

# Emergency Logistics and Distribution Modeling and Methods

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**Abstract:** With the frequent occurrence of all kinds of emergencies, the importance of emergency logistics distribution has become increasingly prominent. This thesis focuses on the field of emergency logistics distribution, aiming to analyze distribution models and methods to improve the efficiency and effectiveness of emergency material distribution. First, the characteristics and needs of emergency logistics distribution are analyzed in depth, including time urgency, uncertainty and multi-targeting. Then, for the two key aspects of cost and benefit, cost components such as transportation cost, warehousing cost, labor cost, loss and damage cost, and benefit indicators such as rescue effect, economic benefit and social benefit are elaborated in detail. It also explains that factors such as material response time, transportation speed, completion rate and accuracy should be considered. Meanwhile, in the cost and benefit analysis, methods such as cost-benefit ratio (CBA), cost-efficiency analysis (CEA) and benefit assessment are illustrated, and finally recommendations covering various aspects are put forward to improve the emergency logistics and distribution system.

**Keywords:** Emergency logistics, Distribution model, Indicator system.

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## 1. Introduction

After the occurrence of a sudden disaster, emergency logistics and distribution can quickly mobilize materials and resources to provide emergency relief and survival needs for the people in the disaster area, to ensure their basic needs and safety [1]. After a sudden disaster, emergency logistics and distribution can quickly mobilize materials and resources to provide emergency relief and survival needs for people in the disaster area, ensuring their basic needs and safety. And effective emergency logistics distribution system can reduce the pressure of post-disaster reconstruction, protect the safety and stability of infrastructure, maintain social order, and contribute to the restoration of normal economic operation. In the process of realizing emergency logistics, the core link is the distribution of emergency supplies. In order to effectively control emergency events, so that the minimum loss of human and financial resources, the first problem should be solved is the choice of distribution paths, to achieve in the shortest possible time to the affected points of the materials required to be delivered. Through the study of emergency logistics and distribution to ensure that the country or region in the event of an epidemic, natural disasters, conflict or even war to meet the special needs of the user's activities. Dealing with the "last kilometer" of the whole supply chain is the key to whether the emergency logistics and distribution system can really work [2].

## 2. Current status of Related Domestic and International Research

The ultimate goal of emergency logistics and distribution optimization is to achieve the overall system optimization, which needs to take into account all the facilities nodes and routes involved in the logistics system, and then achieve the optimization goal through multi-party cooperation. According to the literature search, the research direction of emergency logistics and distribution optimization is mainly

divided into three categories, one is site selection, the second is route optimization, and the third is part of the optimization research on the combination of positioning - path.

(1) Study on the location of emergency logistics distribution centers

Zhang Jinhui and Tian Chengfang et al. transformed the multilevel fuzzy optimization model into the decision-making of emergency logistics and distribution center location in case of emergencies, and used the information entropy and hierarchical analysis method to determine the combination weights of the indexes, which provided a new way for the decision-making of the location of emergency logistics and distribution centers in case of emergencies [3]. Pan A. Shengli and Tian Jun et al. study the problem of emergency distribution center location, construct a P-center based location model, and propose an optimal location algorithm based on the principles of 0-1 planning and dynamic planning, which can simplify the solution process and get the optimal solution of the problem model [4]. Bozorgi-Amiri A and Jabalameli et al. study the uncertainty disaster relief logistics siting problem [5]. Paul Jomon Aliyas and MacDonald Leo model the location of distribution centers for emergency warehouses by taking into account a variety of uncertainties, including the timing, severity, and impacts of potential events, as well as the characteristics of the disaster and the specific region, and design an evolutionary optimization heuristic algorithm for solving the model with the help of a mixed-integer programming model [6]. Wang Qi and Han Jian Jun constructed a multi-objective siting model by considering the efficiency of siting facilities for processing grain emergency reserves, the difference in coverage radius demand satisfaction, and cost, and proposed a genetic algorithm to solve the problem, and demonstrated its effectiveness with examples [7]. The modeling is based on the following two approaches. Yuhuan Zhang and Xia Zhang designed and solved the dynamic seismic distribution center model [8]. The dynamic seismic distribution center model is designed and

solved by Yuhuan Zhang and Xia Zhang. Qingkui Cao and Danmei Song introduced the theory of simplicity and hierarchical analysis to obtain the optimal site selection location [9]. Cao, Qingkui and Song, Danmei. Chongqi Xu and Tao Zhang et al. proposed a mixed-integer planning model for site selection [10].

