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The study on site selection of fresh food logistics distribution center of large supermarket chains

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Abstract: *With the development of fresh food consumption upgrade and the growing consumer demand for high quality fresh food products, traditional fresh food logistics and distribution centers are facing the dual challenges of delivery speed and guaranteeing product freshness. To this end, this paper focuses on the site selection of fresh food logistics center of company Y. First, the fuzzy comprehensive evaluation method is used to screen out suitable alternative logistics nodes and reduce the fixed cost of site selection. Secondly, a mixed integer planning model including freshness index is constructed to reduce the cost of goods loss in the overall distribution process. Finally, the model is solved using Lingo11 to select and confirm the optimal site for the fresh food logistics center.*

Keywords: *Fresh food logistics center site selection, Fuzzy comprehensive evaluation method, Mixed integer programming model*

1. Introduction

According to the data in the China Fresh Food Industry Report 2020, the trading scale of China's fresh food market reached 5 trillion yuan in 2020. In such a huge transaction scale, how to make the quality of fresh products in the logistics of the whole process to maximize the preservation, is the urgent need to think about the enterprise. At present, the logistics management mode of fresh products is relatively single, the logistics facilities are not perfect, and there is a lack of logistics distribution centers, which leads to serious losses of fresh products in the logistics link, resulting in the consequences of low logistics efficiency and high costs. The fresh food logistics and distribution center, as a bridge connecting the production base and end customers, plays a key role in slowing down the corruption process of fresh food in circulation and reducing the cost of the whole circulation process. Whether the layout of fresh food distribution center is scientific and reasonable is related to whether the fresh food products can be delivered to consumers in a timely and safe manner, and whether the enterprise can get the maximum benefit with the optimal cost. Therefore, the site selection problem of fresh food logistics distribution center is of research value.

From the factors of logistics node location, J. Xu et al [1] proposed that the location of logistics center should consider natural environment factors, business environment factors, infrastructure conditions, and other factors. In terms of the methods used to calculate logistics nodes, early site selection methods mainly considered distance and cost with the center of gravity method [2]. As the factors considered for the location of logistics nodes become more and more comprehensive, some scholars have started to study the logistics nodes with multiple objectives. Fang Lei et al [3] used hierarchical analysis (AHP) to derive the siting of emergency facilities. Chunying Wang et al [4] used data envelopment approach (DEA) to improve the credibility of logistics center address evaluation. Zhou Ailian et al [5] used fuzzy integrated evaluation method to improve the robustness of logistics networks. However, the high timeliness of fresh produce poses a greater challenge for fresh logistics site selection. Shanjun Li et al [6] construct a multi-objective vehicle path optimization model with constraints such as vehicle load and time window for the perishability and other characteristics of fresh products. Bing Li et al [7] added penalty costs and cargo damage costs to the costs to build a nonlinear programming model and solved the model using an improved genetic algorithm.

In summary, it is easy to find that the diversity of methods for assigning weights to logistics site evaluation indicators and the application of a single method on the site selection problem limit the multiple optimal considerations for logistics site design. Therefore, this paper adopts a combination of fuzzy comprehensive evaluation method and mixed integer programming model, based on the goal of

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reducing fixed costs and cargo loss costs, to scientifically and effectively design the fresh food logistics distribution center location problem, and ultimately improve the comprehensive efficiency and effectiveness of the fresh food logistics system.

2. The Construction Of Fresh Food Logistics Distribution Center Index Evaluation System

The construction of the evaluation index system is the key to the site selection of the fresh food logistics distribution center and is the first step to be solved. On the basis of adhering to the principles of scientificity, operability, and combination of qualitative and quantitative aspects, and synthesizing the ideas of existing literature, combined with the characteristics of fresh food logistics, the primary indicators of fresh food logistics distribution center site selection evaluation were identified as four aspects, namely: natural environment factors, business environment factors, infrastructure conditions, and service capacity, and further introduced 12 secondary indicators.

