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Research on the Innovation of "Last Kilometer" Delivery Mode of Rural E-commerce in Henan-Based on Dynamic Path Planning Technology (GAT)

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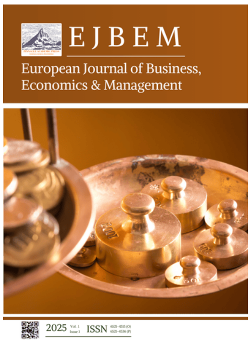

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Abstract: This study proposes an innovative dynamic path planning solution based on Graph Attention Network (GAT) for addressing the "last kilometer" delivery problem in rural e-commerce in Henan Province. The solution analyzes bottlenecks such as complex geographic environments, low operational efficiency, and insufficient technological adaptation. A three-in-one framework of "intelligent path planning, new distribution organization, and optimization of operation mechanisms" is constructed, aiming at cost reduction. The study shows that this solution can shorten the response time to 2 minutes and reduce logistics costs by 15%-20%, providing replicable technical support for rural revitalization.

Keywords: rural e-commerce; last-mile delivery; Graph Attention Network (GAT); dynamic path planning; rural revitalization

1. Introduction

In recent years, rural e-commerce in Henan Province has been developing rapidly under the dual impetus of digital economy and rural revitalization strategy. However, along with the rapid expansion of e-commerce scale, the problem of rural "last kilometer" distribution has become increasingly prominent, which has become a key bottleneck restricting the high-quality development of e-commerce [1].

Henan Province, rural geography is complex, scattered villages, road network structure is not perfect. The average distance between villages in some counties in the east and south of Henan is more than 5 kilometers, and more than 30% of rural roads are not hardened, resulting in multiple challenges to logistics and distribution. In addition, seasonal factors such as busy farming, rain and snow further aggravate the uncertainty of distribution, which not only pushes up the cost of logistics, but also hinders the efficiency of agricultural products upstream.

Currently, rural distribution mainly relies on artificial experience or static path planning algorithms (e.g., Dijkstra, A* algorithms), which are unable to respond to dynamic changes in the road network in real time (e.g., construction, market occupancy), and it is difficult to integrate multi-dimensional constraints, such as road conditions, order density, and vehicle load. With the development of artificial intelligence, graph neural networks (GNN), especially graph attention networks (GAT), show unique advantages, which can dynamically analyze node relationships through the mechanism of attention, and are especially adapted to unstructured rural road networks.

This study explores the application of GAT technology in rural e-commerce logistics path optimization in Henan Province as an example [2]. By utilizing the dynamic weight allocation characteristics of GAT, the real-time capability and accuracy of path planning are improved, and preliminary estimates expect to reduce logistics costs by 15%-20%, helping the e-commerce of agricultural products. The research results can provide replicable technical solutions for the rural areas of Henan Province and even the central and western regions, which is of great significance in promoting the equalization of urban and rural logistics services.

2. Literature Review

2.1. Current Status of Rural Logistics Research at Home and Abroad

Scholars at home and abroad have conducted extensive research on rural logistics issues, mainly focusing on the two levels of model innovation and technology optimization.

2.1.1. International Research Progress

Japan has adopted the "Joint Delivery System" model to solve the problem of high rural logistics costs, which means that multiple logistics companies share the distribution network to reduce repeated transportation and reduce the empty load rate [3]. The model led to a reduction in logistics costs of about 18% in a pilot in Hokkaido. The USPS "Rural Delivery System" improves delivery efficiency in remote areas by optimizing delivery routes and combining dynamic route planning with GIS (Geographic Information System) [4]. The European Union's "Smart Rural Logistics" project utilizes Internet of Things (IoT) technology to achieve real-time monitoring and dynamic scheduling of rural logistics, effectively improving on-time delivery [5].

