Construction of Emergency Material Disturbance Management Model Considering Demand Change

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Abstract. Emergency material dispatching plays an important role in rescue operations. Because of many uncertainties in the objective world, emergency materials will be disturbed by many uncertain events in the distribution process, and the initial distribution plan will be affected. Based on the interference management of emergency material dispatching, this paper combs and discusses the forecast of material demand, the classification of material demand points, and the interference management of emergency material dispatching. And an emergency material disturbance management model considering the change of demand is constructed. Finally, the future research is prospected.

Keywords: Disruption management · Model analysis · Material demand · Emergency material dispatching · Optimal analysis

1 Introduction

In recent years, unexpected disasters have occurred frequently in the world, which has brought great property losses and casualties to people. After disasters occur, emergency materials need to be quickly and effectively distributed to the disaster site. Due to the uncertainty of the objective world, emergency materials are often disturbed by many uncertain events in the distribution process, which makes the original distribution plan affected or even impossible. With the progress of technology and the improvement in human abilities, people begin to take active measures to reduce and eliminate the impact on uncertain events, which results in interference management.

According to the definition of interference management according to Yu and Qi [1], Interference management needs to establish corresponding optimization models and effective solving methods for various practical problems and the nature of interference events, and quickly give an optimal adjustment plan for dealing with interference events. The adjustment plans are based on this state to quickly generate system disturbances. The smallest adjustment plan, although also considering cost savings, is often not the most cost-effective option. How to make full use of the idea of interference management to minimize the disturbance to the original scheme becomes very important.

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2 Research Status of Emergency Material Scheduling and Disturbance Management Considering Material Demand

2.1 Research Status of Emergency Material Scheduling Considering Material Demand Forecasting

After natural disasters occur, it is of great significance to study the post-disaster emergency material dispatch considering material demand forecasting. Xu et al. [2] adopt a hybrid forecasting method which combines empirical mode decomposition with autoregressive integral moving average. Sun et al. [3] considered two fields of emergency material demand to forecast under the framework of rough set theory, and established two fields of fuzzy rough set model. Wang [4] describes the attribute characteristics of post-earthquake secondary disaster events by using multi-case analysis scheme, and establishes a Petri model combined with Markov chain.

2.2 Research Status of Emergency Material Scheduling Considering Material Demand Classification

Disaster itself has great uncertainty and unexpectedness, so considering the classification of material needs is very helpful to improve the efficiency of emergency rescue. Ling et al. [5] establish an emergency medical resource allocation model with the objective function of minimizing the total transportation distance. Wang et al. [6] apply fuzzy comprehensive evaluation method to the corresponding demand urgency level and demand urgency value for different emergency materials. In order to improve the efficiency of emergency material transportation, Cheng [7] takes the first transportation time and the total twice transportation time as two objective functions.

2.3 Research Status of Emergency Material Dispatching Disturbance Management

(1) Analysis of Single-objective Model
The shortest time consuming usually refers to the shortest time consumed in the whole material distribution process, which is also the primary factor for many interference management considerations. Zhao et al. [8] constructed a disturbance management model on the minimum generalized total deviation cost as the objective function. Yang et al. [9] established an interference management model with the objective function of the minimum of the customer time window violation, the total vehicle travel time and the new vehicle preparation time. Li et al. [10] established an operational model that minimizes the sum of operating costs, scheduling interference costs, trip cancellation costs, and delay penalty costs as objective functions.

(2) Analysis of Multi-objective Model
In addition to the shortest time-consuming and the lowest cost, some literatures also consider the shortest route and the least time deviation, which constitute a

multi-objective model. Ruan [11] and others put forward the method of helicopter and vehicle joint transportation for material transportation. Wang et al. [12] identified and analyzed the VRPB problem of changing demand of picking-up customer points. Wang et al. [13] established a mathematical model of the interference problem with the goal of minimizing the deviation from the customer's time window and minimizing the distribution cost. Zhang et al. [14] established a multi-objective model to measure the original problem target and time window deviation from the delay problem.

(3) Model considering demand satisfaction and disaster victim satisfaction
Demand satisfaction and disaster victims satisfaction are very important indicators in the research of emergency material dispatching interference management. They are taken into account in the objective function in the following literature. Ding [15] constructed a dictionary order multi-objective interference management model with the change of customer time window as the interference factor. Liu [17] combines human behavioral science to analyze the interference events from three aspects: the needs of victims, emergency decision-making departments and emergency logistics executives. Zhu [16] and others set up a two-stage relief material dispatching model based on the dynamic characteristics of emergency material demand. Cao et al. [18] established an interference management model considering customer value in order to effectively allocate resources to customers in logistics enterprises.

(4) Model optimization analysis

   (1) Heuristic algorithm
   Heuristic algorithms widely used in the problem of disturbance management of vehicle scheduling in emergency supplies distribution mainly include genetic algorithm, particle swarm algorithm, ant colony algorithm and so on. After considering the complexity of the model, Yang [9] proposed a knowledge-based heuristic algorithm to solve the model. Wang [12] and others proposed a heuristic algorithm based on two strategies to solve the interference problem. Ruan et al. [11] designed an improved genetic algorithm for the interference model of joint transport of emergency medical supplies aiming at the change of transit point. Cao [18] and others designed an improved particle swarm optimization (PSO) algorithm to solve the logistics distribution problem considering different values. Ding [15] and others considered the impact of interference events on the whole logistics distribution system, and proposed an improved ant colony algorithm - hybrid ant colony algorithm. Liu [17] and others proposed a hybrid ant colony algorithm to solve the interference model in order to deal with the interference events effectively. Li et al. [10] proposed a relaxation algorithm based on Lagrange.

