Asian Agricultural Research 2020, 12(10): 7 – 9 DOI: 10.19601/j.cnki.issn1943 – 9903.2020.10.003

Application of Robust Strategies in Location Selection of Logistics Distribution Center for Fresh Agricultural Products

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Abstract In view of the uncertainty in the location selection of logistics distribution center for the fresh agricultural products, the present study established a robust model based on the maximization of principal component score taking budget cost parameters as an example. In the process of model solving, the interval form of the uncertain set was used to clarify the constraint conditions, to transform into a certain 0 – 1 integer linear programming model, so as to solve with the aid of LINGO software. Finally, through studying the location selection of logistics distribution center for fresh agricultural products in the Beijing – Tianjin – Hebei region, it analyzed the application of the robust model and tested the validity of the model.

Key words Fresh agricultural products, Logistics distribution, Center location, Robust model

1 Introduction

Fresh agricultural products are gradually favored by more and more consumers. How to efficiently and quickly bring fresh agricultural products from the market to the hands of consumers has attracted more and more attention. In this situation, it is particularly important to optimize the location of logistics distribution center for fresh agricultural products. On the basis of two-dimensional language information and modified algorithm, Li *et al.* [1] summarized the location of logistics distribution center as a multi-attribute group decision-making problem. M. Yang *et al.* [2] proposed a distributed robust optimization method to deal with the demand uncertainty, refine the bounded disturbance set, and develop a computable safe approximation of the chance constraint. On the basis of the deterministic model, Zhong Weiya *et al.* [3] established an interval two-stage robust optimization model and used robust ideas to solve corresponding problems. Based on theories such as ranking method and gray relational analysis, Song Zhilan *et al.* [4] used fuzzy thinking to obtain the optimal location through the degree of approximation. Xu Xiangjin *et al.* [5] established a location selection model with the goal of the lowest total cost of social fresh agricultural products. In this study, we intended to establish a robust model based on maximizing the principal component score. In view of the uncertainty of the model parameters, using the interval form of the uncertainty set, we transformed the robust model into a certain 0 – 1 integer linear programming problem, which can be solved by the branch and bound method. Finally, we explained the rationality of the model through specific cases.

Received: June 20, 2020 Accepted: September 23, 2020

Supported by Student Innovation and Entrepreneurship Training Program Project of Hebei Agricultural University (2020102).

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2 Robust model for location selection under uncertain information

2.1 Establishment of a general robust model The location selection is based on the maximization of principal component score to determine the logistics distribution center. We first described the establishment of a general robust model based on the principal component score. Suppose i represents the number of alternative locations, $i = 1, 2, \cdots, n$, w, denotes the score of each alternative location in the objective function, p stands for the profit of establishing a logistics distribution center, q represents the capital of investment in the logistics distribution center, and c^0 represents the budget cost of building a logistics distribution center. If the i-th location is selected, then $x_i = 1$, otherwise, $x_i = 0$. However, these parameters are uncertain in actual situation. In this study, we took the budget cost as an example for analysis. The budget cost may be biased due to market environment and other factors, but it will fluctuate around this value. Then, the budget cost of establishing a fresh agricultural product logistics distribution center will belong to an uncertain set U. Therefore, it is of practical significance to study the location selection under uncertain information. Assume that the investment return period for establishing a logistics distribution center is 10 years, if we use $\tilde{c}$ to represent the uncertain cost, that is, the value of any one of the uncertain set may be obtained, then we can establish the following robust model:

$$\begin{cases} \max & \sum_{i=1}^{n} w_i x_i \\ s.t. & \sum_{i=1}^{n} q_i x_i \leqslant n\tilde{c} \\ & \sum_{i=1}^{n} (p_i - q_i) x_i \geqslant \dfrac{n\tilde{c}}{10} \quad \forall \tilde{c} \in U \\ & x_i \in \{0, 1\}, i = 1, 2, \cdots, n \end{cases} \tag{1}$$

In the model, the objective function is the maximum score of each candidate city; the first constraint is that the capital invested to build a factory is not higher than the cost of building a factory; the second constraint is that the return on factory construction should not be less than the return on investment. The robust model itself is a semi-infinite problem, which is difficult to solve directly, so we need to transform it into a linear program, that is, a robust counterpart model.

