

Research on Location of Terminal Distribution Network Based On Comprehensive Satisfaction

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Abstract—The on urban terminal distribution network is the last link of urban distribution under the e-commerce environment. Under the assumption that the location of the distribution center is known, this paper studies the location problem of the terminal distribution network by considering the two goals of maximum resident satisfaction and maximum enterprise satisfaction. Among them, considering population size as the weight, it is the resident satisfaction function that constructs distance satisfaction. The enterprise satisfaction achieves the lowest cost from the perspective of fixed cost and operation cost of the end network, and then the weighted average method is used to construct the end network location model of comprehensive satisfaction. Finally, the improved immune algorithm is used to solve the model.

1 Introduction

With the popularization of mobile internet and the rapid development of e-commerce, online shopping has increasingly become one of the most popular shopping methods for people and also provides an important impetus for economic development. However, with the expansion of online shopping population and the rapid increase of express delivery volume, express delivery logistics has become an important problem hindering the development of e-commerce. Express logistics companies across the country began to gradually establish and continuously improve their own logistics network, but the capacity of urban express terminal logistics distribution is still relatively weak, and the development of express service level is still serious. The problems of delay, loss and breakage are still obvious. Courier delivery the last kilometer is important to highlight the cause of the problem, such as due to the community for safety reasons, limit the Courier literally in and out of the community, possibly because people work, students and other reasons can't even accept delivery, in this way can lead to a Courier often require multiple service, while the secondary distribution can obviously increase the distribution cost of logistics company, also to a large extent affected the terminal logistics distribution efficiency and resident satisfaction, so the end of the city logistics problem become the biggest sticking point of city logistics development.

In order to alleviate the difficulty of terminal logistics distribution and optimize customers' shopping experience, this paper proposes the terminal distribution method of establishing terminal distribution station

between urban distribution centers and customers. The terminal distribution station refers to the logistics node at the end of the urban distribution link that provides services such as receiving and dispatching goods of enterprises and receiving and mailing goods of customers. At present, there are many researches on the location problem of distribution center, but few on the location of terminal distribution network. There are many similarities between the location problem of the terminal distribution station and logistics distribution center. Gita Taherkhani and Sibel a. Alumur studied the location problem of hub for profit maximization. Considering all possible allocation strategies, a mathematical model is established to determine the location and path selection of hubs to maximize profits [1]. Davoudpour studied the design problem of two-stage supply chain network in deterministic, single-cycle and multi-commodity environment, and designed a model to determine the location and scale of manufacturing plants and distribution warehouses [2]. X. Tang and F. Lehu'ed'e put forward the optimal location problem of regional distribution center in collaborative distribution network by considering the distribution system combining vehicle transportation with scattered transportation [3]. Daoping Wang established a multi-objective integer programming model of distribution center location and vehicle path arrangement by using the two-layer programming method in order to solve the problem of distribution center location and multi-center vehicle path optimization combination decision-making with time window [4].

The above literatures take the lowest freight cost between the distribution center and the upstream supplier and the construction and management cost of the

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distribution center itself as the optimization target and take the time factor into consideration, but they do not consider the impact of uncertainty on the site selection problem. In the actual distribution center site selection problem, there are such factors as demand uncertainty and cost uncertainty. Rongbing Huang and Mozart B.C considered the impact of costs under the influence of different supplier prices on the location of distribution center [5]. Lixing Yang and Xiaoyu Ji studied the location problem of fuzzy environment [6]. In the actual distribution center location problem, there are uncertainty of demand, uncertainty of cost, etc., stochastic planning and fuzzy planning are the main methods to deal with these uncertainties in location planning[7-9].

Considering that terminal distribution network is the distribution that meets the personalized needs of customers such as small batch, multiple batches and high frequency, the previous traditional logistics distribution center location model is no longer able to truly reflect the characteristics of express terminal distribution. Pengjue Yang and other comprehensively considering the two delivery modes of door-to-door delivery and customer self-pick-up, a double-target end-point site selection model based on efficiency and convenience was established and solved by genetic algorithm, but the model assumed that the customer only considered the influence of distance on the model site selection [10].

The location problem of the terminal distribution network and its solution method presented in the above literature only adopt the classical site selection model and genetic algorithm. They only consider to minimize the total cost or resident satisfaction, and do not consider logistics enterprise satisfaction and resident satisfaction. Based on the above analysis, this study has the following contributions: 1) A residents satisfaction model based on the number of population in the community is proposed; 2) Establish a site selection model for end outlets based on the satisfaction of enterprises and residents; 3) a special immune algorithm is proposed to solve the end node location model, and the characteristics of the solution are analyzed.