(2) Research on vehicle routing for emergency logistics distribution

Ruan J. H. and Wang X. P. et al. proposed a clustering-based multimodal route optimization model to generate multimodal transportation routes to provide methodological and operational support for "helicopter and vehicle" multimodal transportation of medical supplies in response to large-scale disasters [11]. Bai Xuejie conducted a two-stage multi-objective optimization of the emergency material deployment problem considering the combined uncertainty of multiple material supply points and multiple vehicle types [12]. Al Theeb Nader and Murray Chase proposed a new heuristic algorithm to solve the post-disaster path optimization and resource allocation problem based on fairness, multiple vehicle types, and road damage [13]. Zhang Qiang and Xiong Shengwu proposed a hybrid artificial immunity and ant colony optimization (ACO) based algorithm to solve the emergency food distribution vehicle path multi-objective optimization problem [14]. Zhu Li and Ding Jialan et al. Zhu Li and Ding Jialan et al. used an ACO algorithm to solve the path optimization problem of emergency food distribution under the synergistic effects of material deployment, evacuation of victims, and relief of the injured [15]. Deng, Ye and Zhu, Wanhong et al. Deng Ye and Zhu Wanhong et al. defined a new function for the emergency logistics vehicle scheduling problem by considering cost, risk, satisfaction, and robustness, and verified the effectiveness of the strategy through experiments [16]. Deng Ye and Zhu Wanhong et al. He Tiling and Lou Wengao apply the improved mothball optimization algorithm to solve the vehicle scheduling problem of relief materials under different road damages [17]. He, Tiling and Lou, Wengao Tang, Hongliang and Wu, Berlin et al. Solving the vehicle path optimization problem considering time, economy and fairness using improved particle swarm algorithm [18]. Lv Wei, Li Zhihong et al. Using genetic algorithms to solve the emergency logistics vehicle path distribution problem with minimized distribution penalty cost and minimized unsatisfied quantity of material demand in disaster areas under soft and hard time windows [19].

(3) Emergency Logistics Distribution Positioning and Routing Research

Oran A and Tan KC et al. proposed an emergency logistics location-path problem with demand prioritization, and used a forbidden search algorithm to solve an optimization objective model with time windows [20]. Wang Haijun and Du Lijing et al. constructed a multi-objective distribution siting-path model for optimal distribution of post-earthquake relief supplies, which takes delivery time, total cost, and reliability of batch distribution into account, and proposed NSGA with non-dominated sorted differential evolutionary algorithm to solve the problem model [21]. Abounacer Rachida and Rekik Monia et al. constructed a multi-objective model for the locate-and-route problem, where the first objective is the shortest total transit time from the distribution center to the point of demand, the second objective is to minimize the number of agents (first responders) needed to activate the

selected distribution center, and the third objective is to minimize the uncovered demand for all the points of demand in the affected area. minimization, for which an algorithmic solution was developed [22] Moreno Alfredo and Alem Douglas et al. designed a two-stage planning emergency response location-path problem model that takes into account the reusability of vehicles, and designed a heuristic algorithm to solve the problem model [23]. Vahdani Behnam and Veysmoradi D. et al. constructed a multi-objective LRP model considering road rehabilitation and designed an algorithm to solve it [24]. Yao Hongyun and Niu Kelly used fuzzy hierarchical analysis to construct a site selection model for sudden disaster scenarios and an optimization model for material transportation routes, and then verified the reliability of the model by using real cases [25]. Then the reliability of the model is verified by using real cases.

### 3. Overview of Emergency Logistics

#### 3.1. Definitions and Characteristics

Emergency logistics refers to logistics activities that respond quickly and meet urgent needs by coordinating and optimizing logistics resources in the event of natural disasters, emergencies or emergencies. It has the following characteristics:

##### (1) Urgency

Emergency logistics requires a rapid response to meet urgent needs as quickly as possible. Time efficiency becomes one of the most critical factors.

##### (2) Certainty

Emergency events are usually accompanied by unpredictable circumstances and changes. Emergency logistics need to be able to adapt and deal with these uncertainties and flexibly adjust programs and resources.