2.1.2. Progress of Domestic Research

China's rural logistics research mainly focuses on two aspects: mode innovation and technology application. In terms of mode, "county unified warehouse and common distribution" reduces intermediate links and improves logistics efficiency by integrating warehousing and distribution resources in the county. For example, the pilot project in Anji County, Zhejiang Province, reduced logistics costs by 15% and distribution time by 20%. In addition, the "e-commerce + logistics" synergistic model optimizes the upstream path of agricultural products through in-depth cooperation between e-commerce platforms and logistics enterprises, such as Pinduoduo's "intelligent processing system for agricultural goods" that automatically matches the optimal logistics solutions [6].

However, there are still shortcomings in the existing research. First of all, the localization adaptation is insufficient. The applicability of international advanced models (such as Japan's "common distribution" or the European Union's intelligent logistics) in China's rural areas has not yet been fully verified, due to the large geographical differences and infrastructure imbalance, direct application may lead to efficiency discounts, such as the terrain of remote mountainous areas limits the effectiveness of GIS dynamic path planning. Secondly, technology landing and popularization obstacles. Rural informatization foundation is weak, lack of professionals and maintenance capacity, such as "county unified warehousing and distribution" in the western less developed areas due to the low level of storage digitization and difficult to promote. Then, the lack of cost-sharing mechanism. The existing model relies on unilateral input from the government or enterprises, and lacks a sustainable multi-principal collaboration mechanism, resulting in small and medium-sized farmers bearing higher costs in the "e-commerce + logistics" model, and insufficient willingness to participate in the long term.

2.2. Evolution of Path Planning Algorithms

The development of path planning algorithms has gone through three stages: traditional heuristic algorithms → machine learning → deep learning, and the specificity of rural logistics has put forward higher requirements for algorithms.

2.2.1. Traditional Algorithm Stage

Early research mainly used genetic algorithm (GA), ant colony algorithm (ACO) and Dijkstra's algorithm for static path planning. Optimization of rural distribution paths using improved genetic algorithms reduced transportation costs by 12%. However, such algorithms rely on fixed road network data and cannot adapt to real-time changes in rural roads (e.g., temporary road closures, market occupancy).

2.2.2. Machine Learning Stage

With the increase of data volume, reinforcement learning (RL) and support vector machine (SVM) were introduced for path optimization. A dynamic path planning method based on Q-learning is proposed, which can adjust routes according to real-time traffic data, but its high computational complexity makes it difficult to be applied on a large scale.

2.2.3. Deep Learning Stage

In recent years, graph neural network (GNN) has become a research hotspot for path planning due to its powerful graph structure learning ability. Among them, Graph Attention Network (GAT) dynamically calculates the importance between nodes through Attention Mechanism (Attention Mechanism), and its core formula is:

$$\alpha_{ij} = \frac{exp\left(LeakyReLU\left(a^T\left[Wh_i||Wh_j\right]\right)\right)}{\sum_{k\in N_i} exp\left(LeakyReLU(a^T[Wh_i||Wh_k])\right)}$$

Where α_{ij} denotes the attention weight of node i to node j, W is a trainable parameter, and h_i and h_j are node features. This mechanism enables GAT to adaptively learn the key nodes of rural unstructured road networks and improve the accuracy of path planning.

Currently, GAT has achieved good results in urban logistics (e.g., Meituan takeout path planning), but there are still fewer studies in rural scenarios. This study is intended to explore the optimization effect of GAT in the “last-mile” delivery by combining the characteristics of rural road network in Henan Province, so as to provide technical support for rural revitalization.

2. Henan Rural E-Commerce Logistics Development Status Quo and Problem Analysis

2.1. Overview of the Development of Rural E-Commerce in Henan Province

As a nationally important agricultural and population province, Henan Province has made remarkable progress in the field of rural e-commerce in recent years. According to the latest statistics from the Department of Commerce of Henan Province, the province's online retail sales of agricultural products in the first three quarters of 2024 exceeded 74 billion yuan, an increase of 11.3% year-on-year, a figure that not only set a new record high, but also accounted for 53.4% of the total rural online retail sales. During the same period, rural e-tailing reached 88.113 billion yuan, a growth rate of 12.24%. The coverage rate of express delivery to villages increased from 85% in 2023 to 100% in 2024. Specialty agricultural products such as Xinzheng red dates and Xinyang Maojian are sold nationwide through Taobao, Pinduoduo and other e-commerce channels, and the average annual growth rate of sales has remained above 15%.

