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Research on the Optimization of Emergency Material Distribution Route in "Vehicle" Mode Based on K-Means Clustering and LK Algorithm

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Abstract: For disaster victims, the timely delivery of emergency materials is a key factor to ensure their life safety, and the reasonable scheduling of emergency vehicles is a key link in the distribution of emergency materials, so it is of great significance to optimize the vehicle route of emergency materials. In this paper, the optimization model of emergency material distribution route in "vehicle" mode based on K-means clustering and LK algorithm is used to solve the optimal scheme of overall distribution in 14 locations, and the waiting time of demand points is solved under the constraints of optimization target, vehicle and distribution quantity, and the optimal distribution scheme is 9-13-14-10-6-4-6-5-3-2-5-1-1-11-12-7-8-9.

1. Introduction

Relief efforts must be carried out immediately after natural disasters. The sudden occurrence of disasters often leads to casualties, road damage, building damage, and water and electricity outages, and emergency material distribution has become the top priority of emergency rescue. For disaster victims, the timely delivery of emergency materials is a key factor to ensure their life safety, and the reasonable scheduling of emergency vehicles is a key link in the distribution of emergency materials. Therefore, this paper restores the guarding environment, assuming that all emergency materials are currently concentrated in the 9th location, the maximum load capacity of the delivery vehicle is 1000 kg, according to the 14 locations provided, the distribution mode of only delivery vehicles is adopted, and a mathematical model is established to complete an overall distribution, and the optimal scheme is given. An overall delivery means that the time required to complete an overall delivery is the main consideration of delivery personnel, calculated according to the time from the departure of the delivery vehicle and the drone to the full return to the departure place[0]. During the delivery process, the time taken by the delivery vehicle and drone to load and unload the materials, and the dwell time of the delivery vehicle and drone at each distribution point is not considered.

In this paper, the optimization model of emergency material distribution route in "vehicle" mode based on K-means clustering and LK algorithm is used to solve the problem[0]. The waiting time of the demand point is based on the optimization target, vehicle and distribution volume as the constraints to solve the problem, and after the model is established, the weight of goods required by the nodes in the disaster area and the location of each node are analyzed, and the data is preprocessed to obtain the optimal result.

2. Establishment of Emergency Material Distribution Route Optimization Model in "Vehicle" Mode Based on K-Means Clustering and Lk Algorithm

2.1 Symbol Description

Table 1: Symbol Description

Aggregate	Explain	Aggregate	Explain
D	Collection of demand nodes	c_k	Maximum load
U_i	Unsatisfied material quantity at demand node i	Y_{ik}	Time of arrival at node i
M	Fully large positive number		
Aggregate	**Explain**		
s	Available quantity at the supply point		
n	Number of initial emergency vehicles on standby for the supply point		
ζ_i	Quantity of materials required for the ith demand node		
τ_{ijk}	Time required to transport materials from node i to node j		
Y_{ik}	Quantity of materials delivered by distribution vehicles for demand node i		

2.2 Model Establishment

This paper studies the vehicle path planning problem of transporting emergency materials to m demand points from one supply point by using a distribution transport vehicle, and each transport vehicle returns to the supply point after completing the transportation task. The objective of optimization is to minimize the waiting time of demand points and the total amount of unsatisfied materials.

$$X_{ijk} = \begin{cases} 1, \text{(i,j) is traversed by vehicle k} \\ 0, \text{ otherwise} \end{cases} \tag{1}$$

$$S_{ik} = \begin{cases} 1, \text{node i can be serviced by vehicle k} \\ 0, \text{otherwise} \end{cases} \tag{2}$$

Then, the VRP model of emergency material scheduling in emergencies is:

2.2.1 Optimization Objective

$$\text{minimize} \sum_{i \in D} U_i + \lambda \sum_{i \in D, k \in K} T_{ik} \tag{3}$$

