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Research on Location and Route Optimization of Distribution Center in Smart City

LU Tianyang

Master in Digital Technologies for Business

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TECNOLOGIAS
E ARQUITETURA

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Abstract

This thesis addresses critical issues in urban logistics in China, including low distribution efficiency and high costs exacerbated by traffic congestion, damaged goods, transportation delays, and unexpected weather conditions. To address these challenges, the study integrates the concept of "smart cities" and proposes a transformation strategy focusing on key technologies such as distribution center location and distribution route optimization. Its purpose is to use intelligent optimization and information integration to improve efficiency and reduce costs.

This study compares the improved algorithm with the existing scheme through empirical analysis, and leverages improved genetic algorithms to refine these logistics processes, specifically for Xi'an Hema Fresh. The algorithm simulates natural selection and genetic variation, utilizing random restart and elite retention strategies, and confirms that the integration of smart city concepts and AI technology can effectively address challenges, thereby reducing costs, increasing efficiency, and improving service quality.

This not only proves the effective integration and optimization of smart city technology in urban logistics, but also provides valuable experience and strategies for other cities or regions to implement smart logistics systems. This study validates the application value and feasibility of applying intelligent technology in urban logistics systems. Future research can further optimize the model and explore more practical application scenarios to promote the efficient and sustainable development of smart city logistics systems.

Keywords:

Smart City; Smart logistics; Path optimization; Genetic algorithm.

Resumo

Esta tese aborda questões críticas na logística urbana na China, incluindo baixa eficiência de distribuição e altos custos exacerbados por congestionamento de tráfego, mercadorias danificadas, atrasos no transporte e condições climáticas inesperadas. Para abordar esses desafios, o estudo integra o conceito de "cidades inteligentes" e propõe uma estratégia de transformação com foco em tecnologias-chave, como localização do centro de distribuição e otimização da rota de distribuição. Seu objetivo é usar otimização inteligente e integração de informações para melhorar a eficiência e reduzir custos.

Este estudo compara o algoritmo aprimorado com o esquema existente por meio de análise empírica e aproveita algoritmos genéticos aprimorados para refinar esses processos de logística, especificamente para Xi'an Hema Fresh. O algoritmo simula seleção natural e variação genética, utilizando estratégias de reinicialização aleatória e retenção de elite, e confirma que a integração de conceitos de cidade inteligente e tecnologia de IA pode abordar desafios de forma eficaz, reduzindo custos, aumentando a eficiência e melhorando a qualidade do serviço.

Isso não apenas prova a integração e otimização eficazes da tecnologia de cidade inteligente na logística urbana, mas também fornece experiência e estratégias valiosas para outras cidades ou regiões implementarem sistemas de logística inteligente. Este estudo valida o valor da aplicação e a viabilidade da aplicação de tecnologia inteligente em sistemas de logística urbana. Pesquisas futuras podem otimizar ainda mais o modelo e explorar cenários de aplicação mais práticos para promover o desenvolvimento eficiente e sustentável de sistemas de logística de cidades inteligentes.

Palavras-chave:

Cidade Inteligente; Logística inteligente; Otimização de caminhos; Algoritmo genético.

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Chapter 1 – Introduction

1.1 Context

As urbanization accelerates and e-commerce continues to expand, the demand for more adept and intelligent logistics systems becomes increasingly urgent. Site optimization is strategically important, involving the selection of optimal warehouse locations by analyzing geographic data, transport connectivity, and proximity to markets, thereby minimizing logistics expenses and enhancing service quality. Service quality is an important indicator to measure that service meets or exceeds customer expectations, and its definition and evaluation methods may be different in different industries and situations [1]. In general, quality of service includes several core aspects: reliability, responsiveness, assurance, tangibility, and empathy. Specifically, reliability concerns whether the service is consistent and accurate, that is, whether the service provider can consistently and accurately fulfill its commitments; Responsiveness assessment of the speed of service delivery and rapid response to customer needs; Assurance involves the knowledge and courtesy of the service personnel and the confidence they give to the customer; Tangibility refers to the quality of the physical environment and associated facilities of the service; Empathy refers to personalized attention in service delivery and the ability to understand customer needs. In the field of logistics and supply chain management, the evaluation of service quality often focuses on specific indicators such as on-time delivery rate, delivery speed and customer satisfaction. Through these quantitative measures, companies can analyze service performance, optimize service processes, and improve customer satisfaction and loyalty. To measure improvements in service quality, we will use metrics such as delivery accuracy, delivery speed and customer satisfaction.

More extensively, route optimization is developed to formulate the most cost-effective and efficient delivery pathways. The cost is mainly composed of the following parts: First, monetary costs, including direct expenses such as fuel, vehicle maintenance, tolls and driver salaries, which are the basic operating costs of delivery operations; Second, labor hours, that is, the working hours of drivers and logistics personnel needed to complete the delivery, including the time spent driving on the road and the time spent loading and unloading goods; Third, time cost refers to the length of time required for the delivery route, which directly affects fuel consumption, vehicle wear and customer satisfaction due to the speed of delivery; Finally, other costs may include the environmental impact of the route (such as emissions), the opportunity cost of not using vehicles or people, and possible fines due to late arrival or failure to deliver. By taking into account factors such as traffic conditions, vehicle capacity, delivery time Windows and geographical optimization, route optimization can not only reduce these costs, but also improve service quality and customer satisfaction [2].

This process utilizes sophisticated Geographic Information System (GIS) to analyze spatial data, enabling precise geographical positioning and streamlined route planning. GIS is capable of collecting and processing geographic and environmental data from multiple sources, such as road types, traffic conditions, weather information, and other geographic features that may affect delivery routes. With this data, GIS helps logistics planners identify the shortest or most economical routes, taking into account potential obstacles such as traffic congestion and road closures. In addition, GIS can update data in real time to provide real-time road condition information for logistics operations to adjust routes in real time to avoid traffic jams or accident locations, ensuring delivery efficiency and timeliness.

Additionally, artificial intelligence (AI) is employed to predict logistical challenges and automate decision-making processes, enhancing responsiveness and operational agility. According to this study, we hope to address the challenges in intelligent logistics delivery, including traffic congestion, risk of cargo damage, transportation delays, unexpected weather conditions, and rapid changes in customer demand. AI technologies predict these challenges by analyzing historical and real-time data. For example, AI can use traffic data to predict possible congestion areas and plan routes to avoid them in advance; By analyzing past cargo damage records and current transportation conditions, AI can predict the risk of damage that may be encountered in future transportation and recommend preventive measures; In response to unexpected weather conditions, AI can predict weather changes based on meteorological data and adjust transportation plans in time to reduce weather impacts. In addition, AI can monitor market dynamics and customer behavior in real time, quickly respond to changes in customer demand, and optimize inventory management and distribution plans. In these ways, AI not only helps logistics companies reduce transportation costs and time, but also improves overall service quality and customer satisfaction.

Machine learning (ML) techniques further refine these processes by learning from historical data, continuously improving route suggestions and logistics strategies based on patterns of demand, traffic conditions, and delivery performance. Together, these technologies provide both theoretical and practical insights that significantly improve logistics distribution systems in smart cities, taking into account economic, social, and technological factors. Specifically, economic factors include cost efficiency, capital investment, and market demand dynamics, and ML helps enterprises optimize resource allocation, reduce operating costs, and enhance market competitiveness. Social factors include customer satisfaction, social influence and urban traffic congestion, and by improving delivery efficiency and punctuality, ML technology enhances the customer service experience and mitigated the negative impact on urban traffic. Technical factors include technological advances, data security and system integration, where ML improves data processing capabilities through advanced algorithms, strengthens data security, and seamlessly integrates with existing systems to enhance the overall performance and adaptability of logistics systems. The combined consideration of these factors enables the logistics system to respond more effectively to the complex needs of smart cities and achieve smarter and more efficient logistics solutions.

1.2 Objectives

As an advanced urban development model, smart cities focus on the integration and innovation of Information and Communication Technology (ICT) in order to optimize the allocation of resources, improve the efficiency of urban management, and enhance the quality of life of residents. Achieving this goal involves several key strategies: First, smart cities employ big data analytics techniques to process and analyze data collected from multiple urban sectors such as transportation, public services, and utilities. This data-centric approach enables city planners and managers to make informed decisions, optimize resource utilization and improve service quality. Second, smart cities emphasize sustainable practices and reduce environmental impact by integrating green technologies and strategies. This includes adopting renewable energy, promoting the use of electric vehicles, and implementing advanced recycling and waste management technologies for a more sustainable urban environment. In addition, under the framework of smart cities, urban logistics is an important part of urban economic activities, and its efficient operation is crucial to maintaining urban functions and enhancing urban competitiveness [3]. The efficiency of urban logistics not only depends on traditional logistics management methods, but also needs to be combined with the technical infrastructure and data resources of smart cities. For example, the use of intelligent transportation systems to optimize distribution routes, reduce traffic congestion and environmental pollution, while predicting changes in market demand through real-time data analysis, improving the flexibility and responsiveness of services. The combined application of these strategies not only improves the management efficiency of cities, but also significantly improves the quality of life of residents, making smart cities more efficient, sustainable and livable environments.

Big data analysis in smart cities can help logistics companies predict demand fluctuations and optimize inventory management; The utilization of real-time traffic information can effectively avoid congestion and optimize delivery routes. In addition, the application of Internet of Things (IoT) technology, such as intelligent vehicles and sensors, can monitor the status of goods and traffic in real-time, improving the reliability and timeliness of distribution. In the logistics management of smart cities, reliability refers to the accuracy and timeliness of goods distribution, ensuring that goods can reach their destination on time and accurately [4]. Big data analysis helps logistics companies predict demand fluctuations, optimize inventory management, and ensure that there are enough goods to meet market demand and avoid oversupply. The use of real-time traffic information can effectively avoid traffic congestion and optimize distribution routes, which not only reduces delivery times, but also reduces delays caused by traffic problems. In addition, IoT technology enables real-time monitoring of goods and traffic conditions through intelligent vehicles and sensors, improving the real-time and accuracy of monitoring. Smart vehicles are able to adjust the driving path based on real-time data, while sensors are able to monitor the state of goods during transport, such as temperature and humidity, ensuring that goods are transported under optimal conditions. The integrated application of these technologies not only improves the punctuality rate of distribution, but also enhances the transparency and tracking ability of the distribution process, thus greatly improving the reliability of logistics services. This enhancement has played a key role in increasing customer satisfaction and business competitiveness.

With the advancement of smart cities, urban logistics is also developing towards a more intelligent and systematic direction. In the framework of smart cities, the integration of advanced technologies like cloud computing and AI significantly enhances the capabilities of urban logistics. These technologies enable a heightened degree of automation and optimization in logistics operations. Specifically, cloud computing provides scalable and flexible data storage solutions, facilitating real-time data analysis and decision-making. AI, on the other hand, contributes to the automation of complex logistical tasks by learning from patterns and making predictive adjustments. This refined approach allows urban logistics systems to adapt more effectively and efficiently to the dynamic changes in urban environments and the evolving needs of residents.". This not only improves the efficiency and quality of logistics services, but also helps to reduce environmental pollution and traffic congestion, promoting sustainable urban development. Therefore, the construction of smart cities and the optimization of urban logistics are complementary [5]. Optimizing urban logistics in the context of smart cities can not only improve the efficiency and response speed of logistics services, but also strengthen the comprehensive management and service capabilities of cities, achieving more harmonious and sustainable urban development.

Considering the challenges of integrating smart city technology with urban logistics systems, which include General Data Protection Regulation (GDPR) and privacy protection, traffic congestion, risk of cargo damage, transport delays, unexpected weather conditions and rapid changes in customer demand, technology integration and standardization issues are prominent, Differences in compatibility and interoperability between different technology platforms can lead to challenges such as wasted resources [6]. The objective of the thesis is to explore how to optimize the location and path of logistics distribution centers through smart city technology, in order to improve logistics efficiency, reduce operating costs, and enhance service quality. Specifically, the study aims to address the issues of low efficiency and high cost in urban logistics, by achieving cost reduction and efficiency improvement through intelligent optimization and information integration. The study uses an improved genetic algorithm to simulate and analyze the location selection and path optimization of distribution centers and verifies the application value of the algorithm in actual logistics optimization through case studies. Through this research, we hope to provide scientific and effective solutions for optimizing logistics systems in the context of smart cities and promote the intelligent development of the urban logistics industry.