In terms of logistics infrastructure construction, Henan Province has made breakthrough progress through the implementation of the “Express to Village” project. By the end of 2024, 46,000 administrative villages in the province reached 100% access to courier services, 60 percentage points higher than in 2020. The province has built 126 county-level logistics distribution centers, township express network coverage rate of 100%, more than 38,000 village-level express service stations. A three-tier logistics network system of "county-level logistics centers, township distribution stations and village-level service points" has been formed.

Data show that in 2024, the average time limit for rural express delivery in the province has been shortened to 1.5 days, compared with 4.2 days in 2020, an increase of 64%. Especially in the "Double 11" and other e-commerce promotion period, through the pre-sale of sinking, front warehousing and other innovative modes, some counties have even realized the "same day" service, the courier to the village time from the original 3-5 days shortened to 1-2 days.

Table 1. Comparison of key indicators of rural e-commerce in Henan, from 2020 to 2024.

Indicator	2020	2024	Growth rate
E-tail sales of agricultural products (billion yuan)	420	881	110%
Coverage rate of express delivery to villages (%)	40	100	150%
Number of village-level service stations (10,000)	1.2	3.8	217%
Average delivery timeframe (days)	4.2	1.5	-64%

2.2. Major Bottlenecks in "Last-Mile" Delivery

2.2.1. Challenges Posed by Geographic Factors

Rural areas in Henan Province have the typical characteristics of "large dispersion and small aggregation", and the geographic environment is complex and diverse, which has a significant impact on the efficiency of logistics and distribution. The average distance between villages in the plains of east Henan is 3-5 kilometers, and in the mountainous areas of west Henan and south Henan, some villages are even more than 8 kilometers away from each other due to terrain constraints. This decentralized layout leads to low density of distribution nodes, and the cost of service per unit area is significantly higher than in urban areas. About 30% of the province's rural roads are not hardened non-grade highway, of which Xinyang, Nanyang and other mountainous cities and counties, this proportion is as high as 45%. Muddy roads in the rainy season, snow in winter and other problems further exacerbate the difficulties of access, some remote villages throughout the year 10-15% of the time can not pass the standard delivery vehicles. Geographical constraints, forcing the distribution network presents "capillary" type distribution, end node coverage cost, distribution is difficult. Shangshui County, Zhoukou City, for example, a distribution vehicle average daily mileage of 180 kilometers, but due to circuitous routes and inefficient loading, the effective distribution mileage of only 60%, the idling rate and fuel costs than the city is higher than more than 40%. Mountainous and hilly areas account for 44.3% of the province's area, resulting in limited access for large vehicles, which have to rely on small and medium-sized vehicles or manual transit. For example, some administrative villages in Lushi County, Sanmenxia City, need to be connected by agricultural tricycles, increasing the cost of single-piece delivery by 2-3 times.

2.2.2. Outstanding Operational Efficiency Problems

Henan rural "last kilometer" distribution is not only restricted by geographical conditions, but also faces significant operational efficiency problems, mainly reflected in the high rate of vehicle idling, high distribution costs, irrational resource deployment, etc., which seriously restricts the sustainable development of the rural logistics system. China Federation of Logistics and Purchasing 2024 data show that the average empty rate of rural logistics distribution vehicles in Henan reached 32.5%, much higher than the level of urban distribution of 14.1%. Rural logistics is mainly one-way distribution, and return vehicles often have no goods to carry. In the busy season (such as summer harvest, autumn harvest period) labor shortage, resulting in distribution demand dispersion, some areas of the empty rate even climbed to more than 40%, resulting in a serious waste of capacity resources. Order density in rural areas is less than 1/5 of that in cities, making it difficult to form efficient distribution paths, and the vehicle loading rate is generally lower than 50%.