2.2.2 Constraints

$$\sum_{i \in D} \sum_{k \in K} X_{0ik} \leq n \tag{4}$$

$$\sum_{i \in D} \sum_{k \in K} X_{i0k} \leq n \tag{5}$$

$$\sum_{j\in D} X_{0jk} = \sum_{j\in D} X_{j0k} = 1(\forall k \in K) \tag{6}$$

$$\sum_{j\in C}\sum_{k\in K} X_{ijk} = 1\ (\forall i \in D) \tag{7}$$

$$\sum_{j\in C}\sum_{k\in K} X_{jik} = 1(\forall i \in D) \tag{8}$$

$$\sum_{j\in C} X_{ijk} = \sum_{j\in C} X_{jik}(\forall i \in D, k \in K) \tag{9}$$

$$T_{0k} = 0(\forall k \in K) \tag{10}$$

$$T_{ik} + \tau_{ijk} - T_{jk} \le \left(1 - X_{ijk}\right)M(\forall i,j \in C, k \in K) \tag{11}$$

$$0 \le T_{ik} \le \sum_{j\in C} X_{ijk}M(\forall i,j \in C, k \in K) \tag{12}$$

$$s - \sum_{i\in D}\sum_{k\in K} Y_{ik} \ge 0 \tag{13}$$

$$\sum_{i\in D} Y_{ik} \le c_k\ (\forall k \in K) \tag{14}$$

$$X_{ijk}, S_{ij} = \{0,1\}, Y_{ik} \ge 0, U_i \ge 0, T_{ik} \ge 0, \delta_{ik} \ge 0 \tag{15}$$

Among them, the optimization objective formula (1) represents the quantity of unsatisfied materials and the waiting time at the minimum demand node. Constraints (2) - (7) describe the restrictions on emergency vehicles and their transportation routes; The constraint formula (4) indicates that the distribution vehicle starts from the warehouse and returns to the warehouse after completing the transportation task; Constraints (5) and (6) indicate that each requirement node can be accessed at most twice; Constraint formula (8) indicates that the vehicle is dispatched at time 0; The constraint formula (9) guarantees the correctness of the timing relationship of vehicle access nodes; Constraint formula (10) indicates that if the vehicle does not pass through the demand node, the access time is set as 0. Constraints (11) and (12) ensure the feasibility of cargo logistics: Constraints (11) ensure that the total amount of materials output by the supply point does not exceed the available quantity; Quantity. Constraint equation (13) indicates the limit of decision variable value.

2.3 Algorithm Description

The process of KMLK algorithm is as shown in Figure 1:

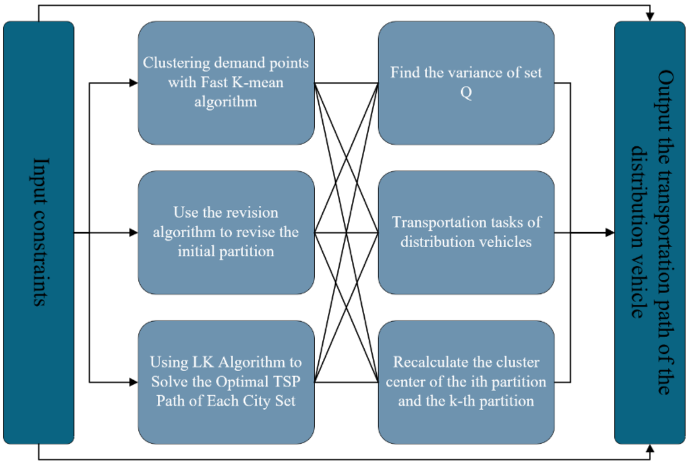


Figure 1: Kmlk Algorithm Flow

2.3.1 Input

Available quantity s of supply point; Quantity of materials required for the ith demand node ζ_i; Maximum load of distribution vehicle C_k; Time required for distribution vehicles to transport materials from node i to node j τ_{ijk}:

Step 1: Use Fast K-mean algorithm to cluster demand nodes. The number of categories is n, and get the initial task division $D = \{D_1, D_2, ..., D_n\}$;

Step 2: Use the revision algorithm to revise the initial partition $D = \{D_1, D_2, ..., D_n\}$, and get a new task partition $D^{'} = \left\{D_1^{'}, D_2^{'}, ..., D_n^{'}\right\}$;

Step 3: Solve each city set C with LK algorithm_ I to minimize the objective function [0].