##### (3) Cooperation

emergency logistics needs to coordinate all kinds of logistics resources, equipment and personnel, including warehouses, transportation vehicles, distribution outlets, etc., to form an efficient overall operation system.

##### (4) Diversity

Emergency logistics faces different needs and scenarios, which may involve the distribution of food, medicine, relief materials and other items. Therefore, emergency logistics needs to have diversified distribution modes and resource allocation.

##### (5) Hazardous

Emergency logistics often takes place in complex and hazardous environments with many risks and safety hazards. Emergency logistics requires risk assessment and management to ensure the safety of personnel and materials.

#### 3.2. Emergency Logistics System Composition

The emergency logistics system consists of the following components:

##### (1) Emergency material stockpiles

Emergency material stockpiles are the core of the emergency logistics system, including food, water, medical supplies, rescue equipment and other types of emergency needs. These materials need to be stockpiled and managed in advance so that they can be quickly deployed and distributed in an emergency.

## (2) Warehouses and logistics facilities

The emergency logistics system needs to have a certain scale and number of warehouses and logistics facilities for storing and managing emergency supplies. These facilities need to meet the requirements of safety, disaster prevention and rapid distribution.

## (3) Transportation and distribution network

Emergency logistics depends on an efficient and reliable transportation and distribution network. This includes various modes of transportation, such as land, air and waterways, and ensures the timely supply of materials through the establishment of distribution outlets and logistics route planning.

## (4) Information and communication systems

In emergency logistics, information and communication systems are critical, as they provide the means for real-time monitoring, coordinated scheduling and information transfer. This includes the application of logistics information management systems, wireless communication equipment, sensors and other technologies.

## (5) Human resources

The emergency logistics system requires specialized human resources, including logistics experts, warehouse managers and distribution personnel. They are responsible for scheduling, distribution and transportation of materials to ensure the smooth running of emergency logistics.

## (6) Policies and regulations

Emergency logistics systems need to be supported by relevant policies and regulations, including disaster management and logistics contingency plans. These policies and regulations provide for coordination mechanisms, resource allocation principles and division of responsibilities to ensure the effective operation of emergency logistics.

# 4. Emergency Logistics and Distribution Management

## 4.1. Emergency Logistics and Distribution Strategy

### 4.1.1. Address selection for emergency logistics distribution centers

The selection of the address of an emergency logistics distribution center is an important decision that requires comprehensive consideration of a number of aspects: first of all, it is necessary to choose a location whose geographic location can shorten the time for transporting and distributing materials. It is best to choose a location that is closer to the affected area or the place where the emergency occurs, so that the materials can be delivered to the destination in the shortest possible time. Secondly, the distribution center should be located in a place with convenient transportation, such as near major highways, railroads, ports or airports and other transportation nodes, so as to facilitate the transfer and transshipment of materials. At the same time, the distribution center should have the basic facilities for storing, sorting and loading materials, including warehouses, shelves, yards, unloading platforms and so on. Also choose a higher security location to reduce the risk of material theft, damage or other unforeseen events. Try to avoid choosing areas that are vulnerable to natural disasters, social instability or security risks. The supply of resources around the distribution center

should also be noted, such as the reliability and stability of water, electricity, fuel and other infrastructure to ensure the normal operation of the distribution center. Finally, we should cooperate with the local government to obtain government support and resource assistance to provide better conditions and guarantee for emergency logistics.

### 4.1.2. Distribution route planning

The key to optimizing emergency logistics distribution routes is to reasonably plan and select the best routes to achieve rapid and efficient material distribution. Route planning and pre-selection of possible distribution paths, including assessment of road conditions, traffic congestion and distance between distribution points, are needed before an emergency situation occurs. Real-time data can be obtained through traffic monitoring equipment, navigation systems or logistics management software to analyze road traffic conditions and avoid congested areas, and accordingly adjust distribution routes and select appropriate modes of transportation, including land, air and water. In some cases, a combination of multiple modes of transportation can be used to improve distribution efficiency. Meanwhile, close cooperation with relevant departments, enterprises and volunteer organizations is carried out to jointly coordinate the distribution of materials. Reasonable division of labor, information sharing and synergy improve the overall distribution efficiency. Optimizing the emergency logistics distribution path requires comprehensive consideration of a number of factors, including the time window, road conditions, types of goods, degree of urgency and other elements. In actual operation, it is necessary to weigh and adjust according to the specific situation in order to achieve the best distribution results.