Distribution costs, rural “last kilometer” distribution costs accounted for about 35% -40% of the total cost of logistics, is 1.8-2 times the cost of similar urban distribution. In Zhumadian City, for example, each single rural express terminal distribution costs up to 3.2 yuan, 1.6 yuan higher than the urban distribution. About 65% of rural logistics enterprises still rely on manual scheduling and lack intelligent path planning systems, leading to problems such as circuitous transportation and repeated distribution. Express, e-commerce, local commerce and other logistics resources are not effectively integrated, failing to realize common distribution, resulting in a waste of resources. The low level of informatization and insufficient scheduling optimization further reduce operational efficiency.

2.2.3. Insufficient Technical Adaptability

The existing path planning system is mostly designed based on the characteristics of urban road network, failing to fully consider the special characteristics of rural road network. Rural roads are characterized by non-standardization (30% unhardened) and strong dynamic changes (average daily road condition change rate over 15%). It was found that in the traditional algorithm application scenario, when encountering unexpected situations such as road construction and market occupancy, the average response time for the system to re-plan the path is more than 30 minutes, much higher than the 8-10 minutes response standard in urban areas. During the “618”, “Double 11” and other e-commerce promotions, the order delay rate in some counties was as high as 38%, of which more than 60% was delayed due to unreasonable path planning. Existing system in a single day when the volume of orders more than three times the peak period, computing efficiency decreased by 40%, resulting in insufficient optimization of the distribution scheme. In addition, during busy agricultural seasons (e.g., wheat harvest season in May) and extreme weather (e.g., flood season in July-August), road occupancy increased by 50%, road access was blocked in about 28% of administrative villages, and the system was not able to update real-time information on road conditions, resulting in a three-fold increase in the delivery failure rate, and a drop in the on-time rate of delivery by 20-25 percentage points.

3. Gat-Based Rural E-Commerce “Last Kilometer” Delivery Mode Innovation Path

The rapid development of rural e-commerce has injected new kinetic energy into rural revitalization, but the “last-mile” distribution problem has always been a bottleneck restricting the development of rural e-commerce. The traditional distribution mode is limited by the weak infrastructure in rural areas, scattered population, complex road conditions and other factors, resulting in high distribution costs, low efficiency, and difficult to guarantee the quality of service. Graph Attention Network (GAT), as a deep learning model based on graph neural network, can effectively handle non-Euclidean spatial data, which is especially suitable for modeling and optimization of complex road network and dynamic distribution demand in rural areas. Based on GAT technology, a new mode of rural e-commerce “last-mile” delivery is constructed from three dimensions: intelligent path planning, distribution organization model innovation and operation management mechanism optimization, so as to enhance distribution efficiency, reduce operation cost and improve user experience.

3.1. Intelligent Path Planning System Empowered by Gat Technology

Distribution path planning in rural areas faces many challenges, such as irregular road networks, lack of real-time traffic information, and sparse and dynamically changing order distribution. Traditional path planning algorithms (e.g., Dijkstra, A* algorithms) often rely on static road network data, which is difficult to adapt to the dynamics and uncertainty of rural distribution [7]. In contrast, GAT technology is able to effectively capture the spatial correlation between road network nodes and dynamically adjust distribution paths through its powerful graph structure learning capability and attention mechanism [8].

The core advantage of GAT lies in its ability to weight the nodes and edges in the graph structure data for learning, so as to identify the critical path nodes and potential congestion points. In rural delivery scenarios, villages, delivery points, and road intersections can be abstracted as graph nodes, and road connectivity relationships can be abstracted as edges, and the GAT model can be utilized to learn the attentional weights between nodes. For remote villages, traditional algorithms may ignore their distribution priority due to low order volume, while GAT can dynamically adjust their weights through the attention mechanism to ensure fairness and coverage of distribution. In addition, GAT is able to fuse multi-source data, such as historical order distribution, weather conditions, road construction information, etc., to generate optimal paths through a multi-layer attention network [9].