2.3.2 Output

Transportation path of distribution vehicle, objective function value:

In step 2, the Fast K-mean clustering results were corrected. K-mean clustering method only aims at the aggregation of demand nodes' geographical locations, and does not consider the load balancing problem of each emergency vehicle transportation task. Based on the Fast K-mean clustering results, the adjustment algorithm adjusts the transportation task of emergency vehicles by considering the transportation load balance of each emergency vehicle [0]. The specific process of the modified algorithm is as follows:

Input: initial partition after Fast K-mean clustering $D = \{D_1, D_2, ..., D_n\}$.

Step 1: calculate the transportation task load of each emergency vehicle under the premise of the current division $D = \{D_1, D_2, ..., D_n\}$, and record it as $Q = \{Q_1, Q_2, ..., Q_n\}$. Find the variance d of set $D^{'} = D$. If d_ If Q remains unchanged for 10 iterations, the correction algorithm will stop and D ^ '=D will be output; Otherwise, go to step 2 to continue iteration.

Step 2: Make $Q_i = \max\{Q_1, Q_2, ..., Q_n\}(i = 1,2, ..., n)$, the transportation task of distribution vehicles is $D_i = \{d_1, d_2, ... d_s\}$, s is the number of demand nodes to be reached by the ith emergency vehicle.

Step 3: Recalculate the cluster center m of the i-th and k-th partitions m_i and m_k Go to step 1.

It can be seen from the process of the modified algorithm that each iteration selects a demand point closest to other division centers in the transportation task division of the emergency vehicles with the largest load and transfers it to the nearest task division. The goal is to minimize the variance of the transportation task load of each emergency vehicle, that is, to balance the transportation load of each emergency vehicle.

3. Solving the Optimization Model of Emergency Material Distribution Route in "Car" Mode Based on K-Means Clustering and Lk Algorithm

3.1 Problem Assumptions

Assuming that all emergency supplies are currently concentrated in the 9th location, and the maximum load capacity of the delivery vehicle is 1000 kg, the 14 locations are given according to Figure 2, and the distribution mode of the delivery vehicle is adopted, and the solid line in Figure 2 represents the route between the locations.

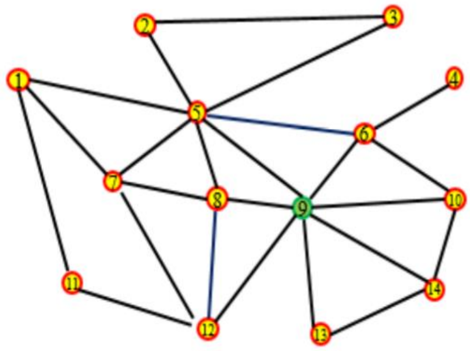


Figure 2: Schematic Diagram of the Connection of Each Location

3.2 Problem Analysis

At present, all emergency materials are concentrated in the ninth location, and the distribution mode of distribution vehicles is adopted. In order to obtain the optimal route, this problem will use the optimization model of emergency materials distribution path under the "vehicle" mode based on K-means clustering and LK algorithm to solve the problem, with the waiting time at the demand point as the optimization goal, vehicles and distribution volume as the constraint conditions. After the model is established, analyze the cargo weight required by the nodes in the disaster area and the location of each node, and conduct data preprocessing to obtain the optimal result. See the flow chart as shown in Figure 3 for specific ideas:

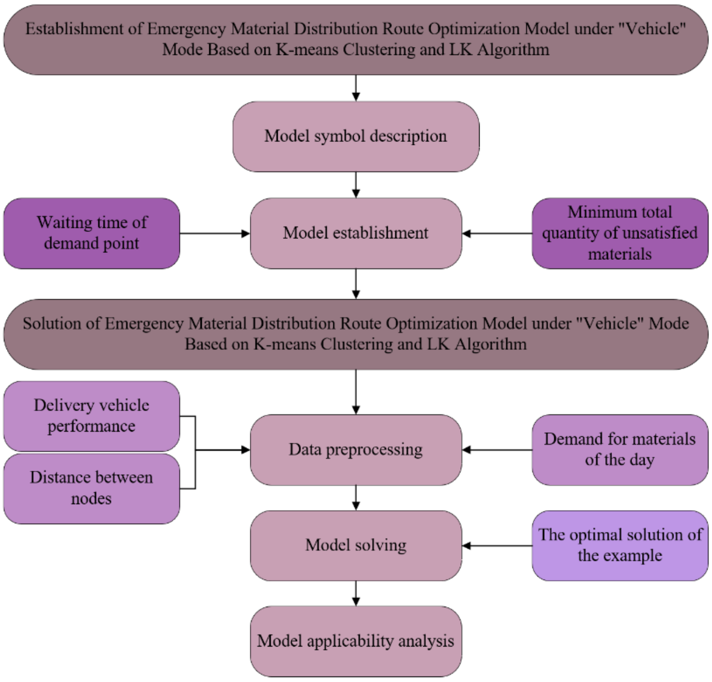


Figure 3: Analysis of Ideas

3.3 Data Preprocessing

In order to verify the effectiveness of the model, a small-scale calculation example (14 nodes) is solved by using matlab. The nodes include 1 emergency material concentration site and 13 disaster affected sites. Therefore, it is necessary to analyze the demand for materials and the carrying capacity of distribution vehicles on the day of 14 nodes to determine whether secondary distribution or increase of distribution vehicles is required. The comparison results are shown in Figure 4:

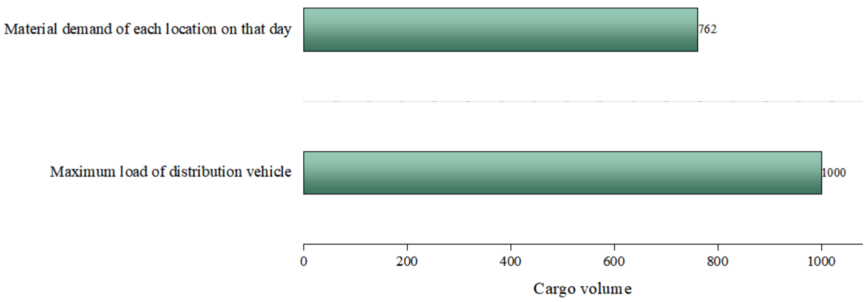


Figure 4: Demand of Materials on the Day of the Node and Load Capacity of Distribution Vehicles

It can be seen from the above figure that only one distribution vehicle is needed to complete a distribution.

The maximum load of distribution vehicles is 1000 kg, and the average speed is 50 km/h, as shown in Table 2:

Table 2: Performance of Distribution Vehicles

Distribution equipment	**Average velocity**	**Maximum load**
Vehicle	50km/h	1000kg

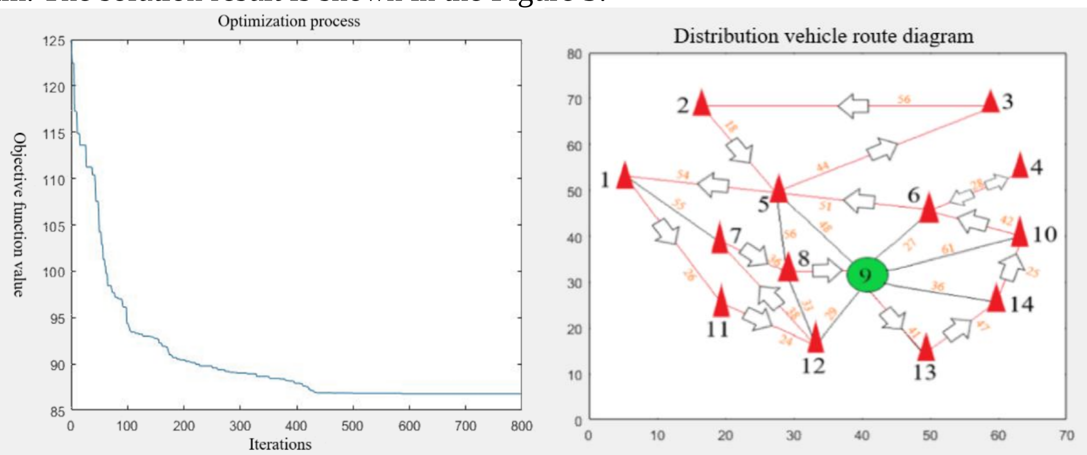
Finally, the location and distance of each distribution node are analyzed, as shown in Table 3:

Table 3: Distance between Nodes in Disaster Area

Nodes in disaster area	Distance from this point (km)						
1	5(54)	7(55)	11(26)				
2	3(56)	5(18)					
3	2(56)	5(44)					
4	6(28)						
5	1(54)	2(18)	3(44)	6(51)	7(34)	8(56)	9(48)
6	4(28)	5(51)	9(27)	10(42)			
7	1(55)	5(34)	8(36)	12(38)			
8	5(56)	7(36)	9(29)	12(33)			
9	5(48)	6(27)	8(29)	10(61)	12(29)	13(42)	14(36)
10	6(42)	9(61)	14(25)				
11	1(26)	12(24)					
12	7(38)	8(33)	9(29)	11(24)			
13	9(42)	14(47)					
14	9(36)	10(25)	13(47)				

3.4 Model Solution

KMLK algorithm is adopted for the above data, which is implemented by VC++6.0 and runs on Intel ® CoreTM2 CPU, 1.86 GHz PC with 2 GB memory, solved the optimization model of emergency material distribution path under the "vehicle" mode of K-means clustering and LK algorithm. The solution result is shown in the Figure 5:



(a) (b)

Figure 5: Solution Results of Example

The running time of the example is 1 minute and 07 seconds, and the value of the objective function is 10.76 hours. Figure 5(b) is the road map of the example. The black line in the map represents the road that is not used by distribution vehicles and UAVs, and the red line represents the road that is used by distribution vehicles. See the following Table 4 for details:

Table 4: Optimal Solution of Calculation Example

Optimal solution	Solution time	Vehicle route
10.76h	1.12min	9-13-14-10-6-4-6-5-3-2-5-1-11-12-7-8-9

In order to show the advantages of the algorithm in this paper more intuitively, Figure 6 describes the difference between the target function solved by TH algorithm and KMLK algorithm under the random model instance and the mixed Gaussian model instance [0]. It can be seen from the comparison results in Figure 6 that the KMLK algorithm has more obvious advantages. This is because this paper uses the most outstanding heuristic algorithm LK algorithm to solve the TSP problem to optimize the travel route of a single emergency vehicle, and has achieved good results.

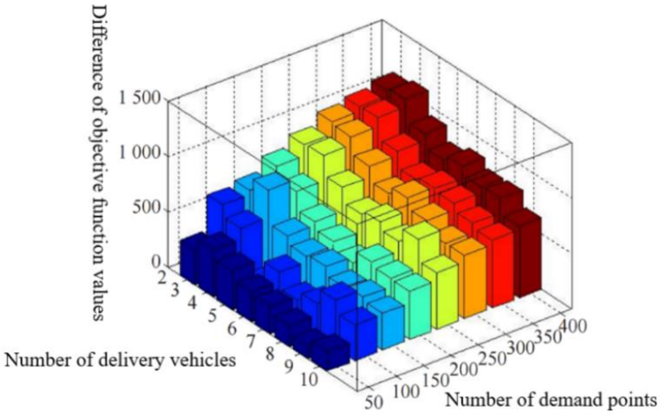


Figure 6: Difference between TH and Kmlk Objective Functions

4. Conclusion

This paper selects the appropriate model according to the hypothetical problem, and establishes the "vehicle" mode emergency material distribution path optimization model based on K-means clustering and LK algorithm. After solving the problem, we can find that this algorithm has a good effect on solving the emergency material distribution path optimization. In order to show the advantages of this algorithm more intuitively, the difference between the objective function solved by TH algorithm and KMLK algorithm in the case of random model and mixed Gaussian model is described respectively. The superiority of KMLK algorithm is more obvious. The simulation results show that KMLK has achieved a better scheduling scheme than TH algorithm and IRA algorithm on the test cases where the demand nodes are uniformly distributed and the mixed Gaussian model is distributed. Moreover, the more demand nodes a single emergency vehicle serves, the more obvious the superiority of KMLK algorithm is.

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