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Study on Site Selection of Cold Chain Logistics in Northwest Territories

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Abstract. In this research, we mainly studied the Site selection problem of cold chain logistics in northwest of China. In the first place, we counted the demands of cold chain products in northwest territories, and then classified it into the Site selection problem in five provinces in northwest territories(Xinjiang, Qinghai, Gansu, Ningxia, Shanxi); Next, we used the Center of gravity Method to select initial location; Finally, we established the location of distribution by using Analytic Hierarchy Process (AHP)and fuzzy comprehensive evaluation method .Comparing with the traditional method, this method not only considered the cost of transportation and distance, but also deliberated the physical condition, social environment and economics condition which associated with Site selection problem .

INTRODUCTION

The production of frozen and cold-storage food is increased by about 10% each year in China in recent years. Local governments and enterprises begin to cultivate and develop cold chain logistics as the market 'Blue Ocean' consciously. Business opportunities are emerging gradually. However, the loss up to one hundred billion Yuan is caused each year in China because of inadequate cold chain logistics infrastructure. The problem of weak cold chain logistics infrastructure is more prominent in China Northwest Territories due to differences in resource endowment and geography. The regional logistics are developed, and rapid development of the logistics industry is promoted in order to allow governments and enterprises to better perfect logistics infrastructure construction in Northwest Territories. Meanwhile, the problem of irrational existing distribution center site selection in Northwest Territories is corrected, thereby providing better reference for logistics enterprises to construct distribution centers in the Northwest Territories. In the paper, a mathematical model is constructed on the basis of the shortest transportation distance, and the site selection of cold chain logistics in Northwest Territories is studied. Therefore, the paper has important theoretical significance for developing research on distribution center site selection problem in Northwest Territories. In addition, the paper also has important guidance significance for resources utilization and regional logistics development of cold chain logistics in Northwest Territories, development demand of infrastructure due to expansion of cold chain product demands, etc.

DOMESTIC AND FOREIGN RESEARCH STATUS

Foreign Research Status

Site selection problem was proposed by Weber for the first time in 1909. He mainly solved the problem of determining the site of a warehouse at that time, thereby the transportation distance between the warehouse and all clients can be the shortest. Foreign research on distribution center site selection has lasted for one hundred years with considerable achievements in theory and practice. Jiaqin Yang and Huei Lee put forward facility site selection and migration of existing facilities through utilizing AHP methods in 1997. Main principles of site selection decision-making by utilizing AHP methods and necessary conditions of utilizing AHP methods were given in

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research. Yiğit KAZANÇOĞLU and Erhan ADA summarized site selection as follows in 2009: factory site selection with discovery of comprehensive investment plans; they combined the linear integer programming model with AHP compared with the site selection model with only consideration of the minimum cost, which were applied in factory and distribution center site selection. Meysam Mr Mousavi combined multi-criteria decision model, AHP and structure evaluation method to ensure the best use of the available information in 2013, thereby ensuring scientific and rigorous site selection. Hanine Mohamed combined multi-criteria decision with AHP to study selection of landfill sites in 2016, thereby providing new solution for landfill site selection.

Domestic Research Status

Domestic research on distribution center site selection in Northwest Territories is more deficient at present. However, many scholars studied distribution center site selection by the centre-of-gravity method and site selection by fuzzy analytic hierarchy process deeply. Yang Maosheng and Li Xia improved the disadvantages of the centre-of-gravity method in 2007. Improved centre-of-gravity method was proposed under the precondition of considering distribution center construction costs and variable costs of operation management, thereby overcoming previous limitation of the centre-of-gravity method. Yu Hong conducted related research on distribution center site selection on the basis of supply chains in 2007. Centre-of-gravity method and analytic hierarchy process were combined from the perspective of supply chains for distribution center site selection, and Matlab program was formulated for solution. Wang Jiaju deeply discussed the application of centre-of-gravity method in the aspect of distribution center site selection in 2008. Advantages, disadvantages and applicable scopes of the centre-of-gravity method were analyzed. Dong Yanping combined analytic hierarchy process with the fuzzy evaluation method in 2010 for studying logistics distribution center site selection, and gave corresponding distribution center evaluation indicator systems, thereby greatly improving the decision-making efficiency. Song Yuping and Wang Zhongwei applied analytic hierarchy process for studying site selection of agricultural product logistics parks in 2012. The paper has higher reference value for site selection of agricultural product logistics parks.