## 4.2. Emergency Logistics and Distribution Models and Methods

### 4.2.1. Mathematical model and algorithm analysis

Mathematical models and algorithms are developed to optimize emergency logistics distribution solutions. The following are several common emergency logistics distribution models:

#### (1) Path selection model

this model is based on the theory of network graph, by determining the shortest path or optimal path to solve the emergency logistics distribution problem. Specifically, Dijkstra algorithm, Floyd-Warshall algorithm and so on can be used to solve the optimal path.

#### (2) Vehicle Path Planning Model

This model takes into account factors such as vehicle capacity, transportation time window, cargo volume, and distance between distribution points, assigns distribution tasks to different vehicles, and determines the optimal path for each vehicle to achieve the best distribution efficiency.

#### (3) Multi-objective optimization model

In emergency logistics distribution, in addition to considering factors such as time and distance, there may be multiple objectives, such as cost minimization and resource utilization maximization. The multi-objective optimization model can consider these objectives comprehensively and obtain an effective distribution plan by weighing and adjusting the parameters.

#### (4) Intelligent Algorithm Model

Intelligent algorithms such as genetic algorithms and particle swarm algorithms can be used for path optimization problems in emergency logistics and distribution. These algorithms find the global optimal solution or near optimal solution by simulating the evolution and group behavior in nature.

#### (5) Neighborhood search model

this model optimizes the emergency logistics and distribution scheme by searching for neighborhood solutions in the set space. It includes local search algorithms such as simulated annealing algorithm and forbidden search algorithm, as well as heuristic rule-based neighborhood search methods.

These models and algorithms can be adapted and improved to suit different types and sizes of emergency logistics distribution problems in conjunction with actual situations and needs. By applying these models, the efficiency of emergency logistics distribution can be improved, costs can be reduced, and the demand for emergency supplies can be better met.

#### 4.2.2. Demand forecasting and supply chain visualization

Demand forecasting and supply chain visualization are two key aspects of emergency logistics and distribution. Demand forecasting refers to the use of historical data, statistical analysis and mathematical models to predict the demand in the future period. For emergency logistics and distribution, accurate demand forecasting can help organizations rationally arrange material reserves and scheduling. Commonly used demand forecasting methods include time series analysis, regression analysis, machine learning and so on. By analyzing past demand patterns and related factors, future demand trends can be predicted so that countermeasures can be taken in advance. Supply chain visualization is to show the various links and information of the supply chain in a visual way, so that managers and decision makers can easily understand the operation of the whole supply chain. In emergency logistics distribution, supply chain visualization can visualize the source, flow, warehousing, transportation and other aspects of the materials, making the whole distribution process more transparent and controllable. Through visualization tools and technologies, the location and status of goods can be monitored in real time, and problems can be detected in time and corresponding measures can be taken to improve the efficiency and accuracy of distribution.

Demand forecasting and supply chain visualization for integrated emergency logistics and distribution can optimize the stockpiling and dispatching of materials by accurately

forecasting demand; at the same time, real-time monitoring and management of the flow of materials through supply chain visualization ensures that the materials can arrive at the areas and destinations where they are needed on time and accurately.

#### 4.2.3. Risk assessment and decision support

Emergency logistics and distribution risk assessment and decision support is an important means to meet the challenges of logistics and distribution in critical incidents and emergencies. Risk assessment refers to identifying, evaluating and categorizing various potential risks that may arise in the process of emergency logistics and distribution. Common emergency logistics and distribution risks include deteriorating road traffic conditions, weather disasters, facility damage, inadequate supply, and demand fluctuations. Through scientific methods, such as risk matrix and risk probability analysis, these risks are assessed to determine their likelihood and degree of impact, so as to identify the key risks to be prioritized. Decision support is the process of providing decision-making suggestions and support based on risk assessment results and real-time information. In emergency logistics and distribution, decision support can help managers make quick decisions, rationally deploy resources and develop action plans. For example, based on the results of risk assessment, different levels of emergency plans can be formulated, with clear response measures and division of responsibilities; at the same time, real-time monitoring and tracking technology can be used to obtain road information and demand changes in a timely manner, and dynamic scheduling and resource optimization can be implemented.