The intelligent path planning system includes three key aspects: first, road network modeling, which transforms the road network in rural areas into graph-structured data and embeds node characteristics (e.g., distance, road class, and real-time traffic conditions); second, dynamic attention computation, which learns dependencies between nodes through the GAT model and predicts the distribution cost and time for different paths; and third, real-time path optimization, which combines real-time order data and vehicle status, to dynamically adjust the distribution route. For example, when a road is temporarily closed due to weather, GAT can quickly recalculate the path to avoid distribution delays. Experiments have shown that GAT-based path planning algorithms can improve delivery efficiency by more than 20% in rural scenarios, while reducing fuel consumption by more than 15%.

In addition, GAT technology can be combined with reinforcement learning to build an adaptive path planning system. By simulating the long-term effects of different distribution strategies, the system can learn the optimal path planning strategy, thus adapting to seasonal demand fluctuations in rural areas (e.g., holiday order surge, concentrated distribution demand during the period when agricultural products are available). In the future, with the popularization of 5G and IoT technologies, the GAT-driven intelligent path planning system will further realize the closed loop of data, and continuously optimize the model performance through the real-time collection of vehicle trajectory, road condition information and other data, and ultimately form an intelligent solution for the rural “last-mile” distribution.

3.2. Construction of New Distribution Organization Mode

Traditional rural e-commerce distribution mainly relies on a single courier enterprise or postal network, but due to the low population density and large distribution radius in rural areas, this model often leads to low resource utilization and poor distribution efficiency. The introduction of GAT technology provides the possibility of constructing a new distribution organization model, the core of which is to achieve an overall improvement in distribution efficiency through resource synergy and network optimization. The focus of the new distribution organization model is to integrate multiple resources, including e-commerce platforms, local logistics enterprises, village-level service stations and even rural passenger lines, to form a flexible distribution network with multi-body synergy.

In this mode, GAT technology can be used to optimize the topology of the distribution network. For example, by analyzing historical order data and geospatial information, GAT can identify distribution hotspots and blind zones in rural areas, thus guiding the layout of village-level service stations or self-pickup points. At the same time, GAT can dynamically allocate distribution tasks and realize flexible scheduling of vehicles and personnel. Taking "common distribution" as an example, orders from different e-commerce platforms can be analyzed by clustering through the GAT model, and distribution tasks for the same or adjacent destinations can be merged, thus reducing duplicate transportation. In addition, passenger buses in rural areas usually have fixed routes and schedules, and GAT can calculate the matching degree between their idle capacity and e-commerce distribution demand, so as to realize "joint transportation of passengers and goods" and further reduce distribution costs [10].

Another key point of the new distribution organization model is the innovation of the end nodes. Traditional express cabinets or self-pickup points in rural areas have limited coverage, while intelligent site selection algorithms based on GAT can optimize the distribution of end nodes to ensure that they cover as many users as possible. At the same time, through the introduction of the "crowdsourcing distribution" mechanism, local villagers or small transport operators can be included in the distribution network [3], the GAT model can be based on their geographic location and transport capacity to allocate orders, forming a "trunk line + capillary" type of distribution system [4]. For example, county-level distribution centers are responsible for transporting goods to township hubs, and then local crowdsourcing personnel complete the end distribution from townships to villages [5]. This model not only improves distribution efficiency, but also provides employment opportunities for rural residents.

The new distribution organization model can further develop in the direction of ecology by recording distribution data through blockchain technology to ensure the transparency and credibility of multi-party collaboration; constructing a virtual mapping of the rural distribution network through digital twin technology, and using GAT for simulation optimization. Eventually, this model will break the linear structure of traditional distribution and form a decentralized and self-adaptive regulation rural e-commerce distribution ecosystem.

3.3. Innovation of Operation Management Mechanism

Technological empowerment and organizational change need to be supported by supporting operation and management mechanisms. In the rural e-commerce "last kilometer" delivery, the innovation of operation management mechanism is mainly reflected in dynamic pricing, service quality monitoring and incentive mechanism design, GAT technology can provide data-driven decision-making support for these mechanisms, so as to realize the double improvement of operation efficiency and service quality.

