Transportation route optimization based on heuristic algorithm

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Abstract. With the rapid development of Internet technology, many enterprises are committed to finding the best solution in transportation organization and solving the vehicle distribution routing problem. Firstly, this paper introduces the current situation of transportation organization of Sichuan Yida Feiniu Transportation Company, and analyzes the main problems of the company. Secondly, through the prediction of freight volume, prepare the truck vehicle operation plan and optimize the company's transportation organization and production plan. Finally, the heuristic algorithm is used to establish a mixed integer programming mathematical model to optimize the pooled vehicle distribution path problem and the vehicle distribution path with time window. In terms of centralized vehicle distribution, combined with the actual situation of Sichuan Yida Feiniu Transportation Company, an example is analyzed, the shortest total path is obtained, and the goal of shortest vehicle travel distance is realized. Through the optimization of the company's transportation organization, this paper is of great significance to improve the company's transportation organization to a certain extent.

Keyword: transportation, heuristic algorithm, mixed integer programming.

1. Introduction

As the end consumer is becoming more and more personalized, entity consumers are gradually turning to online consumption. Efficient, customized and terminal market competition gradually enters the supply side competition and supply timeliness competition. Production and circulation enterprises must quickly respond to the personalized needs of the terminal market, timely optimize and upgrade the transportation system, improve the transportation capacity, and form a stable supply chain system. Therefore, the traditional extensive and random transportation organization must carry out the supply side structural reform and optimize the transportation organization. The optimized transportation organization can meet the urgent requirements of manufacturing enterprises, commercial circulation enterprises and the market, and meet the needs of customers for transportation and timeliness of supply.

Dantzig and Ramser [1] first put forward the topic of vehicle routing problem. Vehicle routing and scheduling problems (VRP & VSP) includes two parts. One is the design of vehicle routing, which uses the knowledge of operations research and other disciplines to find the shortest driving path. The other is vehicle scheduling, which adds time constraints during driving. At present, the methods to solve vehicle routing problems are mainly divided into the following categories: (1) heuristic methods (heuristics), VRP with time window (VRPTW) [2]. Vehicle routing problem with time window refers
to adding the constraint of time to the vehicle routing problem and adding the condition of time to the original condition constraint, which is more in line with the actual situation. The saving method proposed by Clarke [3] and Wright is a landmark method in heuristic algorithms at this stage. Although the solving process of heuristic algorithm is not accurate enough, it can not solve the optimal solution. However, heuristic algorithm is widely used in practice, which can better fit the actual situation. The feasible solution proposed by the heuristic algorithm can meet the needs of the actual situation to a great extent. This is why heuristic algorithms can be widely used in practice. Professor Li [4] of Southwest Jiaotong University proposed his new method on the vehicle routing problem with time window, that is, the saving algorithm of VRP with time window. In terms of time window, Professor Li also broadened the solution surface of the problem, and better popularized and applied the heuristic algorithm, which is more in line with the actual needs. (2) Precise optimization method. It mainly uses mathematical linear programming and nonlinear programming to solve the vehicle routing problem. Since it is an exact optimization method, the obtained solution is an exact solution. The exact optimization method obtains the exact solution, but it is not the optimal solution. The accurate solution method mainly uses mathematical methods to solve the results in the ideal state, but it is not suitable for the actual situation. Moreover, the accurate solution method is too pure without too many conditions. The accurate solution method may be more suitable for theoretical research and not suitable for practical application.

2. Model establishment

2.1. Centralized vehicle distribution route optimization

Collection route refers to the route that a transport vehicle transports goods or loads goods to different customers or distribution points in turn according to the transport task. Start from the starting point each time and return after completing the task.

Collective transportation can be divided into three forms:

1. Distribution type: the transport vehicles unload the goods on the transport route according to the transport plan and arrange them in sequence according to the stations on the route;
2. Collection type: transport vehicles load goods on the transport route according to the transport plan, and carry out them in turn according to the arrangement of stations on the route;
3. Distribution collection type: transport vehicles load and unload on the transport route according to the transport plan. Loading and unloading shall be carried out at the same time, and shall be carried out in turn according to the arrangement of stations on the route;

If transport vehicles are transported by converging routes, the turnover of goods is related to the amount of goods loaded and unloaded at each station. If the driving sequence is different, the transportation turnover will be different. Because it is related to the order of transportation, the mathematical model of collective vehicle routing problem is established with the shortest total travel as the goal.