2.2 Building and solution of robust counterpart model When the disturbance vector Z is an interval, namely $Z = Box = \{\zeta : \zeta \in [-1, 1]\}$, the uncertainty set $U = \{[c_1; c_2] = nc^0 + n\sum \zeta \tilde{c} : \zeta \in Z\}$, for the first constraint in model (1):

$$\sum_{i=1}^{n} q_i x_i \leqslant nc^0 + n\sum \zeta \tilde{c} \qquad \forall (\zeta : \zeta \in [-1, 1])$$

$$\Leftrightarrow \quad \sum_{i=1}^{n} q_i x_i \leqslant \min_{-1\leqslant\zeta\leqslant1} [nc^0 + n\sum \zeta \tilde{c}]$$

$$\Leftrightarrow \quad \sum_{i=1}^{n} q_i x_i \leqslant c_1$$

Then the uncertain problem is transformed into a definite problem processing, similarly, we can transform the second constraint in model (1) into:

$$\sum_{i=1}^{n} (p_i - q_i) x_i \geqslant \max_{-1\leqslant\zeta\leqslant1} [nc^0 + n\sum \zeta \tilde{c}]$$

$$\Leftrightarrow \quad \sum_{i=1}^{n} (p_i - q_i) x_i \geqslant c_2$$

In summary, the robust counterpart model is as follows:

$$\begin{cases} \max & \sum_{i=1}^{n} w_i x_i \\ s.t. & \sum_{i=1}^{n} q_i x_i \leqslant c_1 \\ & \sum_{i=1}^{n} (p_i - q_i) x_i \geqslant c_2 \\ & x_i \in \{0, 1\},\ i = 1, 2, \cdots, n \end{cases} \qquad (2)$$

After model transformation, we transformed a robust model under uncertain information into a 0 – 1 integer linear programming model, and then used LINGO software to solve it.

3 Case study

3.1 Case description According to the GDP of each city in the Beijing – Tianjin – Hebei region in 2019, we selected 6 cities as alternative location. Based on the scores of principal component analysis, we analyzed the relevant indicator data of these 6 cities, established a robust model, and finally selected 3 fresh agricultural product logistics distribution centers, which cover the Beijing – Tianjin – Hebei region well and are favorable for construction of the logistics distribution network system for fresh agricultural products in the Beijing – Tianjin – Hebei region.

By consulting relevant materials, we determined that the main factors influencing the location of the fresh agricultural product logistics distribution center in the Beijing – Tianjin – Hebei region include supply, demand, logistics and environmental conditions. According to the nature of each factor, we further subdivided these factors and obtained a total of 14 secondary indicators. The indicator system for determining the location of the logistics distribution center is shown in Table 1.

Through consulting the *Statistical Yearbooks of Beijing, Tianjin and Hebei Provinces* in 2018, we can get data on relevant indicators. Based on the principal component analysis method, with the aid of SPSS software, we made a quantitative analysis on the main factors affecting the location of the fresh agricultural product logistics distribution center, and determined the indicator weight, to provide a theoretical basis for the final location. The weight of each indicator is shown in Table 2.

Table 1 Indicator system for location selection of logistics distribution center

Overall target	First level indicator	Second level indicator
Location of logistics distribution center (Shijiazhuang, Handan, Tianjin, Cangzhou, Beijing, Tangshan) (A)	Supply conditions (A_1)	Vegetables and edible fungus planting area (B_1)
		Total output value index of agriculture, forestry, animal husbandry and fishery (B_2)
		Meat production (B_3)
		Dairy products production (B_4)
		Total output of aquatic products (B_5)
		Poultry and egg production (B_6)
	Demand conditions (A_2)	Consumer price index (CPI) (B_7)
		Food retail price index (B_8)
	Logistics conditions (A_3)	Expressway mileage (B_9)
		Highway mileage (B_{10})
		Highway freight volume (B_{11})
	Environmental conditions (A_4)	Total COD emissions (B_{12})
		Urban green coverage area (B_{13})
		Sulfur dioxide emissions (B_{14})

Using the weight of each indicator and the expressions about each standardized variable, we obtained the score of each candidate location, as shown in Table 3.