Dynamic pricing is an important means to optimize the allocation of rural distribution resources. Due to the uneven spatial and temporal distribution of rural orders, fixed distribution fees may lead to insufficient capacity during peak periods or idle resources during trough periods. The GAT-based prediction model can analyze historical order data and external factors (e.g., seasons, weather, promotions) to predict fluctuations in distribution demand in different regions and develop differentiated pricing strategies accordingly. For example, in remote villages with sparse orders, the delivery fee can be appropriately increased to incentivize the investment of delivery resources; while in township centers with dense orders, more users can be attracted to choose centralized delivery slots through price reductions. The attention mechanism of GAT can capture the correlation of demand among different regions to formulate the globally optimal pricing scheme.

Service quality monitoring is one of the difficulties in rural distribution. Traditional manual inspection or user feedback methods have poor timeliness and limited coverage.

GAT, on the other hand, can build a real-time service quality assessment model by combining IoT devices (e.g., on-board GPS, temperature and humidity sensors) and user evaluation data. For example, by analyzing indicators such as the deviation of the delivery path, the cargo damage rate, and the timeliness achievement rate, GAT can automatically identify abnormal delivery events and trigger warnings. At the same time, the model can explore the potential correlation between service quality and factors such as distribution paths, vehicle types, and personnel skills, providing a basis for continuous improvement.

Incentive mechanism design is the key to ensure the sustainability of multi-party synergy. In the rural distribution network, the participating subjects include e-commerce platforms, logistics enterprises, village-level agent points and crowdsourcing personnel, each with different interests. The GAT-based game theory model can quantify the contribution of different subjects and design a fair benefit distribution mechanism. For example, for crowdsourcing personnel, they can be rewarded for fulfilling orders in remote areas through a dynamic point system; for village-level agency points, they can be given stepwise subsidies according to service quality and order volume. In addition, GAT is able to simulate the impact of different incentive policies on the overall network efficiency, thus helping managers to develop long-term effective incentive programs.

4. Conclusion

This study focuses on the "last kilometer" delivery problem of rural e-commerce in Henan Province, systematically analyzes the three core bottlenecks of geographic environment, operational efficiency and technology suitability, and innovatively proposes a dynamic path planning solution based on Graph Attention Network (GAT). The study shows that the traditional distribution model has significant limitations in dealing with the unstructured rural road network, dynamic distribution demand and resource coordination, and GAT technology provides a new technical path to solve these problems through its unique attention mechanism and graph structure learning ability, suggesting the establishment of provincial rural logistics big data platform, referring to the experience of the US Postal Service Dynamic Route Optimization Project, and combining the synergy of Japanese common distribution model with the experience of Japan's common distribution model. It is recommended to establish a provincial-level rural logistics big data platform, refer to the experience of the US Postal Service Dynamic Route Optimization Program, combine the synergistic concepts of the Japanese common distribution model, and construct a cost-sharing mechanism with the participation of the government-enterprises-village collectives.

In this study, we have constructed a trinity analysis framework of "technology empowerment-organizational innovation - mechanism optimization", and the GAT-driven intelligent path planning system can shorten the response time of path planning from 30 minutes to less than 2 minutes through the dynamic modeling of the road network, the fusion of multi-source data, and real-time optimization algorithms, which effectively solves the problem of delivery delays caused by the unexpected conditions on rural roads. This effectively solves the problem of distribution delays caused by unexpected conditions on rural roads. The new distribution organization mode breaks through the limitations of the traditional linear distribution structure, and through the "three-order aggregation" network and crowdsourcing coordination mechanism, the vehicle loading rate is increased to 72%, and the return trip idling rate is controlled at less than 15%. The digitalization of the operation and management mechanism, especially the establishment of dynamic pricing and service quality monitoring system, has provided institutional guarantee for the sustainable development of rural logistics.

However, the study also identified challenges to technology diffusion. The weakness of rural informatization infrastructure restricts the deployment of IoT devices, the shortage of digital talents in county logistics affects system operation and maintenance, and the coordination of interests among multiple actors still requires mechanism innovation. Future research should focus on three directions: first, developing a lightweight GAT model to adapt to the limited computing resources in rural areas; second, exploring the application of "5G + edge computing" in real-time road condition collection; and third, constructing a multi-party cost-sharing and benefit distribution mechanism involving the government, enterprises, and village collectives.