(1) Natural environmental factors. Natural environmental factors include meteorological conditions, hydrological conditions, and geological and topographical conditions to consider. For meteorological conditions, this includes consideration of temperature and humidity. For hydrological conditions, including the water level, water volume, flow rate, water quality and flow direction changes and precipitation, evaporation and historical water conditions are considered. For geological terrain conditions, a flat and wide area should be selected as far as possible, and high flooding areas should not be considered.

(2) Business environment factors. The business environment factors mainly reflect the human and material input costs of the cold chain logistics distribution center from four factors: land price, labor cost, local economic development level, and logistics industry policy.

(3) Infrastructure status. The site of the fresh agricultural products logistics node should rely on urban public facilities as much as possible, mainly considering the transportation network, water, electricity, gas supply and waste discharge treatment capacity of the location.

(4) Service Capability: The service capability is evaluated by two indicators, namely, distribution time and distance, to select a suitable cold chain logistics distribution center in the region..

3. Theoretical Model

3.1. Model and steps of fuzzy comprehensive evaluation method

In this paper, the relationship between the factors is studied by using the fuzzy integrated evaluation method. The specific steps are as follows.

(1) Determining evaluation factors and rating levels

Suppose U= $\{u_1, u_2,..., u_m\}$ is the m factors describing the evaluated object, and V= $\{v_1, v_2,..., v_n\}$ is the evaluated object in the state of each factor, i.e., the 7 alternative areas in Jiaxing city mentioned below.

(2) Constructing the evaluation matrix and determining the weights

First, each single factor u_i (i=1,2,...m) is evaluated, and the single factor evaluation set $r_i=(r_{i1}, r_{i2},...r_{im})$ for the i-th factor ui is obtained based on the evaluation set v_j(j=1,2,...n), and a total evaluation matrix is described by obtaining the fuzzy relationship R based on the evaluation object: $R=(r_{ij})_{m*n}=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$. The evaluation is then combined by all factors. In which, the sum of the weights of each level of evaluation factors is 1.

(3) Introduction of fuzzy subsets

$B = (b_1, b_2, \ldots, b_n)$, let $B = A \bullet R$, perform fuzzy operation, compare the operation results to get the ranking of each alternative point, and then analyze it specifically.

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3.2. Mixed 0-1 integer programming model

The mixed integer planning model is to select a certain number of addresses to establish distribution centers among the set of addresses of all alternative points in a given area, so as to establish a series of distribution areas to achieve the minimum total logistics cost of the distribution system formed by the distribution centers established by the selected points and each demand point and supply factory.

The logistics distribution center location problem can be described as follows: there are P supply factories, W alternative distribution centers with limited capacity and C customers, and due to financial constraints, it is proposed to select the right number of distribution centers so as to minimize the total cost.

The objective function is as follows:

$$\mathrm{MinC}=\sum_{k=1}^{m}\sum_{i=1}^{l} C_{ki}W_{ki}+\sum_{i=1}^{l}\sum_{j=1}^{n} H_{ij}X_{ij}+\sum_{i=1}^{l}\sum_{k=1}^{m} G_{i}W_{ki}+\sum_{i=1}^{l} F_{i}Z_{i}+ r\beta*\left(1-(1-\theta)^{\sum_{k=1}^{m}\sum_{i=1}^{l}C_{ki}Z_i+\sum_{i=1}^{l}\sum_{j=1}^{n}H_{ij}Z_i}\right)$$

The constraints are:

$\sum_{i=1}^{l} w_{ki}\le p_k$， k=1,…,m(The amount shipped is not greater than the amount produced)

$\sum_{j=1}^{n} x_{ij}=\sum_{k=1}^{m} w_{ki}$,i=1,…,l(Inbound volume is not equal to outbound volume)

$\sum_{i=1}^{l} x_{ij}\ge d_j$, j=1,…,n(The incoming quantity is not less than the demand)

