Emergency logistics vehicle routing optimization based on insufficient supply

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Abstract. In the face of various emergencies, emergency logistics vehicles are required to meet the needs of the affected areas in a short enough time. However, due to the suddenness of the incident and the shortage of relief supplies, it is necessary to further consider how to optimize the route of emergency vehicles in case of insufficient supply. In this paper, when the supply point is insufficient, the emergency vehicle routing can be optimized in the shortest possible time and at the same time to meet the requirements of the disaster site. By establishing the corresponding mathematical model and using the genetic algorithm to solve the relevant examples, the new solution is provided for the emergency logistics vehicle routing problem when the relief materials are insufficient. According to the analysis results of the example, the effectiveness of the optimization method is further demonstrated, and theoretical support is provided for relevant decision makers.

1 Introduction

With the various major natural disasters that have emerged in recent years, the economic development of the region and even the economic development of the country have been greatly affected. In the event of a major natural disaster, how to rescue the disaster relief site in a short period of time is very important, so the status of emergency logistics is increasingly prominent.

How to quickly and efficiently deliver relief supplies to disaster-stricken areas in the face of unexpected events is an important challenge for emergency logistics. At the same time, due to the suddenness of the incident, it is difficult for relief materials to meet the needs of all disaster-affected sites. How to plan the route of emergency logistics vehicles and the quantity of materials at the disaster site is a problem that emergency logistics often encounters under realistic conditions. Based on the background of major natural disasters and the shortage of relief materials, this paper constructs a corresponding vehicle routing optimization model. Under the constraints of vehicle load and reasonable distribution of rescue materials, the genetic algorithm is used to study the optimal path of emergency vehicles when the relief materials are insufficient.

1.1 Emergency logistics overview

Emergency logistics is a special logistics activity ^[1] generally refers to the emergency protection of the needs of materials, personnel and funds at the disaster site in order to response emergencies such as serious major natural disasters, military conflicts and so on. As with ordinary daily logistics, emergency logistics is also based

on logistics efficiency. The difference is that in addition to logistics efficiency, general logistics also emphasizes logistics efficiency. Emergency logistics is to achieve logistics benefits through logistics efficiency.

After the emergency occurs, the relief materials need to be delivered to the disaster area in the shortest possible time, and the path optimization of the emergency logistics vehicles is a key issue to be considered. Optimizing the route of emergency logistics vehicles, the reasonable distribution of relief materials within the specific time window of the disaster-stricken point can be achieved, and the rescue pressure of the disaster-stricken point can be greatly reduced.

1.2 Research on path optimization of emergency logistics vehicles

At present, relevant scholars at home and abroad have already had rich research results on emergency logistics path planning. For example, Zhao et al. (2010)^[2] studied the optimization of the route of the emergency aid delivery vehicle with time window, and used the ant colony algorithm to solve the constructed model; Sascha et al. (2012)^[3] studied the dynamic path optimization of emergency logistics vehicles under the condition of deterministic demand, which is different from the traditional static planning; Alberto et al. (2014)^[4] studied the location and vehicle routing problems in emergency logistics in the context of drug distribution; Cheng Birong et al. (2016)^[5] aimed at the shortage of emergency supplies in critical rescue period, an optimization model of emergency logistics vehicle routing problem under stochastic demand environment is established, and a solution method based on genetic algorithm is designed; Wu Xinsheng et al. (2018)^[6] introduced two groups of

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intelligent hybrid algorithms for comparative experiments to further optimize emergency logistics path planning model to improve distribution efficiency.

In the context of major natural disasters, this paper aims at the problem of insufficient relief materials, and aims to minimize the maximum value of the difference between the time and the risk of the two disaster-affected points. The model is constructed under the constraint of time window and using genetic algorithm to solve the model. In contrast, there are some innovations in the objective function.

2 Related assumptions and models

2.1 Model description

In this paper, if a major natural disaster occurs in a certain area, it is necessary to timely deliver relief materials to each affected area. The location of the relief supplies distribution center is known and fixed, but there is a shortage of relief supplies. The distribution center has a certain number of emergency vehicles available for rescue, each vehicle is exactly the same, and has a certain load limit. There are multiple disaster sites, and the location of each disaster site and the demand for relief supplies are known. Under the goal of minimizing the delivery time and the minimum value of the difference between the demand and the rate of the two disaster-affected points, how to optimize the load and delivery path of the emergency vehicle, and let each disaster-stricken point receive relief materials in a short period of time as fair as possible is the focus of this study.

