Study on Location Selection of Cold Chain Warehouse Distribution Center of Quick Frozen Food Production Enterprise

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Abstract: With the improvement of people's living standards, food quality and safety are increasingly valued, which has further promoted the progress and upgrade of cold chain technology and facilities and equipment, and has made China's cold chain food industry increasingly prosperous. In order to solve the problem of unreasonable site selection of China's cold chain storage, we use the TOPSIS evaluation method to study the site layout of the national warehouse network of quick-frozen food production enterprises. First, the factors affecting the location of the cold chain logistics center were sorted out, and then the TOPSIS evaluation method was used to calculate weights of influencing factors for the construction of cold chain logistics centers in various regions of the country. Finally, the center of gravity method was used to find out the location of the cold chain logistics centers in each region, and the warehouse coordinates nationwide were obtained.

1. Introduction

98% of China's quick-frozen food companies are mainly private and foreign companies. Companies such as Sinian, Sanquan, and Wanzai have new products launched every year with distinctive product features. Henan is a major food industry province, and the output value of the food industry has been ranked second in the country since 2006 [1]. At the same time, Henan is also the origin and production province of quick-frozen food, accounting for more than 60% of the country's market. The company's production plants are located in Zhengzhou, Henan, Kunshan, Sichuan, Chengdu, Guangzhou, Guangdong; it is one of the large-scale professional companies in China. Due to the technical efficiency limitations of the cold chain, refrigerated truck holding time, and pre-cooling and charging of cold storage equipment during the distribution process, it is necessary to arrange cold storages throughout the country to improve its cold chain warehouse distribution network and improve logistics turnover efficiency to guarantee product quality [2].

2. Status Of Food Cold Chain Storage Structure

At present, China's food cold chain has not yet established a complete system that can monitor and guarantee the quality of the entire process of food production, packaging, storage, transportation, and sales. The lack of relevant temperature legislation and poor implementation of food hygiene regulations has caused the food quality of the entire logistics process cannot be effectively controlled and guaranteed. In terms of warehousing in China's food cold chain, there are mainly unreasonable cold storage structures, scattered layouts, and low utilization rates. Inadequate cold storage facilities and cold chain equipment and old equipment are outdated. The existing new equipment has high cost, uneven development and distribution, and cannot provide low temperature protection for the perishable food circulation. Domestic cold chain logistics technology needs to be improved. At present, the effective temperature control facilities are limited, and there is a serious shortage of the management and operators, and an entire cold storage temperature control operation management system is urgently needed to be established [3].

In our country, due to the backwardness of fresh-keeping technology and the lack of full-scale cold chain logistics in the low-temperature storage and refrigerated transportation of perishable products, about 80% -90% of fruits, vegetables, poultry, and aquatic products are transported by ordinary trucks. As a result, 1 million tons of fruit are rotted or devalued every year, and about 400,000 tons of fish are rotted every year. It is estimated that the loss and waste of perishable food in China is as high as 100 million yuan each year.

It is understood that about 20% -25% of fruits and 30% of vegetables in China are rotten during transit transportation and storage, with a total amount of hundreds of millions of tons per year and a value of about 75 billion yuan. China's current total cold storage capacity is more than 8 million cubic meters, many cold storages are limited to frozen storage of meat and fish, and when the production season is low and raw material resources are insufficient, cold storages are often in an idle state of energy consumption.

Due to the different temperature requirements of various foods, the self-operated cold storage cannot meet the temperature requirements of various foods. At present, the capital investment for the construction of cold storage is very large. Now the cost of building a medium-sized cold storage is more than 20 million. Due to the small scale and low level of most enterprises at this stage, the imported equipment does not adapt to national conditions and the utilization rate is not high, resulting in unstable product quality and relatively high product costs.

In contrast, the development of foreign cold chain logistics is relatively mature, and many developed countries in Europe and the United States have formed a complete food cold chain system [4]. In the process of transportation, all refrigerated trucks or refrigerators are used, accompanied by advanced management information technology has established a freezing and refrigerating chain for fresh items including production, processing, storage, transportation, and sales, which has greatly improved the freezing and refrigerated transport rates of fresh items and the integrity rate of transport quality.

3. 3. Research Methods

3.1 S Enterprise Cold Storage Warehouse Network Site Selection Principle

This article considers the rational division of 31 provinces, and establishes a cold chain warehouse for each region, which is responsible for the storage and distribution of each province in the region. This article divides the 31 provinces into regions based on the following three principles: The first factor is the consumption of production capacity of the four factories, which is the principle of production and sales balance. The inter-provincial distance (the actual distance from the provincial capital to the provincial capital) is used as the second element of regional division, that is, the principle of close geographical location. Take the principle of sales balance as the third element of regional division.

3.1.1 Supply and marketing balance principle

The principle of supply and marketing balance refers to the division of 31 provinces into 4 large regions based on the location of 4 factories. These 4 regions are provided by 4 factories, and the production capacity of the 4 factories meets the sales of the 4 large regions. That is, the capacity of the first i plant is M_i, the sales of section i coverage j province are Q_{ij} which should satisfy:

$$\sum_{j=1}^{m} Q_{ij} = M_i \tag{1}$$

If a suitable province combination cannot be found during the division process, so that the supply and marketing relationship is satisfied, the individual provinces in the relevant region can be "divided", that is, the sales volume of a certain province is divided in proportion and supplied by different factories, that is, the two parts of a province belong to two different factories.