$\sum_{k=1}^{m} w_{ki}\le a_i z_i$,i=1,…,l(incoming shipments not greater than warehouse capacity)

$\sum_{i=1}^{l} z_i\le z_{max}$(Selection of distribution centers does not exceed the maximum limit number)

The meaning of each of these letters:

m - the number of supply plants; n - the number of customers; l - the number of alternative distribution centers; p_k- - indicates the output of the k-th plant; d_j - indicates the demand of the j-th customer; g_i - indicates the unit management cost of the i-th distribution center; f_i- - indicates the fixed cost of establishing the i-th distribution center; z_i - indicates whether the i-th distribution center is selected, 1 means selected, 0 means not selected; z_{max} - indicates the maximum limit number of distribution centers ; c_{ki} - indicates the transportation unit price from the k-th plant to the i-th distribution center; h_{ij} - indicates the distribution unit price from the i-th distribution center to the j-th customer; w_{ki}- - denotes the transportation volume from the k-th factory to the i-th distribution center; x_{ij} - denotes the transportation volume from the i-th distribution center to the j-th customer; β - the percentage decrease in demand for each percentage point decrease in freshness; r - the production cost of fresh produce; θ - the rate of freshness loss per unit distance.

4. Empirical study

Based on the above analysis of factors and modeling of the location of fresh agricultural products logistics distribution center in Jiaxing, this chapter uses the location of fresh agricultural products logistics distribution center of company Y in Jiaxing as an example to verify the applicability of the proposed model. By analyzing Company Y's demand for distribution center layout, we give a distribution center site selection plan for this company and analyze the results. The data required for this paper were learned from a web survey of Company Y's official website, various news reports in Jiaxing City and interviews with staff at each distribution network node using the field survey method.

4.1. Case Background

The subject of this case study is Company Y, which was established in 2001 and was one of the first distribution companies in mainland China to introduce fresh agricultural products into modern supermarkets. The company is directly connected with local farmers and has a rich and complete range of products. Compared to the traditional farmers' market which is dirty and messy, it has the advantage of a clean and comfortable shopping environment and safer and healthier products. Due to its unique business model, clean shopping environment and low purchase price, it has attracted a large number of people and has been widely recognized by the public. Y currently has nine stores in Jiaxing City. To

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ensure better service to people, we intend to add a new distribution center and design and plan a supporting distribution network system.

4.2. The choice of supply points

The selection of supply points is based on the total production of fresh produce in each district of Jiaxing. According to the Jiaxing City Statistical Yearbook, in 2019, the total output value of fresh produce was 126650.7 million yuan, of which the output value with Jiashan and Tongxiang was larger, accounting for 22% and 20% of the total output value, as shown in Figure 1.

