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Optimization Analysis of Multi-Vehicle Dispatching for JD Logistics Based on the Scanning Method

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Abstract. With the rapid development of living standards and the leap up of national economy, the logistics industry has ushered in a vigorous development, which has played a great guiding role in promoting consumption and driving economic growth. To further expand their business and meet the different needs of customers, more and more enterprises have established many logistics distribution centers and applied a variety of car models to deliver different types of goods. Taking JD Logistics Company in Hubei Wuhan Province as an example, this paper has studied the optimization problem of multi-vehicle routing allocation, and gives corresponding solutions according to the actual situation of JD logistics in China based on scanning method and assignment model. The loading rate has been greatly improved and stabilized from 84.3% to about 95.5% based on the scanning method. The transportation time can reach to the minimum level based on the assignment model.

Key Words. Multi-vehicle; Scanning Method; Assignment Model; JD Logistics.

1. Introduction

With the rapid development of the social and economic system, a single depot and vehicle type can no longer meet the current situation. More types of vehicles and depots are needed to meet the needs of society [1]. Therefore, the establishment of multiple depots and multiple vehicle types has become the mainstream of current development. However, the existing constraints of "multiple vehicle yards" and "multiple vehicle types" limit the development momentum, making the already complex situation even more difficult to solve [2].

Based on the multi-vehicle routing problem of JD logistics, which is one of the biggest logistics companies of China, this study explores how to optimize the logistics distribution route under the constraints of vehicle type, and to improve the efficiency of logistics operation and reduce the cost consumption of logistics. It is a challenge to make reasonable deliveries and optimize the routes of each vehicle especially in the case of limited types of vehicles [3-6]. Considering the distribution needs and respective

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distribution costs in the operation process, the efforts of this research are to analyze the current situation and problems in the distribution process of JD logistics, formulate corresponding distribution optimization plans, optimize distribution routes, reduce respective costs in the distribution process, and provide a certain basis for decision-making. At the same time, a series of reliable mathematical models can also be developed to provide a solution to optimize the logistics distribution route [7-10], to achieve the goal, thus contributing to the realization of the goal of sustainable development.

2. Methods

2.1. Scanning Method

The scanning method is a frequently used iterative optimization method [11]. The basic idea of the scanning method is to select an entry point from the solution set of the problem, search the entry point in a certain way, find the local optimum, and then use this entry point as a new entry point, and keep searching until the overall optimum is found or the predefined termination conditions are met.

For vehicle paths of multiple models, starting from an arbitrary starting point, the optimal path solution is searched continuously according to the regular pattern determined by the algorithm until the overall optimum is obtained and the predefined termination conditions are met.

2.2. Assignment Model

If we subtract the elements in each row (column) of the coefficient matrix, we obtain a new matrix which is the optimal solution obtained by the coefficient matrix, and the result obtained by the original matrix is the same [12]. On this basis, the original coefficient matrix is transformed into a new matrix containing many zero elements while retaining the original optimal solution.

First, we can use *Cij* to represent the work time consumed by driver *j* to complete the task, and introduce the variable *Xij* which indicates that *i* is completed by driver *j*, $j \in \{I,II,III,IV,V\}$, $i \in \{A,B,C,D,E\}$. As shown in equations (1) and (2) below.

$$\sum_{\mathrm{j}} X_{ij} = 1, j \in \{I, II, III, IV, V\} \tag{1}$$

$$\sum_{i} X_{ij} = 1, i \in \{A, B, C, D, E\} \tag{2}$$

At the same time, *Xij* is a *0-1* variable, which means that when it is *1*, driver *j* is assigned to complete the task, and when it is *0*, it is not assigned. In other words, *Xij* is a binary variable. The model (3) and (4) is as follows:

$$\min Z = \sum_{i} \sum_{j} C_{ij} X_{ij} \tag{3}$$

$$\mathrm{X_{ij}} = 0,1 \tag{4}$$

3. Problem Analysis of JD Logistics Vehicle Delivery

In this paper, the vehicle allocation data of JD Logistics Company in May 2024 is selected, as shown in *Table 1* below, where the driving distance is calculated from the odometer when they leave and return to the distribution center, and the driving time is calculated from the time when they leave and return to the warehouse.

