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Location model of railway freight transportation acceptance station considering customer satisfaction

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Abstract: In order to plan the railway freight transport acceptance network rationally and improve the service quality and market share, we build the location model of railway freight acceptance network based on the customer satisfaction and the construction cost. Combined with the classical location theory of logistics facilities, we propose a solution based on the shortest distance ideal point method for multi-target characteristics of the model: Calculating the distance between feasible solution set and single objective ideal solution. Then, in the feasible solution set, we find the closest solution to ideal solution as the optimal solution, and obtain the result by Lingo11.0 software.
Keywords: freight transportation acceptance station, Customer satisfaction, Location model, shortest distance ideal point method.

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1. INTRODUCTION

For a long time, railway freight transportation has always used the mode of transport organization under the planned economy system, various problems such as complicated procedures, long examination and approval cycle, service lag of "door to door". It is difficult to meet the customers' needs of fast and convenient transportation service. Since June 15, 2013, the CHINA RAILWAY (CR) has fully promoted the reform of the freight organization, including the way of freight handling, the transportation of "real freight system". Although these reforms have played a certain role in the development of railway freight transport, new problems, such as uneven distribution of capacity resources, low efficiency of supply organization, still exist. In order to further stimulate the vitality of freight market and improve the efficiency of freight transport, we must optimize the allocation of resources as much as possible in the development of the large-scale construction of railway facilities. The reasonable location and layout of the transportation acceptance station is an important means to optimize the allocation of resources. It also effectively organize the source of goods, save the cost of transportation, and make the transportation acceptance station adapt to the change of the market.

Railway freight transportation acceptance station refers to railway business sites that can provide freight transportation services for customers. The site selection of railway freight transportation acceptance station is subordinate to the site selection of railway stations, such as railway freight transportation station, loading station[1-4], but the location of the freight transportation acceptance

station is relatively small. In this paper, through the analysis of the factors affecting the site selection for acceptance station, the factors involved in the cost and the satisfaction of the customer in the station construction are fully considered, as well as the constraints in the site selection, we construct the location model of the transportation acceptance station.

2. INFLUENCE FACTORS OF FREIGHT TRANSPORTATION ACCEPTANCE STATION

The location of railway freight transportation acceptance station is a complex system engineering which involves technical factors, economic factors and natural factors. Site selection should aim at saving cost, convenient service, strong radiation and improving social benefits. The acceptance station is the inevitable product of the increase of freight transportation. The new acceptance station has formed an interconnected transport mode with railway stations and enterprises[5], as shown in Figure 1.

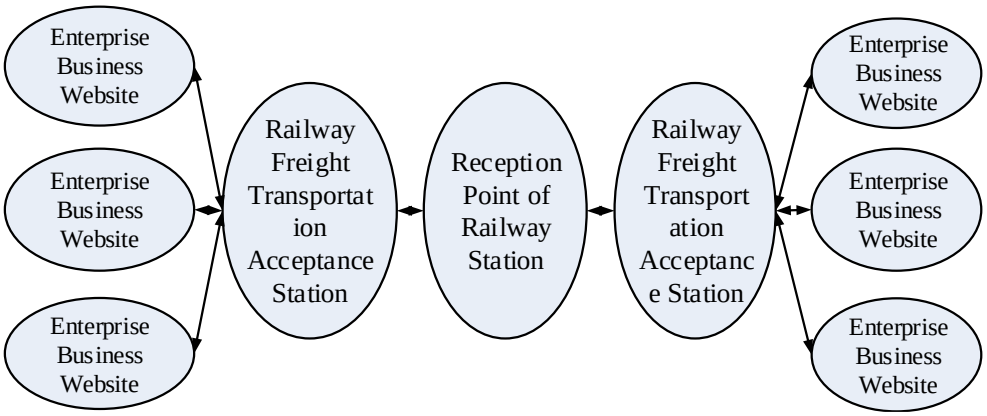

Fig. 1 Business schema chart of railway freight transportation acceptance station

According to the acceptance process and characteristics of railway freight transport business[6], the main factors affecting the location of railway freight transportation acceptance station include:

(1) Freight demand. Freight demand is the most direct influence factor of the acceptance station location and construction. If the demand for goods is low, the establishment of a freight transportation acceptance station location in this area will not only bring benefits to the railway freight department, but on the contrary will produce a large number of construction costs and operating costs. Therefore, when the freight demand increases, we need to expand the capacity of the original station, or add new acceptance station to meet the transport demand. Conversely, we need to shut down or reorganize the acceptance station.