2 Problem Description And Symbol Description

This paper studies the process of logistics enterprises delivering express to residents in the e-commerce mode: delivering express to the city transfer station; According to the address of residents, the transfer station will send the express to the relevant distribution center; The distribution center sends the goods to the terminal distribution station under its jurisdiction, and residents pick up the goods at the terminal distribution station. The whole process constitutes the urban logistics distribution network. The model is defined as follows: given the location of the distribution center and the location of the customer group, the distribution center will deliver the express to the terminal distribution station, and then the terminal outlet will inform the residents to pick up the goods from the nearest terminal distribution station.

From the perspective of residents, due to the change of consumption concept, residents are more inclined to flexible and free express self-pick-up service and pay attention to the time satisfaction of service. Coverage radius will be an important standard of residents' satisfaction. For the enterprise itself, how to choose the location of the terminal network to maximize its own interests, the cost of building the terminal network is an important standard of enterprise satisfaction.

In order to facilitate the establishment of the model, the following model assumptions are proposed.

1) Considering that only one urban distribution center serves the terminal outlets and its location is determined, its processing capacity is greater than the demand of residents in the coverage area.

2) Residents are divided into sub-customer groups based on geographical location, regardless of the distance between customers within the sub-customer group.

3) Do not consider the competitive relationship between each terminal distribution station (Each sub-customer group only one terminal distribution station for distribution).

4) Sub-customers groups are all covered.

Based on the above assumptions, the site selection model of terminal logistics distribution outlets is established, which is the site selection and distribution model of logistics distribution center.

1) $i = 1, 2, \dots, m$, Represents the number of the alternative terminal distribution station

2) $j = 1, 2, \dots, n$, Represents the number of the sub-customer group

3) x_i That's a 0-1 variable. If the i alternative terminal distribution station is selected, $x_i=1$, otherwise $x_i=0$

4) y_{ij} That's a 0-1 variable. If terminal distribution station i serves sub-customer group j , $y_{ij}=1$, otherwise $y_{ij}=0$

5) d_{ij} Distance from terminal distribution station i to sub-customer group j

6) d_a Maximum distance from terminal distribution station to sub-customer group

7) d_k The ideal distance from the terminal distribution station to the sub-customer group

8) g_i Construction cost of terminal distribution station i

9) c_m Company accept the highest cost

10) Q_j Demand from sub-customers j

11) r Terminal distribution station per capita wage level

3 Analysis of the Location Model

In reality, the problem of location selection of terminal distribution station can be reduced to a location-allocation problem. There are two main factors to consider. The number of terminal distribution station is the first consideration, because the number of terminal distribution station will make the coverage different, resulting in different resident satisfaction. The second is the construction cost of terminal distribution station. The enterprise funds that should be invested increase as the number of terminal distribution station. The multi-objective terminal distribution network location problem model established in this section mainly considers the two goals of enterprise satisfaction and resident satisfaction. The total cost of the enterprise mainly includes the construction cost of the terminal distribution network, the operation cost, and the transportation vehicle transportation cost from the distribution center. The construction cost of the terminal distribution network is a one-time input cost, and corporate satisfaction is based on the perspective of the enterprise to consider the relationship between the total expected cost of the enterprise and the total cost of the enterprise; and the customer satisfaction goal is mainly from the perspective of the customer's pickup time set off.

3.1 Resident Satisfaction

Timeliness is the most important consideration direction for online shoppers to express delivery service quality. Under other equal conditions, residents are more inclined to logistics enterprises with high delivery efficiency. Efficient delivery is often easier to bring good shopping experience to residents and improve their satisfaction. Therefore, when optimizing the express delivery network in the e-commerce environment, time must be taken as the measuring factor of resident satisfaction. According to the change of residents' time satisfaction, the time axis can be divided into three different intervals: absolute satisfaction time, relative satisfaction time and dissatisfaction time. For the delivery method taken by residents, the measurement of time is directly reflected in the distance between residents and terminal distribution station. Therefore, all the sub-customer groups within the service scope of the terminal distribution station should be as close as possible to the terminal distribution network. The goal is to minimize the maximum distance between all the demand points and the corresponding facilities allocated under the condition of covering the demand points in a specific range.

Therefore, the membership function of satisfaction of sub-customer group j to terminal distribution station i is:

$$f(d_{ij}) = \begin{cases} 1 & d_{ij} \leq d_k \\ 1 - \left(\frac{d_{ij} - d_k}{d_a - d_k} \right)^\beta & d_k < d_{ij} < d_a \\ 0 & d_{ij} \geq d_k \end{cases}$$

β is the sensitivity coefficient. When $\beta > 1$, the time-direction satisfaction curve is convex. When $\beta < 1$, the satisfaction curve is concave; When $\beta = 1$, the bump time satisfaction function becomes a straight line. In order to facilitate the solution of the subsequent model and combine with the actual situation in this paper, the linear function model is adopted in this paper, $\beta = 1$.