This article cuts the three provinces of Jiangsu, Chongqing, and Jiangxi based on the sales box volume, and divides the sales volume that these three provinces need to meet into four factories (capacity), so that the total regional sales can be compared with the supply balance.

3.1.2 The principle of geographical proximity

The principle of close geographical location refers to the actual distance between provincial capitals. The closer the distance, the higher the efficiency and quality of cold chain distribution. That is to further divide small areas into 4 areas, so that the inter-provincial distance in each small area is as close as possible.

3.1.3 Sales balance principle

In order to solve the problem that in the process of regional division, multiple provinces with huge sales (demand) may be divided into the same region, the principle of sales balance should be further adopted, that is, the provinces with larger sales are divided into different regions as much as possible. In order to make the total sales volume of each region more balanced, avoid excessive pressure on warehouses in a certain region.

3.2 Overview of Site Selection Factors

This article considers four factors, including the affected area, regional sales, retail prices of goods, and regional land prices. The reasons are briefly described as follows:

In the affected area, bad weather conditions can easily cause damage to road facilities, hinder logistics and distribution, make it impossible to operate normally, and cause losses. Therefore, it is necessary to avoid the establishment of warehouses in provinces and cities with frequent occurrence of bad weather. Provinces or cities near large sales will save most of the product distribution fees; the retail price index of goods, which reflects the price level in the region, leads to relatively high product sales prices, which increases the income level of product sales; regional land price factors in provinces, and fixed assets has a great impact on sales profits. According to the land price levels of major cities in each province, the average land price level in each province can be obtained, and the optimal location area can be measured to achieve better economic benefits [5].

4. Research Process

4.1 Division Results

In summary, this article divides 31 provinces according to the above principles, and the results are as follows:

Table 1. Regional division and sales table

Owned factory	region	province	annual sales	Factory capacity
Zhengzhou Factory	Area a	Heilongjiang, Jilin, Liaoning	12245000	46580000
	Area b	Hebei, Tianjin, Beijing	12452500	
	Area c	Jiangsu 1, Shandong, Henan	10467500	
	Area d	Shaanxi, Shanxi, Inner Mongolia, Chongqing1	11415000	
Kunshan Factory	Area e	Jiangsu 2, Anhui, Shanghai	9130000	17467500
	Area f	Zhejiang, Fujian, Jiangxi 1	8337500	
Guangzhou factory	Area g	Jiangxi 2, Hubei, Hunan	11570000	23290000
	Area h	Guangdong, Guangxi, Hainan	11720000	
Chengdu factory	Area i	Chongqing 2, Guizhou, Sichuan, Yunnan	15777500	29112500
	Area j	Gansu, Ningxia	5332500	
	Area k	Qinghai, Tibet, Xinjiang	8002500	

4.2 Weight Analysis of Warehouse Location Factors Based On Topsis Comprehensive Evaluation Method and Center Of Gravity Method

4.2.1 Weight calculation of site selection factors

The TOPSIS method is a commonly used method for multi-objective decision analysis of finite projects in systems engineering. It is based on the normalized raw data matrix to find the best and worst schemes of the finite scheme (using the optimal vector and the worst vector), and then calculate the distance between the evaluation object and the optimal solution and the worst solution, and obtain the relative closeness of each evaluation object to the optimal solution as the basis for evaluating the good and bad [6]. Take the area G (Jiangxi 2, Hunan, Hubei) as an example, collect the data of the above factors (statistical yearbooks of various provinces [7]), the results are as follows:

Table 2. Numerical values of the constraints on location selection of area G

region	province	Sales (box)	retail price index	Land price (yuan / m ^{2})	Affected area (thousand hectares)
Area G	Jiangxi 2	3260000	101.3	6050.5	347.512
	Hunan	3957500	101.4	4512.4	990.2
	Hubei	4352500	101.2	5291.2	692.7

Suppose there are n provinces in the area, get n provincial capital locations, and evaluate the matrix as X, where x_{ij} is index evaluation value of the first i provincial capital j, $X=\left(x_{ij}\right)$. The matrix is as follows:

$$X=\left(x_{ij}\right)=\begin{bmatrix} 3260000 & 101.3 & 6050.5 & 347.512 \\ 4352500 & 101.2 & 5291.2 & 692.7 \\ 3957500 & 101.4 & 4512.4 & 990.2 \end{bmatrix} \tag{2}$$

Because the unit of each index value is different, in order to avoid the special index value from affecting the evaluation result, the evaluation value is hereby normalized [8]. That is: $r_{ij}=x_{ij}\Big/\sum_{i=1}^{m}x_{ij}$

The normalized index evaluation matrix as follows:

$$R_{ij}=\begin{bmatrix} 0.282 & 0.333 & 0.382 & 0.172 \\ 0.376 & 0.333 & 0.334 & 0.341 \\ 0.342 & 0.334 & 0.285 & 0.487 \end{bmatrix}$$

This solution uses the concept of information entropy to determine the weight of the evaluation index based on the TOPSIS method. The information entropy value is calculated for each column of the matrix, and the formula is as follows w_j :

$$w_j=-k\sum_{i=1}^{m}\left(r_{ij}\lg r_{ij}\right) \tag{3}$$

Among them, $k=\frac{1}{\ln m}=\frac{1}{\ln 3}=0.91$.