(2) Infrastructure. The infrastructure is also divided into traffic conditions and public facilities: traffic conditions have a direct impact on the cost and efficiency of the delivery of goods. Therefore, the location of the transportation acceptance station must take into account its external traffic status and the factors of future development. The public facilities mainly refer to the urban construction, basic communication and other facilities which are supported by the transport network. In the era of highly developed information technology, information flow and sharing mechanism can effectively reduce transportation costs.

(3) Economic factors. Economic efficiency is another important consideration for railway departments to set up an acceptance station. The way to increase profits is to raise revenues and reduce costs. The income is related to the demand for regional freight and the quality of network service. The cost is made up of construction costs, rents, depreciation of equipment and other fixed costs, as well as the operation costs of manual, storage and transportation. These costs can be greatly reduced through rational site selection.

(4) Transportation competition. As the main competitor of the freight market, there is no obvious difference between road transportation and railway transportation in unit transportation cost. However, due to the advantage of "door to door" transportation, the share of railway transportation is not high in scattered goods and other small and medium-sized freight market. Therefore, we should give full consideration to the layout of highway freight transportation station in the location decision.

(5) Environmental factors. Infrastructure is also divided into natural environment and social environment: natural environment includes geographical conditions and hydrological conditions. The social environment includes the development status of regional agglomerations, the characteristics and aggregation of regional industry, the quantity of labor and the situation of education.

3. LOCATION MODEL

The location problem of railway freight acceptance station is based on the socio-economic development and freight demand, using the theory of management and operations research to optimize the quantity and location of freight acceptance station. The problem has the characteristics of the general location problem [7].

3.1 Model hypothesis

The main function of the railway freight transport network is to provide the customer with the service of the freight business consulting, and the transportation admissibility business., etc. The size of the network and the channels for the import and export of the goods can be adjusted according to the actual business. In order to simplify the construction process of the model and eliminate unnecessary factors, the premise conditions for the problem are as follows:

(1) We assume that the freight demand and demand point in the study area are stable.

(2) The total freight capacity of railway freight stations in the study area is sufficient to accept the carrying capacity.

(3) The cost of land resources, the cost of hardware facilities, the wages of personnel and the cost of water and electricity are fixed in the construction cost of freight outlets, which are not affected by the influence of the market fluctuation.

(4) The satisfaction degree of shipper is only related to the time of cargo handling, without considering the transportation time generated by regional traffic conditions.

3.2 Model construction

For a given railway freight network $G(V,E)$, $V = V_1 \cup V_2$ is a set of vertex, in which $V_1 = \{v_i \mid i = 1,...,n\}$ is a set of demand points for freight transport, and $V_2 = \{v_j \mid j = 1,...,m\}$ is a set of candidate points for

railway transportation acceptance; E is a road network edge set; $P=\{p_i \mid i=1,...,n\}$ is a set of business requirements for freight demand points; $C=\{c_j \mid j=1,...,m\}$ and $S=\{s_j \mid j=1,...,m\}$ are the set of construction costs and service capabilities for the candidate points for railway freight forwarding. $A=\{a_j \mid j=1,...,m\}$ is the cover distance set of candidate points for railway freight handling sites; $T=\{t_{ij} \mid i=1,...,n; j=1,...,m\}$ is the freight handling time matrix of the demand point of freight transport v_i to the acceptance of the transport network v_j; η is the freight handling time acceptance coefficient of the freight demand point, its value is generally greater than 1; x_j is the 0-1 decision variable, $x_j=1$ indicates that the choice candidate v_j is a cargo handling network, $x_j=0$ indicates no choice; y_{ij} is a decision variable table. It represents the ratio of demand point v_i select the proportion of v_j transport services.

The objective of the general logistics facilities site selection is to minimize the cost of construction, and the goal of freight forwarding site selection model should include the minimum construction cost. At the same time, the goal of the transportation acceptance station is to improve the quality of transportation service to attract more sources, so the goal of the model should consider the satisfaction degree of the handling time of the customer.