Table 1. JD Logistics delivery status within two days

Date	Vehicle	Loading rate	Distance（km）	Driving time（min）
Day 1	R1	91.3%	354	514
	R2	84.5%	362	550
	R3	93.8%	378	567
	R4	94.5%	368	552
	Y1	84.3%	380	569
	Y2	91.7%	383	576
	Y3	90.5%	365	546
	Y4	92.3%	398	598
Day 2	R1	91.2%	349	523
	R2	84.9%	353	528
	R3	95.6%	371	556
	R4	93.4%	356	538
	Y1	85.6%	400	603
	Y2	94.4%	392	588
	Y3	91.3%	383	572
	Y4	90.4%	380	570

The following are the results of the analysis:

1) According to the loading rate of the cargo vehicle

It's clear that there is a big difference in loading rate. The loading rate of vehicles of the same type can differ by about 3% within 2 days, while the loading rate of vehicles of different types can differ by nearly 10%.

As shown in *Table 2* for the loading rate of JD Logistics vehicles.

Table 2. JD Logistics vehicle loading rate status

Date	Item	R vehicle	Y Vehicle
Day 1 distribution task	max loading rate	94.5%	92.3%
	min loading rate	84.5%	84.3%
	average loading rate	91.0%	89.7%
Day 2 distribution task	max loading rate	95.6%	94.4%
	min loading rate	84.9%	85.6%
	average loading rate	90.4%	90.4%

2) In terms of distribution time

Driving times and distances also varied considerably. Most of the working hours exceeded the normal working hours.

The imbalance of working hours and overtime would have a great impact on the

drivers' work enthusiasm, which in turn would have a bad impact on the transport experience.

The specific driving conditions of JD Logistics vehicles are shown in *Table 3*.

Table 3. vehicle driving time (unit: h)

Item		R vehicle	Y vehicle
Day 1	max driving time	567	598
	min driving time	514	546
	average driving time	546	573
Day 2	max driving time	556	603
	min driving time	523	570
	average driving time	536	583

Based on the above data, it's obvious that the main problems in the vehicle distribution of JD Logistics are as follows:

1) Unreasonable distribution path

JD drivers rely on their own experience to choose the delivery order of customers, which requires its drivers to be familiar with the work in this field. With the increasing scale of JD enterprises, the efficiency of path optimization only by experience will become worse and worse, so it is necessary to carry out a reasonable path planning.

2) Low loading rate

Judging by the distribution, the loading rate of JD's vehicles is too low at only 84.09%, and the average loading rate is around 90%. There is still a lot of room for improvement that has not been fully exploited. Based on existing research, a new solution is proposed to solve the huge consumption of transport capacity.

3) Suboptimal travel time and distance

Throughout the day, there are huge variations in delivery time and distance, vehicle driving time and distance between the same type of vehicle. This leads to inconsistent working hours for JD drivers, especially when faced with unexpected situations that require temporary overtime.

4. Case Results

4.1. Scanning Method Results

All pick-up tasks are completed by trucks with a load capacity of 10 tons. There are currently 13 customers in Wuhan China who have pick-up requirements. The amount of goods to be delivered to each customer and the geographical location of each customer are shown in *Table 4*. It is known that the coordinates of JD Logistics in Wuhan are (19.6, 6.1). It is required to arrange reasonable vehicles to make the total distance the shortest.

Table 4. cargo transport information data

Customer	1	2	3	4	5	6	7	8	9	10	11	12	13
Di（t）	2	3	3.1	2.3	1.9	2.9	2.2	1.7	1.7	2.1	1.5	2.5	1.4
Xi	18	17	17.1	17.1	16.6	17	17.5	18.0	18.0	17.5	17.7	17.5	18.3
Yj	4.7	5.1	4.7	4.7	5.8	5.8	5.9	5.5	5.5	4.5	4.5	5.1	5.1

Step 1: Establish and describe the coordinates of each coordinate position.

Label the passenger volume of each customer next to the customer number. The warehouse is the polar coordinate origin, and the horizontal line to the right is the zero angle line. As shown in *Figure 1*.

