

Study on Vehicle Scheduling Optimization of Emergency Medical Logistics Distribution

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ABSTRACT

In the world, the frequent occurrence of natural disasters, man-made disasters and other emergencies have a serious impact on the society and individuals, so the distribution of emergency logistics has attracted worldwide attention. Therefore, based on the theoretical basis of emergency logistics and medical logistics, combined with the typical characteristics of emergency logistics and medical logistics, this paper studies the optimization of distribution vehicle scheduling in the transportation and distribution of emergency medical supplies in the core link of emergency medical logistics. According to the typical characteristics of emergency medical logistics, a two-objective vehicle scheduling model with the shortest delivery time and the highest customer satisfaction as the objective function is established. At the same time, the factors influencing the vehicle scheduling of emergency medical logistics distribution were analyzed by combining the calculation examples, and the vehicle scheduling problem was optimized by combining the theory with the calculation examples. Finally, MATLAB software is used to solve the example.

Keywords: *Emergency logistics, medicine logistics, vehicle scheduling*

1. INTRODUCTION

China is a country with frequent emergencies such as natural disasters, and emergencies usually have the following characteristics: one is that the outbreak of an emergency is often accidental and most of the time it is difficult to predict; the other is an emergency's development speed is extremely fast, although the cycle is short, the spread of emergency events is extremely fast; Third, the emergency events are dangerous. In some cases, the emergency events may worsen and develop into local areas or even Crisis events of the whole society, such as the outbreak of new coronavirus pneumonia in China this year; Therefore, it is very necessary to effectively and timely control and deal with emergencies, and it is especially important to provide emergency rescue and emergency supplies to the people in the area of emergencies.

But at present, there are few researches on medical logistics in emergency logistics, and most of the researches separate the two aspects and do not combine them. In order to solve this problem, based on the theoretical basis of emergency logistics and medical logistics, this article optimizes the distribution vehicle scheduling in the transportation and distribution of emergency medical items at the core of emergency medical logistics, so that the medical supplies arrive in a short time and exert the maximum effect, improve the efficiency of rescue in emergencies.

2. CONSTRUCTION OF EMERGENCY MEDICAL LOGISTICS DISTRIBUTION VEHICLE SCHEDULING MODEL

2.1. Analysis, Description and Assumptions of Emergency Medical Logistics Distribution Vehicle Scheduling Problem

2.1.1. Analysis of emergency medical logistics distribution vehicle scheduling problem

The primary goal of emergency rescue operations is the safety of the lives of the people. Residents of the disaster-stricken areas may be harmed to varying degrees in emergencies, and emergency rescue is required in most cases, otherwise they may be threatened. Therefore, in the vehicle dispatching model of emergency medical logistics distribution, consideration should also be given to whether the demand for medicines in the disaster-stricken area is satisfied and the timeliness of people's demand for medicines in the affected areas. The timeliness of people's demand for medicines in the affected areas is reflected in the ability of emergency logistics to deliver the required medicines to the disaster-stricken areas within the expected time of the disaster-stricken areas, that is, when the

emergency logistics can deliver the required medicines within the expected time of the disaster-stricken areas. When delivered to the affected area, the affected people will be satisfied with the emergency logistics; otherwise they will be dissatisfied. So here we will use the satisfaction of the disaster site to explain the timeliness, so we need to consider the vehicle scheduling model based on the satisfaction of the disaster site.

2.1.2. Problem description and assumptions

a) Problem description

In the vehicle scheduling problem of emergency medical logistics distribution, we must first consider the suddenness, contingency of emergency events, and the extremely high requirements for rescue speed in emergency events. Therefore, when establishing the emergency medical logistics distribution vehicle scheduling model, one of the goals should be to minimize the total time of drug delivery; secondly, considering that emergency medicines are one of the relief materials, emergency medicines must be delivered within the time period required by the disaster site and meet the needs of the disaster site. Drug satisfaction is another objective function.

Satisfaction with drug demand at the disaster site is a vague concept, therefore, it will be described by using ambiguity.

Defined $[E_j, L_j]$ as the largest range of services that the injured at the disaster site can receive, $[e_j, l_j]$ as the expected service time of the injured at the disaster site. In addition, a number between 0 and 1 is used to indicate the satisfaction of the disaster site with the drug demand, and 0 is the dissatisfied drug demand at the disaster site, 1 is that the disaster site is fully satisfied with the drug demand. Therefore, the satisfaction function of disaster site j for drug demand is:

$$S(t_j) = \begin{cases} 0, & \text{otherwise} \\ \frac{(t_j - E_j)}{(e_j - E_j)}, & E_j \leq t_j < e_j \\ 1, & e_j \leq t_j \leq l_j \\ \frac{(L_j - t_j)}{(L_j - l_j)}, & l_j < t_j < L_j \end{cases}$$

where t_j is the time when service point j starts to receive services.

