility and dynamic adaptability. After completing initial route planning, dispatchers find it difficult to quickly adjust distribution routes according to real-time scenario changes. When facing sudden situations, they can often only rely on improvised adjustments, which easily leads to problems such as chaotic distribution order, overdue orders, and cargo accumulation, resulting in unstable distribution timeliness and persistently high customer complaint rates, severely affecting the service reputation and market competitiveness of logistics enterprises.

2.4 Insufficient Resource Coordination Capability and Low Distribution Efficiency

Logistics distribution route optimization is not merely a route selection problem but also a problem of coordinated allocation of vehicle resources, human resources, and order resources. Limited by the data processing capacity of the human brain, the manual planning model cannot simultaneously consider multiple constraints such as vehicle load capacity, vehicle quantity, order priority, and customer timeliness requirements, making problems such as wasted vehicle capacity, delayed delivery of high-priority orders, and imbalanced capacity allocation prone to occur [8]. Some vehicles have excessively concentrated distribution tasks and complex routes, while others have idle capacity, resulting in an overall imbalance in resource allocation. Consequently, the work efficiency of the entire distribution team cannot be maximized, and the overall operational efficiency of the logistics distribution system remains relatively low.

3. Feasibility Analysis of Applying Artificial Intelligence Technology to Route Optimization

3.1 Powerful Data Processing and Global Coordination Capabilities

Compared with the limited information processing capacity of humans, artificial intelligence technology possesses advantages in rapid processing of massive data and integrated analysis of multi-dimensional information. In the logistics route planning process, AI technology can automatically collect and organize multi-dimensional data such as distribution point coordinates, road traffic conditions, distance parameters, and timeliness requirements. Through algorithmic models, it conducts global coordinated analysis of all distribution nodes, abandoning the one-sidedness and subjectivity of manual experience, selecting optimal driving routes from the perspective of the overall distribution network, thoroughly resolving the problems of one-sidedness and unscientificity in manual planning, and ensuring the globality and rationality of route planning [9].

3.2 Excellent Complex Scenario Adaptability

Artificial intelligence algorithms possess extremely strong robustness and adaptability,

capable of efficiently handling complex combinatorial optimization problems involving multiple constraints and variables. Facing the current complex scenarios of logistics distribution characterized by multiple points, broad distribution, and dynamism, AI algorithms can rapidly screen optimal distribution schemes from massive feasible routes through iterative optimization mechanisms, effectively avoiding the problems of route redundancy and severe detours in traditional planning models, precisely adapting to the complex distribution scenarios of modern logistics, and compensating for the shortcomings of traditional manual planning and basic mathematical programming methods

3.3 Efficient Dynamic Adjustment and Real-time Optimization Capabilities

Artificial intelligence technology supports real-time updating of dynamic data and rapid iteration of schemes, possessing dynamic response capabilities unmatched by manual planning. When sudden situations such as new orders, road congestion, or road segment control occur during the distribution process, the AI system can update scenario data in real time, quickly re-iterate calculations, and immediately adjust distribution sequences and driving routes, achieving dynamic optimization of route schemes, effectively ensuring distribution timeliness, and enhancing the flexibility and stability of logistics scheduling.

4. Logistics Distribution Route Optimization Scheme under Artificial Intelligence Technology

4.1 Construction of a Standardized Route Planning System Based on AI Algorithms

To address the problems of strong subjectivity and lack of standards in traditional manual planning, this paper relies on artificial intelligence algorithms to construct a standardized and normalized route planning system. With classical artificial intelligence heuristic algorithms such as genetic algorithms and ant colony algorithms as core technical support, constraint conditions including distribution point distances, road traffic efficiency, vehicle load capacity, and distribution timeliness are incorporated into algorithmic models. Through intelligent processes of encoding, iteration, and optimization, traditional manual subjective

judgment is replaced. AI algorithms can systematically sequence and match routes for all distribution nodes, outputting standardized distribution schemes according to core objectives of shortest mileage, lowest cost, and highest efficiency, thoroughly eliminating the arbitrariness of manual planning and enhancing the scientificity and standardization of route planning [10].

4.2 Leveraging AI Global Optimization to Eliminate Distribution Route Redundancy

To address the problems of severe route redundancy and resource waste in traditional distribution, artificial intelligence global optimization capabilities are utilized to optimize distribution route layouts. AI algorithms can traverse all feasible distribution routes, compare mileage and cost differences among different distribution sequences and driving routes, and screen out globally optimal closed-loop distribution routes, maximally avoiding repeated road segments, detour segments, and invalid driving paths. Through AI intelligent optimization, invalid vehicle mileage can be effectively compressed, hard operational costs such as fuel consumption and vehicle wear can be reduced, efficient utilization of transportation resources can be achieved, helping logistics enterprises effectively reduce expenditures and enhance overall profitability [11].

4.3 Constructing an AI Dynamic Scheduling Mechanism to Improve Distribution Timeliness Stability

To resolve the problems of poor dynamic response and unstable timeliness in traditional models, an artificial intelligence dynamic route scheduling optimization scheme is established. Relying on AI real-time data processing capabilities, dynamic collection of traffic condition information, order change information, and distribution progress information is achieved, enabling real-time iterative updating of distribution routes [10]. During distribution operations, if sudden situations such as temporary order additions or road congestion occur, the AI system can quickly complete secondary planning, adjust distribution sequences and driving routes in real time, minimize the impact of sudden situations on distribution timeliness, ensure on-time order delivery, enhance customer service experience, and resolve the problems of large timeliness

fluctuations and weak emergency response capabilities in traditional distribution models.