1.3 Dissertation challenges

The efficient operation of smart cities and urban logistics directly affects the quality of life of residents. Through an optimized logistics system, residents can enjoy faster and more accurate delivery of goods and services, reducing waiting times and potential inconveniences. At the same time, measures to reduce traffic congestion and improve energy efficiency not only optimize the urban environment, but also reduce the living pressure of urban residents. In these ways, the improvement of smart city functions and the improvement of residents' quality of life are closely linked, reflecting the core role of smart city technology and urban logistics in modern urban management and life.

Although smart cities provide technical support for location selection and route optimization of urban logistics, there are still many challenges in the implementation process, especially in terms of data collection and analysis. These activities involve significant data privacy and security issues, which makes ensuring data security and protecting user privacy all the more critical. In the context of smart cities, a large amount of data is used to optimize traffic flow, logistics distribution routes and demand forecasting, which often includes sensitive information such as individual location information, consumption habits and behavior patterns. In order to prevent the improper use or disclosure of this information, it is necessary to take appropriate data protection measures. This includes data encryption to protect data during storage and transmission, implementation of data anonymization to avoid revealing personal identities during analysis, strict data access controls to ensure that only authorized personnel have access to sensitive data, and further strengthening data security through role-based access rights. In addition, smart cities must comply with relevant data protection regulations, such as the European Union's GDPR, through regular audits and evaluation of data processing activities to comply with legal requirements. At the same time, users should be provided with a clear privacy policy, which clearly informs them how their data is collected, used and protected, and provides corresponding rights to access, modify or delete data, so as to ensure the security of data and the protection of user privacy. Together, these measures help smart cities improve logistics efficiency while ensuring data security and respect for personal privacy.

Secondly, issues of technology integration and standardization are prominent, and differences in compatibility and interoperability between different technology platforms may lead to resource waste

[7]. In addition, high construction and maintenance costs may become limiting factors for the development of smart logistics systems in some cities. Technology dependence exacerbates the demand for professional skills, and skill gaps and training needs may become obstacles to implementation. Solving the compatibility and interoperability issues between different technology platforms is the key to driving the development of intelligent logistics systems in smart cities. To this end, the following strategies can be used: by promoting uniform technical standardization and ensuring seamless interaction between different systems and equipment, it can participate in the activities of international standardization organizations such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) to adopt and implement their standards. This measure not only reduces the waste of resources caused by technological incompatibilities, but also facilitates the integration and application of technologies on a global scale. It is also critical to drive the development of open architectures and shared interfaces. Interoperability between different platforms can be greatly improved by designing an open system architecture and encouraging technology providers to develop compatible solutions. In addition, implementing a modular design can make system updates and maintenance more flexible, reducing the overall replacement cost due to technology changes. Through these strategies, we can not only solve the existing interoperability problems, but also lay a solid foundation for the continuous development and expansion of future intelligent logistics systems [8]. Meanwhile, complex policy and regulatory frameworks may also limit the operation of smart logistics systems. Finally, the limitations of existing infrastructure, such as traffic congestion and insufficient communication networks, can also affect the efficiency of smart logistics systems [9]. These issues need to be addressed through policy support, technological innovation, and sustained investment to fully leverage the potential of smart cities in optimizing urban logistics.

1.4 Dissertation outline

Chapter 1 Introduction: Introduces the critical role of location selection and route optimization in smart city logistics management, how to select the best warehouse location through geographic data analysis, transportation connectivity, and market proximity to reduce logistics costs and improve service quality.

Chapter 2 Literature Review: This thesis reviews the background knowledge, related work and summaries in related fields. This chapter analyzes how the development of smart cities can optimize resource allocation, improve the efficiency of urban management and the quality of life of residents through advanced information and communication technologies.

Chapter 3 Research Methodology: A detailed description of the study design, data collection methods, model development, validation and testing, etc. Through qualitative and quantitative research methods, combined with field investigations and case studies, the location selection and path optimization model of the logistics system is constructed and validated.

Chapter 4 Application and Impact of Distribution Center Location Selection and Path Optimization: Through case studies, such as the Xi'an Hema Fresh Retail Distribution Center, show how smart city technologies can be integrated and optimized in real-world urban logistics. The improved genetic algorithm is used to optimize the location and distribution routes of distribution centers, and the actual effect of technology application and the improvement of logistics efficiency are analyzed.

Chapter 5 Conclusion: This thesis summarizes the findings, proposes future research directions, and discusses potential improvements and applications of smart city logistics systems.

This thesis combines the concept of smart city with AI technology to solve the challenges faced by urban logistics in China, optimize the location of distribution centers and distribution routes to improve efficiency and reduce costs, and also promote the development of intelligent distribution services in the urban logistics industry.

Chapter 2 - Literature review

2.1 Background

The concept of "Logistics" was first proposed by R. Bosod, an American scholar, and gave a comprehensive definition [10]. In 1980, China Society of Material Economics started the study of modern logistics in China, and the establishment of China Logistics Association in 1984 marked a new stage of vigorous development of logistics research. New technologies, new markets, new business models and new customer expectations are making the logistics industry face dramatic changes, which bring unprecedented risks and opportunities. New technologies such as the IoT, cloud computing, big data and blockchain have greatly simplified logistics processes and improved logistics efficiency. These new things have improved delivery efficiency and customer satisfaction, but they have also created greater competition. Many scholars have carried out in-depth research on the intelligence of logistics industry [11]. In modern society, with the acceleration of urbanization and the improvement of residents' living standards, the demand for urban logistics has sharply increased, which puts higher requirements on the efficiency of urban transportation systems and logistics distribution. Especially in the context of smart cities, how to solve these challenges through technological innovation has become a hot topic in research and practice [12]. Smart cities utilize advanced information and communication technologies to create an efficient, sustainable, and livable urban environment, with intelligent logistics systems being one of its core components. The main problems faced by urban logistics include low delivery efficiency, traffic congestion, environmental pollution, and high delivery costs [13]. Effective location selection and route optimization of logistics distribution centers can significantly improve logistics efficiency, reduce transportation costs, alleviate traffic pressure, reduce environmental pollution, and thereby improve the operational efficiency of the entire city and the quality of life of residents. This not only requires the logistics system to accurately predict and respond to changes in demand, but also to be able to adjust delivery strategies in real-time to respond to emergencies. Studying logistics site selection and route optimization in smart cities involves interdisciplinary applications such as GIS, operations research, AI, and big data analysis [14]. By integrating these technologies, dynamic optimization, real-time monitoring, and intelligent decision-making of logistics networks can be achieved, thereby better adapting to changes in urban environments and the diversity of resident needs. In the context of the development of smart cities, the site selection and route optimization of logistics distribution centers are key to improving urban logistics efficiency. With the acceleration of urbanization and the improvement of residents' living standards, urban logistics is facing increasing challenges, including low delivery efficiency, traffic congestion, environmental pollution, and increased costs. Smart cities utilize advanced information and communication technologies, such as AI, big data analysis, and the IoT, committed to solving these challenges through technological innovation, optimizing the efficiency and cost of logistics distribution [15]. However, the application of these technologies is not without risks. Data security and privacy protection are major challenges, and the high cost of technology integration and the high demand for professional skills are also limiting factors. In addition, the logistics system of smart cities also faces uncertainty in policies and regulations, lack of uniformity in technical standards, and social acceptance issues. These risks and challenges may not only affect the efficiency and effectiveness of logistics systems, but also constrain the overall sustainable development of smart cities [16].

In order to explore in depth how to overcome these risks and maximize the effectiveness of technology, researchers have proposed a series of theories and models aimed at optimizing logistics site selection and route design through scientific methodology. These theories not only include traditional methods in operations research, such as linear programming and network flow analysis, but also include the latest AI and ML algorithms that can handle complex datasets, predict demand, and optimize resource allocation.

2.2 Related work

In the theoretical development of smart city logistics systems, many researchers have conducted in-depth research on logistics site selection and route optimization by introducing innovative methodologies and technologies. These studies not only improve logistics efficiency, but also address the complex challenges in smart cities. Govindan [17] and his companions made contributions in the early stages of logistics network design and location selection.

Guo [18] proposed a logistics location analysis model combining GIS, which can integrate the spatial analysis function of GIS and optimize the selection of warehouse locations.

In the field of AI, Guo and Qu's [19] research has promoted the application of intelligent algorithms in logistics. They explored how to predict logistics demand through ML and use optimization algorithms to design more effective delivery routes. Their work indicated that AI technology can significantly improve the response speed and adaptability of logistics systems.

Huang et al.'s [20] research on genetic algorithms provided a method for solving complex optimization problems, especially in route planning and scheduling. Genetic algorithm can effectively find approximate optimal solutions by simulating natural selection and genetic principles, which is particularly important for logistics route optimization in dynamic and uncertain environments.

The application of IoT technology in the logistics field is also increasing day by day. Jin et al.[21] proposed the concept of IoT, and this theory emphasized that in logistics management, efficiency can be greatly improved through real-time data collection and analysis. IoT devices such as sensors and

RFID tags make real-time tracking and monitoring possible, thereby optimizing the entire logistics process.

Turban & Aronson [22] explored Decision Support Systems (DSS) in supply chain management in their research. They pointed out that DSS can integrate complex data, provide real-time, actionable insights, and help logistics managers make more effective decisions.

In the development process of smart city logistics systems, although technology has brought significant efficiency improvements and cost savings, researchers have also pointed out the risks associated with these developments. The following are the researches and theories of several scholars on the development risks of smart city logistics systems:

LaLonde & Pohlen [23] proposed in their research on data security and privacy that smart city logistics systems rely on a large amount of data collection, which not only involves personal privacy issues but may also face the risk of data being illegally accessed or abused. It emphasized the importance of encryption technology and access control policies to protect data security and enhance user trust.

Lang et al.[24] explored the impact of technological dependence on the decision-making process, particularly in the application of smart city logistics systems. It suggested that excessive reliance on automation and algorithmic decision-making may lead to "decision errors", as algorithms, although highly efficient, may overlook non quantitative human factors and complex social environments.

Laporte [25] analyzed the social acceptance of smart city technology from the perspective of humanities and social sciences.It emphasized that the promotion and application of technology need to consider the influence of culture, social structure, and public ideology, otherwise it may encounter social resistance, which may affect the widespread adoption and implementation of technology.

Liu et al.[26] discussed the social inequality issues that smart city logistics systems may lead to in his urbanization theory. It proposed that although technological progress has improved overall economic efficiency, it may also exacerbate the wealth gap, as technological benefits are often concentrated in the hands of a few people rather than widely benefiting all members of society.

Liu et al.[27] pointed out in their discourse on the impact of technological decision-making that excessive reliance on technology may lead to the degradation of professional skills. In the field of smart city logistics, this dependence may weaken the emphasis of practitioners on traditional logistics knowledge and intuitive judgment.

From AbdAllah et al.’s research, it is said that since the Vehicle Routing Problem (VRP) was proposed by the famous scholars Rasmer and Dantzig in 1959, it has been widely studied and discussed by the academic circle. Their research direction mainly focused on the best choice of vehicle transportation route planning between oil stations and oil depots [28]. According to the specific geographical location, demand and the maximum safe loading capacity of each vehicle, he continuously analyzed and optimized the running path of various vehicles between various gas stations and oil depots to achieve the reduction of the total vehicle transportation mileage and the total transportation cost. Lahyani et al. classified and summarized the problem of road distribution optimization of vehicles with multiple constraints, and provided a more detailed concept, which established the basis of this research direction [29]. Anderluh et al. improved the genetic algorithm to a certain extent, so that it could better avoid falling into local optimality. Also, Cardoso et al. established a dynamic method for automobile route planning modeling [30] Automobile route planning problems are divided into two categories, dynamic fitness is used to measure their dynamics, and they are divided into two research aspects: information quality and evolution, which opened up the richness of dynamic route research [31].