3.2 Calculation results In the robust counterpart model, the investment $q = (2\,500, 1\,500, 3\,000, 2\,000, 5\,000, 2\,000)$ (10^4 yuan), the profit $p = (3\,250, 1\,950, 3\,900, 2\,600, 6\,500, 2\,600)$ (10^4 yuan), the number of established logistics distribution center $n = 3$, assume $\zeta = 0.15$, the budget cost $c_1 = 2\,295$ (10^4 yuan), $c_2 = 3\,105$ (10^4 yuan). Based on principal component analysis, the score of each candidate location in the objective function is $W = (-1.2963, -1.3958, 1.4776, 0.1460, 2.3967, -1.3282)$. According to the operating results of the LINGO software, $x_1 = 0$, $x_2 = 1$, $x_3 = 1$, $x_4 = 0$, $x_5 = 0$, $x_6 = 1$, indicating that the three fresh agricultural product logistics distribution centers are located in Handan, Tianjin, and Tangshan, as shown in Fig. 1.

Table 2 Results of indicator weight

First level indicator	Weight	Second level indicator	Weight
Supply conditions (A_1)	-0.582 1	Vegetables and edible fungus planting area (B_1)	0.493 1
		Total output value index of agriculture, forestry, animal husbandry and fishery (B_2)	0.477 3
		Meat production (B_3)	0.548 6
		Dairy products production (B_4)	0.128 5
		Total output of aquatic products (B_5)	0.004 5
		Poultry and egg production (B_6)	0.459 7
Demand conditions (A_2)	0.162 8	Consumer price index (CPI) (B_7)	0.706 7
		Food retail price index (B_8)	0.706 7
Logistics conditions (A_3)	0.563 7	Expressway mileage (B_9)	0.607 7
		Highway mileage (B_{10})	0.630 8
		Highway freight volume (B_{11})	-0.482 8
Environmental conditions (A_4)	0.562 5	Total COD emissions (B_{12})	0.602 8
		Urban green coverage area (B_{13})	0.572 0
		Sulfur dioxide emissions (B_{14})	-0.556 9

Table 3 Score of each candidate location

Candidate location	Score
Shijiazhuang	-1.296 3
Handan	-1.395 8
Tianjin	1.477 6
Cangzhou	0.146 0
Beijing	2.396 7
Tangshan	-1.328 2

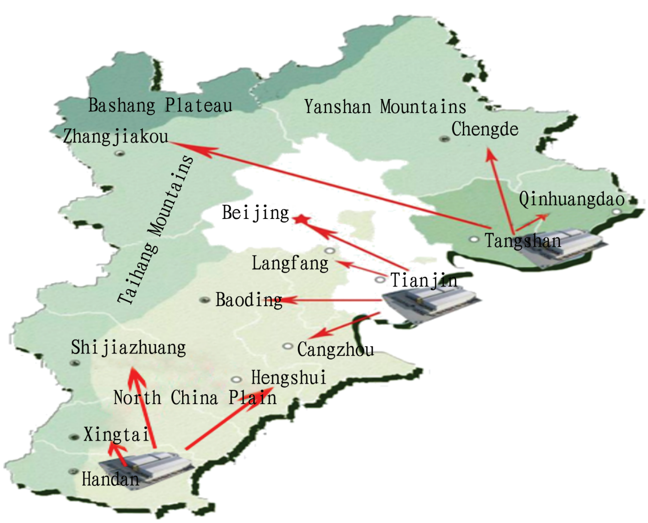

Fig. 1 Distribution of location of logistics distribution center for fresh agricultural products in Beijing – Tianjin – Hebei region

4 Conclusions

Uncertainty is common in real life, so the robust model of location problem under uncertain information has a wide range of applications. In this study, through extending the budget cost parameter from a value to a possible value in an interval, we transformed the robust model is transformed into a definite 0 – 1 integer linear programming problem for solving. In view of the changes in the market environment and other factors, the model we established is relatively realistic.

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