The weight of sub-customer group is the ratio of the population size of sub-customer group j served by terminal distribution station i to the average population size of terminal distribution station.

$$\omega_j = \frac{z_j}{\sum_{j=1}^n y_{ij} z_j}$$

The satisfaction degree of the sub-customer group to the terminal distribution station.

$$k_i = \sum_{j=1}^n y_{ij} \omega_j f(d_{ij})$$

The average satisfaction of the sub-customers on all the selected terminal distribution station.

$$F_1 = \frac{\sum_{i=1}^m x_i k_i}{\sum_{i=1}^m x_i}$$

3.2 Enterprise Satisfaction

The location of the terminal distribution station should not only consider improving resident satisfaction, but also the satisfaction of the company itself. Logistics enterprises build terminal distribution station to reduce logistics costs. Therefore, controlling the total cost of newly-added terminal distribution station is also the main goal that needs to be considered when deciding on the terminal distribution station location. Under the premise that all sub-customer groups must be served by one end network, the lower the total cost of the end network, the higher the satisfaction of the enterprise. Therefore, understanding the cost structure of the warehouse location is helpful to provide more scientific theoretical support for the final location decision. The main cost components of end site selection are: fixed cost and operating cost of the terminal distribution station.

The fixed cost is the fixed cost of the new terminal distribution station. Operation cost mainly refers to the labor cost incurred by warehouse staff in picking, reviewing, packaging and weighing goods according to the order content.

$$c_r = \sum_{i=1}^n x_i \left[\text{round} \left(\frac{\sum_{j=1}^n Q_j y_{ij}}{k} \right) r \right]$$

Where $\text{round}(x)$ is the rounding function.

The total cost of building terminal distribution station

$$i: c = c_r + \sum_{i=1}^n g_i x_i$$

Then the enterprise satisfaction function is:

$$F_2 = 1 - c / c_m$$

3.3 Model Building

Based on the analysis of resident satisfaction and enterprise satisfaction, the optimization model of e-commerce logistics terminal site selection is constructed.

$$\max F_1 = \frac{\sum_{i=1}^m x_i k_i}{\sum_{i=1}^m x_i} \quad (1)$$

$$\max F_2 = 1 - c / c_m \quad (2)$$

$$\begin{cases} \sum_{j=1}^n y_{ij} = 1 & (3) \end{cases}$$

$$\begin{cases} d_{ij} < d_m & (4) \end{cases}$$

$$\begin{cases} 1 < \sum_{i=1}^m x_i < m & (5) \end{cases}$$

$$\begin{cases} \sum_{j=1}^m Q_j y_{ij} < F_i & (6) \end{cases}$$

$$\begin{cases} x_i > y_{ij} & (7) \end{cases}$$

(3) means that each sub-customer group can only have one terminal distribution station; (4) indicates that each sub-customer group is within the service scope; (5) indicates that the number of selected terminal distribution station is a constraint; (6) indicates that the selected terminal distribution station capacity is greater than the community demand; (7) indicates that only when the alternative terminal distribution station is selected can it serve the sub-customer group.

4 Solution Procedure

Because there are two objective functions, multi-objective optimization problems generally do not have a unique global optimal solution, but there are one or more sets of non-inferior solutions. The optimization problem is transformed into a single-objective optimization problem, and then the general linear or nonlinear programming method is used to solve it. For this model, a linear weighted method can be used to convert the multi-objective function into a single-objective function. The weight coefficient can be determined by the decision maker according to the enterprise's strategy (cost leadership or service level leadership), and the weight describes the different decision consciousness of different decision makers. Reflects the degree to which decision makers attach importance to each goal.

The objective function of establishing the end node location model with the highest comprehensive satisfaction is as follows:

$$\max F = w_1 F_1 + w_2 F_2$$

The w_1 and w_2 are the weights of government satisfaction and average resident satisfaction in the objective function, Here $w_1, w_2 \geq 0, w_1 + w_2 = 1$.

Next, considering that this is the problem of site selection of terminal nodes, when there are many alternative nodes and a large number of residential areas, it is difficult to use traditional planning methods and the complexity of algorithms is relatively high. So we use

the immune algorithm. Immune algorithm is a new intelligent algorithm which is inspired by biological immune system and developed on the basis of immunological theory. It uses the diversity generation and maintenance mechanism of the immune system to maintain the diversity of the population, overcomes the precocity problem of the general optimization process, especially the multi-peak function optimization process, and finally obtains the global optimal solution.