It is suggested that Henan Province should set up a special project on rural intelligent logistics in the 14th Five-Year Logistics Development Plan, give priority to the promotion of GAT technology in the 20 key counties for rural revitalization, formulate technical standards for rural dynamic path planning, and set up a financial subsidy fund to encourage e-commerce platforms, logistics enterprises and village-level service stations to jointly build an intelligent distribution network.

This study provides theoretical basis and practical solutions for the transformation and upgrading of rural e-commerce logistics, and its innovative value is mainly reflected in the following: the first systematic verification of the applicability of GAT technology in complex rural scenarios, the creation of a replicable "technology + organization + mechanism" collaborative innovation model, and the filling of the research gap in the field of dynamic path planning in rural logistics. Gap. With the continuous iteration of technology and the expansion of application scenarios, this model is expected to be widely promoted in the rural areas of central and western China, and ultimately realize the strategic goal of equalization of urban and rural logistics services, providing solid support for the construction of digital villages.

References

1. W. Liu, "Route Optimization for Last-Mile Distribution of Rural E-Commerce Logistics Based on Ant Colony Optimization," *IEEE Access*, vol. 8, pp. 12179-12187, 2020, doi: 10.1109/ACCESS.2020.2964328.
2. X. Wang and R. Almajed, "Distribution route planning of fresh food e-commerce based on ant colony algorithm," in *Proc. Int. Conf. Appl. Technol. Cyber Intell.*, Cham, Switzerland: Springer, 2022, pp. 211-219, doi: 10.1007/978-3-031-28893-7_26.
3. Q. Zhang, Y. Li, and Q. Cai, "Investigation on the last-mile delivery of rural logistics under crowdsourcing transportation in China," *Int. J. Traffic Transp. Eng.*, vol. 11, no. 1, pp. 75-93, 2021, doi: 10.7708/ijtte.2021.11(1).04.
4. R. Mangiaracina, A. Perego, A. Seghezzi, and A. Tumino, "Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review," *Int. J. Phys. Distrib. Logist. Manag.*, vol. 49, no. 9, pp. 901-920, 2019, doi: 10.1108/IJPDLM-02-2019-0048.
5. Y. Zhang, X. Fan, and L. Zhou, "Analysis and research on the 'last mile' distribution innovation model of e-commerce express delivery," *J. Phys.: Conf. Ser.*, vol. 1176, no. 4, p. 042044, Mar. 2019, doi: 10.1088/1742-6596/1176/4/042044.
6. Y. Peng, "Research on countermeasures for the development of rural e-commerce logistics," *E3S Web Conf.*, vol. 275, p. 01029, 2021, doi: 10.1051/e3sconf/202127501029.
7. Z. Ma, J. Zhang, H. Wang, and S. Gao, "Optimization of sustainable bi-objective cold-chain logistics route considering carbon emissions and customers' immediate demands in China," *Sustainability*, vol. 15, no. 7, p. 5946, 2023, doi: 10.3390/su15075946
8. T. Zdolsek Draksler, M. Cimperman, and M. Obrecht, "Data-driven supply chain operations—the pilot case of postal logistics and the cross-border optimization potential," *Sensors*, vol. 23, no. 3, p. 1624, 2023, doi: 10.3390/s23031624.
9. H. Yu, X. Sun, W. D. Solvang, and G. Laporte, "Solving a real-world urban postal service system redesign problem," *Sci. Program.*, vol. 2021, no. 1, p. 3058472, 2021, doi: 10.1155/2021/3058472.
10. J. Song and S. Ma, "Discussion on existing problems and solutions on the last mile in rural logistics of Jilin Province," in *Proc. 2018 3rd Int. Conf. Politics, Economics and Law (ICPEL 2018)*, Atlantis Press, 2018, pp. 17-20, doi: 10.2991/icpel-18.2018.4.