As for the research on the multi-VRP, Chen et al. included the "synchronization" and "gray area" consumers of the traffic system into the research scope when studying the two-way car routing problem of multiple objects and studied the effects of three different urban spatial distributions on the system. Finally, three optimal Pareto solution methods are obtained [32]. Dantzig et al. studied the routing problem of multi-type vehicles, organically combined different types of vehicles with the characteristics of station duration, station dependence, split transportation and return trip, and proposed a hybrid heuristic algorithm based on hybrid heuristic, which integrated the variable neighborhood descent and local iterative search solutions. In this way, the research methods of such problems are optimized and improved, and on the basis of this work, the set partition formula which is convenient for searching historical records is proposed. In addition, the combined class neighborhood region is studied, and the heuristic algorithm is run on the basis of the access sequence to modify the scheme, and the optimal vehicle path planner is obtained [33]. Based on this category, Fuqaha et al. set up a vehicle route optimization model with user satisfaction as the index from the perspectives of economy and income. In this model, carbon emission cost is built based on carbon emission mechanism, customer satisfaction is set strictly within the time limit, and return is required for delay. In addition, genetic algorithm of cyclic evolution is used to solve vehicle route. Through the numerical analysis of the model results, a logistics distribution scheme with high economic value was obtained [34].

Penna et al.'s work took the real-time logistics model as the research goal and made an in-depth discussion on the problem of automobile route planning with time-window constraints and proposed a method that can integrate the existing resource scheduling scheme without causing any interference to the current sales process, which can be well applied to logistics management [35]. Tamke & Buscher combined unmanned aircraft and unmanned vehicles to solve the "last kilometer" problem of logistics distribution. Based on the premise of two different time objectives, a dual-objective mixed integer linear programming model was proposed, and the model was studied and verified. The research results showed that the application of UAV in short-distance delivery route optimization may not improve the efficiency of delivery service and customer satisfaction but will reduce the dispatch rate of delivery vehicles and reduce certain distribution costs [36]. Ritzinger et al. designed an adaptive sampling algorithm based on two different situations for the time window problem of random traffic vehicle path planning. Finally, by introducing examples, they conducted an empirical analysis of the two schemes, proving that to a certain extent, the combination of correlation and time dependence can effectively improve the effectiveness of the schemes. That is, the accuracy of feasibility decisions [37]. Wang et al. believed that electric vehicle distribution, due to its limited driving distance in a dynamic environment, customers' requirements would change with the growth of time. In the construction of the model aiming at this, the encoding mode in the coding framework is improved, which effectively improved the solving efficiency of such dynamic distribution problems. With the support of practical examples, it is proved that compared with other algorithms, the improved algorithm has higher stability and solving efficiency [38].

This multidimensional consideration not only promotes the healthy development of smart city logistics systems, but also helps to achieve broader social sustainable development goals. Through the contributions of these theories, the logistics system of smart cities can not only solve traditional efficiency and cost problems, but also address emerging challenges in data security and technology integration. However, the development of smart city logistics systems must comprehensively consider the impact of multiple dimensions such as technology, economy, society, and culture. To overcome these risks, comprehensive strategies and policies need to be developed, including strengthening data protection, enhancing the scientific and technological literacy of the public, ensuring fairness in technological development, and appropriately maintaining the value of traditional skills and human decision-making. Future researches need to further explore how to integrate these theories and overcome the obstacles faced by implementing advanced technologies in practical operations [39].

Many achievements have been made in the research of urban logistics, distribution center location and distribution route optimization. As for the location of the center, due to the different business of the distribution center, scholars usually introduce different cost factors according to the types of commodities in the distribution center for research, and at the same time include different variables for measurement based on the characteristics of commodities in the modeling. Most of the studies adopt quantitative methods for location selection, but few combine qualitative and quantitative decision analysis. For the path optimization problem, due to the abundant reference scenarios and case data, the expansion and innovation of the model are very diverse. Due to the diversity of distribution service objects, fresh, agricultural products, power grid materials, etc., are optional research objects for model construction.

There is also a wealth of considerations that need to be introduced into different commodities. At the same time, because of the variety of reference scenarios, there are still many scenarios that are not involved in the path optimization problem. Under the environment where the government vigorously promotes the concept of smart city, the informatization, intelligence and digitalization of logistics and transportation means will be greatly improved, the information gap between distribution network systems will be further reduced, and the high-tech positioning system and transportation means will further reduce the cost and increase the efficiency of distribution services. Therefore, the study of distribution center location and route planning based on the background of smart city is an important direction for the development and upgrading of China's logistics industry.

2.3 Summary

This chapter reveals multidimensional research findings and their impact on urban logistics management by examining in detail the relevant theories and practices of logistics system site selection and route optimization in smart cities. We analyzed the applications of operations research methods, GIS, AI, and the IoT in smart city logistics systems, and how these technologies help solve logistics efficiency and cost issues. In addition, the potential risks associated with the integration and application of these technologies were also explored, including data security, technological dependence, social acceptance, and their potential impact on social inequality. These studies indicate the complex challenges that smart city logistics systems need to face in realizing their potential, and the need for balanced technological applications to ensure that critical human skills and judgment are not compromised.

In summary, the successful implementation of smart city logistics systems not only requires efficient technical solutions, but also requires a deep understanding and sufficient preparation for the economic, social, and cultural issues that these solutions may cause. Therefore, future research and practice should focus on how to build a smart city logistics system that is both efficient, inclusive, safe, and sustainable. This requires extensive and effective collaboration among policy makers, technology developers, and urban planners to jointly promote the development of smart logistics systems towards a more humane and socialized direction. Through such efforts, the logistics system of smart cities can not only improve the efficiency of urban operations, but also achieve sustained and balanced development in a broader social context.

Chapter 3 - Research methodology

3.1 Basic concepts

"With the rise in urban populations, the consumption patterns of residents have diversified and expanded significantly” [40]. This increase primarily encompasses a wider variety of goods and services, including enhanced demand for technology products, healthcare services, recreational activities, and environmentally sustainable options. Additionally, there is a noticeable rise in the consumption of gourmet and international cuisine, as well as luxury goods, reflecting the growing affluence and cosmopolitan tastes of urban dwellers. This shift not only impacts local economies but also drives changes in supply chain logistics and urban planning to accommodate the evolving market demands.

"Customers today expect not only efficiency and economy from delivery services but also a high standard of service quality” [41]. This concept of service quality in the context of delivery services can be defined by several key metrics: reliability, whereby deliveries are consistently on time; responsiveness, the speed and effectiveness with which service providers address customer inquiries and resolve issues; accuracy, ensuring that orders are correct and undamaged upon delivery; and communication, keeping customers informed throughout the delivery process]. These metrics collectively contribute to a customer’s perception of quality, significantly influencing their satisfaction and loyalty to the service. Therefore, it is essential to establish an intelligent urban distribution network system. The conceptual definition of a smart city involves using the progress of science and technology to support and integrate urban services and functions, thereby enhancing the overall management efficiency of cities and improving the quality of life for urban residents. The construction and operation of the smart city logistics network and transportation system require the advancement of high-tech levels and stable economic development. Therefore, the transformation of the concept of smart cities into policy development can provide theoretical basis and research support for the logistics field. The key factors in realizing the "intelligence" of cities are cooperation and interaction between digitalized enterprises, as well as technological innovation [42].

3.2 Research design

In the research design section, this study adopted a mixed research method, combining qualitative and quantitative research methods, to comprehensively understand and analyze the problem of logistics distribution center location and path optimization in the context of smart cities.

In terms of qualitative research, in-depth exploration and understanding of the integration process between smart cities and urban logistics systems are conducted through detailed observations and interviews. Specifically, researchers will conduct in-depth interviews with logistics managers and urban planners to understand their experiences and challenges in practical operations. These interviews will help reveal pain points in existing logistics systems and the potential impact of smart city technology in practical applications. Meanwhile, by observing the daily activities of urban logistics operations, first-hand practical operational data and scenarios can be obtained, which have important reference value for the establishment and validation of models [43].

In terms of quantitative research, this study will conduct extensive data collection and statistical analysis to obtain quantitative data on the performance and cost structure of logistics systems. Use GIS for spatial analysis to determine the optimal distribution center location and analysis the impact of different location options on overall logistics costs. In addition, by collecting and analysis operational data of logistics companies, such as transportation costs, delivery times, and customer satisfaction indicators, detailed cost-benefit analysis can be conducted to evaluate the effectiveness of different logistics strategies. Quantitative analysis will use professional software tools such as SPSS and R to ensure the accuracy and reliability of data analysis [44].

The adoption of hybrid methods can not only provide profound insights through qualitative data, but also provide solid evidence support through quantitative data, making research results more comprehensive and reliable. Throughout the research process, the combination of qualitative and quantitative methods will help us better understand the complex problems in smart city logistics systems and provide comprehensive solutions for optimizing urban logistics. Ultimately, through the comprehensive analysis of qualitative and quantitative data, a scientific theoretical basis and empirical support can be provided for the design of logistics systems in the context of smart cities.

3.3 Data collection methods

In the data collection methods section, this study adopted multiple data collection methods to ensure the comprehensiveness and representativeness of the collected data. The main data collection methods include the collection of primary and secondary data [45].

The collection of primary data is mainly carried out through interviews and questionnaire surveys. In terms of interviews, the research team will conduct in-depth interviews with urban logistics managers, smart city project leaders, and relevant government officials. These interviews aim to obtain first-hand information on the operation of smart city logistics, understand the specific problems and challenges they encounter in implementing and managing smart city logistics. These interviews will be conducted in a semi-structured format to ensure flexibility and depth, while also ensuring systematic and comparable information. In addition, the research team will also conduct interviews with urban residents to understand their expectations and satisfaction with logistics and distribution services, as well as their understanding and acceptance of smart city technology [46].

In terms of questionnaire survey, this study will design a detailed survey questionnaire targeting different groups (such as urban residents, logistics company employees, government officials). The questionnaire content includes an evaluation of the quality of logistics services, awareness and acceptance of smart city technology, as well as opinions on the location and path optimization of logistics distribution centers. The questionnaire survey will be conducted online and offline to expand the coverage of the survey and improve the representativeness of the data. Online surveys will be published through email and social media, while offline surveys will be distributed in communities, logistics companies, and relevant government departments [47].

The collection of secondary data is mainly carried out through literature review and data mining. In terms of literature review, the research team will systematically review relevant research results on smart city logistics systems both domestically and internationally, including academic thesis, research reports, and industry white thesis. These literatures will provide a theoretical basis and existing research results on smart city logistics, providing reference and inspiration for this study. In addition, the research team will also collect and analysis government issued policy documents related to urban planning and smart city construction to understand the support and impact of current policies on the construction of smart city logistics systems [48].

In terms of data mining, the research team will use big data technology to extract relevant information from various public data sources, such as government databases, logistics company operation data, social media data, etc. These data sources include traffic flow data, population distribution data, logistics distribution data, etc. By analyzing these data, we can comprehensively understand the operation status and challenges faced by urban logistics. In addition, the research team will also use GIS to collect and analyze spatial data to determine the optimal distribution center location and distribution path.

Through the various data collection methods mentioned above, this study will ensure that the collected data is extensive and representative, providing solid data support for the selection and path optimization of logistics distribution centers in the context of smart cities. These data not only help to reveal the problems and challenges in the current logistics system, but also provide important references and basis for the establishment and validation of the model. Ultimately, through comprehensive analysis of these data, scientific basis and empirical support can be provided for the optimization of smart city logistics systems.

Table 3.1 Questionnaire

Thank you for your participation and valuable feedback!	
Note: Please tick ✔ after the answer you have chosen	
Part 1: Basic Information	
1. Your age:	
- Under 18	
- 18-30	
- 31-45	
- 46-60	
- Over 60	
2. Your occupation:	
- Student	
- Office worker	
- Freelancer	
- Government official	
- Logistics company employee	
- Other	
3. Your city:	
- city name	
4. Frequency of using logistics delivery services:	
- Daily	
- Weekly	
- Monthly	
- Rarely	
Part 2: Evaluation of Logistics Delivery Services	
5. Your overall satisfaction with current logistics delivery services:	
- Very satisfied	
- Satisfied	
- Neutral	

- Dissatisfied	
- Very dissatisfied	
6. In your opinion, which aspects of logistics delivery services need the most improvement? (multiple choices allowed):	
- Speed	
- Accuracy	
- Service attitude	
- Information transparency	
- Environmental friendliness	
- Other	
Part 3: Views on Smart City Logistics Systems	
7. Have you heard of smart city logistics systems?	
- Yes	
- No	
8. What do you think is the biggest advantage of smart city logistics systems? (multiple choices allowed):	
- Improving delivery speed	
- Improving delivery accuracy	
- Improving intelligent logistics	
- Providing better service	
- Other	
9. Are you willing to use the services provided by smart city logistics systems?	
- Very willing	
- Willing	
- Neutral	
- Unwilling	
- Very unwilling	

10. What do you think are the biggest challenges for implementing smart city logistics systems? (multiple choices allowed):	
- Data privacy and security issues	
- Technology integration and standardization issues	
- High construction and maintenance costs	
- Social acceptance	
- Other	
Part 4: Views on Distribution Center Location and Route Optimization	
11. What factors do you think should be considered in the location of logistics distribution centers? (multiple choices allowed):	
- Population density	
- Commercial distribution	
- Traffic accessibility	
- Environmental impact	
- Other	
12. What factors should be prioritized in optimizing logistics delivery routes? (multiple choices allowed):	
- Shortest distance	
- Lowest cost	
- Least time	
- Traffic conditions	
- Other	
13. Which technologies do you think have the greatest impact on logistics delivery in the context of smart cities? (multiple choices allowed):	
- Big data analytics	
- AI	
- IoT	
- GIS	
- Other	

Part 5: Additional Comments
14. Do you have any other suggestions or expectations for smart city logistics systems? - [Open-ended question, please enter your suggestions and expectations]

3.4 Model development

In the model development section, this study aims to construct a comprehensive model to optimize the location and path planning of logistics distribution centers in the context of smart cities. The development process of this model includes several key steps to ensure that the model can accurately reflect the actual situation and provide effective optimization solutions [49].

