An Overview of Emergency Logistics Routing and Location: Models and Future Research Directions

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Abstract. Emergency logistics refers to the transportation, storage, and distribution of materials to ensure the safety of people's lives and property and social stability in an emergency or disaster. Since the outbreak of COVID-19, the state and society have paid more attention to constructing emergency logistics systems. In recent years, the research on route optimization and location selection of emergency logistics has also increased. The study of emergency logistics location and routing is significant for improving emergency logistics efficiency, optimizing resource allocation, improving emergency response capabilities, and reducing emergency risks. It can provide scientific decision-making support for emergency management departments and logistics enterprises, promote social emergency management level improvement, and ensure the safety of people's lives and property. This article studies relevant literature on domestic and international emergency logistics routing and location issues in recent years, summarizes the main models and related algorithms to solve this problem, analyzes the current research status in recent years, and looks forward to future research directions.

1 Introduction

In case of sudden public events, all sectors of society must carry out emergency response work quickly. Unlike traditional logistics, which emphasizes cost and quality control issues in transportation and warehousing processes, emergency logistics needs to pay more attention to issues such as rapid response, emergency delivery, safety, and stability to ensure the safety of people's lives, property, and social stability. Therefore, establishing a sound and comprehensive emergency logistics system is of great significance for constructing the national and social logistics system and is crucial for maintaining social harmony and ensuring the high-quality development of the national economy.

There is a large amount of domestic and international research on emergency logistics path selection problems with specific scenarios such as epidemics, earthquakes, floods, etc., involving many modelling and optimization algorithms. This article aims to compare and summarize these existing research methods and provide prospects to identify future research priorities and directions.

2 Emergency logistics path problem

The path problem of emergency logistics refers to how to transport materials and resources quickly and efficiently to the required places through scientific and reasonable path planning in the case of limited supplies and rescue resources. Path optimization research includes multiple aspects such as route selection, vehicle scheduling, and determination of distribution points. Its main purpose is to improve logistics transportation efficiency while reducing energy consumption, time, and logistics costs.

In studying emergency material delivery routes, scholars usually establish single or multi-objective models with the goals of total time, total cost, satisfaction, etc. Yan Sen et al. used road damage during earthquakes as an important factor affecting material delivery, established a dual objective model with the minimum total time and cost, and solved the model by designing a hybrid algorithm combining a genetic algorithm and a simulated annealing algorithm [1].

The joint distribution of “delivery vehicles and drones” is an emerging logistics distribution method with advantages such as fast speed, wide range, and low cost compared to traditional distribution methods. It is particularly suitable for logistics distribution in remote areas or emergencies. In recent years, it has also been studied by scholars. Zhu Guona et al. focused their attention on rural areas and comprehensively considered two different delivery methods: “delivery vehicles” and “delivery vehicles+drones” [2]. They used simulated annealing and Floyd optimization algorithms and constructed models to select the most suitable delivery route for rural emergency logistics distribution activities in different scenarios, which helps to enhance the disaster resilience of rural residents. Liu et al. proposed a mixed integer programming model and designed a two-layer solution to solve the emergency logistics transportation planning problem [3]. They solved the

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inner layer single task path recommendation problem through the multimodal transportation network shortest path algorithm. They improved the particle swarm optimization algorithm to solve the outer layer problem of finding solutions for multi-commodity emergency logistics planning. The results showed that this method effectively and practically solves the multimodal transportation emergency logistics planning problem.

The hybrid artificial fish swarm algorithm is an optimization algorithm that combines a genetic algorithm and an artificial fish swarm algorithm. This algorithm effectively combines the advantages of global and local search by combining the ideas of population evolution and local search and can find high-quality approximate optimal solutions. The hybrid artificial fish swarm algorithm has good application potential in emergency logistics path optimization. Liu Yanqiu et al. =pointed out that disaster events require a timely emergency response from the country [4]. A two-stage model for emergency logistics path optimization was established while considering the fair distribution of affected materials, and an adaptive hybrid artificial fish school algorithm was designed to solve the problem.

Since the outbreak of the COVID-19 epidemic, domestic research on the path problem under the background of public health events has begun to increase. Liu pointed out that the current construction of China's grassroots emergency logistics system is not yet perfect and proposed a “distribution vehicle+drone” emergency logistics joint distribution model [5]. The improved heuristic algorithm is used to solve the problem of selecting drone distribution centers and optimizing the path of distribution vehicles traversing drone distribution centers, providing support for grassroots governments to improve their emergency material support system. Zhao et al. took Wuhan as the research object [6]. They established a multi-index evaluation system and built a distribution model considering the constraints, such as the urgency of demand based on the actual data of medical equipment demand during the COVID-19 epidemic and combined with the characteristics of emergencies. The model was simulated and verified using CRITIC and genetic algorithms, and the results showed that this method could effectively improve the efficiency of medical material distribution and reduce the total cost.