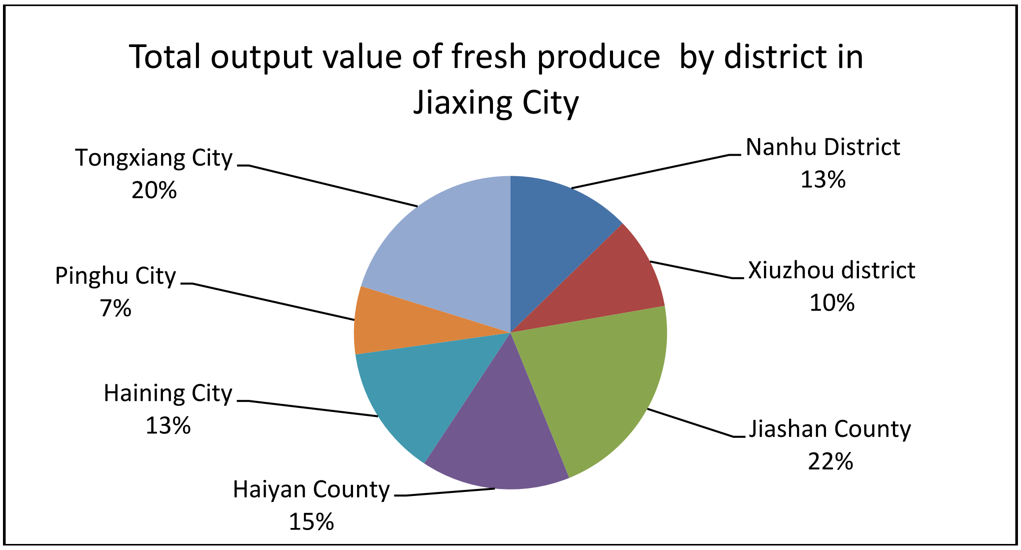

Figure 1: Total output value of fresh produce by district in Jiaxing City

For the convenience of the study, Jiashan and Tongxiang are taken as the main production bases in this paper, and their supply can be seen in Table 1 as learned from the interviews with the enterprises.

Table 1: Production sites and weekly supply Pi (tons)

Production base	Jiashan	Tongxiang
Supply P_i	243	221

4.3. Selection of the place of demand

According to the data on Y's official website, Y has opened nine stores in Jiaxing. Three of them are in Nanhu District, two in Haining City, one in Tongxiang City, one in Jiashan County, one in Pinghu City, and one in Haiyan County. The three stores in Nanhu are C1, C2 and C3, the two stores in Haining are C4 and C5, the one store in Tongxiang is C6, the one store in Jiashan County is C7, the one store in Pinghu is C8 and the one store in Haiyan County is C9. By analyzing the historical demand of the stores, the demand of each store in 2022 is forecasted, and the forecast results are shown in Table 2.

Table 2: Weekly demand of each store of Company Y (tons)

Company Y stores	C1	C2	C3	C4	C5	C6	C7	C8	C9
Demand(d)	36.14	33.42	31.89	39.52	34.37	33.61	38.16	40.20	37.24

4.4. Alternative logistics center site selection

4.4.1. The establishment and calculation of fuzzy comprehensive evaluation model

According to the constructed index system and its weights are determined by experts in the field, as shown in Figure 2.

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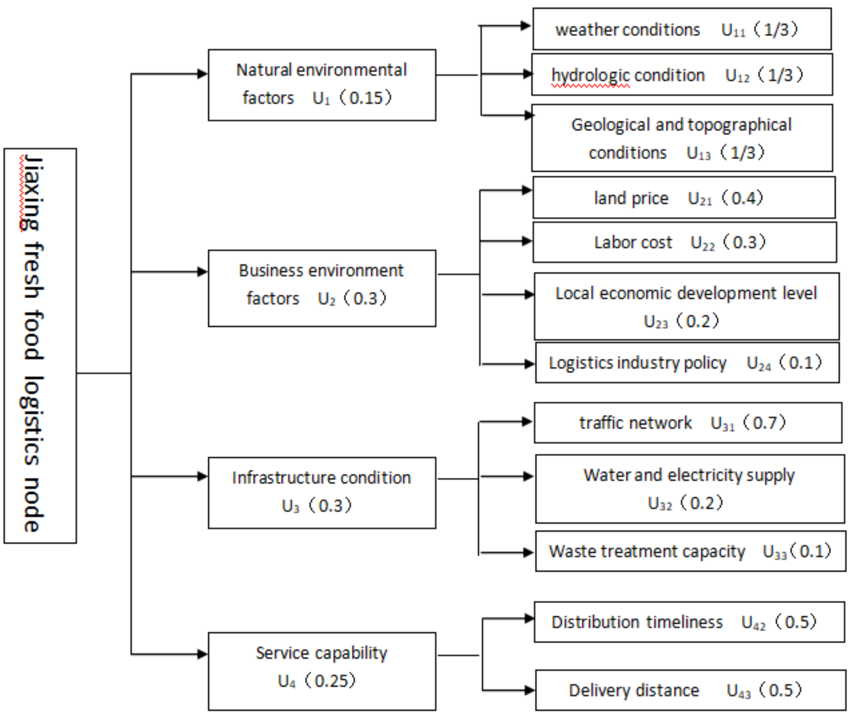

Figure 2: Location of fresh food logistics nodes in Jiaxing

Combined with the comprehensive judgment scoring of industry experts, the fuzzy comprehensive judgment table of each district in Jiaxing was obtained through the collation and statistics of the results, as shown in Table 3.