ANALYSIS ON LOGISTICS STATUS IN NORTHWEST TERRITORIES

The logistics quantity and transportation line length show a trend of steady growth in five northwestern provinces. Statistical yearbook data of National Bureau of Statistics shows that total freight volume was 1.57012 billion tons in Shanxi; total freight volume was 572.4 million tons in Gansu; total freight volume was 146.38 million tons in Qinghai; total freight volume was 413.08 million tons in Ningxia Hui Autonomous Region; total freight volume was 721.68 million tons in Xinjiang Uygur Autonomous Region in 2014. Transportation line construction: railway operation length and highway transportation length were respectively 4524.1 km and 167145 km in Shanxi; railway operation length and highway transportation length were respectively 3403.4 km and 138084 km in Gansu; railway operation length and highway transportation length were respectively 2124.6 km and 72703 km in Qinghai, railway operation length and highway transportation length were respectively 1289.5 km and 31276 km in Ningxia, railway operation length and highway transportation length were respectively 5462.8 km and 175468 km in Xinjiang. Growth of logistics quantity and transportation line length shows that logistics business demand is increased gradually in Northwest Territories. Meanwhile, supporting transportation facilities are also perfected gradually. Beneficial infrastructure conditions are provided for developing cold chain logistics in Northwest Territories.

2014 GDP proportion condition in Northwest Territories collected by National Bureau of Statistics is combined for analysis. The economic status in different provinces in Northwest Territories is analyzed: GDP was the highest in Shaanxi, namely 1.768994 trillion Yuan. GDP was the lowest in Qinghai, namely 230.332 billion Yuan. GDP of other provinces was ranked from top to bottom as follows: Xinjiang 927.346 billion Yuan, Gansu 683.682 billion Yuan and Ningxia 275.21 billion Yuan. GDP of different provinces in Northwest Territories was analyzed. There was more prominent gap of economic development among different provinces mainly because of geographical location, policy support effort, people's consumption level, etc. However, economic development is gradually accelerated in five provinces in Northwest Territories with the proposal of national 'One Belt One Road' development plan and unique geographical advantages of five provinces of Northwest Territories, which are located in 'One Belt One Road' hinterland. It also has beneficial conditions for developing cold chain logistics in five provinces of Northwest Territories.

PROBLEM AND MODEL ESTABLISHMENT

A mathematics model is set up through designing the centre-of-gravity method model of the discrete point site selection during the study of distribution center site selection in Northwest Territories. Site selection in Northwest Territories problem primarily belongs to single distribution center site selection, the centre-of-gravity method is applied for calculating the distribution center coordinates. It is necessary to assume as follows:

(1) The cost difference caused by different geographical positions of distribution centers is not considered, such as land use fee, construction fee, labor cost, inventory cost, etc.;

(2) Changes of benefits and costs possibly caused by enterprise operation are not considered, thereby ensuring that the decision-making environment is relatively static;

(3) The distribution center coordinates are directly proportional to the linear distance between the distribution center and the demand points only, and urban traffic conditions are not considered.

Calculation formula: $$\overline{X} = \sum_{i=1}^{n} h_i w_i X_i / \sum_{i=1}^{n} h_i w_i \quad (1)$$

$$\overline{Y} = \sum_{i=1}^{n} h_i w_i Y_i / \sum_{i=1}^{n} h_i w_i \quad (2)$$

Symbol description: h_i — distance coefficient;

w_i — demand weight (demand of destinations) ;

X_i —Abscissa of demand destinations;

Y_i —Ordinate of demand destinations;

Formula (1) represents the abscissa of to-be-determined center of gravity; formula (2) represents the ordinate of the to-be-determined center of gravity.

In the paper, the centre-of-gravity method of discrete point site selection is mainly used; the obtained optimal solution is different from the actual best site selection position of the distribution center due to a few factors of the centre-of-gravity method, such as only consideration of distance, transportation cost, etc. We firstly utilize the centre-of-gravity method to obtain one ideal position as a result. Then, the point is regarded as the center of the circle, and R is regarded as the radius for determining M initial candidate sites. In addition, the distance coefficient h_i is introduced for complying with practical condition conveniently since linear distance cannot be used directly for the distance between the distribution center and all demand points.