Information systems have many advantages in studying emergency logistics, mainly reflected in their strong data integration ability, decision support ability, collaborative management ability, real-time monitoring ability, etc. Therefore, scholars often use methods such as information systems and artificial intelligence to study the path of emergency material distribution. Sun Yubo et al. proposed a grid GIS-based method for selecting the optimal path of maritime emergency logistics to solve the problem of maritime emergency logistics path [7]. They used swarm intelligence optimization algorithms and grey theory to screen out the optimal indicators of alternative paths, providing feasible solutions for solving the optimal path problem of ship emergency logistics.

The research on path optimization of emergency logistics is significant for managing and controlling unexpected events and emergencies. Firstly, the response time of emergency logistics is very important, and path optimization research can help emergency logistics reach disaster areas faster and improve logistics response efficiency. Secondly, emergency logistics costs are relatively high, and path optimization can reduce logistics costs, improving material utilization efficiency and resource recovery rate. When the path of emergency logistics is optimized, it can reduce the waste of workforce, time, and resources. Once again, emergency logistics is an important component of the supply chain, and supplies are still needed during disasters. Path optimization can reduce the uncertainty and risk of emergency logistics and improve the supply chain stability of logistics. In addition, path optimization can ensure that materials and rescue personnel can be fully and efficiently delivered, meet the basic needs of disaster victims in a timely manner, and reduce casualties and property losses caused by disasters. In short, research on optimizing emergency logistics paths can provide scientific and efficient solutions for emergency logistics, reduce costs and losses, and effectively improve emergency response capabilities and rescue efficiency in disasters.

3 Emergency logistics site selection

Emergency logistics site selection refers to determining the location of logistics centers or other logistics facilities to respond quickly to emergencies and provide rapid transportation and distribution services for emergency supplies to affected areas or populations. In the process of selecting emergency logistics sites, various factors need to be considered, such as the terrain, hydrology, climate and other natural conditions of the disaster area, transportation conditions such as roads and transportation facilities, the population and property conditions affected by the disaster area, as well as the types, quantities, and transportation methods of emergency supplies. Based on the comprehensive consideration of these factors, technical tools such as GIS (Geographic Information System) can be used for emergency logistics site selection analysis to support rapid response and emergency decision-making of the emergency logistics system.

Natural disasters are frequent emergencies that pose a serious threat to the entire society. When dealing with natural disasters, emergency logistics location selection is a very important link to determine the efficiency and speed of emergency material allocation. In the location problem, scholars often use geographic information systems, spatial analysis technology, intelligent algorithm optimization and other methods to study. Teng Hongjun et al., based on the risk assessment data of earthquake disasters, used the ArcGIS platform to form a Voronoi diagram to express the zoning scheme of earthquake emergency preparedness visually and then considered the demand weight and used LINGO software programming to solve it to obtain the location selection scheme of logistics distribution center based on earthquake emergency preparedness, which provided a reference for regions to improve the ability of earthquake emergency logistics management [8]. Sun et al.proposed the IABC algorithm to solve the problem of emergency logistics center location to minimize total cost and maximize customer satisfaction [9]. Experimental verification showed that this algorithm is superior to the ABC and GABC algorithms regarding optimal objective function solving and global search ability. It can effectively calculate the optimal location and rescue material requirements of emergency logistics centers for sudden disasters and solve the problem of time satisfaction.

The research on emergency logistics site selection for national and provincial cities includes multiple aspects and requires careful consideration of multiple factors. At the same time, to study national and provincial emergency logistics site selection, it is necessary to consider the region's unique characteristics, such as population density, geographical location, geological environment, climate conditions, and other factors. Wu Zhuang et al. constructed a national macro level emergency material reserve site selection planning model, using various provinces and cities as alternative cities for emergency material reserve [10]. The variable neighborhood algorithm was selected to solve the model, and the results showed that it is advisable to set up 8 national-level emergency material reserve sites. A national emergency material reserve base selection platform was also designed on this basis. Research has shown that the selection model and the designed platform are feasible. The algorithm is scientific and reasonable. Zhou Lei et al. established a double objective mixed Integer programming model with the maximum time satisfaction and the minimum location cost and constructed an immune simulated annealing algorithm [11]. Taking the Wenchuan earthquake data as an example, they studied 29 counties and cities on the Longmenshan fault zone in Sichuan Province and selected 8 emergency logistics center addresses. The research results show that the location selection scheme can effectively reduce the location cost and improve time satisfaction. It can provide a reference for the location selection of emergency logistics centers in Sichuan Province.