Table 3: Fuzzy comprehensive evaluation table

influence factor	Nanhu District	Xiuzhou District	Jiashan	Haixian	Haining	Pinghu	Tongxiang
weather conditions	0.91	0.85	0.87	0.88	0.84	0.79	0.81
hydrologic condition	0.93	0.81	0.93	0.87	0.77	0.75	0.74
Geological and topographical conditions	0.91	0.83	0.86	0.80	0.85	0.84	0.86
land price	0.90	0.89	0.85	0.87	0.88	0.86	0.84
Labor cost	0.89	0.84	0.83	0.88	0.91	0.85	0.89
Local economic development level	0.93	0.87	0.83	0.80	0.95	0.85	0.92
Logistics industry policy	0.91	0.85	0.84	0.83	0.87	0.82	0.83
traffic network	0.91	0.85	0.83	0.90	0.85	0.84	0.83
Water and electricity supply	0.83	0.82	0.80	0.79	0.82	0.76	0.83
Waste treatment capacity	0.91	0.93	0.85	0.87	0.86	0.82	0.85
Distribution timeliness	0.75	0.78	0.71	0.70	0.76	0.73	0.72
Delivery distance	0.81	0.79	0.72	0.76	0.73	0.73	0.75

Using the model M(•,+) after calculation, the calculation results are obtained.

The natural environmental factors were judged as follows:

$B_1=A_1 \bullet R_1=(0.927 \quad 0.830 \quad 0.887 \quad 0.850 \quad 0.820 \quad 0.793 \quad 0.803)$

The business environment factors are judged as:

$B_2=A_2 \bullet R_2=(0.904 \quad 0.867 \quad 0.839 \quad 0.855 \quad 0.902 \quad 0.851 \quad 0.870)$

The state of the infrastructure was judged by:

$B_3=A_3 \bullet R_3==(0.894 \quad 0.852 \quad 0.826 \quad 0.875 \quad 0.845 \quad 0.822 \quad 0.832)$

The service capability is judged by:

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B_4=A_4 • R_4=(0.780 0.785 0.715 0.73 0.804 0.730 0.735)

After all single-factor judging is completed, then a high-level comprehensive judging is performed:

Since $U = \{u_1 \quad u_2 \quad u_3 \quad u_4\}$, its weight $A = (0.15 \quad 0.3 \quad 0.3 \quad 0.25)$, the combined judging result is:

B=A • R==(0.8735 0.8365 0.8113 0.8290 0.8481 0.8034 0.8148)

4.4.2. Analysis of results

As can be seen from the final data, the evaluation results of the seven districts of Jiaxing as alternative points are: the first is Nanhu District, the second is Haining City, the third is Xiuzhou District, the fourth is Haiyan County, the fifth is Tongxiang City, the sixth is Jiashan County, and the seventh is Pinghu City. Therefore, this paper selects Nanhu District, Haining County and Xiuzhou District, which are highly evaluated, as the site selection sites of Y supermarket logistics nodes in Jiaxing City. Combining the analysis of factors such as the distribution of production bases and supermarket stores, traffic conditions and land conditions, and the opinions of the management of Company Y, the following four alternative points, named W1, W2, W3 and W4, are selected in this paper, as shown in Figure 3.

Figure 3: Alternative logistics center location

5. Site selection model application and solution

5.1 Relevant data preparation

Previously, we have obtained data on the production sites and the corresponding supply and demand for stores. The next step is to prepare other data related to site selection, including transportation prices, fixed costs of alternative sites, unit management costs and warehouse capacity.