DATA COLLECTION AND NUMERICAL CALCULATION

Data Collection

Cities with better logistics industry and economic development in five provinces of Northwest Territories are selected. The demand information thereof is collected, and the traffic network status of all cities is analyzed. Meanwhile, the longitude and latitude of all cities are determined. They are converted into plane coordinates. Finally, distance coefficients and corresponding coordinates of all cities are determined. Related information tables of Shanxi are shown from Table 1.According to the method described above, we also get the data of the related measures in Gansu, Qinhai, Ningxia and Xinjiang.

TABLE 1. Demand, city distance coefficient and city coordinate of Shanxi

City	Demand (ten thousand t)	City distance coefficient	Abscissa	Ordinate
Xi'an	50118.82	1.6	3.81	0.03
Yulin	11916.52	1.4	4.27	0.18
Xianyang	11188.00	1.5	3.84	0.06
Baoji	6578.00	1.2	3.85	-0.12
Weinan	15440.67	1.5	3.87	0.12
Yan'an	6187.00	1.3	4.10	0.12

Numerical Calculation

Demand data, city distance coefficient, abscissa and ordinate of different provinces are brought into the model for solution, thereby obtaining Barycentric coordinates of different provinces, and they are converted into longitude and latitudes, and the results are shown in table 2.

Table 2. Barycentric coordinates and longitude and latitude in different provinces

Province	Abscissa	Ordinate	Corresponding longitude and latitude
Shaanxi	3.88996967	0.06031207	108.56E; 34.95N
Gansu	4.18392078	0.26444544	103.39E; 36.48N
Qinghai	3.69309059	1.38419084	102.19E; 36.97N
Ningxia	4.24224247	0.60000417	106.24E; 38.68N
Xinjiang	4.7418878	1.19927662	87.25E; 42.74N

Barycentric coordinates of different provinces are regarded as the center of a circle, 250km is regarded as the radius for selecting different regions in the scope as candidate positions of different provinces. The results are shown as follows: Shaanxi: Xi'an, Xianyang, Weinan; Gansu: Lanzhou, Baiyin; Qinghai: Xining, Haidong; Ningxia Hui Autonomous Region: Ningxia: Yinchuan, Shizuishan, Wuzhong, Zhongwei; Xinjiang: Urumqi, Korla.

DETERMINATION OF FINAL POSITIONS BY ANALYTIC HIERARCHY PROCESS AND FUZZY COMPREHENSIVE EVALUATION METHOD

Determination of Candidate Site Screening Indicators

Evaluation indicators of the distribution center are divided into the three aspects of economy, society and environment. Then, the indicators are further divided in details, including ten factors of social fixed assets investment, support efforts, traffic convenience, freight volume, etc. A hierarchy model is established according to the ten above factors as shown in Figure 1.

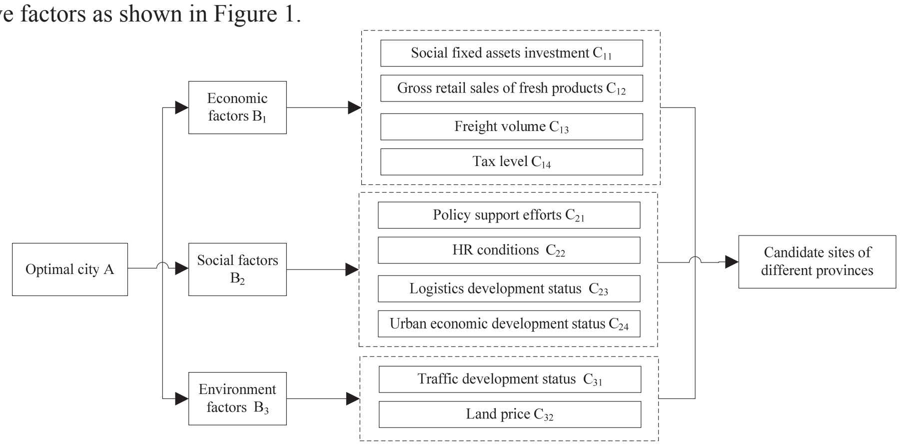

FIGURE 1. Hierarchical structure model

Establishment of Pair-Wise Comparison Matrixes at All Levels

Pair-wise comparison matrixes of criterion layer 1 to destination layer and criterion layer 2 to criterion layer 1 are established.