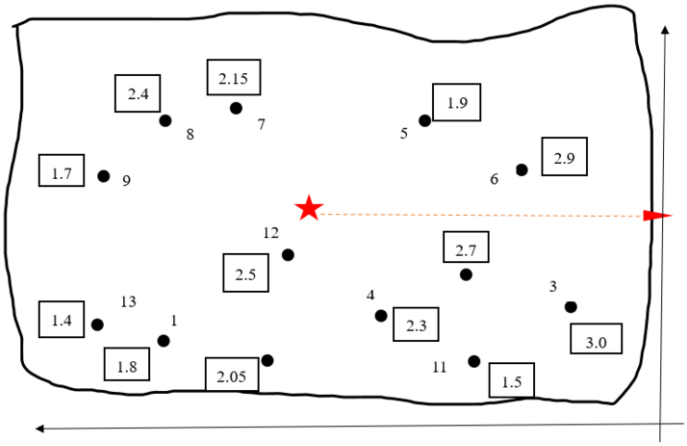

Figure 1. Establish a coordinate system

Step 2: Scan and divide the customer base

Starting from the zero-angle limit of the company's coordinate point, scan clockwise to divide the scanned customers into routes as required, as shown in *Figure 2*. Customer 2 is scanned first, with a cargo weight of 2.7. Then, customers 3, customer 11, customer 4, the total weight of the goods is 9.55. If there is one more customer, it will exceed the 10-ton limit, so customers 2, 3, 11, and 4 are completed by the first vehicle, and route 1 is obtained.

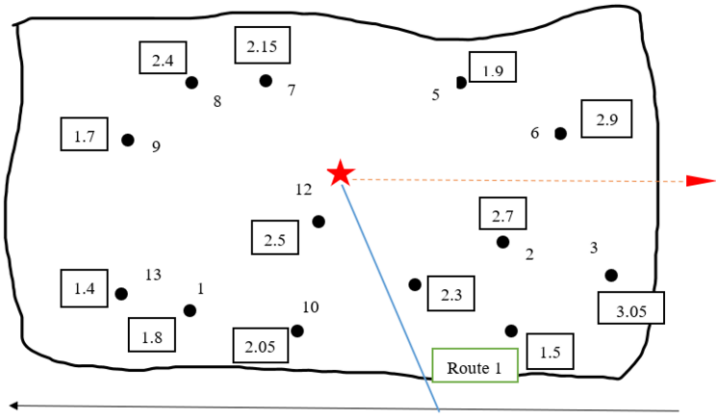

Figure 2. Route 1 from the scan

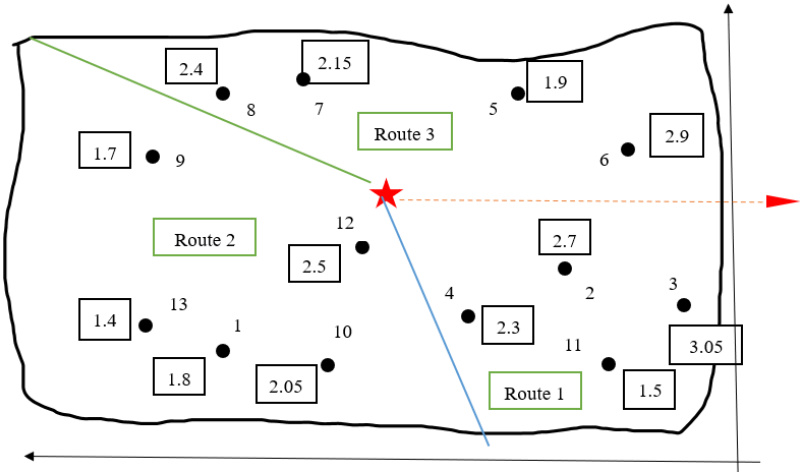

Figure 3. Routes 2 and 3 after continuous scanning

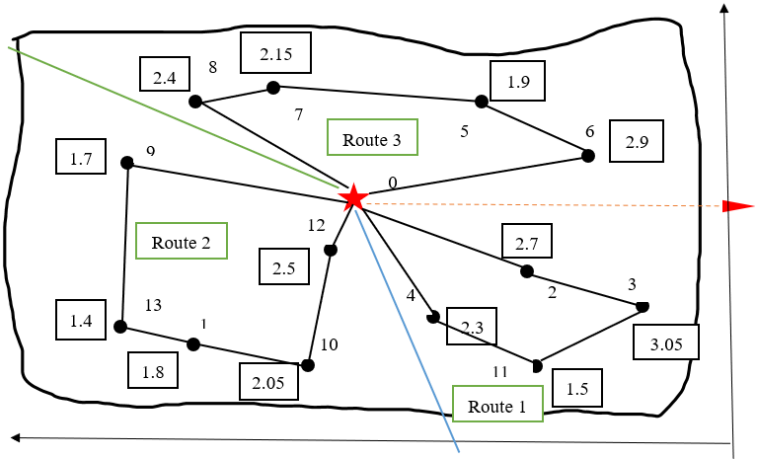

Figure 4. Planned route after the final scan

Continue scanning clockwise in the same way. Customers 12, 10, 1, 13 and 9 are scanned in turn. The total weight of goods for the five customers is 9.45. It is agreed that if one more customer is added, the 10-ton vehicle load limit will be exceeded, so it can be confirmed that Route 2 should be the remaining customers. The total weight of the goods is less than 10, so it can be confirmed that the remaining route is 3. As shown in *Figure 3* above.