(1) Transportation prices

The transportation price is known by calculating the transportation distance multiplied by the transportation rate, which is known from Baidu map and field survey, and the transportation rate is assigned as 1 (yuan/ton kilometer). The transportation prices for the two transportation stages are shown in Tables 4 and 5.

Table 4: Transportation price of supply factory and alternative distribution center (yuan)

	W_1	W_2	W_3	W_4
P_1	23.2	33.1	27.7	24.2
P_2	30.6	26.5	34.3	26.3

Table 5: Transportation price from the alternative distribution center to the store of company Y (yuan)

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
W_1	9.5	8.9	7.8	12.2	13.1	15	17.9	16.1	18.7
W_2	10.9	11.8	18.6	9.7	5.2	4.8	7.3	7.4	8.9
W_3	12.5	19.4	25.9	10.7	13.1	10.6	8.2	11.8	7.1
W_4	8.3	5.8	13.1	15.6	7.3	14.4	12.8	6.4	8.0

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(2) Other data

The weekly apportioned fixed costs, unit overhead costs and warehouse capacity for the alternative sites are shown in Table 6. Other parameters are shown in Table 7.

Table 6: Weekly allocated fixed costs, unit management costs and warehouse capacity of alternative distribution centers

Alternative distribution center	W1	W2	W3	W4
fixed cost(f)	14000	12500	13000	11700
Unit management cost(g)	45	30	40	35
Warehouse capacity(a)	480	375	420	350

Table 7: Other parameters

Parameter name	Symbol	Parameter value
Production cost of fresh agricultural products per unit weight (yuan / ton)	r	2000
Freshness loss rate	θ	0.005
Percentage of demand decrease for every 1% decrease in freshness	β	1

5.2. Solving results and analysis

After organizing the data, we can see that there are four alternative logistics and distribution center sites, two manufacturing sites supplying them, and nine company stores needing products. The data is substituted into the model and calculated using Lingo11. The specific output of the above model run by LINGO11 is as follows.

Table 8: Output results of alternative points

Variable	Value
W1	0
W2	1
W3	0
W4	0

From Table 8, it can be seen that among the four alternative distribution centers, W2 was selected as the best site location for building the distribution center, and the total cost shared per week for the selected alternative distribution center was $34,532.82. The point is located in Haiyan County, with convenient transportation in the center of Changtai Expressway, Jiasu Expressway and Hangzhou Bay Ring Road Expressway, and close to the production base located in Jiashan, which shortens the transportation distance and eases the corruption of fresh products. Once the location is determined, the supply and distribution plan for fresh produce throughout the distribution process is analyzed. Among them, the Jiashan base supplies 103.55 tons of raw products to alternative point W2 every week, and the Jiashan base supplies 221 tons of raw products to alternative point W2 every week. The supply quantities from the alternative point W2 to the nine stores are shown in Table 7. Since only one alternative point is selected in this model, the demand of all nine stores is distributed by W2.

6. Conclusions

Cost is an important variable that limits the efficiency and effectiveness of logistics distribution centers. In this paper, the two important cost elements of fixed cost based on site selection and loss of goods based on freshness are considered, and a site selection evaluation including natural environment factors, business environment factors, infrastructure condition and service capability is constructed to analyze the distribution of production base and supermarket stores, traffic conditions and land conditions of company Y as the object of analysis, and design the alternative distribution center of the company in a targeted manner to arrive at the optimal solution of fixed cost. By considering the location of Company Y's stores and the characteristics of fresh products, introducing the freshness function and incorporating the cost of goods loss into the cost function, a mixed integer planning model for distribution center location was established to arrive at the solution with the lowest cost of goods loss. In the practical application, the conclusion that Jiaxing Haiyan County is the best site from the perspective of reducing the fixed cost of site selection and cost of goods loss is an important reference value for the iterative

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selection of Company Y's case.

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