Because the transportation task of Sichuan Yida Feiniu Transportation Company is to transport scattered goods to users, this paper studies the distribution path optimization of collection and distribution vehicles. The heuristic algorithm is used to establish the model and optimize the vehicle distribution path.

With the refinement and deepening of research problems, vehicle routing problem has developed into many different forms. VRP can be divided into many categories according to the focus of solving the problem.

1. According to the characteristics of distribution tasks
   Pure delivery problem: the task of distribution vehicles is to deliver goods at the customer point;
   Pure pick-up problem: the task of distribution vehicles is to collect goods at the customer point;
   Mixed delivery and pick-up problem: the task of distribution vehicles is to send and receive goods at the customer point.

2. According to the customer's time requirements
   No time window problem: customers requiring delivery have no restrictions on delivery time;
Soft time window problem: customers who require delivery have a limited range of delivery time, which is not within the required range. To be punished;

Hard time window problem: the delivery time point of distribution vehicles must be within the scope of customer requirements.

3) According to the actual load of the vehicle
   Full load problem: when a distribution task cannot be completed by one distribution vehicle, the distribution vehicle will carry out full load transportation;
   Non full load problem: the actual load of the distribution vehicle is less than its maximum load.

4) According to the type of distribution models owned by the distribution center
   Single vehicle problem: when transporting goods from the distribution center, the carrying capacity of each vehicle completing the transportation task is the same;
   Multi vehicle type problem: when transporting goods from the distribution center, the carrying capacity of each vehicle completing the transportation task is different;

5) By number of distribution centers
   Single yard problem: complete the distribution tasks of all customers in one distribution center;
   Multi depot problem: the distribution tasks of all customers are carried out in multiple distribution centers.

6) Score according to the number of vehicle route optimization problems achieved
   Single objective decision-making problem: optimize the distribution vehicle route to achieve the unique objective optimization;
   Multi-objective decision-making problem: optimizing the distribution vehicle route requires multiple objective optimal solutions

7) Separate distribution according to the distribution center performing the task and the relationship between the vehicles: the vehicles that complete the distribution task do not return to the original distribution center;
   Closed distribution problem: after completing the distribution task, the vehicle returns to the original distribution center.

Problem description and model establishment:
The assumptions of this problem are as follows: 1. Each vehicle starts from the yard and needs to return to the yard after completing the transportation task. 2. Each task point is served only once by one vehicle. 3. The transportation volume on each transportation route shall not exceed the loading capacity of transportation vehicles.

The vehicle routing problem has many constraints, but the standard logistics distribution vehicle routing problem is the most basic vehicle routing problem. Its most basic condition is the maximum loading capacity of transportation vehicles, while other multi constraint logistics distribution vehicle routing problems are extended from the most basic vehicle routing problem (VRP).

For the vehicle distribution routing problem, the following are the definitions of relevant symbols and variables:

- $k$: Indicates the load limit of the vehicle;
- $q_i$: indicates the customer I's demand for goods;
- $D = \{0, 1, \ldots, n\}$: indicates the starting point, destination and customer collection of the vehicle, where 0 is the starting point (distribution center) of the vehicle and N is the destination (distribution center) of the vehicle;
- $K = \{0, 1, \ldots, m\}$: indicates the collection of vehicles;
- $c_{ij}$: indicates the transportation cost from any customer I to customer J;

Vehicle J travels from customer I to customer J $x_{ijk} = \begin{cases}1 & \\
0 & \end{cases}$
Customer I is serviced by vehicle K

\[ \mathcal{V}_{ik} = \begin{cases} 1 & \text{if vehicle K is selected} \\ 0 & \text{otherwise} \end{cases} \]

Aiming at minimizing the transportation cost, the following logistics distribution vehicle routing problem model is established by using heuristic algorithm:

\[ \text{Min} Z = \sum_i \sum_j \sum_k c_{ijk} x_{ijk} \]  
\[ \sum_j y_{ijk} \leq Q_k, k \in K \]  
\[ \sum_i y_{ijk} = 1, (i = 1, 2, \ldots, n) \]  
\[ \sum_i y_{ijk} = K \]  
\[ \sum_j y_{ijk} = y_{i0k}, \{j = 1, 2, \ldots, n \}, k \in K \]  
\[ \sum_j y_{ijk} = y_{i0k}, \{i = 1, 2, \ldots, n \}, k \in K \] (2)

In the above model, (1) is the objective function and (2) is the limiting condition.