Step 3: Determine the optimal route for each vehicle

The previous steps can be used to determine the optimal customer number for each route, so that the total transport distance is the shortest. So, as shown in *Figure 4* above, it can be determined that:

Route 1 passes through the following sequence of customers: 0—2—3—11—4—0 (loading capacity of 9.55 tons)

Route 2 passes through the following sequence of customers: 0—12—10—1—13—9—0 (loading capacity of 9.45 tons)

Route 3: 0—8—7—5—6—0 (load capacity 9.35 tons)

After the above analysis, the loading rate has been greatly improved and stabilized, basically remaining at 93.5% to 95.5%.

4.2. Assignment Model Results

Take route distribution in Wuhan China as an example. The time required for each type of vehicle to deliver to each park is shown in *Table 5* below.

Table 5. Timetable for four vehicle types to JD Logistics Park (unit: h)

Logistics Park	Park 1	Park 2	Park 3	Park 4
Type A（heavy）	6	7	11	2
Type B（medium）	4	5	9	8
Type C（light）	3	1	10	4
Type D（mini）	5	9	8	2

The first step is to transform the coefficient matrix so that there is a *0* element in each row and column.

(1) Subtract the smallest element in the row from each row of the coefficient matrix.

(2) Subtract the resulting coefficient matrix from each column of the coefficient matrix.

The calculation is as follows:

$$C_{ij}=\begin{bmatrix}6&7&11&2\\4&5&9&8\\3&1&10&4\\5&9&8&2\end{bmatrix}\begin{matrix}2\\4\\1\\2\end{matrix}\longrightarrow\begin{bmatrix}4&5&9&0\\0&1&5&4\\2&0&9&3\\3&7&6&0\end{bmatrix}\longrightarrow\begin{bmatrix}4&5&4&0\\5&1&0&4\\4&0&4&3\\0&7&1&0\end{bmatrix}\longrightarrow$$

$$\min$$

$$\begin{bmatrix}4&5&4&\otimes\\\varphi&1&\otimes&4\\2&\otimes&4&3\\3&7&1&\varphi\end{bmatrix}\longrightarrow\begin{bmatrix}4&5&4&\otimes\\\varphi&1&\otimes&4\\2&\otimes&4&3\\3&7&1&\varphi\end{bmatrix}\quad\cdots\cdots\begin{bmatrix}0&0&0&1\\1&0&0&0\\0&1&0&0\\0&0&1&0\end{bmatrix}$$

This means that Type A vehicles (heavy) are designated to go to Park 4, Type B vehicles (medium) to go to Park 1, Type C vehicles (light) to go to Park 2, and Type D vehicles (mini) to go to Park 3. The minimal total time required is 15 hours.

$$\min Z=\sum_i\sum_j C_{ij}\,\mathrm{X_{ij}}=15(h)$$

The total time can be kept to a minimum of 15 hours by assigning tasks as described above.

5. Conclusion

With rapid economic development, people's requirements for logistics and transportation efficiency and satisfaction with logistics service quality are also constantly improving. As an important part of the logistics system, the issue of more reasonable planning of multi-vehicle routes has gradually evolved into a battle between alliances and alliances. This paper conducts an in-depth study of the multi-model vehicle dispatching problem in JD Logistics and proposes a corresponding solution based on this. Firstly, for the

capacity scheduling problem, this project uses a scanning method to determine the precise path of the transport vehicle to ensure the accuracy of the transport and the loading rate. The results show that this method can greatly improve the loading rate and achieve better results in a variety of situations. It is a very practical method. Secondly, this project proposes an algorithm for capacity scheduling based on an assignment model. This algorithm can effectively reduce the capacity allocation time and minimize the total transportation time.

This paper focuses on the optimization of JD logistics and distribution business, and is based on the problem of multi-model vehicle routing. It provides a practical solution for logistics and distribution operations. The field studied in this paper is not only of theoretical importance, but can also be supported and applied in practice to support the sustainable development of logistics companies.

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