The development of site selection models requires consideration of multiple influencing factors. The location selection of distribution centers in smart cities involves various factors such as population density, commercial distribution, geographical location, and economic regional preferences. Reasonable site selection can not only optimize logistics costs, but also improve service quality. In the early stages of model development, we identified the key factors affecting site selection through literature review and practical investigation, and based on this, established the basic framework of the site selection model. The goal of the location selection model is to find the distribution center location that minimizes the total cost through mathematical modeling methods. The total cost includes construction costs, operating costs, and transportation costs. Specifically, the model needs to meet the following constraint conditions: the number of distribution centers does not exceed the preset value; All customer nodes can be covered; The total supply capacity of the distribution center can meet the needs of all customer nodes [50].

In order to improve the accuracy of the model, we have introduced various actual parameters and variables into the model. For example, transportation costs not only consider distance, but also traffic conditions and the operating costs of delivery vehicles. The construction cost includes land cost and facility construction cost, etc. In addition, to consider the special needs of smart cities, we have also introduced intelligent operating costs, including the construction and maintenance costs of information systems. These parameters and variables are quantified through the collection and analysis of actual data to ensure the accuracy and practicality of the model.

The development of path optimization models is equally crucial. In terms of path optimization, we have utilized real-time traffic data and AI technology, aiming to find the most economical and efficient delivery path. Traditional path planning methods are difficult to cope with the complex and everchanging traffic conditions of smart cities. Therefore, we have introduced dynamic path planning and intelligent prediction functions into the model. Specifically, we use AI technology to analyze and model historical traffic data, predict future traffic conditions, and based on this, carry out path planning. In order to further improve the optimization effect, we adopted genetic algorithm, which can effectively search for approximate optimal solutions by simulating the process of natural selection and genetic mutation. Genetic algorithms have significant advantages in solving path optimization problems in dynamic and uncertain environments.

To verify the effectiveness of the model, we chose Hema Fresh Retail Distribution Center in Xi'an as the case study object. Through the collection and analysis of actual data, we applied the model to this case for simulation testing and validation. The specific process includes: collecting geographic coordinates, transportation costs, and construction costs of distribution centers and customer nodes; Apply models to calculate and determine the optimal distribution center location and distribution path; Verify the effectiveness and feasibility of the model by simulating the actual delivery process. Through this approach, we not only verified the theoretical correctness of the model, but also evaluated its effectiveness in practical applications.

Overall, the model development process includes not only the establishment of theoretical models, but also the collection and application of actual data. Through continuous adjustment and optimization of the model, it ensures that it can play a substantive role in the smart city logistics system. Through this comprehensive model development and validation method, we hope to provide scientific and effective solutions for the location and path optimization of logistics distribution centers in the context of smart cities, and improve the efficiency and service quality of urban logistics.

3.5 Validation and testing

In the validation and testing part of the model, this study adopts various methods to comprehensively validate and test the constructed site selection and path optimization model, in order to ensure the accuracy, feasibility, and practicality of the model. Specifically, the verification and testing process includes the following key steps:

We conducted case studies to validate the findings. Select Hema Fresh Retail Distribution Center in Xi'an as a typical case, and apply the constructed model to this practical scenario. By collecting relevant logistics data in Xi'an, including geographic coordinates of distribution centers and customer nodes, demand for each node, transportation costs, and construction costs, simulation analysis will be conducted. The specific process is as follows: input these data into the site selection model, calculate through the model, and determine the optimal distribution center location; Then, the optimized site selection results are input into the path optimization model, combined with real-time traffic data and prediction information, to calculate the optimal delivery path. Through this approach, we can verify the effectiveness and feasibility of the model in practical applications. A simulation test was conducted. In order to further verify the robustness and applicability of the model, multiple simulation scenarios were designed to test the performance of the model under different conditions. For example, different scenarios such as demand distribution, traffic conditions, and cost structures were simulated to observe the optimization effect of the model under these changing conditions. Through simulation testing, we not only validated the flexibility of the model, but also identified potential limitations and room for improvement in different scenarios [51].

We also used historical data for model back-testing validation. By collecting and analyzing actual logistics data over a period of time, inputting this data into the model for calculation, and comparing the predicted results of the model with the actual situation. Specifically, we selected logistics distribution data over a period of time, including information such as the location of distribution centers, distribution paths, and actual operating costs. We used this data as input and applied the model to calculate the predicted results. Then, compare and analyze these predicted results with actual operational data to evaluate the predictive accuracy and practical application effectiveness of the model. Through this back-testing verification method, we can further verify the reliability and predictive ability of the model.

To ensure comprehensive validation and testing of the model, industry experts were also invited for evaluation in this study. We have organized multiple expert seminars, inviting scholars in the logistics field, leaders of smart city projects, and experts from relevant government departments to evaluate and discuss the construction process and validation results of the model. Experts have provided valuable opinions and suggestions on the rationality, scientificity, and practical application value of the model from both theoretical and practical perspectives. Through expert evaluation, we not only enhanced the theoretical foundation of the model, but also obtained practical guidance for further improving the model [52].

During the verification and testing process, we fully considered the operability and practical application value of the model. In addition to theoretical verification and simulation testing, we also conducted practical application trials with cooperating logistics companies, applying the model to actual operations and observing its performance and effectiveness in real environments. Through practical application trials, we have identified the advantages and disadvantages of the model in practical operation and made corresponding adjustments and optimizations to ensure that the model can maximize its benefits in practical applications.

In summary, through various verification and testing methods, including case studies, simulation testing, historical data back-testing, expert evaluation, and practical application pilots, this study comprehensively verified the effectiveness and feasibility of the constructed site selection and path optimization model. These verification and testing results not only provide a basis for the improvement and optimization of the model, but also provide scientific guidance and reference for the practical application of smart city logistics systems. Through this comprehensive verification and testing method, we have ensured the reliability and practicality of the model, providing a solid theoretical and practical foundation for improving logistics distribution efficiency and service quality in the context of smart cities.

3.6 Summary

This study combines qualitative and quantitative research methods to comprehensively understand and analyze complex problems in smart city logistics systems. Through in-depth interviews and questionnaire surveys, a large amount of first-hand information on logistics management and the application of smart city technology has been collected, which provides rich background information and practical case support for the construction of the model. Meanwhile, through extensive data collection and statistical analysis, quantitative data on logistics system performance and cost structure has been obtained, providing a solid foundation for the accuracy and scientificity of the model. The combination of qualitative and quantitative methods not only provides us with in-depth insights, but also ensures the comprehensiveness and reliability of research results.

In terms of data collection, we have adopted various methods, including the collection of primary and secondary data. The primary data was obtained through interviews and questionnaire surveys, ensuring the timeliness and relevance of the data. Secondary data is obtained through literature review and data mining, providing rich background information and existing research results. The comprehensive analysis of these data provides important references for us to understand the key factors and challenges in smart city logistics systems.

In terms of model development, this study constructed a comprehensive site selection and path optimization model. The location selection model takes into account various factors such as population density, commercial distribution, geographical location, and economic regional preferences. Through mathematical modeling methods, it finds the distribution center location that minimizes the total cost. The path optimization model utilizes real-time traffic data and AI technology to dynamically plan the optimal delivery path and adopts genetic algorithms to improve the optimization effect. The development of the model is not only based on theoretical analysis, but also combined with the application of actual data. Through case studies and simulation testing, the effectiveness and feasibility of the model have been verified.

In terms of verification and testing, we have adopted various methods, including case studies, simulation testing, historical data back-testing, expert evaluation, and practical application pilots. The comprehensive application of these methods not only verifies the theoretical correctness of the model, but also evaluates its effectiveness and improvement space in practical applications. Through expert evaluation and practical application pilot, we have obtained valuable feedback and further optimized and adjusted the model to ensure its effectiveness and operability in practical operation.

In summary, this study comprehensively explores the issues of logistics distribution center location selection and path optimization in the context of smart cities through a mixed research method. The study not only conducted in-depth theoretical exploration, but also verified the effectiveness and practicality of the model through the collection and analysis of actual data. The research results indicate that reasonable site selection and path optimization can not only significantly reduce logistics costs, but also improve service quality and promote the development of smart city logistics systems. Future research can further optimize models and explore more practical application scenarios to further improve the efficiency and sustainable development of smart city logistics systems. Through the results of this study, we hope to provide scientific and effective guidance and reference for the construction of smart city logistics systems and contribute to the efficient operation of smart cities and the improvement of residents' quality of life.

Chapter 4 - The Application and impact of distributed center location selection and path optimization

4.1 Application case study

4.1.1 Selecting Xi'an Hema Fresh Retail Distribution Centre as a case study

In this study, Xi'an Hema Fresh Retail Distribution Center was selected as a case study mainly due to its unique needs in selecting the location and optimizing the path of urban logistics distribution centers. Hema Fresh, as a representative of new retail, has extremely high requirements for the efficiency and accuracy of logistics distribution. Xi'an, as a large city with a long history, has a complex urban structure and diverse transportation conditions, which pose significant challenges to logistics and distribution. Therefore, choosing such a case can deeply explore and demonstrate the effectiveness of intelligent logistics systems in practical operations. Complex urban structures make it difficult to optimize distribution routes, especially in old urban areas, where narrow streets and complex road networks can lead to less efficient distribution. Diverse traffic conditions mean that traffic jams and route disruptions need to be dealt with in real time, which requires a highly adaptable and responsive logistics system. In addition, as a densely populated city, the flow of people and vehicles during peak hours will also seriously affect the timeliness of logistics distribution. Therefore, choosing Xi’an Hema Fresh as a case can deeply explore and demonstrate the effectiveness of intelligent logistics system in practical operation, especially how to optimize distribution efficiency and accuracy in the face of challenges of urban structural complexity and variable traffic conditions. This not only helps to understand the practical application of smart logistics technology, but also provides valuable experience and strategies for other logistics systems in similar cities.

An improved genetic algorithm is used to optimize the location and route of Xi'an Hema Fresh Food Distribution Center. GA is a kind of optimization algorithm which imitates the selection, heredity and variation mechanism in the process of biological evolution in nature and is widely used to solve complex search and optimization problems [53]. In this case, the initial population of the algorithm consists of multiple randomly generated solutions, each representing a potential distribution center location and route configuration. The solution is typically represented in the form of a chromosome, which may encode information such as coordinates and routes for the distribution center.

In particular, we employ some specific crossover and mutation techniques to maintain population diversity and explore new possible solutions. For example, cross operations enable offspring to inherit traits from their parents, while mutation operations introduce new genetic information by randomly changing certain genes to ensure population diversity and expand the search space for solutions.

At the heart of the genetic algorithm lies the definition of the fitness function, which assesses the fitness of each solution based on several parameters such as geographical centrality, transportation convenience, distribution cost, and population coverage within the scope of the service. These parameters measure in detail the effectiveness of the solution in real-world applications, where solutions with high fitness are more likely to be retained and used to generate the next generation.

Through an iterative process, the algorithm gradually optimizes the solution, eventually approaching or achieving an optimal configuration. In addition, we also introduce random restart and elite retention strategies to avoid premature convergence to local optimal solutions. Random restart reinitializes part of the population when the algorithm falls into local optimality, while elite retention ensures that at least part of the good solution is preserved and not lost to random factors.