In practice, emergency logistics may also be hindered due to damage to roads, bridges and other infrastructure during the disaster, leading to an increase in the time required for vehicles to travel from the rescue site to the affected site. The road condition coefficient will be used to measure in this model, let be the road condition coefficient, and its value ranges from 1 to 2. When the value is 1, it indicates that the road is accessible; on the contrary, when the value is 2, it indicates that the road is most blocked.

b) Problem assumptions

- The vehicle departed from a rescue site and passed through a series of disaster-stricken areas before returning to the rescue site.
- The demand for medicines in a disaster area is not greater than the maximum load capacity of a delivery vehicle.
- Distribution vehicles of the same model are used for distribution, and the maximum load capacity of the vehicle is constant.
- The coordinates of the location of each rescue and disaster area are known.
- The speed of the delivery vehicle and the unloading speed are constant.
- The road obstruction factor in the model can be measured by a constant.

2.2. Establishment of Emergency Medical Logistics Distribution Vehicle Scheduling Model

The model formulation, with a full definition of its notations, is as follows:

- Sets:
 - I: Set of rescue sites
 - J: Set of disaster-stricken sites
 - R: Set of vehicles
- Parameters:
 - Q_j : Demand of disaster-stricken sites j
 - v_1 : Average vehicle speed
 - v_2 : Average unloading speed
 - Z: Load capacity per vehicle
 - R_i : Maximum number of vehicles in rescue location i
 - t_{ijr} : The time required for vehicle r to go from rescue site i to disaster site j
 - t_{jr} : The unloading time of vehicle r in the disaster site j
 - t_j : Time when disaster site j started receiving services
 - d_{ij} : Distance from rescue site i to disaster site j
 - α_{ij} : Road condition coefficient
- Decision variables:
 - X_{ijr} : 1 if vehicle r goes from the rescue site i to the disaster site j, 0 otherwise
 - X_{jr} : 1 if vehicle r is responsible for delivery to the disaster site j, 0 otherwise
- Model

$$\min t = \sum_{i=1}^n \sum_{j=1}^m \sum_{r=1}^p x_{ijr} (t_{ijr} + t_{jr})$$

$$\max \frac{\sum_{j=1}^m S(t_j)}{m}$$

s.t.

$$\sum_{j=1}^m x_{jr} \cdot Q_j \leq Z, \forall r \tag{1}$$

$$\sum_{r=1}^p x_{jr} = 1, \forall j \tag{2}$$

$$\sum_{j=1}^m \sum_{r=1}^p x_{ijr} \leq R_i, \forall i \tag{3}$$

$$t_{ijr} = \alpha_{ij} \cdot \frac{d_{ij}}{v_1}, \forall i, j \tag{4}$$

$$t_{jr} = \frac{Q_j}{v_2} \tag{5}$$

$$x_{ir} = 0(\text{or})1, \forall j, r \tag{6}$$

$$x_{ijr} = 0(\text{or})1, \forall i, j, r \tag{7}$$

First objective function represents the shortest total travel time on the route; Second objective function indicates the highest average satisfaction of all affected points; constraint(1) indicates that the total delivery volume of each vehicle to the disaster-stricken point it serves does not exceed the maximum load capacity of the vehicle; constraint(2) indicates that the needs of each disaster site can be met by a vehicle; constraint (3) indicates that the number of vehicles dispatched by each rescue place cannot exceed the maximum number of vehicles that the rescue place has; constraint(4) represents the time required for vehicle r to reach the affected area j from the rescue area i;

constraint (5) indicates the unloading time of vehicle r in the affected area j; constraint(6) and constraint(7) are decision variables.

3. SOLUTION OF EMERGENCY MEDICAL LOGISTICS DISTRIBUTION VEHICLE SCHEDULING MODEL

3.1. Algorithm Overview

Genetic algorithm is a computational model of biological evolutionary processes that draws on the natural selection and genetic mechanism of Darwin’s theory of biological evolution. It is a randomized search method that searches for the optimal solution by simulating the natural evolutionary process. The genetic algorithm mainly includes five execution processes: initialization, individual evaluation, population evolution, termination criteria, and operating parameters.