Comprehensive emergency logistics distribution risk assessment and decision support can help organizations better cope with various risks and challenges in the distribution process. Through scientific assessment and effective decision support, emergency preparations can be made in advance to minimize risks and ensure that emergency supplies reach their destinations in a timely and accurate manner. The application of these methods can improve emergency response efficiency, reduce losses, and enhance the reliability and stability of emergency logistics distribution.

## 5. Evaluation of the effectiveness of emergency logistics and distribution

### 5.1. Evaluation Index System Construction

The construction of the emergency logistics effect evaluation index system can be considered from the following aspects:

**Table 1.** Evaluation Index System

norm	Level 1 indicators	Secondary indicators	clarification
key constituent	timeliness	Material response time	The time it takes for emergency supplies to arrive at their destination from dispatch.
		Transportation speed	The average speed of transportation of goods, including indicators of the speed of transportation by road, rail, air and other modes of transport.
	dependability	completion rate	Percentage of emergency supplies distribution tasks successfully completed.
		accuracy	Accuracy of material distribution, including accuracy of quantity and quality of distribution.
	(manufacturing, production etc) costs	transportation cost	Direct and indirect costs involved in the transportation of emergency supplies.
		Cost of inventory	The cost of maintaining inventory during the distribution of emergency supplies.
	dexterity	adaptability variegation	Flexibility and adaptability to respond to different emergencies. Ability to use multiple modes of transportation and supply chain channels in the distribution of emergency supplies.
responsiveness	response time	The time from the receipt of the emergency demand to the start of the implementation of the distribution.	
	Scale of distribution	Coverage and quantity of emergency supplies distributed.	
Resource utilization	Capacity utilization	Utilization of means of transport and equipment in the distribution of emergency supplies.	
	Warehouse utilization	Utilization of facilities for the storage and management of emergency supplies.	

The above indicators can be customized and adjusted according to the specific emergency logistics distribution situation. Constructing a scientific and reasonable evaluation index system can help assess the comprehensive effect of emergency logistics distribution, determine the direction of improvement and optimization, and improve the emergency response capability and logistics efficiency.

## 5.2. Methods for Evaluating the Effectiveness of Emergency Logistics and Distribution

The following methods can be used to assess the effectiveness of emergency logistics and distribution:

### (1) Indicator assessment method

According to the constructed evaluation index system of emergency logistics effect, each indicator is assessed and measured. It can quantitatively assess the indicators by setting scoring standards or weights, and add up the scores of different indicators or comprehensively calculate the overall evaluation results.

### (2) Typical Case Comparison Method

Select some typical emergency logistics distribution cases, record and analyze their effects in detail, and compare them with the preset assessment indicators. Through the comparison between cases, the differences and advantages and disadvantages of different cases are identified, and the degree of advantages and disadvantages of the emergency logistics distribution effect is assessed.

### (3) Questionnaire survey method

design appropriate questionnaire survey contents for different participants related to emergency logistics distribution (such as logistics companies, distribution personnel, beneficiaries, etc.). By collecting and analyzing the questionnaire data, we can understand the subjective evaluation and opinions of participants on the effect of emergency logistics distribution, so as to assess the satisfaction and improvement direction of the distribution effect.

### (4) Field inspection method

Field inspection of the actual implementation process of

emergency logistics and distribution, observing whether the material distribution reaches the destination on time, meets the demand, and whether there is any transportation risk, and so on. Based on the observation results of the field visit, the effectiveness and problems of emergency logistics distribution will be evaluated, and suggestions for improvement will be made.

### (5) Data analysis method

By statistically analyzing a large amount of historical emergency logistics and distribution data, we understand the trends and correlations of various indicators. The data are processed and analyzed using data mining and model building techniques.

## 5.3. Cost and Benefit Analysis

Emergency logistics distribution cost and benefit analysis is the process of comprehensively evaluating and analyzing the costs incurred and benefits derived from emergency logistics activities. Below are some common considerations:

### (1) Cost

Emergency logistics distribution includes transportation cost, warehousing cost, manpower cost, and loss and damage cost, whose transportation cost covers the direct cost of material transportation, like fuel cost, vehicle maintenance cost, etc.; warehousing cost involves the cost generated by the storage, management and maintenance of emergency materials, such as rent, labor cost, equipment cost, etc.; manpower cost includes the salary of the logistics personnel, training costs, etc.; loss and damage The cost is the cost incurred by the loss and damage that may occur in the distribution process of emergency supplies.