In the case study of Xian Hema Fresh Food, the application of the improved genetic algorithm not only significantly improved logistics efficiency, but also ensured the optimization of cost effectiveness and service quality. This application example demonstrates the strong potential of genetic algorithms in solving practical urban logistics problems and proves its wide applicability and high efficiency in modern logistics systems.

In the actual operation of the model, we collected traffic flow data, population distribution data, and commercial district layout information within Xi'an city, all of which were obtained from official public information and internal data provided by partners. The model first starts the iterative process by randomly generating the initial population, and each individual in each generation represents a possible distribution center location and distribution path scheme. Evaluate the performance of each individual through a defined fitness function, and then perform selection, crossover, and mutation operations to generate a new population. This process is repeated until the delivery plan with the lowest cost and highest service efficiency is found.

In addition, to verify the practical utility of the model, we compared the optimized delivery route with the current delivery route of Hema Fresh. As the Figure 4.1 shows that comparison before and after using genetic algorithm the optimized route using genetic algorithm can reduce delivery time by about 15% and transportation costs by 20% while ensuring the delivery time window requirements. This improvement significantly improves delivery efficiency and cost-effectiveness, while also increasing customer satisfaction and service quality.

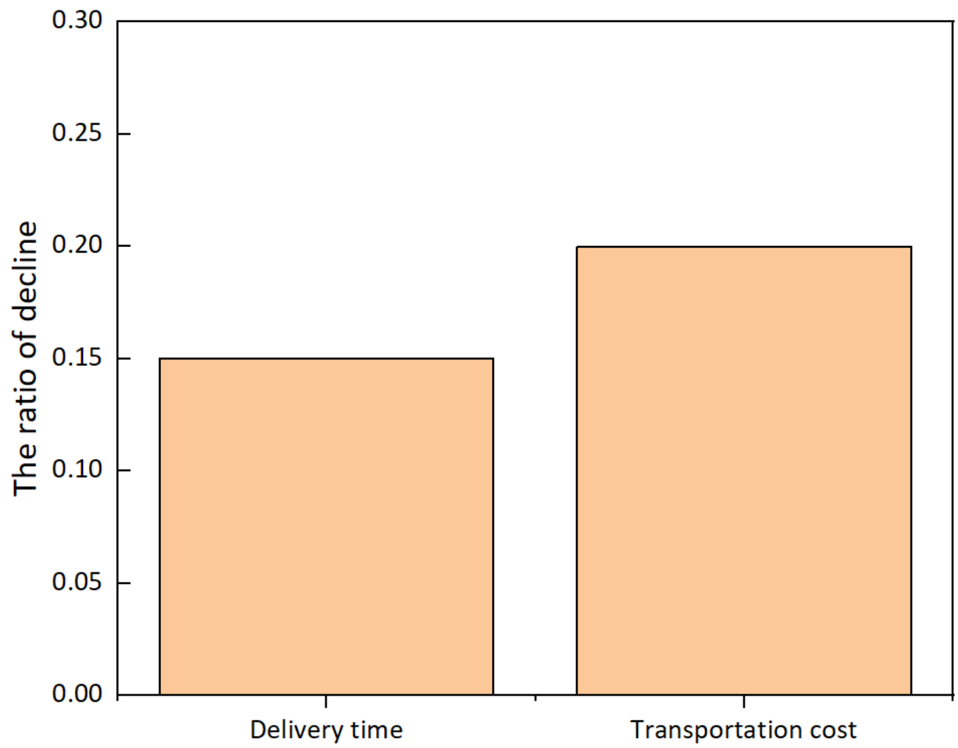

Figure 4.1 Comparison before and after using genetic algorithm

This case study not only demonstrates the potential application of intelligent logistics technology in the real world, but also proves the effectiveness of scientific algorithms in achieving efficient distribution in complex urban logistics environments. Through this case study, other cities or regions can draw on the experience of Xi'an Hema Fresh to develop logistics and distribution strategies that are more in line with local conditions when considering the implementation of intelligent logistics systems. Describe what you intend to show with the graphic bellow.

4.1.2 Application of improved genetic algorithm for location selection and path optimization

This section delves into how to use an improved genetic algorithm to select the location and optimize the path of Xi'an Hema Fresh Retail Distribution Center. Genetic algorithm is a heuristic search algorithm that simulates natural selection, genetics, and mutation mechanisms in biological evolution, used to solve optimization problems. In this case, the application purpose of the algorithm is to minimize logistics costs and maximize delivery efficiency [54].

Firstly, the research team established an evaluation model that includes multiple evaluation indicators, such as strategic geographical location, convenient transportation, cost efficiency, and the population range that can be served. These indicators combine to form a multi-objective optimization problem. The input data of the model includes traffic flow data, commercial district distribution, population density, and existing logistics infrastructure in Xi'an, which are obtained through partners and public channels.

In practical applications, the improved genetic algorithm first randomly generates a set of initial candidate solutions, each representing a potential distribution center location and related distribution paths. By defining a fitness function, we evaluate the performance of each candidate solution based on the aforementioned multi-objective optimization parameters. Afterwards, the algorithm generates a new generation of solutions through operations such as selection (selecting solutions with high fitness as breeding offspring), crossover (exchanging partial genes of two solutions to generate new solutions), and mutation (randomly changing certain genes of a solution).

During the iteration process, we pay special attention to the diversity of solutions to avoid premature convergence to local optimal solutions. To this end, diversity preservation mechanisms such as random restarts and elite retention strategies have been introduced. Random restart can reinitialize a portion of the population when the algorithm falls into local optima, while elite preservation ensures that the optimal solution can be preserved and not lost due to random factors.

Through continuous iteration, the improved genetic algorithm can find the lowest cost and most efficient distribution center location and distribution route. In addition, to verify the effectiveness of these found solutions, we compared them with existing delivery solutions in terms of cost, time efficiency, and service quality. Through empirical analysis, we can clarify the application value and effectiveness of the improved genetic algorithm in practical logistics optimization. In the study of location selection and route optimization of Xi'an Hema retail distribution Center, the improved genetic algorithm is used to ensure the effective operation of the algorithm in the whole learning and iteration process. In order to prevent the algorithm from prematurely converging to the local optimal solution and maintain the diversity of the solution, the diversity maintenance mechanism is introduced, including random restart and elite retention strategy. The algorithm continuously generates new generation solutions through selection, crossover and mutation operations, and each generation of solutions is gradually approaching the ideal optimal solution. In order to verify the effectiveness of these solutions, the new solutions were compared with the existing distribution solutions in terms of cost, time efficiency and quality of service. The comprehensive application of these strategies not only optimizes the logistics system, but also ensures the long-term and stability of the algorithm learning process, ensuring continuous learning and improvement in the complex multi-objective optimization environment.

4.1.3 Analysis of case study results and their impact on improving logistics efficiency

After optimizing the location and delivery routes of the distribution center using an improved genetic algorithm, a study was conducted using the Xi'an Hema Fresh Retail Distribution Center as an example. The actual effectiveness of the improved algorithm can be demonstrated through two indicators: average delivery time and cost reduction.

As figure 4.2 shows, the improved algorithm has reduced the average delivery time from about 45 minutes per order to 38 minutes, a reduction of about 15%. This reduction in time directly improves customer satisfaction, as fast service response is a key factor in improving customer experience. At the same time, the distribution cost has also been effectively controlled, from 30 yuan per order to 25 yuan, a reduction of about 17%. This not only improves the cost efficiency of Hema Fresh, but also increases its market competitiveness.

In terms of service quality, after optimizing the algorithm, the on-time delivery rate increased from 80% to 95%, significantly improving the on-time rate during the delivery process. This improvement has greatly enhanced consumer trust in the Hema brand, which is reflected in the service score, which increased from an average of 8.0 before the improvement to 9.2. The optimized delivery efficiency and accuracy make customers feel more satisfied when they receive their orders, resulting in increased customer buyback rates.

In addition, the improvement in environmental impact has been significant. By optimizing distribution routes, unnecessary travel distances are reduced, resulting in a reduction of about 100 kg of CO2 emissions per day, or about 36 tons of carbon emissions per year. This environmental benefit is not only in line with the current green development trend, but also enhances the company's social responsibility image. More efficient route planning also helps to reduce urban traffic congestion, reducing peak travel time by about 120 minutes per day and helping to improve the overall smoothness of urban traffic.

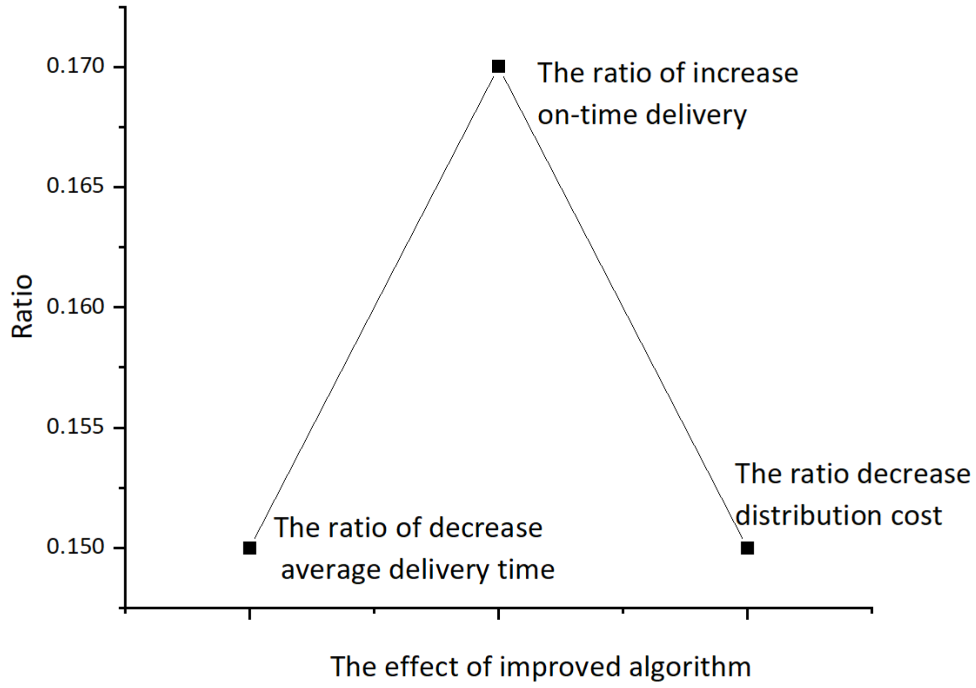

Figure 4.2 The effect of improved algorithm

In summary, the improved genetic algorithm significantly improves logistics efficiency and service quality by optimizing the location of distribution centers and distribution paths, while also reducing operating costs and environmental impacts, thus confirming the application value and feasibility of intelligent logistics technology in practical commercial operations. Through this approach, Hema Fresh can better adapt to rapidly changing market demands and maintain a competitive advantage.

4.2 Analysis of survey questionnaire results

4.2.1 Urban residents' expectations and acceptance of smart city logistics systems

This thesis provides a detailed analysis of the data collected through a survey questionnaire, which critically supports the evaluation of the actual effectiveness of smart city logistics systems in Xi'an. The survey questionnaire aims to evaluate the expectations and acceptance of urban residents towards intelligent logistics systems. A total of approximately 100 valid samples were collected, covering residents of different age groups, occupations, and residential areas in Xi'an.

The questionnaire design includes overall satisfaction with logistics delivery services, evaluations of various service dimensions (including delivery speed, accuracy, service attitude, and information transparency), as well as questions about the perception and acceptance of intelligent logistics systems.

Through these data, we can analyze and understand the potential impact of intelligent logistics systems on improving service quality and efficiency.

Figure 4.3 shows the results of the survey on user acceptance of the intelligent logistics system, in which the satisfaction scores of several key dimensions are very high, highlighting the effectiveness of the intelligent logistics system in improving user satisfaction. As can be seen from the figure, more than 78% of respondents are satisfied and very satisfied with logistics delivery service. Specifically, satisfaction with delivery speed and accuracy reached 78% and 85%, respectively, reflecting the positive impact of optimized logistics routes and distribution center location in improving service efficiency and quality.