2.2 Variable definitions

Based on the questions raised in this study, the following related variables are defined:

N : the number of disaster sites;

K : number of vehicles in the distribution center;

V : the speed of the vehicle;

i, j : At the disaster site, $i, j = 0, 1, \dots, N$, at the disaster site $i, j = 0$ indicates the distribution center;

d_{ij} : the distance between the disaster site i and the disaster site j ;

t_{ij} : the time from the point of disaster i to the point j of disaster;

m_i : the point i of disaster demand for relief supplies;

z_i : The actual amount of relief materials obtained at the disaster site i ;

s_i : the ratio of actual relief supplies to demand received by the disaster site i ;

Q : the maximum carrying capacity of each vehicle;

t_i : The time when the vehicle first arrives at the disaster site i ;

L_i : the time when the vehicle finally arrives at the disaster site i ;

s_i : The ratio of the supply of the disaster-stricken point to the demand at the end of the rescue. The larger the value, the more sufficient the supply.

The corresponding decision variables are:

$$x_{ijk} = \begin{cases} 1 \\ 0 \end{cases}$$

When the decision variable is 1, it means that vehicle K comes from point i to point j .

2.3 Related assumptions

(1) Vehicles k starts from the distribution center, and eventually returns to the distribution center;(2) There is no difference in the types of relief materials delivered, and there is no need to distinguish between materials;(3) A vehicle can transport supplies for multiple disaster sites, and each disaster relief site is serviced by only one vehicle;(4) The vehicle must meet the time window of the disaster site during the delivery process;(5) The amount of materials required for each disaster site is greater than the vehicle capacity.

2.4 Model building

$$\min T = \sum_{k=1}^K \sum_{j=0}^N \sum_{i=0, i \neq j}^N \alpha x_{ijk} t_{ij} + \beta \max(s_i - s_j) \quad (1)$$

$$\sum_{i=1}^N \sum_{k=1}^K x_{ik} z_i \leq Q \quad (2)$$

$$\sum_{k=1}^K x_{ik} = 1, \quad i \in \{1, 2, \dots, N\} \quad (3)$$

$$\sum_{i=0}^N x_{ijk} = x_{kj}, \quad j \in \{1, 2, \dots, N\}, k \in \{1, 2, \dots, K\} \quad (4)$$

$$\sum_{j=0}^N x_{ijk} = x_{ki}, \quad i \in \{1, 2, \dots, N\}, k \in \{1, 2, \dots, K\} \quad (5)$$

$$s_i = \frac{z_i}{m_i}, \quad i \in \{1, 2, \dots, N\} \quad (6)$$

$$t_j = \sum_{i=0, i \neq j}^N x_{ijk} (t_i + t_{ij}), \quad j \in \{1, 2, \dots, N\} \quad (7)$$

$$t_{ij} = \frac{d_{ij}}{V}, \quad i, j \in \{1, 2, \dots, N\} \quad (8)$$

$$t_i < L_i, \quad i \in \{1, 2, \dots, N\} \quad (9)$$

Equation (1) is the objective function of the model, which consists of two parts: the delivery time and the maximum value of the difference between the requirements of the two disaster-affected points. Equation

(2) means that the relief supplies loaded in each vehicle cannot exceed the maximum load. Equation (3) means that each disaster-stricken point can only be served by one car. Equations (4) and (5) indicate that the emergency vehicle k arrives at the disaster site i from the disaster site j . Equation (6) indicates the proportion of the supply of the disaster site i to meet the demand. Equation (7) indicates that the time when the vehicle arrives at the disaster site j is the sum of the time when the emergency vehicle leaves the disaster site i and the travel time between the two disaster sites. Equation (8) indicates that the time from the disaster site i to the disaster site j is the distance between the two disaster sites divided by the vehicle speed. Equation (9) represents the time window constraint of each disaster site.

3 Algorithm introduction

3.1 Algorithm description

Various types of algorithms applied to the vehicle routing problem, different algorithms have their own characteristics, for example, the Tabu search algorithm^[7] can avoid the criterion of stopping with local optimum; The calculation process of simulated annealing^[8] has a simple calculation process and is suitable for parallel processing, but at the same time, the convergence speed is slow, the execution time is long, the performance of the algorithm is related to the initial value and the parameters are sensitive; the genetic algorithm^[9] finds the optimal solution by imitating the choice of nature and the mechanism of inheritance. The search starts from the group and has potential parallelism, which can simultaneously compare multiple individuals. Therefore, combined with the relevant characteristics of emergency logistics, this paper will apply genetic algorithm to solve the vehicle routing planning of emergency logistics.

3.2 Solution process

The solution process of the genetic algorithm ^[10] is as follows:

(1) Initialization

a. Combine the actual, select a relatively suitable coding scheme, and convert the variable with certain characteristics into the corresponding chromosome, that is, the numeric string. In general, choose binary encoding.

b. Set the appropriate parameters, including the group size (M), crossover probability P_c , and mutation probability P_m .

c. Further determine the fitness function $f(x)$.

(2) Form an initial group (including M individuals). In the slope slip surface search problem, the analyzed possible slip surface group is taken as the initial group.

(3) Calculate the fitness value f_i for each chromosome, that is, the numeric string, and calculate the total fitness value of the population.