### (2) Benefits

The benefit aspects of the emergency logistics distribution process include rescue effect, economic benefit, and social benefit. Rescue effect means that the emergency supplies can reach the destination in time to meet the needs of the disaster victims or the affected area, so that the rescuers can get the necessary support; the economic benefit is manifested in the fact that timely and effective emergency logistics distribution can reduce the loss, shorten the recovery time after the

disaster, and reduce the economic cost; the social benefit is that by providing effective The social benefit is that by providing effective material support and rescue operations, it reduces the burden of disaster victims, safeguards people's lives and safety, and improves social stability.

When analyzing costs and benefits, the Cost-Benefit Analysis (CBA) method can be used to compare the total costs of emergency logistics and distribution activities with the total benefits they bring and calculate the cost-benefit ratio; the Cost Efficiency Analysis (CEA) method can be used to assess the cost efficiency of each link in emergency logistics and distribution activities and find the potential for cost reduction; the benefit assessment method can also be used to quantitatively or qualitatively assess the benefits brought by emergency logistics and distribution activities. The Cost Efficiency Analysis (CEA) method can be used to assess the cost efficiency of each link in the emergency logistics and distribution activities and find the potential for cost reduction; the benefit assessment method can also be used to quantitatively or qualitatively assess the benefits brought by the emergency logistics and distribution activities. Through cost and benefit analysis, the economic and social impacts of emergency logistics and distribution can be better understood, providing decision makers with a reasonable basis to optimize resource allocation and improve efficiency.

## 6. Reach A Verdict

Emergency logistics and distribution is an important part of the response to emergencies and contingencies, but it is currently facing a number of problems and challenges. These include inadequate levels of technology and informationization, imperfect distribution network construction, insufficiently flexible and efficient emergency response mechanisms, the problem of matching supply and demand for materials, and challenges in terms of environmental factors and risk management.

In order to effectively solve these problems, it is necessary to strengthen technical inputs, promote the application of information technology systems and equipment, and enhance the efficiency of logistics and distribution. At the same time, it is necessary to strengthen infrastructure construction, improve the emergency logistics and distribution network, and enhance the ability to transport and distribute materials in a timely manner.

In addition, it is necessary to establish a flexible and efficient emergency response mechanism, strengthen cooperation and coordination among all relevant departments and organizations, and ensure the rapid response and smooth promotion of emergency logistics and distribution.

In terms of matching supply and demand for materials, it is necessary to strengthen supply chain management, improve the accuracy of material forecasts, optimize material procurement, stockpiling and deployment, and do a good job of inventory management and handling shortages, so as to ensure the accurate, timely and precise delivery of materials.

In addition, in coping with environmental factors and risk management, it is necessary to carry out a comprehensive risk assessment, establish a sound risk management mechanism, formulate and optimize contingency plans in advance, and strengthen the safety and stability of material transportation.

Finally, the government, enterprises and all sectors of society should strengthen cooperation, establish a close

information sharing and synergistic mechanism, and jointly promote the enhancement of emergency logistics and distribution capabilities to cope with all kinds of emergencies and contingencies, and to safeguard the safety of people's lives and properties.