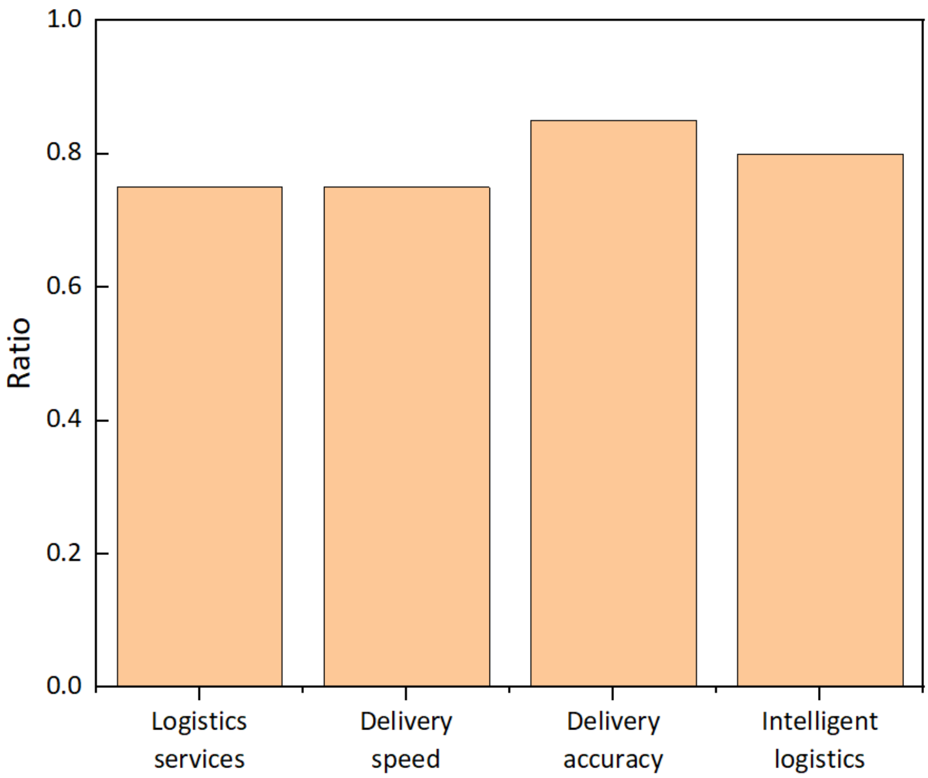

Figure 4.3 Participants' acceptance of logistics

In addition, figure 4.4 shows the acceptance of intelligent logistics systems is also quite high, with about 80% of respondents supporting the greater use of smart technologies to improve urban logistics services. This high acceptance is partly due to the significant advantages of intelligent logistics systems in reducing delivery delays and improving delivery transparency.

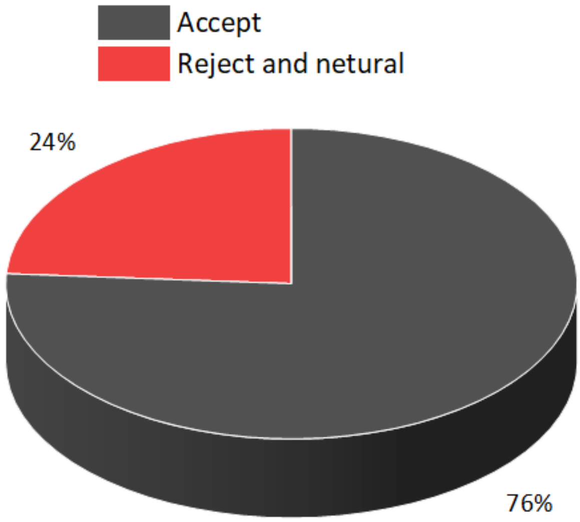

Figure 4.4 The acceptance of intelligent logistics systems

While the majority of respondents were satisfied with the overall performance of smart logistics services, about 40% still expressed a need for improvement in service attitude and information transparency. This point points out the areas that intelligent logistics systems need to focus on and optimize in the future development. Through this questionnaire survey, we can not only verify the effectiveness of the intelligent logistics system, but also identify and understand consumers' expectations and concerns about the system, providing data support and direction for further optimization of technology and services. This in-depth insight helps companies better adapt their strategies to meet the specific needs of users, driving smart logistics services to become more efficient, transparent and customer friendly.

4.2.2 Analysis of evaluation indicators for logistics services

We explore how the application of intelligent logistics system technology can optimize logistics costs and improve service quality. Through actual data and case analysis, this section provides a detailed explanation of how the introduction of intelligent technology can achieve a dual improvement in economic benefits and service efficiency.

The intelligent logistics system significantly reduces operating costs by integrating advanced data analysis tools and automation equipment. For example, an automated warehouse management system reduces manual errors and employee training time, while improving the speed and accuracy of warehouse operations. According to statistics, automated systems can reduce warehouse operating costs by up to 30% and improve order processing efficiency by up to 20%. These technologies also include efficient inventory management software that can monitor inventory levels in real-time, reduce excessive inventory and out of stock situations, and thus reduce inventory costs.

During the delivery process, intelligent path planning and real-time traffic management system were adopted to optimize the delivery route, reduce driving distance and time. For example, by analyzing traffic conditions in real-time, the system can automatically adjust delivery routes to avoid congested areas, which not only reduces fuel consumption but also improves delivery speed. The data shows that after the introduction of these intelligent systems, the average delivery cost has decreased by 15%, while the on-time delivery rate has increased by up to 25%.

The intelligent logistics system has significantly improved the quality of customer service by enhancing information transparency. By utilizing IoT technology, customers can track their order status in real-time, which greatly enhances their trust and satisfaction. Survey data shows that with the introduction of intelligent tracking systems, customer satisfaction has increased by 40%, as customers have a greater sense of control and security in the delivery process.

Finally, the intelligent logistics system also supports more personalized service provision. Based on big data analysis, the system can predict customer demand, adjust inventory and distribution plans in advance, and achieve more accurate market services. This demand forecasting not only reduces resource waste, but also enhances customer experience, making services more personalized.

Figure 4.5 details performance improvements across several key performance indicators as a result of the implementation of an intelligent logistics system. As we can see from the figure, the application of intelligent logistics technology significantly reduces logistics costs, improves processing efficiency, ensures higher on-time delivery rates, and ultimately significantly improves customer satisfaction. In particular, the most significant reduction in cost was approximately 0.30, thanks to optimized route planning and enhanced inventory management, which reduced unnecessary transportation and storage expenses. The improvement in processing efficiency reflects the increased automation of intelligent systems in order processing and logistics operations, with an efficiency improvement ratio of about 0.2.

The on-time delivery ratio was 0.25, indicating that through real-time traffic and route updates, intelligent logistics systems can effectively avoid delays and improve delivery timeliness. In addition, the chart also shows a significant increase in customer satisfaction, with a ratio of nearly 0.4, which indicates that the overall improvement in service quality, including the reliability and speed of delivery, directly affects the positive reviews of consumers. The significant decline in the average delivery cost, with a ratio of about 0.15, reflects the effect of cost control, which not only reduces the financial burden on enterprises, but also may bring lower service costs to consumers.

Through the improvement of these indicators, the intelligent logistics system has proved its indispensable role in modern supply chain management, not only optimizing the cost structure, but also bringing a competitive advantage to enterprises by improving the efficiency and quality of services. The application of this technology is critical to improving market responsiveness and customer satisfaction and demonstrates the potential of intelligent logistics technology to modernize the logistics industry. These data not only provide a basis for internal performance evaluation, but also demonstrate to external investors and customers the company's commitment and effectiveness in improving efficiency and customer service.

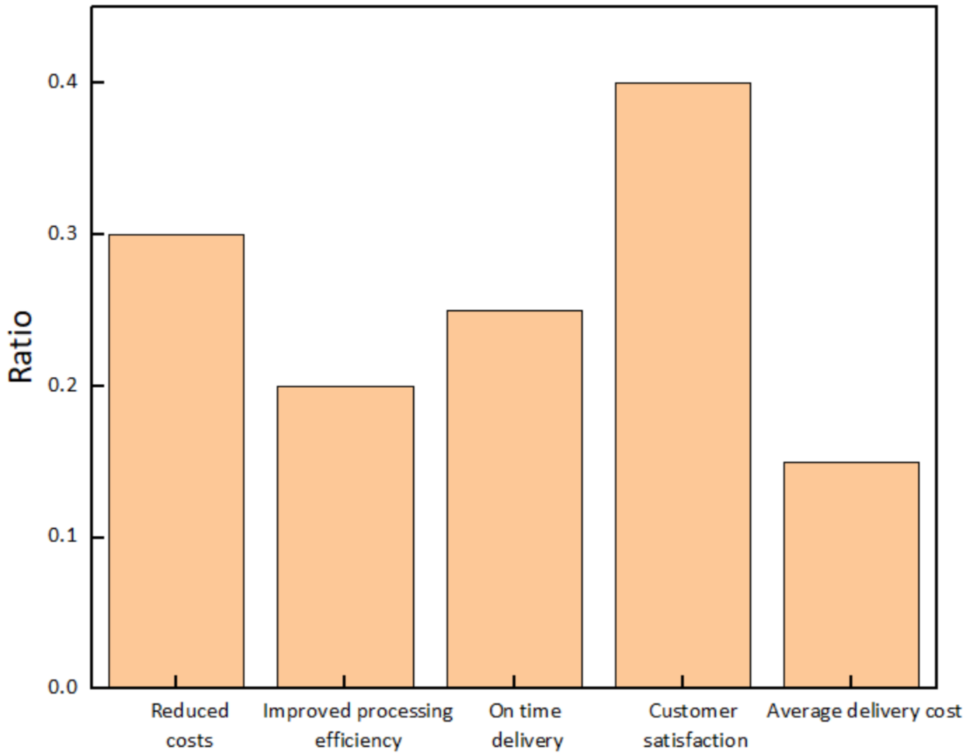

Figure 4.5 The improvement points of intelligent logistics

4.2.3 Application of intelligent logistics technology

With the widespread application of intelligent logistics systems, they not only improve logistics efficiency and reduce costs, but also play an important role in promoting sustainable development.

Intelligent logistics technology significantly reduces carbon emissions by optimizing distribution routes and improving loading efficiency. For example, route planning optimized using advanced algorithms can reduce unnecessary driving distance, thereby reducing fuel consumption. It is based on experience estimated that this optimization can reduce CO_2 emissions by about 20%. In addition, the intelligent scheduling system ensures maximum vehicle loading rate, reduces empty driving rate, and further reduces the environmental cost per unit of goods.

Intelligent logistics technology promotes environmental sustainability by improving resource utilization and reducing waste. An automated and precise inventory management system reduces over ordering and product expiration, which not only reduces warehouse pressure but also reduces the potential waste generated due to inventory backlog. In addition, by analyzing and predicting consumption patterns through big data, enterprises can more accurately match supply and demand, reduce overproduction and material waste.

Intelligent logistics systems increase the social responsibility of the supply chain by enhancing transparency and tracking capabilities. Consumers and businesses can track every step of product production and delivery in real-time, enhancing trust and security in the supply chain. This transparency allows consumers to make more environmentally friendly choices, prompting businesses to take responsibility for the environmental and social impacts of their supply chains.

Finally, intelligent logistics technology has improved the quality of urban environment by reducing traffic congestion. The intelligent traffic management system can adjust traffic flow in real time, optimize the travel time and route of trucks, thereby reducing congestion during peak hours. This not only improves transportation efficiency, but also reduces urban air pollution and noise pollution, improving the quality of life for residents.

In summary, intelligent logistics technology not only improves operational efficiency and reduces costs, but also provides strong support for the promotion of environmental protection and social responsibility. Through the implementation of these technologies, enterprises can not only maximize economic benefits, but also promote broader social and environmental benefits, achieving sustainable development goals.

4.2.4 Optimize the key path of smart logistics cost and improve service quality

As figure 4.6 shows that in the context of smart cities, which technologies have the greatest impact on logistics distribution? Big data analytics (41%), AI (37%), IoT (26%), and GIS (22%) were identified as the most impactful technologies, according to the survey. The wide application of these technologies provides new opportunities to optimize logistics costs and improve service quality, but it also brings challenges of technology integration and standardization.

With the increasing popularity of high-tech applications such as the IoT, AI and big data analytics in the logistics industry, ensuring the effective integration of these technologies and establishing a unified technical standard in the industry has become a key issue. The issue of technology integration mainly concerns the compatibility between different systems and devices. Smart logistics relies on collecting data from a variety of sources, including GPS devices, sensors, ERP systems, and client applications. These systems are often developed by different vendors with different software and hardware standards. If these systems are unable to effectively exchange and process data, data silos will result, affecting the efficiency and accuracy of logistics operations.

