Research on Location of Logistics Center based on Graph Theory

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Abstract: As the most important node of logistics activities, the location method of the logistics center must be very important, which is directly related to the operation cost and efficiency of logistics activities in the future. In the location model of the logistics center, the barycenter method is a classical and common method, but it is only applicable to the plane space, which is not feasible in the actual location of the logistics center. In practice, the address of logistics center must be chosen beside the road, so this paper builds the location model of logistics center line based on mathematical graph theory, and finally solves a calculation example to illustrate the feasibility of this method. This method can also solve the location problem of multi-point logistics center line.

1. Introduction

After the combination of Internet technology and commerce, China's e-commerce has developed rapidly, which also promotes the demand for logistics in China. As the most important node of logistics activities, the location method of the logistics center must be very important, which is directly related to the operation cost and efficiency of logistics activities in the future.

At present, there are abundant research results on the location method of the logistics center. From the number of site selection, it can be divided into single site selection and multi-site selection. There is only one number of logistics centers to be established in the single-point location problem, while there are many logistics centers to be established in the multi-point location problem, usually 2-5. From the point of view of location method, it can be divided into the barycenter method, differential method (improved barycenter method) and evaluation model. As a classical location method of logistics center, the barycenter method is based on the plane selection method. That is to say, the selection range of the optimal point is the whole plane, but it is obviously not feasible in practice, because most points on the plane are not feasible solutions, and public places or other companies may occupy these points. More importantly, the points on the plane are not necessarily beside the road. If the logistics center solved by the gravity method is not beside the road, it also needs to build the road to connect the logistics center with the existing road, which increases the construction cost. Another method of locating logistics centers is the evaluation model. Before using this method, several locations have been identified as candidate addresses of logistics centers. Then, according to the purpose of establishing logistics centers, a set of the evaluation system is set up to evaluate and rank the candidate points. Finally, the best candidate points for comprehensive evaluation are selected as the final logistics centers. In this evaluation model, the fuzzy parity method, the analytic hierarchy process and the optimization method in operational research are often used.

In this paper, aiming at the shortcomings of the barycenter method, the scope of the feasible set is limited to the line, that is, the roadside. By using graph theory, an optimization model based on the line is established to find the optimal position on the line (that is, the roadside). In this way, the model can be applied to the actual logistics center location activities, to make the location more scientific and accurate.

At the theoretical level, the online logistics center location method proposed in this paper enriches the method of logistics center location and combines optimization theory with graph theory to establish a method of finding the optimal point in the graph, which has certain reference significance for similar optimization problems with graph theory characteristics.

2. Problem Description and Modeling

2.1 Description of Location Problem on Logistics Center Line

A company needs to develop the market in a certain area. Now it needs to choose a logistics center to serve the customers in this area. Firstly, the company forecasts the turnover of goods between each customer point and logistics center every year, considering that the logistics center and customer point will be transported frequently in the future. In order to reduce the construction cost, the second requirement is that the logistics center must be built beside the existing road.

2.2 Symbolic Description

If the set of customers served by logistics center is N, the location of these customers is abstracted as points in the graph, and the road between customers is abstracted as edges in the graph, where set N* represents the set of adjacent points in the graph. The number of customers is n. The distance between customers in the graph is d_{ij}, where (i, j) ∈ N*. The shortest distance between customers is $d_{ij}*$, of which i, j ∈N. Each customer's demand for goods is m_i, of which i ∈ N. The goal of our solution is to find a point Z at the edge or point of the graph so that the sum of the turnover of goods (transportation distance multiplied by freight volume) from Z to each customer point is minimized.

2.3 Establishment of Location Model for Logistics Center Line

Assuming the objective function, that is, the sum of cargo turnover at each customer point is Q, Q_{ij} represents the cargo turnover when Z points are selected on edge (i, j), and the corresponding distance between Z points and i point is expressed by x_{ij}.

First, we establish the expression of Q_{ij}:

$$Q_{ij} = x_{ij}m_i + \left(d_{ij} - x_{ij}\right)m_j + \sum_{k\in\{N-i,j\}} \min(x_{ij} + d_{ik}^*, \left(d_{ij} - x_{ij}\right) + d_{jk}^*) \tag{1}$$

The first two items in the formula denote the turnover of goods from point Z to point i and point j, and the third item denotes the total turnover of goods from point Z to other customer points except point i and point J.