3.2. Example Description and Result Analysis

3.2.1. Example description

Sudden natural disaster occurred in one place, there are 15 disaster-stricken sites, and the existing 3 rescue sites can provide emergency medical assistance. Assume that the average traveling speed of the rescue vehicle is 45 km/h, the average unloading speed is 70 units/h, and the maximum load capacity of each vehicle is 65 units. The demand quantity, location coordinates of each disaster site, and the maximum service range and expected service time that the disaster site can accept for the required resources are shown in Table 1.

Table 1 Information on the affected and rescue points

disaster-stricken sites	Position coordinates	demand	maximum service range	expected service range
1	(37, 52)	10	(0, 2)	(0.3, 1)
2	(52, 64)	12	(0, 2)	(0.5, 1.4)
3	(28, 34)	22	(0, 1.5)	(0.5, 1)
4	(40, 30)	33	(0, 1.5)	(0.5, 1.2)
5	(31, 62)	20	(0.5, 1.5)	(0.5, 1)
6	(13, 13)	25	(0, 1.5)	(0.5, 1)
7	(36, 16)	13	(0, 1.5)	(0.5, 1)
8	(12, 42)	18	(0, 1)	(0.3, 0.8)
9	(31, 32)	30	(0, 1)	(0.3, 0.7)
10	(43, 45)	10	(0, 2)	(1, 1.5)
11	(42, 57)	11	(0, 2.5)	(0.4, 1)

12	(8, 52)	23	(0, 2)	(0.7, 1.5)
13	(62, 24)	25	(0, 1.5)	(0, 0.9)
14	(43, 67)	8	(0.5, 2)	(0.8, 1.5)
15	(27, 68)	19	(0, 2)	(1, 1.4)
16	(25, 20)			
17	(35, 45)			

3.2.2. Analysis of results

This paper uses MATLAB 2018b software and genetic algorithm to solve this example. Since the intelligent algorithm is used to solve the local optimal solution, the results of each operation cannot be guaranteed to be

consistent, so three are selected from multiple local optimal solutions, and the three local optimal solutions are calculated according to the satisfaction function $S(t_j)$. The superior solution's satisfaction point is compared. The local optimal solution obtained is shown in Table 2.

Table 2 Local optimal solution

local optimal solution	Optimal distribution route	Optimal total time	Disaster satisfaction
First local optimal solution	16->3->9->7->16;16->6->16; 17->1->5->15->14->17; 17->8->12->17; 18->4->13->18; 18->10->11->2->18	18.830760	0.7273
Second local optimal solution	16->7->6->16; 17->1->11->2->14->15->17; 17->8->12->17;17->9->3->17; 17->5->17;18->4->10->18; 18->13->18	18.780727	0.698
Third local optimal solution	16->8->12->16; 16->9->3->16; 16->6->16;17->10->5->17; 17->1->11->2->14->15->17; 18->4->7->18;18->13->18	18.848162	0.6027

In short, there is not much difference in the optimal time of the three local optimal solutions. According to the satisfaction function $S(t_j)$ of the disaster point j for the drug demand, the satisfaction points of the three local optimal solutions are 0.7273, 0.698, 0.6027. Therefore, the first solution with the highest satisfaction level for drug demand

in disaster site j is selected, and its distribution path is shown in Fig.1 below.

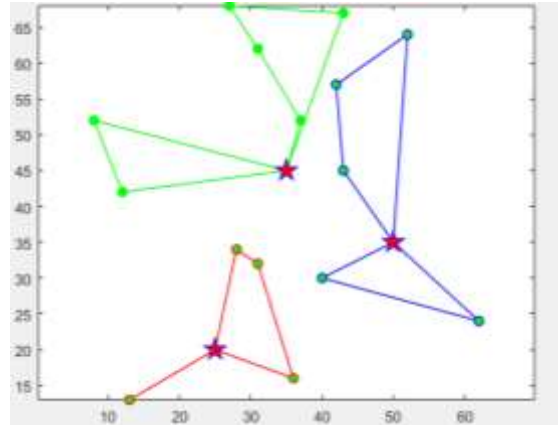


Figure 1 Optimal distribution route

4. CONCLUSION

With the increase of people's awareness of prevention of emergency events such as natural disasters, emergency logistics has become a hot research topic in the field of logistics. In-depth research on emergency logistics will not only improve the efficiency of disaster relief, but also strengthen the protection of people's lives and property Safety. Based on the theoretical basis of emergency logistics and medical logistics, and considering the typical characteristics of emergency logistics and medical logistics, this paper optimizes the dispatch vehicle scheduling in the transportation and distribution of emergency medical items at the core of emergency medical logistics.

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