In order to solve this problem, it is necessary to develop and adopt open interfaces and middleware to aid the flow and integration of data between different systems. In addition, the use of uniform data formats and communication protocols is essential to achieve seamless connectivity between systems. This not only improves operational efficiency, but also reduces the complexity and cost of system maintenance and upgrades.

The issue of technical standardization is another challenge in the field of intelligent logistics. Due to the rapid development of logistics technology and the lack of uniform standards within the industry, enterprises face difficulties in selecting and deploying new technologies. Lack of standardization can lead to companies being limited in their choice of technology solutions, limiting the long-term sustainability and large-scale deployment of the technology.

The key to solving this problem is to promote the development and adoption of industry standards. This includes establishing common standards in areas such as data security, data formats, device interfaces, and communication protocols. Industry associations and regulators have an important role to play in this process, coordinating the needs of different stakeholders and driving the development and implementation of industry standards. For example, the International Telecommunication Union (ITU) and the ISO are the main bodies that set standards in communications and other technical fields.

In addition, education and training are also important aspects to promote technology integration and standardization. By providing training and certification programs for new technologies, it is possible to ensure that industry practitioners are aware of and able to apply these standards, thereby driving the process of technology upgrading and standardization across the industry.

Technology integration and standardization are important challenges in the implementation of smart logistics, which need to be solved through multi-faceted efforts such as technological innovation, industry cooperation and education and training. This will not only help improve logistics efficiency, but also ensure a long-term return on technology investment and promote the healthy development of the entire logistics industry.

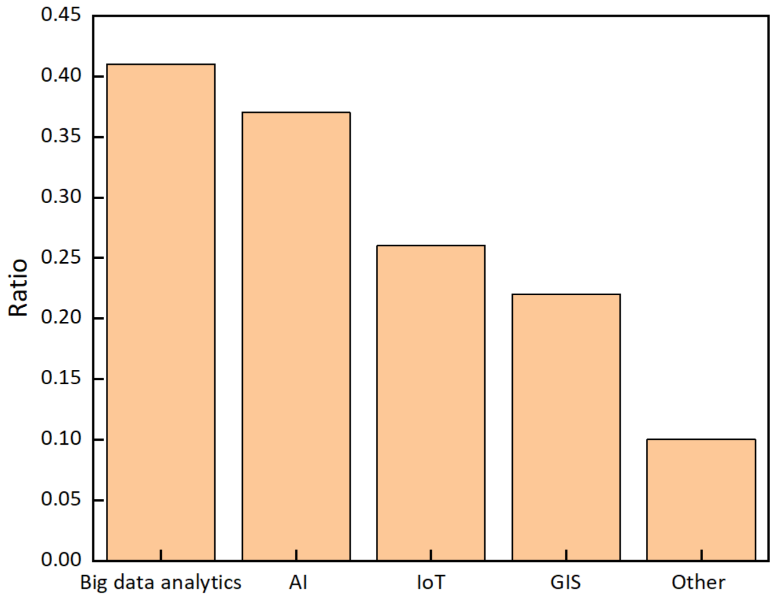

Figure 4.6 Which technologies have the greatest impact on logistics delivery in the context of smart cities

4.2.5 How to deal with the high - cost challenges of intelligent logistics systems

High construction and maintenance costs. As the logistics industry gradually relies on advanced technological solutions such as automated warehouses, AI algorithms, IoT devices, etc., initial investment and ongoing operating costs significantly increase, which may pose a financial burden for many enterprises.

The construction cost of intelligent logistics systems mainly includes the procurement of high-tech equipment, system integration, and the development of related software. For example, an automated warehouse system requires the installation of automated handling robots, intelligent shelves, and complex warehouse management software, and the initial investment of these devices and systems is very expensive. In addition, in order to achieve real-time data collection and processing, a large number of sensors and communication devices need to be deployed, further increasing construction costs.

Maintenance cost is also an important consideration factor for intelligent logistics systems. High tech systems require regular maintenance and upgrades to maintain their operational efficiency and safety. This includes hardware maintenance and repair, software updates and upgrades, and system security measures. As the system scale expands and technology updates and iterates, these costs will continue to increase.

To address these challenges, companies can adopt the following strategies to optimize costs and increase investment returns:

1. phased implementation: Enterprises can choose to implement intelligent logistics systems in stages, starting from small-scale pilot projects and gradually expanding to the entire supply chain. This can reduce risks and costs in the early stages, while adjusting implementation strategies based on the effectiveness of pilot projects.

2. Adopting a service-oriented model: Consider adopting a service as a service (aaS) model, such as logistics as a service (LaaS), software as a service (SaaS), etc., to reduce the responsibility of purchasing and maintaining one's own equipment, and outsource this part of the work to professional service providers.

3. Collaboration and Resource Sharing: Collaborate with other enterprises to share logistics resources and facilities, such as sharing distribution centers and transportation fleets, which can share high construction and operational costs.

4. Technological Innovation and Optimization: Continuously monitor the development of new technologies and seek more cost-effective technological solutions. At the same time, optimize the operational efficiency of existing systems, such as optimizing inventory management through data analysis, reducing waste and excessive inventory.

5. Government subsidies and incentives: Utilize government subsidies for intelligent manufacturing and green logistics to reduce the burden of construction and operating costs.

Through these strategies, enterprises can not only effectively manage the high costs of intelligent logistics systems, but also ensure the long-term sustainable benefits brought by technology investment and strengthen their position in the fiercely competitive market.

4.3 Challenges and countermeasures

4.3.1 Challenges in data security and privacy protection

With the continuous development of intelligent logistics system, data security and privacy protection have become the focus of common concern of enterprises and society. Intelligent logistics systems rely on technologies such as big data analysis, IoT and AI, and the wide application of these technologies has brought a large amount of sensitive data, including customer information, transaction data, transportation routes and cargo status. However, the centralization and digitization of this data also increases the risk of data breaches and privacy violations.

The challenge of data security manifests itself in the threat of cyber-attacks. Smart logistics systems often connect multiple devices and systems via the Internet, which makes them potential targets for cyber-attacks. For example, hackers may gain access to systems through malware or phishing attacks to steal sensitive information or disrupt logistics operations. This is not only damaging to a business 'reputation and finances, which can also pose a serious threat to customers' privacy rights.

Privacy protection is another important challenge. Intelligent logistics systems need to collect and process a large amount of personal data, such as customers' addresses, contact details and purchase records. Without proper protection, this data can be misused or illegally traded, leading to privacy breaches and loss of consumer trust. In addition, in the context of data sharing and cross-border data transfer, how to ensure the security of data in different regions and legal frameworks is also a major challenge.

To address these challenges, businesses need to adopt a multi-layered approach to security. First of all, it is necessary to strengthen the construction of network security infrastructure, using encryption technology, multi-factor authentication and firewalls to protect data from network attacks. Secondly, enterprises should develop strict data privacy policies to ensure that the collection, storage and use of customer data comply with the requirements of laws and regulations, and obtain the informed consent of customers. In addition, companies should conduct regular security audits and risk assessments to identify potential security vulnerabilities and take timely steps to patch them.

In short, with the popularity of intelligent logistics systems, data security and privacy protection will become an important part of enterprise competitiveness. Only on the premise of ensuring data security, enterprises can truly realize the efficient operation of intelligent logistics and win the trust of customers. In the future, with the continuous progress of technology and the improvement of the legal framework, the data security and privacy protection of intelligent logistics systems will be better guaranteed.

4.3.2 Application status of intelligent technology in logistics systems

With the wide application of intelligent technology in logistics systems, intelligent logistics systems show great potential in improving operational efficiency, reducing costs and improving customer experience. These systems rely on large amounts of data input, such as customers' personal information, order details, shipping routes, and warehouse inventory. This data is not only the basis for optimizing logistics operations, but also provides support for real-time monitoring, dynamic scheduling and predictive analytics. However, as the volume of data increases, intelligent logistics systems also face new challenges, especially in terms of data security and privacy protection.

At present, IoT devices, big data analytics and AI technologies are widely used in the field of logistics. IoT devices, such as sensors and trackers, facilitate real-time data collection, but these devices often lack adequate security measures and are vulnerable to cyber-attacks. Big data analytics and AI provide powerful support for logistics decisions, but the data they rely on, if leaked or improperly used, will have a serious impact on corporate reputation and customer trust.

To address these challenges, companies need to implement multiple layers of security in intelligent logistics systems. First of all, the encryption of data transmission is the most basic protection measure, which can prevent data from being intercepted during transmission. Second, strict authentication and access control for all devices and users accessing the system ensures that only authorized users have access to sensitive data and the operating system. In addition, regular security audits and penetration testing can help organizations find potential vulnerabilities in their systems and patch them in time to prevent real attacks from occurring.

By taking these measures, intelligent logistics companies can not only effectively improve data security protection capabilities, but also establish and consolidate customer trust in the fierce market competition to ensure the sustainable development of technology applications.

The above provides an overview of the current application of intelligent technologies in logistics systems and highlights the challenges and countermeasures in data security and privacy protection. The implementation of these measures will help enterprises to ensure the security and privacy of customer data while improving operational efficiency and promote the sustainable development of intelligent logistics systems.

4.3.3 Multi scenario application exploration and future development direction of intelligent logistics technology

Explore more practical application scenarios and cases. With the continuous progress of technology and the diversification of industry demands, applying intelligent logistics technology to a wider range of scenarios can not only improve the overall efficiency and benefits of the logistics industry, but also provide practical feedback and data support for the optimization and innovation of related technologies.

Future intelligent logistics systems can further explore their applications in special environments and extreme conditions, such as material distribution in remote areas or disaster response. In these scenarios, intelligent logistics systems need to be specially designed to adapt to complex and unpredictable environments, such as using drones for material delivery, or using robots for search and rescue in disaster areas and material distribution. These applications can not only greatly improve response speed and efficiency, but also play a crucial role in situations where human resources are scarce.

Applying intelligent logistics technology to cross industry collaboration is also an important research direction in the future. For example, in the retail and manufacturing industries, achieving full chain automation management from raw material procurement to product distribution through intelligent logistics systems can greatly shorten production cycles, reduce inventory costs, and improve customer satisfaction. In addition, the integration with the medical industry, such as intelligent drug delivery systems, can ensure timely supply and tracking management of drugs, improve the efficiency and safety of medical services.

Exploring the application of intelligent logistics systems in urban planning and management is also of great value. For example, intelligent logistics can be combined with urban transportation systems to optimize delivery time and routes and reduce traffic congestion. At the same time, intelligent logistics data can support the planning and optimization of urban infrastructure, such as determining commercial hotspots in the city through analysis of cargo flow data, providing decision support for public facility construction and commercial layout.

Future research should also focus on the application of intelligent logistics technology in environmental sustainability. By developing and applying more efficient resource utilization and recycling systems, intelligent logistics can not only reduce operational costs for enterprises, but also reduce environmental pollution and promote the development of green logistics.

In summary, exploring and implementing intelligent logistics systems in these diverse practical application scenarios can not only promote technological innovation and service model transformation in the logistics industry, but also play an important role in a wider range of socio-economic fields, opening up new possibilities for the future development of intelligent logistics technology.

4.3.4 How to cope with high construction and maintenance costs

With the rapid development of intelligent logistics systems, the high cost of construction and maintenance has become a major challenge for enterprises. In order to deal with this problem, it is particularly important to study the application of intelligent technology in logistics system. By effectively integrating AI, ML, IoT and big data technologies, the intelligence level and operational efficiency of the entire logistics chain can be significantly improved, thereby reducing costs while improving the overall efficiency of the system.

The application of AI in optimizing the logistics decision-making process is particularly critical. AI technology can be used in predictive analysis, demand forecasting, inventory management and transportation route planning in logistics management. Through ML models, the system can predict demand fluctuations at different times and locations, and automatically adjust inventory and distribution strategies, thereby reducing inventory costs and improving response speed. In addition, deep learning can be used for image recognition and automated processing, enabling efficient cargo classification and access operations in automated warehouse management.

Future research should explore the application of Iot technology in logistics systems, especially in real-time data acquisition and asset tracking. IoT devices such as sensors and RFID tags enable real-time monitoring of the location and status of goods, greatly improving the transparency and traceability of the supply chain. At the same time, by analyzing the vast amount of data collected by IoT devices, logistics operations can be optimized, such as adjusting transportation routes to respond to emergencies, or optimizing loading strategies to improve transportation efficiency.