Formula (1) only considers the feasible solution on a particular edge (i, j), and considers the points on other edges. The objective function can be expressed as follows:

$$\min_{(i,j)\in N^*} Q_{ij}$$

Constraint 1, the target point must be on edge (i, j), the expression is as follows:

$$0 \le x_{ij} \le d_{ij} \quad \forall(i,j) \in N^*$$

Constraint 2, the target point can only be on one edge of the graph; that is, the edge of the target point must belong to only one of the set N*. The expression is as follows:

$$\begin{cases} x_{ij} \le l_{ij}^* M & \forall(i,j) \in N^* \\ \sum_{(i,j)\in N^*} l_{ij} = 1 & \forall(i,j) \in N^* \\ l_{ij} \in \{0,1\} & \forall(i,j) \in N^* \end{cases}$$

To sum up, the objective expression (1) and constraints can be taken into account. The location model of the whole logistics centerline is as follows:

$$\min_{(i,j)\in N^*} Q_{ij} = x_{ij}m_i + \left(d_{ij} - x_{ij}\right)m_j + \sum_{k\in\{N-i,j\}} \min\left(x_{ij} + d_{ik}^*, \left(d_{ij} - x_{ij}\right) + d_{jk}^*\right)$$

$$s.t.\begin{cases} 0 \le x_{ij} \le d_{ij} & \forall(i,j) \in N^* \\ x_{ij} \le l_{ij}^* M & \forall(i,j) \in N^* \\ \sum_{(i,j)\in N^*} l_{ij} = 1 & \forall(i,j) \in N^* \\ l_{ij} \in \{0,1\} & \forall(i,j) \in N^* \end{cases}$$

3. Solution Algorithms

Firstly, the model needs to calculate the shortest distance d_{ij} between each customer point, where i, j ∈ N, which has been studied quite mature in graph theory, can be solved well by Floyd algorithm, and will not be repeated here.

For the comprehensive model of this problem, we can use hierarchical calculation. The first layer can calculate the optimum points on each edge step by step, and the second layer can choose the optimum points on the optimum edge from the optimum points calculated on these edges.

4. Examples Calculation and Result Analysis

For this model, this paper designs an example to illustrate the calculation process of logistics center location based on online. In order to develop the market, a company needs to distribute materials to five customer points in a region. Five customer locations are shown in Fig. 1. The demand of five customer points is known. As shown in Table 1, the distance matrix between five customer points is as shown in Table 2. The company needs to select a point on this graph as the location of the logistics center, to minimize the sum of total cargo turnover.

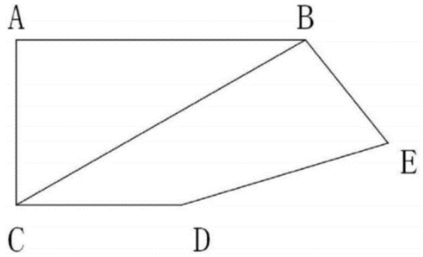

Fig.1 Customer Location Map

Table 1. Customer Requirements Table

Customer Points	A	B	C	D	E
Demand/ton	109	65	89	231	78

Table 2. Distance between Customers

Distance/km	A	B	C	D	E
A	0	35	60	M	M
B	35	0	24	M	54
C	60	24	0	15	M
D	M	M	15	0	76
E	M	54	M	76	0

Firstly, the Floyd algorithm is used to calculate the shortest distance matrix between each customer point, such as Table 3.

Table 3. Minimum distance between customer points

Distance/km	A	B	C	D	E
A	0	35	59	74	89
B	35	0	24	39	54
C	59	24	0	15	78
D	74	39	15	0	76
E	89	54	78	76	0

Finally, according to the above hierarchical algorithm, the optimal freight turnover on each side is calculated, such as table 4.

Table 4. Freight turnover at optimal points on each side

Freight turnover/ton km	A	B	C	D	E
A	0	19172	18112	0	0
B	0	0	17860	0	18112
C	0	0	0	17771	0
D	0	0	0	0	17864
E	0	0	0	0	0

We can see that when the optimum point is on CD, the freight turnover is the smallest, which is 17,771 tons kilometers, so the logistics center is at the optimum point on the edge CD. Then we look at the optimum points on each side of the program, as shown in Table 5.

Table 5. Distances from smaller points when the optimal points are obtained on each side

Distance/km	A	B	C	D	E
A	0	35	60	0	0
B	0	0	24	0	0
C	0	0	0	0	0
D	0	0	0	0	0
E	0	0	0	0	0

It can be seen that the distance between the optimum point and the C point is 0 when the optimum point is chosen on the edge CD, so the logistics center should be built at the C point.

5. Conclusion

In summary, this paper mainly considers that the restrictions of logistics center location must be on-line, establishes a mathematical model, and solves the algorithm and program. Finally, according to a specific example, the solution process of this model is elaborated, and the feasibility of the solution is illustrated.

This model can also be extended. If there are some sections on some lines that cannot be used as alternative points, such as those sections have been occupied, in view of this situation, only need to change the formula (3), the section that cannot be selected can be removed.

The model only considers freight turnover. If other restrictions are added, such as land price, operation cost, environment and other factors, it needs to change the objective function and restriction conditions on the basis of this model, which can be used as the follow-up research content.

In future research, the idea of this method can also be considered to solve the location problem of multi-point logistics centerline.

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