2.2. Optimization

Vehicle distribution route optimization with time window

The selection of distribution route is the basis for completing the transportation task. According to different situations, the vehicle distribution route will also vary, precisely because this will produce a variety of vehicle routing problems. Because of urban congestion, users have requirements for delivery time and try to avoid peak periods in the morning and evening.

This paper mainly studies the logistics distribution path optimization problem with soft time window for single distribution from a single distribution center to multiple customer points in the city. In order to build a vehicle path planning model with time window, the following assumptions are made: (1) There is only one distribution center; (2) The coordinates of the distribution center and all customers are known and unchanged; (3) All vehicles are of the same type, and the vehicle capacity is known and equal; (4) The load capacity of distribution vehicles shall not exceed the load limit; (5) Each transport vehicle only carries out one transport task, and the vehicle must start or return to the distribution center at the specified time; (6) The cargo demand of each customer is known and does not exceed the load limit of distribution vehicles; (7) Each customer can only be served by one vehicle; (8) Every customer must be served; (9) The time window of each customer is known. If the delivery service is carried out outside the time window, it needs to accept the penalty and give the penalty cost. In the process of logistics distribution, enterprises often violate customers' time window constraints for various reasons, which is bound to reduce customers' logistics distribution service experience, increase time cost and produce certain economic losses. Therefore, when logistics enterprises pursue the minimization of total cost, the consideration of time cost is very necessary. Because the time constraint of the vehicle routing problem with soft time window is relatively loose, the distribution vehicles are allowed to carry out distribution services outside the customer's time window, but whether they arrive early or late, they will be punished, and the punishment will be embodied in the form of cost. This paper constructs the cost penalty function, as shown in formula (3):

\[ P(r_i) = \begin{cases}  
  s_1 \max((e_i - r_{ik}), 0), & (r_i \leq e_i) \\
  0, & (r_{ik} \in (e_i, l_i)) \\
  s_2 \max((r_{ik} - l_i), 0), & (r_i \geq l_i) 
\end{cases} \]

(3)

In the above formula, the parameter symbols are defined as follows:
S1: penalty coefficient indicating that the vehicle arrives at the customer point before the customer time window;

S2: refers to the penalty coefficient when the vehicle reaches the customer point after the customer
time window;

R_k: the time when vehicle K reaches customer point I;

E_I: indicates the starting time of the time window when the customer I accepts the distribution service;

L_I: indicates the end time of the time window when the customer I accepts the delivery service.

Equation (3) indicates that if the distribution vehicle arrives at the customer point I before the EI
time, the distribution vehicle needs to wait for the customer to receive the goods, and the waiting cost
S1 (EI R_k) will be incurred; If the vehicle arrives at customer point I after time L_I and the delivery
service is delayed, the cost S2 of delayed delivery will be incurred (R_k L_I); If the vehicle arrives at the
customer point just within the customer time window, there will be no cost.

Aiming at minimizing the total cost of logistics distribution, the variables needed to establish the
mathematical model of vehicle routing optimization with time window (VRPTW) are as follows:

K: Represents a collection of vehicles;

D: Represents the starting point, destination and customer collection of the vehicle, where 0 is the
starting point of the vehicle (distribution center) and N is the destination of the vehicle (distribution
center);

\( t_{ij} \): indicates the time taken for the distribution vehicle to travel from customer point I to customer
point J, I, j = 2,..., n-1;

\( \tau_i \): represents the service time for customer I, I = 1,..., n-1, in particular, the service time of starting
point and ending point=0;

\( C_k \): represents the maximum load capacity of vehicle K, K \( \in \) K;

\( q_i \): represents the demand of customer I, I = 1,..., n-1;

\( L_I \): represents the time window of customer I, I = 1,..., n-1;

\( R_y \): indicates the latest time when the vehicle K must return to the destination, K \( \in \) K;

\( r_{ij} \): indicates the distance from any customer point I to J.