Weight Determination and Consistency Check

Weights among factors at different levels are calculated, and consistency check is implemented as shown in 3-Table 6. The results show that all pair-wise comparison matrixes are qualified in consistency check.

TABLE 3. Pair-wise comparison matrixes and weights of criterion layer 1 to destination layer

A	B_1	B_2	B_3	W_A	Consistency check
B_1	1	7	6	0.7	CR=0.0961<0.1
B_2	1/7	1	1/3	0.08	
B_3	1/6	3	1	0.22	

TABLE 4. Pair-wise comparison matrixes and weights of criterion layer 2 to criterion C_1

B_1	C_{11}	C_{12}	C_{13}	C_{14}	W_{B1}	Consistency check
C_{11}	1	1/4	1/4	1/2	0.07	CR=0.0883<0.1
C_{12}	4	1	4	5	0.50	
C_{13}	4	1/4	1	3	0.30	
C_{14}	2	1/5	1/3	1	0.13	

TABLE 5. Pair-wise comparison matrixes and weights of criterion layer 2 to criterion C_2

B_2	C_{21}	C_{22}	C_{23}	C_{24}	W_{B2}	Consistency check
C_{21}	1	7	5	3	0.54	CR=0.0932<0.1
C_{22}	1/7	1	1/4	1/2	0.06	
C_{23}	1/5	4	1	3	0.28	
C_{24}	1/3	2	1/3	1	0.12	

TABLE 6. Pair-wise comparison matrixes and weights of criterion layer 2 to criterion C_3

B_3	C_{31}	C_{32}	W_{B3}	Consistency check
C_{31}	1	6	0.86	CR=0
C_{32}	1/6	1	0.14	

Plan Evaluation by Delphi Method

Delphi method is utilized for scoring and calculating comprehensive evaluation grades of different plans. Experts of logistics majors in universities and colleges are selected for scoring according to all indictors, including a total of 10 experts. The scoring standards are divided into five grades, namely excellent, good, general, worse, bad. They are respectively quantifying into 5, 4, 3, 2 and 1. Xi'an is adopted as an example. Expert scoring results are shown in Table 7.

Table 7. Statistic table of scoring results of experts on Xi'an

Indicator Grade	Excellent 5	Good 5	General 3	Worse 2	Bad 1
C_{11}	2	5	3	0	0
C_{12}	1	4	5	0	0
C_{13}	3	4	2	1	0
C_{14}	1	3	5	1	0
C_{21}	1	3	3	2	1
C_{22}	1	2	5	2	0
C_{23}	2	5	3	0	0
C_{24}	2	4	3	1	0
C_{31}	1	4	3	1	1
C_{32}	1	3	5	1	0

Determination of Evaluation Grade Membership Matrixes of Different Indicators

Fuzzy evaluation grade membership matrixes of all indicators at the criterion layer 2 are determined according to the above statistics results.

$$R_1=\begin{bmatrix}0.2 & 0.5 & 0.3 & 0 & 0\\ 0.1 & 0.4 & 0.5 & 0 & 0\\ 0.3 & 0.4 & 0.2 & 0.1 & 0\\ 0.1 & 0.3 & 0.5 & 0.1 & 0\end{bmatrix}\quad R_2=\begin{bmatrix}0.1 & 0.3 & 0.3 & 0.2 & 0.1\\ 0.1 & 0.2 & 0.5 & 0.2 & 0\\ 0.2 & 0.5 & 0.3 & 0 & 0\\ 0.2 & 0.4 & 0.3 & 0.1 & 0\end{bmatrix}$$

$$R_3=\begin{bmatrix}0.1 & 0.4 & 0.3 & 0.1 & 0.1\\ 0.1 & 0.3 & 0.5 & 0.1 & 0\end{bmatrix}$$

Determination of Site Selection Results by Fuzzy Comprehensive Evaluation Method

Comprehensive evaluation results of Xi'an are determined according to the fuzzy comprehensive evaluation method.