4.2.2 Calculation results of weighting factors

From formula (4), the weights of the four constraint factors of the province's annual sales, retail price index, average land price of major cities in the province, and the area affected by annual natural disasters in the province can be calculated. The weight vector is calculated:
$W=\left(w_1,w_2,w_3,w_4\right)=\left(0.43,0.43,0.43,0.40\right)$

The weighted evaluation value matrix of each indicator is obtained as:

$$V=\left(w_j r_{ij}\right)=\begin{bmatrix}0.122 & 0.145 & 0.165 & 0.069\\ 0.162 & 0.145 & 0.144 & 0.137\\ 0.148 & 0.145 & 0.123 & 0.196\end{bmatrix}$$

The optimal index weighted evaluation value set is obtained from this A^+. That is, the highest sales volume; the highest retail price index; the lowest land price; the "optimal area" with the smallest affected area; and the least ideal index weighted set of evaluation values A^-. That is, the lowest sales volume; the lowest retail price index; the highest land price; and the "worst area" with the largest affected area are:

$$A^+=\left(v_1^+,v_2^+,v_3^+,v_4^+\right)=\left(0.162,0.145,0.123,0.069\right)$$

$$A^-=\left(v_1^-,v_2^-,v_3^-,v_4^-\right)=\left(0.148,0.145,0.144,0.196\right)$$

The Euclidean distance formula is used to calculate the evaluation value of each provincial capital in area G and A^+ with A^- distance, recorded as L_i^+ with L_i^- :

$$L_i^+=\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^+\right)^2},\quad L_i^-=\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^+\right)^2} \tag{4}$$

Table 3 Area G and A^+ with A^- Distance value

	Jiangxi 2	Hubei	Hunan
L_i^+	0.058	0.072	0.128
L_i^-	0.132	0.061	0.021

Based on the above distances, the provincial capitals are sorted and optimized. The formula for calculating the TOPSIS comprehensive evaluation value of each provincial capital is as follows:

$$Y_i=\frac{L_i^-}{L_i^++L_i^-}\ (5)$$

among them, Y_i is closer to 1, it indicates that the province is farther away from the adverse factors such as the lowest sales volume and the highest land price, and it is more suitable to build a warehouse.

$$Y_i=\left(Y_1,Y_2,Y_3\right)=\left(0.693,0.460,0.142\right)$$

According to the above calculation, the TOPSIS evaluation value is normalized to obtain the weight vector of each province in the area G on the problem of warehouse location $H_G=\left(0.535,0.355,0.110\right)$.

5. Research Result

5.1 Gravity Method Site Selection Results

The center of gravity method is a simulation method that considers the demand and resources of each point in the logistics system as the weight of the object, and the center of gravity of the object system is the optimal setting point of the logistics network to determine the location of logistics outlets [10].

The geographical coordinates (capital cities) of the three provinces in area G are as follows:

Table 4 Geographical coordinates of provinces in region G

province	longitude x_i	latitude y_i
Jiangxi 2	114.99	27.12
Hubei	114.21	30.37
Hunan	113	28.11

Assume (X_d, Y_d) is the warehouse coordinates of the area, the weights to be calculated under TOPSIS H_G Substituting into the formula gives:

$$X_d = \frac{\sum H_G(i)x_i}{\sum H_G(i)} = 114.495,\quad Y_d = \frac{\sum H_G(i)y_i}{\sum H_G(i)} = 28.383$$

That is, the coordinates of the warehouse location were obtained by the center of gravity method (114.495, 28.383), and the location of the warehouse was roughly selected in Yichun City, Jiangxi Province.

Extend the above method to other areas. According to the coordinate positioning, we can get the coordinates of the warehouses in various regions across the country and mark them on the map. The results are as follows:

Figure 1 Schematic diagram of warehouse location

(Note: Provinces of the same color represent the same area, and blue dots indicate warehouse locations in the corresponding area)

6. Conclusion

With the improvement of people's living standards, the cold chain technology has also made great progress. Taking 2008 as an example, S enterprises need to supply frozen food produced in 4 factories to 31 provinces and regions in the country. Restrictions on technical efficiency such as holding time, pre-cooling and charging of cold storage equipment, need to arrange cold storage all over the country to improve its cold chain warehouse distribution network, improve logistics turnover efficiency, and ensure product quality. This article uses the factory capacity and sales distribution, through TOPSIS evaluation method selects the factors that affect the location of the warehouse, uses the center of gravity method to determine the number and location of the warehouse, and finally obtains the coordinates of the warehouse in each region across the country.

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