Based on the above analysis, the location model of freight acceptance station is constructed as Model 1:

$$\max Z_1 = \sum_{i\in V_1} \max_{j\in V_2} F[f(y_{ij})\cdot t_{ij}] \tag{1}$$

$$\min Z_2 = \sum_{i\in V_2} c_j \cdot x_j \tag{2}$$

$$s.t.\begin{cases} \sum_{j\in V_2} y_{ij} = 1, \forall i \in V_1 \\ t_{ij}\cdot f(y_{ij}) \le \eta \cdot \min_{j\in V_2}\{t_{ij}\}\cdot x_j, \forall i \in V_1 \\ \sum_{i\in V_1} y_{ij}\cdot p_i \le s_j \cdot x_j, \forall j \in V_2 \\ \sum_{i\in V_1} y_{ij} \le x_j, \forall j \in V_2 \\ 0 \le y_{ij} \le 1 \\ x_j \in \{0,1\} \end{cases} \tag{3-8}$$

In the model, the formula (1) and (2) are the objective functions, and (1) represents the minimization of the total construction cost of the freight acceptance station. (2) indicates that the customer's total maximum satisfaction, in which $f(x)$ is a step function, when $x=0$ and $f(x)=0$, when $x>0$ and $f(x)=1$, $F(t)$ is a discrete time satisfaction function, usually represented by a piecewise step function.

The formula (3) ~ (8) are constraint conditions, formula (3) indicates that each demand point is sent to the balance of the total amount of service; formula (4) indicates the cover constraint of the freight transport network to the demand point. Only when the handling time of the transport network meets the requirement of the demand point, the demand point is likely to be covered by the carrier; formula (5) indicates that the business of each freight transportation acceptance station can not exceed its business handling capacity; formula (6) indicates that only when the network is opened can the

volume of freight be accepted by each demand point; formula (7) indicates the range of the value of decision variables, and formula (8) shows the range of the value of the decision variables.

Model 1 is a multi-objective nonlinear programming model. The object function Z_1 takes the customer requirements as the center, the freight owner hopes the higher the satisfaction degree of the consignment goods, but it may lead to the larger quantity of the freight acceptance stations and the higher construction cost of the railway department; the object function Z_2 takes the railway infrastructure as the center, the railway infrastructure department expects the lower the construction cost the better, but it may lead to the lower satisfaction degree of the customer. So there is a contradiction between the goals.

This paper adopts the ideal point method to transform the above multi-objective programming model into a single objective programming model. The essential principle of this method is to calculate the distance between the feasible solution set and the ideal solution, and then to find the nearest solution of the ideal distance solution in the feasible solution centralization as the optimal solution. This method is a common means in the decision of multi-objective problems[8].

The specific process of the model is as follows:

Step1: Transform target 1 to minimize expression as shown below.

$$\min Z_3 = \frac{M}{\sum_{i \in V_1} \max_{j \in V_2} F[f(y_{ij}) \cdot t_{ij}]} \tag{9}$$

M is a suitable positive integer, and its size depends on the specific value of the problem studied.

Step2: calculate the minimum value of all the objectives of the original model under all constraints, and use it as a component to form the following vectors.

$$Z = (z_2^{\min}, z_3^{\min}) \tag{10}$$

Step3: according to the definition of ideal point method, the evaluation function is constructed as follows:

$$U(z_2^{\min}, z_3^{\min}) = \sqrt{\sum_{j=1}^{m} (z_j - z_j^{\min})^2} \tag{11}$$

Step4: due to the difference between the two objectives of customer's satisfaction and railway construction cost, the above evaluation function is amended as follows:

$$U'(z_2^{\min}, z_3^{\min}) = \sqrt{\sum_{j=1}^{m} (\frac{z_j - z_j^{\min}}{z_j^{\min}})^2} \tag{12}$$

Step5: the original multi-objective programming model is transformed from the above steps into the following single objective programming model, which can be directly invoked by the commercial software Lingo11.0.

$$Z = \min U'(z_2^{\min}, z_3^{\min}) \tag{13}$$

4. CONCLUSION

In the case of highway, air transportation competition and the continuous decline of freight demand, as the platform of railway freight transport department and customers, the reasonable location of railway freight transportation acceptance station is of great significance to improve the quality of railway service and improve market share. We analyzed the business model of the acceptance station

and the influencing factors. On the basis of the comprehensive consideration of the railway construction cost and the satisfaction of the freight customers, the optimization model for the location of the railway freight transportation acceptance station is built, and the multi objective model based on the ideal point is designed to provide some reference for the railway construction department. However, in the course of the actual location and construction of the acceptance station, the construction cost of the special line, the limitation of the location, the method of management, etc., still need to be further explored and studied.

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