(4) Selection process

Calculate the selection probability p_i of each digit string and the corresponding cumulative probability. The selection process is done by rotating the wheel, and M strings can be selected after rotating M times. The steps implemented on the computer are: generating a random number r between $[0, 1]$, if $r < q_1$, then the first string v_1 is selected, otherwise v_2 is selected to satisfy $q_{i-1} < r < q_i (2 \leq i \leq m)$. It can be seen that the digital string selection probability with large adaptation value is large.

(5) Cross operation

a. If, in the k th selection, the number randomly generated from $[0, 1]$, if $r > P_c$, then the string participates in the crossover operation, and after selecting the group that participates in the intersection, the pair is randomly matched.

b. For each pair of digit strings, a random number between $[1, m]$ is generated to determine the position of the intersection.

(6) Mutation operation

If the probability of mutation is set to P_m , the expected value of the number of possible variations is $P_m * m * M$, and each digit string will mutate with the same probability. That is, a random number r between $[0, 1]$ is generated for each bit in each string. If $r < P_m$, the corresponding digit string will be inverted, that is, the binary code of the chromosome is changed to a number 0 to 1, and 1 becomes 0.

After a round of initialization and selection, crossover, and mutation, a new population is created. The new evolutionary round will continue to a certain number and be repeated, and finally the optimal chromosome will be the solution to the problem.

4 Case analysis

According to the model constructed above and the specific example for further verification, in this example, it is assumed that there is one distribution center and 10 disaster sites in the disaster area, the coordinates of each point and the corresponding specific information are as table 1 shows.

According to the specific data in Table 1, the position distribution map shown in Figure 1 is obtained. From the distribution center in Figure 1 and the location of each demand site, the distribution center is located in the central area of the demand site, and the location of each demand site is distributed around the distribution center, which can further judge the distribution of the distribution center and the demand site.

In the distribution center, there are 5 distribution vehicles, each of which is exactly the same. The maximum

load is 10t, the speed of the emergency vehicle is $V=40\text{km/h}$, and the corresponding objective function is $\alpha=\beta=0.5$.

Based on the established model, the genetic algorithm is used to perform MATLAB programming, and finally the results shown in Table 2 are obtained:

According to Table 2, the path of each vehicle is shown in the position map as shown in Figure 2. According to the result of the vehicle route, the vehicles in the distribution center are fully utilized, starting from the distribution center, and returning to the distribution center after each disaster site. The resulting vehicle route meets the needs of each demand site to a certain extent, and saves rescue time.

5 Conclusion

This paper mainly studies the vehicle routing problem of emergency logistics. When the relief materials are difficult to meet the needs of all demand sites, the relief

materials will be distributed to all disaster sites as soon as possible and fair. This study first establishes a vehicle routing model when the materials are insufficient. The distribution time is as short as possible, and the maximum value of the difference between the demand and the rate of the two disaster-affected points is as small as possible, solving the optimal vehicle routing under certain constraints. In the process of solving with a specific example, the genetic algorithm is used to further solve the model. The final example analysis shows that the model in this paper is effective and feasible.

As an important part of emergency rescue, emergency logistics still needs to be improved in some places, especially under the influence of big data and Internet of Things, intelligent logistics including emergency rescue has emerged ^[11], so emergency logistics learning and research is a long process. In the theoretical study of emergency logistics, it is necessary to further contact with the actual situation, and the combination of theory and practice can solve the problems related to emergency rescue more efficiently.

Table 1. Information about the distribution center and the disaster sites.

CUST NO.	XCOORD. (KM)	YCOORD. (KM)	DEMAND (t)	READY TIME	DUE DATE	SERVICE TIME (min)
0	40	40	0	0	1236	0
1	22	22	16	912	967	30
2	36	26	12	825	870	30
3	21	45	11	65	146	30
4	45	35	12	727	782	30
5	55	20	11	15	67	30
6	33	34	19	621	702	30
7	50	50	15	170	225	30
8	55	45	14	255	324	30
9	26	59	16	534	605	30
10	40	66	13	357	410	30

Table 2. Vehicle routes.

VEHICLE	ROUTES
VEHICLE 1	0→4→1→0
VEHICLE 2	0→3→2→0
VEHICLE 3	0→9→6→0
VEHICLE 4	0→8→10→0
VEHICLE 5	0→5→7→0

Figure 1. Distribution center and specific demand.

Figure 2. Specific roadmap for each vehicle.

Acknowledgments

In the process of writing the paper, I thanked my advisor for his valuable advice. With the help of my advisor, I corrected the small mistakes in details in time and improved the logic of the paper. This research was funded by National Key Research and Development Program of China, grant number 2016YFC0803206, and Fundamental Research Funds of Beijing University of Posts and Telecommunications, grant number 2018XKJC07, 2018RC27.

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