\( \theta \): Represents the time when the vehicle K reaches the customer I point, I = 1,..., n-1, K \( \in \) K; If
the vehicle K do not go to customer I, R_k = 0. In particular, r0k represents the time when vehicle K
starts from the starting point, K \( \in \) K, RNK represents the time when vehicle K returns to the
destination;

\( \omega \): Indicates the number of vehicles used;

\( \eta \): indicates the unit vehicle activation cost.

The objective function is established by minimizing the transportation cost, and the mathematical
model of logistics distribution path optimization with time window is established as follows. The
objective function (4) is:

\[
Min Z = \sum_{i=0}^{n-1} \sum_{j=1}^{n} \theta R_y y_{jk} + \sum_{k \in K} \sum_{i=1}^{n-1} P(\tau_i) + \omega \eta
\]  

(4)

The limiting condition (5) is:
The following is an example to optimize the vehicle distribution route for one of the transportation tasks of Sichuan Yida Feiniu Transportation Company. Now suppose that there is a distribution center (label 0) for 4 users (label 1, 2, 3, 4). See Table 1 for the distance between the distribution center and users.

Table 1. Distance between distribution center and user

|   | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 8 | 11| 10| 7.5 |
| 1 | 8 | 0 | 9 | 4 | 6  |
| 2 | 11| 9 | 0 | 6 | 4  |
| 3 | 10| 4 | 6 | 0 | 4.5|
| 4 | 7.5|6 | 4 | 4.5| 0  |

So \(L_1\) equal to be 36.5, \(L_1\) is 27, \(L_2\) is 30, \(L_3\) is 24.5, \(L_4\) is 22. Then \(L_3\) Table 2 is obtained by listing the calculation results in the bottom row of Table 2.

Table 2. Freight mileage coefficient

|   | \(B_0(K)\) | \(B_1\) | \(B_2\) | \(B_3\) | \(B_4\) |
|---|-----------|---------|---------|---------|---------|
| 0 | 0         | 1       | 2       | 3       | 4       |
| 1 | 0         | 8       | 11      | 10      | 7.5     |
| 2 | 8         | 0       | 9       | 4       | 6       |
| 2 | 11        | 9       | 0       | 6       | 4       |
| 3 | 10        | 4       | 6       | 0       | 4.5     |
| 4 | 7.5       | 6       | 4       | 4.5     | 0       |
| \(L_j\) | 3605 | 27     | 30      | 24.5    | 22      |

(1) Determine the primary cycle circuit. Select three freight points (B0, B2, B1) to form the primary cycle circuit according to the value from large to small, and the freight points \(r = 3\). (2) Confirm to insert the freight point.

Among the remaining freight points, the larger B3 (\(L_3 = 24.5\)) is selected as the freight point to be inserted, i.e. \(x = 3\). Calculate the mileage increment after each road is inserted into the freight point:
\( \Delta_{2,1} = L_{2,3} + L_{3,1} - L_{2,1} = 6 + 4 - 9 = 1 \)
\( \Delta_{1,1} = L_{3,0} + L_{3,0} - L_{4,0} = 4 + 10 - 8 = 6 \)

(3) Determine the insertion position and organize the new circuit. Select the smallest section as the section inserted into the freight point. Since \( \Delta_1 = 1 \) is the minimum value of three road sections, select road section as the insertion position of the point to form the following new circuit:

\[
\begin{align*}
B_0 &\longrightarrow B_2 & B_3 &\longrightarrow B_1 & B_0 \\
\end{align*}
\]

Since the number of freight points in the existing circulation loop is 4, you must return to step (2) and continue to select the next freight point until all freight points enter the circulation loop. The final circulation circuit is as follows:

\[
\begin{align*}
B_0 &\longrightarrow B_4 & B_3 &\longrightarrow B_2 & B_3 &\longrightarrow B_1 & B_0 \\
\end{align*}
\]

According to the detour sequence of the cycle circuit, the total travel of the vehicle is 29.5km.

4. Conclusion

Through an example, it is verified that the total travel of the vehicle is 29.5km, that is, the shortest distance for the vehicle to bypass the total travel between the freight points in the area. In the case analysis of the centralized vehicle distribution path optimization problem, although the vehicle distribution path is optimized, the establishment of the model does not consider the selection of vehicles, load, load of goods and other problems in reality. From the actual situation, the vehicle distribution path optimization needs to be further improved.

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