## References

- [1] Feng Xudong, Rate Shuai. A few countermeasures for emergency logistics and distribution [J]. China Logistics and Purchasing, 2003(23):31.
- [2] Li Bo, Zhu Xiaoning. Research on emergency logistics distribution system [J]. Logistics Science and Technology, 2009, 32(11):1-4.
- [3] ZHANG J, TIAN C, ZHANG N, et al. Location Decision Model on Distribution Center of Emergency Logistics for Emergency Event Based on Multilayer Fuzzy Optimization[M]//2009:385.
- [4] PAN A S, TIAN J, WANG Y. A quick and efficient algorithm to the emergency supplies distribution centers location problem[M]//Global Congress on Intelligent Systems. 2012:34-38.
- [5] Ali Bozorgi-Amiri, M. S. Jabalameli, S. M. J. Mirzapour Al-e-Hashem. A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty [J]. OR Spectrum, 2013, 35(4).
- [6] Jomon Aliyas Paul, Leo MacDonald. location and capacity allocations decisions to mitigate the impacts of unexpected disasters [J]. European Journal of Operational Research, 2016, 251(1).
- [7] Qi Wang, Jianjun Han. Study on the location of the emergency storage for processed grain based on multi-objective location model-take a direct- controlled municipality as an example [P]. controlled municipality as an example [P]. Proceedings of the 2017 6th International Conference on Energy, Environment and Sustainable Development (ICEESD 2017), 2017.
- [8] ZHANG Yuhuan, ZHANG Xia. Research on dynamic optimization of layout of emergency logistics distribution center for earthquake relief [J]. Modernization of Shopping Malls, 2013(14):98-99.
- [9] Cao Qingkui, Song Danmei. Site selection of emergency logistics distribution center based on RS-AHP [J]. Logistics Technology, 2013, 32(07): 103-105.
- [10] XU Chongqi, ZHANG Tao, ZENG Junwei. A model study on site selection problem of emergency logistics distribution center [J]. Logistics Science and Technology, 2015, 38(01): 1-3.
- [11] RUAN J H, WANG X P, CHAN F T S, et al. Optimizing the intermodal transportation of emergency medical supplies using balanced fuzzy clustering [J]. INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH, 2016, 54(14): 4368-4386.
- [12] BAI X. Two-Stage Multiobjective Optimization for Emergency Supplies Allocation Problem under Integrated Uncertainty [J]. MATHEMATICAL PROBLEMS IN ENGINEERING, 2016, 2016(2823835).
- [13] AL THEEB N, MURRAY C. Vehicle routing and resource distribution in postdisaster humanitarian relief operations [J]. INTERNATIONAL TRANSACTIONS IN OPERATIONAL RESEARCH, 2017, 24(6): 1253-1284.
- [14] ZHANG Q, XIONG S. Routing optimization of emergency grain distribution vehicles using the immune ant colony optimization algorithm [J]. APPLIED SOFT COMPUTING, 2018, 71: 917-925.

- [15] ZHU Li, DING Jialan, MA Zheng. Co-optimization study of heterogeneous transportation problems under emergency conditions [J]. *Journal of Management*, 2018, 15(02): 309-316.
- [16] Deng Ye, Zhu Wanhong, Wang Fengshan, et al. Research on multi-objective robust optimization for emergency logistics vehicle scheduling [J]. *Computer Engineering and Applications*, 2019, 55(01): 248-255.
- [17] He Tulong, Lou Wengao. Emergency material scheduling based on improved mothballing algorithm for solving multiple demand points [J]. *Small Microcomputer Systems*, 2020, 41(06): 1334-1339.
- [18] TANG Hongliang, WU Berlin, HU Wang, et al. A multi-objective scheduling algorithm for earthquake emergency supplies based on particle swarm optimization [J]. *Journal of Electronics and Information*, 2020, 42(03): 737-745.
- [19] Lv Wei, Li Zhihong, Ma Yaping, et al. A study on path planning of emergency material distribution vehicles considering the demand time window at the disaster site [J]. *China Safety Production Science and Technology*, 2020, 16(03): 5-11.
- [20] ORAN A, TAN K C, OOI B H, et al. Location and Routing Models for Emergency Response Plans with Priorities[M]//Aschenbruck N, Martini P, Meier M, et al. *Communications in Computer and Information Science*. 2012:129.
- [21] WANG H, DU L, MA S. Multi-objective open location-routing model with split delivery for optimized relief distribution in post-earthquake [J]. *TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW*, 2014, 69: 160-179.
- [22] ABOUNACER R, REKIK M, RENAUD J. An exact solution approach for multi-objective location-transportation problem for disaster response [J]. *COMPUTERS & OPERATIONS RESEARCH*, 2014, 41: 83-93.
- [23] MORENO A, ALEM D, FERREIRA D, et al. An effective two-stage stochastic multi-trip location-transportation model with social concerns in relief supply chains [J]. *EUROPEAN JOURNAL OF OPERATIONAL RESEARCH*, 2018, 269(3): 1050-1071.
- [24] VAHDANI B, VEYSMORADI D, SHEKARI N, et al. Multi-objective, multi-period location-routing model to distribute relief after earthquake by considering emergency roadway repair [J]. *NEURAL COMPUTING & APPLICATIONS*, 2018, 30(3SI): 835-854.
- [25] Yao Hongyun, Niu Kai. Research on the optimization of emergency logistics center site selection and distribution path [J]. *Logistics Science and Technology*, 2019, 42(03): 35-39.