The outbreak of the novel coronavirus epidemic has brought new challenges to emergency logistics site selection. In this context, the research on emergency logistics site selection is significant for strengthening the construction of emergency logistics systems, improving national and local emergency management capabilities, and ensuring people's life safety and social stability. Wang Fuyu et al. built a double-objective emergency logistics center location model with minimum economic cost and maximum satisfaction [12]. They divided the location problem into two stages to solve it. Based on the research on fuzzy demand prediction of material demand, they designed an improved grey wolf optimization algorithm and particle swarm optimization algorithm to analyze the case of a novel coronavirus emergency material center location in Hubei Province. Research has shown that the design of algorithms can effectively reduce economic costs while improving time satisfaction. Min et al. focused their vision on improving the ability of rural areas to respond to public health events [13]. Considering the poor conditions of rural emergency medical facilities and uneven mountain roads, they used the entropy method and Analytic Hierarchy Process to analyze the six influencing factors related to the selected emergency material center. They then established a multi-objective location selection model with minimum distance, solved it using the IPSO algorithm, and ultimately selected the optimal construction location for emergency medical facilities. This study can provide a reference for the decision-making of location selection for rural emergency material centers. Ma et al. took COVID-19 in the Beijing Tianjin Hebei region as an example [14]. To minimize emergency response time and maximize the satisfaction rate of emergency supply demand, established a double objective mixed integer programming model, designed a genetic algorithm to solve the emergency logistics location and distribution model, and obtained Pareto optimal set. The results showed that the model and algorithm were feasible and effective in practical applications.

The significance of emergency logistics site selection research is very significant. In the face of emergencies such as natural disasters, public health events, wars, etc., the timely arrival of emergency and rescue materials in the disaster area directly affects the life safety and physical health of the people in the disaster area. Therefore, research on site selection can help plan and establish a reasonable emergency logistics network to respond quickly and provide support during crises. At the same time, it can effectively improve the emergency logistics system's operational efficiency, optimize resource allocation and utilization, and provide more scientific solutions for the reserve and distribution of emergency supplies.

Aiming at the problem of emergency logistics location, this paper mainly analyzes the research on emergency logistics location in the context of specific natural disasters, emergency logistics multi-level facilities, national and provincial emergency logistics location, and emergency logistics location in the context of the COVID-19 epidemic. The current research still has the following shortcomings: Firstly, the calculation of emergency logistics site selection for specific regions needs to be more accurate. There are many studies on the overall system of emergency facility construction in a certain province. Still, these studies need to calculate various cities' coverage ranges accurately. The next research step should continuously narrow the regional scope based on the province so that specific regions can respond well to various emergencies. What' more, insufficient consideration of factors in site selection.

Many studies only select quantifiable indicators for analysis when conducting site selection and lack consideration for nonquantifiable indicators such as decision-maker preferences and environment. The next step should be incorporating non quantifiable indicators into the research scope.

4 Conclusion

This article mainly analyzes the location and routing issues of emergency logistics. It summarizes the main objectives and model establishment, specific scenarios, algorithm usage, and commonly needed research tools considered in such research. In recent years, China's public health emergencies and natural disasters have occurred from time to time, especially COVID-19, which has had a serious impact on the development of all aspects of China and the safety of people's lives and property, which further indicates that the construction and improvement of a national social emergency logistics system are very important and urgent. China's emergency logistics research has made great progress in various aspects. However, it is still impossible to accurately estimate the actual logistics demand due to the unpredictability and suddenness of emergency logistics. Based on this, this article points out the shortcomings of current research: In the research process, it is often necessary to assume certain conditions and sometimes consider factors that need to be more comprehensive, and their accuracy still needs to be improved. What's more, research on emergency material supply issues mostly uses mathematical modeling methods, which differ from the real environment and need more consideration for uncertain and dynamic environments, reducing practical significance. In addition, the application of new-generation information technology in emergency logistics is relatively lacking, and further research is needed. I hope that future research can be further improved on the original basis and provide more reliable solutions to specific problems.

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