Research on Distribution Path of Single-center Medical Rescue Materials

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Abstract. Reasonably planning the vehicle's distribution path can effectively improve the distribution efficiency of the distribution center. This article takes the distribution of medical rescue materials as an example. Under the conditions of meeting the needs of hospital and the loading capacity of the vehicle, with the goal of the shortest distribution route, an optimization model is established and the model is solved with the help of MATLAB to obtain an optimized distribution route plan. The two schemes are compared and analyzed before and after the optimization. The results show that the optimized scheme can effectively shorten the distribution path and increase the full load rate of the vehicle.

Keywords: logistics distribution, route optimization, vehicles, ant colony optimization algorithm.

1. Introduction

With the development of the logistics and transportation industry, vehicle distribution path optimization has become one of the main contents of research. Due to the diversified distribution needs and distribution goals, scholars at home and abroad have conducted a lot of research on vehicle distribution path optimization. Due to the increase of distribution nodes and the complication of the distribution network, it is easy to reduce the distribution efficiency and waste the transportation resources.

Secomandi used a dynamic programming algorithm to solve the vehicle routing problem with random demand (Secomandi, 2000). Baker et al. combined genetic algorithm and neighborhood search algorithm to propose a hybrid genetic algorithm for vehicle path optimization (Baker, 2003). Lee et al. used dynamic programming theory to effectively solve the vehicle path optimization problem through the shortest path algorithm (Lee, 2006). Ping Chen et al. used the iterative neighborhood descent algorithm to solve the VRP problem that requires periodic distribution, which is a new attempt to solve this type of problem (Ping Chen, 2011). Guojun Yue et al. combined the application of ant colony algorithm in the travel salesman problem and analyzed the basic principles and implementation process of ant colony algorithm (Guojun Yue, 2018).

In this paper, under the conditions of meeting the needs of customers and the loading capacity of the vehicle, the ant colony algorithm is used to optimize the vehicle's path with the shortest total mileage.
2. Model

2.1. Problem Description
In early 2020, novel coronavirus pneumonia (NCP) broke out in Wuhan. After a period of intensive treatment, medical rescue materials were in short supply. A large number of materials were donated to Wuhan across the country. A distribution center received medical rescue materials from all over the country and adopted the way of direct distribution to various hospitals. From the perspective of the distribution center, the distribution work is carried out according to the demand of the hospital, hoping to achieve the purpose of the shortest total distribution path length, thereby effectively reducing the distribution cost.

2.2. Hypothesis
This article simplifies the problem of optimizing the distribution path of medical rescue materials and proposes the following hypotheses:
1. Each hospital accepts distribution 24 hours a day, and there is no requirement on the delivery time of medical rescue materials, as long as it is delivered on the same day;
2. Known geographical locations of distribution center and hospitals;
3. Known the demand of each hospital and the weight limit of each vehicle;
4. The dispatched vehicles of the distribution center depart from the distribution center, deliver the materials to hospitals one by one, and then return to the distribution center;
5. Each hospital has only one vehicle delivery, and the daily delivery times are once;
6. Do not consider the restrictions on vehicle flow and road conditions on the distribution road, that is, the route between each hospital is unobstructed;

2.3. Variable and Parameter Symbol Definitions
M——Total number of customers needing service;
\( i, j \)——Customer set (\( i, j = 0,1,2 \ldots M, \text{and} \ i \neq j \)), When \( i = 0 \) or \( j = 0 \), it means the distribution center;
\( x_{ijk} = \begin{cases} 1, & \text{vehicle k is driving from customer i to customer j;} \\ 0, & \text{otherwise} \end{cases} \ (i, j = 0,1,2 \ldots M) \);
\( y_{ik} = \begin{cases} 1, & \text{the demand of customer i is satisfied by vehicle k;} \\ 0, & \text{otherwise} \end{cases} \ (i = 1,2,3 \ldots M) \);
\( b_k \)——Maximum load of the k-th vehicle;
\( q_i \)——Demand for the i-th customer (\( i=1,2,3\ldots M \));
\( L \)——Objective function, that is, total path length;
\( l_{ij} \)——Distance from customer i to customer j (\( i, j = 0,1,2,3\ldots M \));

2.4. Objective Function
Before optimizing the logistics distribution path, we must first optimize the purpose according to the actual situation and objective conditions of the distribution center. The research objective of this article on the optimization of distribution path is to provide distribution services for multiple hospitals with different needs for medical rescue materials. The distribution center can meet the needs of hospitals by rationally planning the driving route of one or more distribution vehicles. In the condition of meeting the hospital demand and vehicle load, the goal of the shortest total mileage is achieved.

\[
\min L = \sum_i \sum_j \sum_k l_{ij} x_{ijk}
\] (1)
Constrains:
1) In each distribution route, the total demand of each hospital is less than the load limit of the distribution vehicle;
\[ \sum_i q_i x_{ijk} \leq b_k \]  
(2)
2) Meet the demand of each hospital;
\[ \sum_i \sum_j x_{ijk} \leq M \]  
(3)
3) Integer constraints;
\[ x_{ijk} = \{0,1\}, \ i \in M; \forall k \]  
(4)
\[ y_{ik} = \{0,1\}, \ i \in M; \forall k \]  
(5)
4) There is only one vehicle for each hospital;
\[ \sum_k y_{ik} = 1, \ i \in M \]  
(6)
5) The delivery route of the delivery vehicle is a closed loop;
\[ \sum_i x_{ijk} = y_{ik}, \ i \in M; \forall k \]  
(7)
\[ \sum_j x_{ijk} = y_{ik}, \ j \in M; \forall k \]  
(8)