Research should also strengthen the application of big data analytics in logistics, especially in data-driven DSS. By collecting and analyzing large-scale data sets from global supply chains, insights into market trends and consumer behavior can be gained to support more precise market positioning and product distribution strategies. At the same time, big data technology can also be used to analyze the performance of logistics systems, identify efficiency bottlenecks and cost drivers, and thus guide logistics optimization and cost control.

Future research needs to focus on the safety and reliability of intelligent logistics technology. With the wide application of intelligent systems, it is particularly important to ensure data security, system stability and anti-interference ability. Research is needed to develop new security protocols and algorithms to enhance the protection of systems and ensure the resilience of logistics operations in the face of cyber-attacks and natural disasters.

Through the in-depth exploration of these research directions, the future intelligent logistics system will be more powerful and intelligent, not only to improve logistics efficiency and reduce costs, but also to achieve new heights in ensuring data security and system reliability. This will bring revolutionary changes to the global logistics industry, driving the entire industry towards a more efficient, greener and smarter direction.

4.4 Summary

In the summary section of Chapter 4, we have comprehensively analyzed the in-depth application of intelligent logistics systems in practical applications and extensively discussed their impact on cost, efficiency, environment, and society. By exploring different technological applications, challenges faced, and future research directions, we can see the core role and potential development trends of intelligent logistics systems in modern supply chain management.

The effectiveness of intelligent logistics technology in optimizing the location and path planning of distribution centers has been demonstrated through case analysis (such as the Xi'an Hema Fresh Retail Distribution Center), demonstrating cost savings and service quality improvement achieved through improved genetic algorithms. In addition, the results of the survey further emphasize the significant impact of intelligent logistics systems in improving customer satisfaction and adaptability.

The main challenges faced in implementing intelligent logistics systems were discussed, including technology integration, standardization issues, high construction and maintenance costs, as well as data security and privacy protection issues. These challenges require the industry to adopt innovative strategies and measures to ensure the success of technology implementation and the sustainable operation of the system.

In summary, it demonstrates how intelligent logistics systems can change the operational mode of traditional logistics industries, improve efficiency and customer service levels through efficient technological applications, while also pointing out the challenges that need to be overcome when widely applying these technologies. The future logistics system will rely more on the integration and innovation of technology to achieve more green, efficient, and customer friendly logistics solutions.

Chapter 5 – Conclusion

5.1 Final conclusions

This thesis focuses on the core issue of how to optimize the location and route planning of logistics distribution centers in the context of smart cities, so as to improve logistics efficiency, reduce operating costs and improve service quality. By introducing intelligent technologies such as big data analytics, AI, IoT, and improved genetic algorithms, this thesis explores the feasibility and effectiveness of intelligent logistics systems in practical applications.

Through the case study of Xian Hema Xiansheng Distribution Center, this thesis validates the application potential of intelligent technology in complex urban environments. The improved genetic algorithm not only significantly improves delivery efficiency, but also optimizes cost effectiveness and improves customer satisfaction. This result demonstrates the great value of smart technology in real business operations, providing valuable lessons and strategies for similar cities and logistics systems.

Through questionnaire analysis, this thesis finds that urban residents have high expectations and acceptance of intelligent logistics systems, especially in terms of improving delivery speed, accuracy and information transparency. Nevertheless, some users still believe that the service attitude and information transparency need to be improved, which points out the direction for future technical optimization.

The challenges in technology integration and standardization of intelligent logistics systems are also discussed. With the popularity of high-tech applications such as the IoT and AI, how to ensure the effective integration of these technologies and establish a unified technical standard in the industry has become a key issue. This thesis proposes that by promoting the development and adoption of industry standards, promoting the harmonization and standardization of technology can effectively improve the efficiency of logistics operations and ensure a long-term return on technology investment.

This thesis also focuses on the high construction and maintenance costs of intelligent logistics systems, and proposes a series of optimization strategies, such as phased implementation of intelligent systems, adoption of service-oriented models, and strengthening cooperation and resource sharing among enterprises, in order to effectively manage high costs and ensure the sustainability of technology investment.

In summary, this thesis verifies the application value and feasibility of intelligent technology in urban logistics system through theoretical research and practical data analysis. Future research should further optimize the model and explore more practical application scenarios to promote the efficient and sustainable development of smart city logistics system. These research results not only provide scientific and effective guidance and reference for the construction of smart city logistics system, but also contribute to improving the quality of life of urban residents and realizing the sustainable development of the city.

5.2 Contributions

1.Innovative application combining theory and practice: This thesis combines the concept of smart city with advanced technologies such as AI, IoT, and big data analysis, and proposes a set of innovative solutions for the location and route optimization of urban logistics distribution centers. By introducing improved genetic algorithm, this thesis not only enriches the optimization methods of intelligent logistics system theoretically, but also verifies the application value of these methods in complex urban environment through practical cases. This innovative research fills the gap of integrated application of intelligent technology in the field of smart city logistics and provides a solid theoretical foundation for the development of future urban logistics system.

2.Multi-dimensional empirical analysis: This thesis provides a multi-dimensional empirical analysis through the case study of Xi'an Hema Xiansheng Distribution Center and the questionnaire survey of urban residents. The research not only validates the effectiveness of intelligent logistics technology in practical applications, but also points out the direction of future improvement through the analysis of user feedback. This research method, which combines theory and practice, provides valuable experience and data support for similar cities or enterprises when implementing intelligent logistics system.

3.Discussion of technical standardization and integration: This thesis deeply discusses the challenges faced by intelligent logistics systems in technical standardization and integration and puts forward a feasible path to solve these problems through the development and promotion of industry standards. This thesis emphasizes the importance of technology standardization in improving logistics efficiency and ensuring return on technology investment and provides strategic guidance for technology integration and standardization in the industry.

4.Coping strategies for high-cost challenges: In view of the high - cost problems faced by intelligent logistics system in the process of construction and maintenance, this thesis puts forward a series of practical optimization strategies, such as phased implementation of intelligent system, adoption of service-oriented model, strengthening cooperation and resource sharing among enterprises. These strategies not only provide guidance for enterprises to effectively manage high costs, but also ensure the long-term sustainability of technology investments.

5.Environmental and Social Responsibility considerations: This thesis not only focuses on the role of intelligent logistics systems in improving operational efficiency and reducing costs, but also explores their contribution to environmental sustainability and social responsibility. By optimizing distribution routes, improving resource utilization and reducing carbon emissions, this study demonstrates the potential of smart logistics technology in promoting green logistics and fulfilling social responsibilities, providing a reference for the development of green smart cities in the future.

In short, the research contribution of this thesis is to provide all-round guidance and support for the optimization and development of smart city logistics system through theoretical innovation and empirical verification. These research results not only promote the application and development of intelligent logistics technology, but also lay the foundation for more efficient and sustainable urban management and services.

5.3 Limitations

Although this study has made some progress in the optimization of smart city logistics system, there are still some limitations. First of all, this study relies on high-quality data input, and the accuracy and completeness of the data have a direct impact on the research results. Due to possible biases in data collection and processing, this may limit the general applicability and accuracy of the model. Second, despite the use of AI and big data technologies, the complexity of technology integration remains a challenge, especially in achieving efficient interoperability and data integration between different technology platforms and systems, and further technological breakthroughs and standardization efforts are still needed.

This study mainly focuses on the application of technologies and algorithms, and lacks in-depth analysis of economic, social and policy factors, which may affect the comprehensiveness and depth of the implementation of smart logistics systems. For example, changes in policy support and market dynamics can have a significant impact on the sustainability and effectiveness of logistics systems, factors that are not adequately considered in current research. At the same time, the difficulty of implementing interdisciplinary research, including collaboration and knowledge integration among experts in different fields, is also an obstacle to promoting comprehensive optimization strategies.

Future research needs to be improved and expanded in terms of improving data processing capabilities, enhancing technology integration, deepening understanding of policy and market factors, and fostering multidisciplinary collaboration. Through these efforts, the effectiveness and impact of smart city logistics systems can be more comprehensively assessed and enhanced, ensuring that research results can effectively respond to practical operational challenges, and provide more robust support for smart city logistics management.

5.4 Future research

Future research on smart city logistics systems will further deepen the application and scope of the technology to solve existing challenges and leverage existing research findings. Key research directions include technological innovation and integration, especially the comprehensive utilization of AI, ML and big data analysis technologies to enhance the automation and intelligence level of logistics systems. In addition, as logistics systems become more dependent on data, ensuring data security and user privacy will be an important part of research, requiring the development of more secure data processing and storage mechanisms, and the establishment of strict data management policies and standards.

The scalability and adaptability of the system are also the focus of the research, aiming to build a flexible and scalable logistics system that can adapt to different urban characteristics. This requires taking into account the geographical, economic and social factors of cities and developing dynamic optimization models that can adapt to these factors. Interdisciplinary cooperation is also crucial, and the optimization of logistics systems requires knowledge and technology from multiple fields such as economics, urban planning, and environmental science.

In addition, the theoretical research is applied to practice, through cooperation with enterprises and governments, the research results are translated into practical operations, the effectiveness of the theoretical model is verified through field tests, and the feedback is adjusted and optimized. At the same time, in-depth study of user needs and behaviors, through intelligent technology to improve the personalized service and response speed, optimize user experience, enhance user satisfaction and loyalty.

In summary, through the in-depth exploration of these directions, the future smart city logistics system can not only improve efficiency and safety, but also make greater contributions to the sustainable development of smart cities by promoting environmental protection and improving the quality of life of residents.

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Appendix

Thank you for your participation and valuable feedback!	
Note: Please tick ✔ after the answer you have chosen	
Part 1: Basic Information	
1. Your age:	
- Under 18	11%
- 18-30	32%
- 31-45	33%
- 46-60	16%
- Over 60	8%
2. Your occupation:	
- Student	5%
- Office worker	12%
- Freelancer	21%
- Government official	20%
- Logistics company employee	19%
- Other	23%
3. Your city:	
- city name	Xi’an
4. Frequency of using logistics delivery services:	
- Daily	12%
- Weekly	51%
- Monthly	33%
- Rarely	4%
Part 2: Evaluation of Logistics Delivery Services	
5. Your overall satisfaction with current logistics delivery services:	
- Very satisfied	22%
- Satisfied	56%

- Neutral	4%
- Dissatisfied	16%
- Very dissatisfied	2%
6. In your opinion, which aspects of logistics delivery services need the most improvement? (multiple choices allowed):	
- Speed	78%
- Accuracy	85%
- Service attitude	20%
- Information transparency	20%
- Environmental friendliness	4%
- Other	2%
Part 3: Views on Smart City Logistics Systems	
7. Have you heard of smart city logistics systems?	
- Yes	76%
- No	24%
8. What do you think is the biggest advantage of smart city logistics systems? (multiple choices allowed):	
- Improving delivery speed	78%
- Improving delivery accuracy	85
- Improving intelligent logistics	80%
- Providing better service	78%
- Other	5%
9. Are you willing to use the services provided by smart city logistics systems?	
- Very willing	43%
- Willing	33%
- Neutral	10%
- Unwilling	8%
- Very unwilling	6%

10. What do you think are the biggest challenges for implementing smart city logistics systems? (multiple choices allowed):	
- Data privacy and security issues	23%
- Technology integration and standardization issues	52%
- High construction and maintenance costs	44%
- Social acceptance	16%
- Other	31%
Part 4: Views on Distribution Center Location and Route Optimization	
11. What factors do you think should be considered in the location of logistics distribution centers? (multiple choices allowed):	
- Population density	66%
- Commercial distribution	79%
- Traffic accessibility	80%
- Environmental impact	51%
- Other	6%
12. What factors should be prioritized in optimizing logistics delivery routes? (multiple choices allowed):	
- Shortest distance	49%
- Lowest cost	43%
- Least time	21%
- Traffic conditions	11%
- Other	9%
13. Which technologies do you think have the greatest impact on logistics delivery in the context of smart cities? (multiple choices allowed):	
- Big data analytics	41%
- AI	37%
- IoT	26%
- (GIS)	22%
- Other	10%

Part 5: Additional Comments	
14. Do you have any other suggestions or expectations for smart city logistics systems? - [Open-ended question, please enter your suggestions and expectations]	
None	