$$R=\begin{bmatrix}B_1\\ B_2\\ B_3\end{bmatrix}=\begin{bmatrix}W_{B1} & R_1\\ W_{B2} & R_2\\ W_{B3} & R_3\end{bmatrix}=\begin{bmatrix}0.167 & 0.394 & 0.396 & 0.043 & 0\\ 0.14 & 0.362 & 0.312 & 0.132 & 0.054\\ 0.1 & 0.386 & 0.328 & 0.1 & 0.086\end{bmatrix}$$

$$A_1=W_A R=\begin{pmatrix}0.15 & 0.39 & 0.37 & 0.06 & 0.02\end{pmatrix}$$

A_1 Refers to the membership of Xi'an's comprehensive evaluation belonging to different evaluation grades, the membership thereof belonging to 'good'-0.39 is the maximum value, and we determine Xi'an's evaluation as 'good'. It can be concluded that the membership of Xianyang and Weinan is respectively shown as follows according to the above method:

$$A_2=\begin{pmatrix}0.10 & 0.11 & 0.66 & 0.09 & 0.03\end{pmatrix}$$

$$A_3=\begin{pmatrix}0.09 & 0.11 & 0.59 & 0.15 & 0.07\end{pmatrix}$$

It is obvious that the evaluation results of Xianyang and Weinan are general. Therefore, Xi'an is selected as the site of the distribution center in Shaanxi, the sites of distribution centers in other provinces are determined respectively according to the above methods, and the results are shown in Table 8.

TABLE 8. Table of site selection results

Province	Site selection result
Shaanxi	Xi'an
Gansu	Lanzhou
Qinghai	Xining
Ningxia	Zhongwei
Xinjiang	Korla

CONCLUSION AND COUNTERMEASURE SUGGESTIONS

The development status of five provinces in Northwest Territories are surveyed and studied, and related data is collected on the basis of using site selection theories of the centre-of-gravity method. Several candidate sites are selected in five provinces of Northwest Territories. Finally, final sites of distribution centers are determined among all candidate sites by analytic hierarchy process and fuzzy comprehensive evaluation method. The following conclusions are obtained through study in the paper: Xi'an, Lanzhou and Xining are respectively selected as sites of distribution centers in Shaanxi, Gansu and Qinghai. Zhongwei is selected as the site of the distribution center in Ningxia. Korla is selected as the site of the distribution center in Xinjiang. The site selection results are analyzed, and the provincial capital city quantity as the sites of distribution centers is higher than the quantity of non-provincial capital cities because of more rapid economic development, large policy support efforts and more abundant resource conditions in the provincial capital cities. In addition, the demand of the provincial capital cities is significantly higher than that of other cities. Citizens living in the provincial capital cities have higher material requirements and stronger ability of consumption, which drive the demand of logistics services greatly. Enterprises are closer to the demand market due to larger business demands, thereby producing more business opportunities to enterprises. In fact, many domestic logistics enterprises set up the distribution centers in the provincial capital cities currently. Unique geographical advantages of provincial capital cities are utilized for meeting the demand of customers more rapidly on the one hand, provincial capital cities have relatively perfect supporting resources for facilitating the enterprises to carry out the logistics activities on the other hand. Though Zhongwei is not the provincial capital city in Ningxia, it is located in the Midwest of Ningxia and has better convergence ability with other cities, and it is easier to form a logistics transportation network covering the entire province. Xinjiang Korla is located in Eurasia and Xinjiang hinterland. It is an important transportation hub and a material distribution center in Southern and Northern Xinjiang. Regional advantages and relatively perfect infrastructure construction can provide better conditions for enterprise business.

Enterprises should give full consideration to own business characteristics during distribution center site selection. Actual development status of the candidate sites is combined for selection. Both resource advantages and future development potentials should be considered. Some non-provincial capital cities are not as developed as provincial capital cities in the aspect of economic development, but better hub roles may be provided for future logistics network construction of enterprises in the future. When enterprises select site selection evaluation indicators, the rationality and comprehensiveness of the evaluation indicators should be noted, and the indicators not only should cover related influence factors as far as possible, but also should provide scientific theoretical basis for site selection, thereby laying solid foundation for future business of enterprises.

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