2.5. Model
In summary, according to the analysis of the objective function and the constrains, a mathematical model for the optimization of the distribution path can be obtained, as shown below:

2.6. Algorithm
This article uses the ant colony algorithm, which uses ants to replace the delivery vehicle. When the actual loading capacity of the vehicle exceeds the maximum loading capacity of the vehicle, the delivery vehicle needs to return to the distribution center, which indicates that the transportation is completed; The distribution center continues to serve other customers until all customers are served; In this cycle, when all the ants traversed all the cities, the algorithm ended. The following Table 1 shows the values of each model parameter in the ant colony algorithm:

| Name                        | Value |
|-----------------------------|-------|
| Pheromone volatility factor α | 1     |
| Self-heuristic factor β     | 5     |
| Pheromone volatility coefficient ρ | 0.75  |
| Number of ants m            | 20    |
| The maximum number of iterations int-max | 100   |

3. Case study
Assume that the coordinates of the material distribution center are (50, 50). We need to call vehicles to deliver to 11 hospitals. The location and demand of each hospital are known, as shown in the following Table 2:
Table 2. Location and demand of each hospital.

| Hospital number | 0  | 1  | 2  | 3  |
|-----------------|----|----|----|----|
| Abscissa(km)    | 50 | 60.7 | 15.2 | 35.6 |
| Ordinate(km)    | 50 | 60.7 | 72.3 | 64.7 |
| Demand(t)       | 0  | 0.382 | 1.354 | 0.707 |

| Hospital number | 4  | 5  | 6  | 7  |
|-----------------|----|----|----|----|
| Abscissa(km)    | 22.8 | 8.8 | 93.2 | 37.8 |
| Ordinate(km)    | 43.2 | 24.6 | 47.8 | 35.9 |
| Demand(t)       | 1.824 | 1.432 | 0.132 | 0.302 |

| Hospital number | 8  | 9  | 10 | 11 |
|-----------------|----|----|----|----|
| Abscissa(km)    | 66.7 | 57.9 | 79.8 | 70.6 |
| Ordinate(km)    | 72.5 | 42.4 | 44.3 | 30.5 |
| Demand(t)       | 0.646 | 0.273 | 0.776 | 0.625 |

4. Conclusions
The initially planned path of the distribution center is known, but the total vehicle travel path is long and the vehicle's full load rate is not high, that is, the vehicle utilization rate is low. Using the ant colony algorithm optimization principle, the optimized distribution path network is obtained through MATLAB programming. As shown in Figure 1 and Figure 2:

Figure 1. The fitting results from MATLAB.

Figure 2. Diagram of optimization path.
4.1. Mileage Analysis
The total mileage of different distribution schemes before and after optimization can be obtained by MATLAB programming, as shown in Table 3:

| Number | Delivery route | Total mileage(km) |
|--------|----------------|-------------------|
| 1      | 0-1-8-2-0      | 121.2002          |
| 2      | 0-3-4-7-0      | 80.9271           |
| 3      | 0-6-10-11-9-0  | 101.0174          |
| 4      | 0-5-0          | 96.8008           |
| Total  |                | 399.9455          |

| Number | Delivery route | Total mileage(km) |
|--------|----------------|-------------------|
| 1      | 0-3-4-7-0      | 80.9271           |
| 2      | 0-2-5-0        | 137.8598          |
| 3      | 0-1-8-6-10-11-9-0 | 123.3975 |
| Total  |                | 342.1844          |

As can be seen from the above table, the total mileage of the vehicle is reduced, the total mileage before optimization is 399.9455km, the total mileage after optimization is 342.1844km, a reduction of 57.7611km, which effectively improves the distribution efficiency;

4.2. Load Factor Analysis
One of the important factors to be considered in the optimization of the distribution route is the vehicle load factor, that is, the utilization rate of the vehicle. By increasing the loading capacity of each vehicle to increase vehicle load factor, the transportation cost can be effectively reduced.

\[
L = \frac{\sum q_i}{b_k} \tag{9}
\]

Vehicle load factor before and after optimization can be obtained as follows:

| Number | Delivery route | Total demand(t) | Vehicle load factor(%) |
|--------|----------------|-----------------|-----------------------|
| 1      | 0-1-8-2-0      | 1.735           | 57.8                  |
| 2      | 0-3-4-7-0      | 2.833           | 94.4                  |
| 3      | 0-6-10-11-9-0  | 2.406           | 80.2                  |
| 4      | 0-5-0          | 1.432           | 47.7                  |
| Average|                |                 | 70.025                |

| Number | Delivery route | Total demand(t) | Vehicle load factor(%) |
|--------|----------------|-----------------|-----------------------|
| 1      | 0-3-4-7-0      | 2.833           | 94.4                  |
| 2      | 0-2-5-0        | 2.786           | 92.9                  |
| 3      | 0-1-8-6-10-11-9-0 | 2.834     | 94.5                  |
| Average|                |                 | 93.9                  |

Before the optimization, the distribution center dispatched five vehicles for delivery. Since the maximum loading capacity of each vehicle was 3t, the average load factor before optimization was low,
which was 70.025%; after the optimization, the distribution center only needed to send three vehicles, and the average load factor increased to 93.9%.

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