4.4 AI Intelligent Coordination of Transportation Capacity to Optimize Resource Allocation Efficiency

Artificial intelligence multi-dimensional resource coordination capabilities are utilized to optimize the matching configuration of logistics capacity and order resources. The AI system can intelligently allocate distribution tasks based on data such as order quantity, point distribution, cargo weight, and vehicle capacity, balancing the distribution load of each vehicle and avoiding imbalance problems such as idle capacity or task overload. Through intelligent resource scheduling, optimal matching of human, vehicle, and order resources is achieved, maximizing the overall effectiveness of the logistics distribution team and comprehensively improving the overall distribution efficiency of last-mile logistics [12].

5. Application Advantages of the Artificial Intelligence Route Optimization Scheme

Compared with traditional manual route planning models, the artificial intelligence optimization scheme possesses significant advantages in scientificity, economy, timeliness, and flexibility. First, AI planning relies on data and algorithmic iteration, abandoning subjective experience interference, making route planning more scientific and precise. Second, global optimal route screening can effectively reduce invalid transportation, significantly lower enterprise logistics distribution costs, and help enterprises reduce costs and increase efficiency. Third, the dynamic scheduling mechanism can quickly adapt to various sudden scenarios, ensuring stable distribution timeliness and improving logistics service quality. Finally, artificial intelligence intelligent scheduling requires no extensive manual intervention, can substantially reduce manual scheduling costs, and enhance the intelligent and standardized operational level of logistics enterprises.

Overall, artificial intelligence technology has restructured the traditional logistics distribution scheduling model, promoting the transformation of route planning from experience-based and extensive to data-driven, refined, and intelligent, carrying important practical significance for improving the overall operational level of the logistics industry and promoting the

high-quality development of smart logistics.

6. Conclusion and Outlook

6.1 Research Conclusions

Based on the current development status of the logistics distribution industry, this paper systematically reviews various problems existing in traditional manual logistics distribution route planning, primarily including core pain points such as insufficient planning scientificity, severe route redundancy, weak dynamic response capability, and low resource allocation efficiency. To address the above problems, this paper relies on the advantages of artificial intelligence technology in data analysis, global optimization, dynamic iteration, and intelligent scheduling to construct a complete set of intelligent optimization schemes for logistics distribution routes. Through methods such as building a standardized AI planning system, globally optimizing route layouts, dynamic real-time scheduling, and intelligent coordination of transportation capacity, the shortcomings of traditional route planning are comprehensively resolved. Research results indicate that artificial intelligence technology can effectively innovate the traditional logistics distribution scheduling model, achieve scientific, refined, and dynamic optimization of distribution routes, significantly improve logistics distribution efficiency, reduce enterprise operational costs, and carry important practical value for promoting the intelligent transformation and upgrading of small and medium-sized logistics enterprises.

6.2 Research Outlook

This paper primarily analyzes the existing problems in logistics distribution routes and artificial intelligence optimization schemes from a theoretical level. In the future, big data, the Internet of Things, and other technologies can be combined to further improve the intelligent route optimization system, incorporating real-time traffic conditions, multi-vehicle coordination, multi-objective optimization, and other content, constructing a more comprehensive, precise, and intelligent dynamic route optimization model, further enhancing the adaptability of the intelligent scheduling system in complex logistics scenarios, and providing more complete technical and theoretical support for the high-quality development of the smart logistics industry.

Acknowledgments

This paper is supported by Guangdong University of Science and Technology 2025 School-Level Research Project "Research on Logistics Distribution Route Optimization Based on Artificial Intelligence Technology" (GKY-2025KYYBW-7).

References

- [1] Chen Xi. Obstacles and countermeasures for intelligent upgrading of last-mile delivery in the context of smart logistics. *Logistics Technology*, 2022, 41(09): 95-98.
- [2] Duan Zhengyu, Yang Dongyuan. Research progress on dynamic route optimization for urban distribution vehicles. *Journal of Traffic and Transportation Engineering*, 2020, 20(03): 1-16.
- [3] Feng Jia, Li Ming. Research on new energy delivery vehicles empowering the development of urban intelligent last-mile logistics. *Journal of Commercial Economics*, 2024(03): 151-153.
- [4] Wang Jing, Chen Huaili. A review of research on delivery route optimization for small and medium-sized logistics enterprises. *Logistics Sci-Tech*, 2022, 45(06): 112-115.
- [5] Liu Gang. Research on urban last-mile logistics distribution route optimization based on artificial intelligence algorithms. *Logistics Technology*, 2021, 40(05): 88-92.
- [6] Ma Xin, Zhu Jianrong. Delivery route optimization based on heuristic algorithms in the context of smart logistics. *Journal of Commercial Economics*, 2023(08): 147-150.
- [7] Wang Jian, Lin Hang. Research on urban delivery route optimization and low-carbon development from the perspective of green logistics. *Logistics Engineering and Management*, 2022, 44(07): 112-114.
- [8] Özarık S S, da Costa P, Florio A M. Machine learning for data-driven last-mile delivery optimization. *Transportation Science*, 2024, 58(1): 27-44.
- [9] Zhang Jingling, Zhao Yanwei. A review of research on vehicle routing optimization problems. *Journal of Mechanical Engineering*, 2010, 46(20): 1-11.
- [10] Kinable J, Sluijk N, Gendreau M, et al. Fair stochastic vehicle routing with partial deliveries. *Transportation Science*, 2025,

- 60(2): 264-283.
- [11] Vieira B S, Frazzon E M, Coelho L C. An exact linearization-based refinement algorithm to the carrier-vehicle traveling salesman problem. *Transportation Science*, 2025, 60(4): 589-607.
- [12] Kuo J Y, Hsieh T F, Lin H C. Optimal route selection for supporting lines in logistics companies. *Journal of Industrial and Management Optimization*, 2026, 22(5): 2479-2502.