   (2) Multi-stage and hybrid algorithms
   Zhu et al. [16] proposed a two-stage emergency resource scheduling model. In the first stage, branch and bound algorithm was adopted, and in the second stage, fast non-dominant sequencing genetic algorithm with elite strategy was adopted. Wang et al. [13] proposed the method of route enumeration and route selection to solve the distribution vehicle scheduling interference problem with

travel time delay. Zhang et al. [14] designed a hybrid algorithm combining ant colony algorithm with discrete search algorithm for multi-objective model.

3 Construction of Disturbance Management Model Considering the Change of Demand

3.1 Model Assumptions

(1) In the early post-earthquake period, the local emergency material distribution center is an important supply point of emergency rescue, without considering the transfer from other places, and the total amount of materials in the local emergency material distribution center are in short supply.
(2) An emergency material distribution center is allowed to supply materials to multiple demand points, and one demand point can receive materials from multiple distribution centers.
(3) The number of rescue vehicles for the local emergency distribution center is limited.
(4) Vehicles carry the same cargo and the same load capacity.
(5) The demand point where the vehicle is serving for the time of interference is regarded as the completed point.
(6) The supply of emergency materials distribution centers is known, and the demand of each disaster site may change from the early post-earthquake period.

3.2 Problem Description

When an earthquake occurs to a certain area, several disaster spots occur. How to distribute emergency materials reasonably in the early period after the disaster without external material assistance, so that the disturbance of path and cost is minimal under the constraints on shortage of supply and demand, the change of demand of the disaster site and a certain time.

3.3 Definitions of Parameters and Variables

K: remaining rescue vehicles assemble when interference occurs, $K = \{k \mid k = 1, 2, \ldots\ldots, n\}$; N: number of unserved disaster sites when interference occurs; L: number of vehicles in transit when interference occurs; R: local emergency material distribution center, $R = \{r \mid r = 1, 2, \ldots a\}$; RQ_r: remaining material quantity of distribution center after interference occurs; Q_k: the amount of residual materials loaded by vehicles k after interference occurs; Q_{max}: maximum load of distribution vehicle; C_1: fixed cost of a new car dispatched from the distribution center; C_2: vehicle driving cost per unit path length; D_{ij}: the distance from disaster site i to disaster site j; P: the position of vehicle k in the course of driving when disturbance occurs; D_{pj}: distance of vehicle k from current location to disaster site j after disturbance occurs; D_k: the total driving distance of the remaining unserved disaster areas after the interference occurs; q_j: demand for materials not serving the disaster site j after the interference occurs; T_{ik}: the time when the vehicle k arrives at the disaster site i; LT_i: the latest time for emergency materials to arrive at the disaster site i; T_{ijk}: the travel time of vehicle k from disaster site i to disaster site j; $\mathrm{x_{ijk}}$: when the vehicle k is from the disaster point i to the disaster point j, $x_{ijk} = 1$, otherwise $x_{ijk} = 0$; y_{ir}: when the distribution center r provides material for disaster site i, $y_{ir} = 1$, otherwise $y_{ir} = 0$.

3.4 Model Construction

$$MinZ = \sum_{k=1}^{K} C_1 x_{0jk} + \sum_{k=1}^{L} C_2 (\sum_{j=0}^{N} x_{pjk} \mathrm{d_{pj}} + \sum_{i=1}^{N} \sum_{j=0}^{N} x_{ijk} \mathrm{d_{ij}} - \mathrm{d_k}) \tag{1}$$

$$\sum_{i=1}^{N} q_j y_{\mathrm{ir}} \geq \sum_{r=1}^{R} RQ_r \tag{2}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{N} q_j x_{ijk} \geq Q_k \tag{3}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{N} q_j x_{ijk} + \sum_{j=1}^{N} q_j x_{0jk} \geq Q_{max} \tag{4}$$

$$\sum_{k=1}^{K} \sum_{j=1}^{N} x_{0jk} \leq K \tag{5}$$

$$\sum_{r=1}^{R} y_{ir} \geq 1 \tag{6}$$

$$\lambda_i = \frac{\sum_{i=1}^{N} q_j}{\sum_{r=1}^{R} RQ_r} \tag{7}$$

$$T_{jk} = T_{ik} + t_{ijk} \tag{8}$$

$$T_{ik} \leq LT_j \tag{9}$$

$$x_{ijk} = \{1, 0\}, y_{ir} = \{1, 0\}, \lambda_i \geq \mathrm{m} \tag{10}$$

The objective function represents the minimum disturbance to the path cost. Constraints (2) indicates that the total capacity of the distribution center is not greater than the total demand of the disaster site. Constraints (3) indicates that the amount of vehicle surplus in transit is not greater than the demand for the next service disaster site. Constraints (4) denotes the constraints on newly dispatched vehicle transport materials. Constraints (5) indicates that the number of additional rescue vehicles should not exceed the number of remaining vehicles in the distribution center. Constraints (6) means ensuring that each disaster site has at least one emergency material distribution center to serve it. Constraints (7) defines the overall satisfaction function of material demand in all disaster areas. Constraints (8) represents the time window constraint of material demand in disaster areas. Constraints (9) denotes the time constraints of vehicle transportation. Constraints (10) denotes the constraints of decision variables and m is the lowest satisfaction.

4 Conclusion

According to the literature review of emergency material dispatch about demand change, a disturbance management model about demand change is constructed, and the satisfaction factor of disaster victims is added. The next step is to solve the model algorithm. In recent years, many new algorithms have emerged, which can be combined with existing algorithms to form a hybrid algorithm to solve the model. In the future, the interference in simultaneous changes of multiple factors of emergency material dispatching can be comprehensively considered. In addition, the combination of human behavior factors and interest pursuit of interference management is also a problem worth studying.

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