Step 1: analyze the characteristics of the problem and its solution, and use binary coding form to generate the initial antibody group and generate $N + m$ antibodies randomly. The initial antibody of the immune system is generated randomly within the range of feasible solutions.

Step 2: allocate the sub-customer groups according to the selected terminal distribution station (residents will only choose the nearest terminal distribution station).

Step 3: evaluate $N + m$ antibodies:

1) Antigen recognition. The objective function and constraint condition are regarded as antigens.

2) Calculate the affinity between antibody and antigen: $AV = FV$ (where FV target function);

3) Calculate the affinity between antibody and antibody: CV (the affinity between antibody and antibody reflects the similarity between antibodies, using the r-bit continuous method);

4) Calculate the expected reproduction rate of each antibody P (where λ is the diversity evaluation parameter);

Step 4: forming a parent group:

1) they were arranged in descending order according to the expected reproduction rate P , and the first N were taken as parent groups;

2) Elite retention strategy (m antibodies were stored in memory bank);

Step 5: immunize (for parent groups):

1) Select. Select according to pre-set selection probability (roulette);

2) Cross. Carry out single crossing according to the pre-set crossover probability;

3) Variation. Carry out random variation site variation according to the preset mutation probability;

Step 6: N new antibodies were generated in step 5, and m antibodies in the memory bank were added to form new $N + m$ antibodies.

Step 7: judge whether the objective function reaches the optimal value or whether the algorithm runs to the number of iterations. If the above conditions are met, it ends; otherwise, return to step 3.

5 Application Case

In this case, we have investigated the express delivery volume of S Express's 30 sub-customer groups in the main urban area, and there are 10 alternative end points. Map technology was used to measure the geographical coordinates of alternative end-of-line logistics

distribution outlets and various other communities. Residents' expected pick-up distance was [0,500] and acceptable pick-up distance is (500,1100]. The distribution center coordinates is (1120,640). Assume that the per capita workload is 40 pieces and the per capita wage is 2000. Table.1 shows the related coordinates of each alternative Terminal distribution station.

Table 1 Performance and relevance

Terminal distribution station Code	Coordinates
1	(1100,290)
2	(700, 740)
3	(1260, 1280)
4	(1800, 1240)
5	(2100, 580)
6	(2000, 900)
7	(500, 340)
8	(700, 1180)
9	(2300, 800)
10	(1500, 700)

The parameters of the algorithm are: population size 50, memory inventory 10, number of iterations 200, crossover probability 0.5, mutation probability 0.4, and diversity evaluation parameter set to 0.95. Solve the model with MATLAB2017b and get the solution.

Table 2 Results for the model

Solution Model	Optimal Solution (Locations)	Resident Satisfaction	Enterprise Satisfaction
$w_1=0, w_2=1$	{2,4 }	84%	39%
$w_1=0.5, w_2=0.5$	{2,3,4,6 }	95%	34%
$w_1=0.7, w_2=0.3$	{1,6,7,8}	98%	27%
$w_1=1, w_2=0$	{1,2,3,4,5,7,8,9, 10}	99%	0.4%

In the model, the smaller the weight of w_1 , the less attention is paid to the average satisfaction of residents. The greater w_1 , the greater the degree of concern for the average satisfaction of residents. Specifically, if $w_1 = 0, w_2 = 1$, the comprehensive satisfaction model is converted into a corporate satisfaction model, and if $w_1 = 1, w_2 = 0$, the comprehensive satisfaction model is converted into a residents satisfaction model. Therefore, the model's solution exhibits different decision thinking. Here can will make $0.6 < w_1 < 0.7$, which pay more attention to average resident satisfaction with the result that average resident satisfaction becomes larger.

6 Conclusion

The biggest difference between location problem of terminal distribution station and other facility site

selection problems is that it directly faces consumers. In order to solve the planning model of this kind of site selection problem, a kind of terminal distribution station site selection model based on comprehensive satisfaction is established through analysis and model application. A multi-objective site selection model considering enterprise satisfaction and residents' satisfaction is constructed, which is a method to comprehensively consider the interests of logistics enterprises and consumers. The relationship between enterprise satisfaction and residents' average satisfaction is an important factor to solve the problem. It produces different decision mentality, and analyzes the advantages and disadvantages of different solutions under different decision thinking modes. Then we use the model to get a different solution. This method is of great significance to guide the decision-making process. Now only the number of people in each residential area is considered to calculate the residents' satisfaction. The next step to consider is to focus more on resident satisfaction based on the demand forecast for each sub-customer group.

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