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Study on Location Selection of Logistics Distribution Center Based on Spider Chart

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Abstract

The logistics distribution center, as a circulating site or organization between manufacturers as well as the manufacturers and consumers, is an important node in the logistics network system, and plays a very important role in the modern logistics activities. As a key logistics node, it has not only basic operational functions of the traditional logistics center, but also more assumes such management functions as command and dispatch, information processing, and operational optimization. It has become a soul of whole supply network operation, and its construction and development are concerned more and more by enterprises. However, there are some differences in understanding and functional orientation to the logistics distribution center in the circles. This paper is intended to analyze the influencing factors for location selection of logistics distribution center and construct a location selection index system. Furthermore, it tries to conduct the evaluation on logistics distribution center location selection by the spider chart, so as to select the optimal distribution route.

Keywords*: Logistics distribution; distribution center; location selection; spider chart*

1. Introduction

The location selection of a logistics distribution center refers to the planning process that a location is selected reasonably as the distribution center within the economic area with realistic or potential supply and demand. An optimal distribution-center site scheme can minimize the composite costs in such links as convergence, transit shipment and distribution of goods to ultimate users through the distribution center.

The centroid method is mostly applied in existing logistics distribution center selection methods, where the simple linear function is used for the calculation of transport and distribution expenses. However in reality, a certain expense must be borne often for one vehicle dispatching, whether it is fully loaded or runs in a long or short distance. In one model the fixed expense in the management costs of logistics distribution center is often ignored in calculation of marginal costs. Thus, the effectiveness of the model is reduced greatly.

There are relative merits for other methods, which are summed up in Table1:

Pro. Aikens [1] established nine basic model of nine logistics distribution center location selection in linear programming, dynamic programming and 0—1 integer programming. The objective function can minimize the sum of fixed investment cost and transport cost, and the different forms of programming methods are dependent on the data forms of cost function.

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Table 1. Summary of Methods for Location Selection of Logistics Distribution Center

Model type	Feature	Merit	Demerit	Typical method	Influencing factor
Successive type	The location is any point in a plane	More feasible; not limited to selection of specific alternative points	May be located in the place hardly operated but is an optimal location theoretically.	Centroid method	Transport cost
Discrete type	Alternative. The optimal location should be selected in the expected scheme	If data are enough, the solution by this method more tallies with the actual situation.	Most of them are proved as the NP problem, which is handled more complexly.	Integer programming	Transport cost, operating management cost, and construction cost
				Baumol_Wolfe method	Transport cost, goods operating costs, and construction cost
				Huehn-Hamburgers method	Transport cost, inventory variable fees in distribution center, shortage costs, construction cost, etc.
				Bi-level programming model	Top-layer objective function: difference of total cost and attracted demand quantity; Low-layer objective function: distribution of users' demands.
Delphi method	Make the judgment by expert experience and specialized knowledge, and make a decision quantifiably after the overall analysis on all schemes.	The method is valid relatively if the influencing factors are fully considered and the selection indexes are enough.	Enough basic data are needed in the complement with quantitative analysis.	Analytic hierarchy process (AHP); Fuzzy evaluation method	Social benefit (social, biological and natural environment), economic benefit (operating and investment environment), and technology and transportation (function design, layout and location selection, and scale of construction)

Taniguchi [2] applied the bi-layer programming method to establish the selection question about the transfer sites of public logistics distribution center in the transport network near the expressway cross. Its top-layer objective is to minimize the number of transport vehicles and costs of location selection, while the low-layer programming considers road networks for balancing distribution of vehicles according to the user demands.

Holmberg [3] studied the location selection problem about nonlinear transport cost, and solved it by the branch and bound method. The main objective functions for the model were involved in transport cost and fixed expenses for goods storage.

Francisco [4] *et. al.*, studied the warehouse location model by mixing integer programming, mainly considering fixed cost of location selection, transport cost and inventory charges.

The transport forms of simple location selection model and other discrete location selection models are available by minimizing the linear transport costs. But actually, most transport costs are non-linear. In One literature the location selection problem of non-linear transport costs was considered, and the solution is carried out by the branch and bound method. In other literatures the warehouse location model was built by mixing integer programming, where, inventor cost was considered besides fixed expense and transport costs. This model is used for solution by Dantzig-Wolfe decomposition algorithm, and the gradient optimization method was applied for accelerating the convergence of above algorithm.

With the flourishing e-commerce, logistics also becomes a focus, so that more and more people start to study the location selection of logistics distribution center. They not only established the models tallying with actual situations, but also applied more and more solving methods, such as linear programming, greedy method, simulated annealing (SA), and genetic algorithm (GA).

As early as 1985, Prof. Cai Xixian [5] complied the book—*Quantitative Method of Logistics Rationalization*, where a general study was done on the location selection of logistics distribution center (called "circulation center" in the book), the analysis was done on location selection of circulation center by Baumol-Wolfe method and centroid method, and the solution is calculated by the Capacitated Facility Location Problem (CFLP) and the mixing integer programming.

Ru Yihong, Tian Yuan *et. al.*, [6]. (2002) wrote the *Distribution Center Planning*, studying the location selection of distribution center. What they applied are still centroid method, and Baumol-Wolfe method. In the *Logistics System Planning—Modeling and Case Analysis* written by Cai Linning [7] in 2003, P-mid-value and cross mid-value methods were applied for the studies on location selection of logistics distribution center.

Lu Xiaochun *et. al.*, [8] conducted the in-depth analyses on the location selection of distribution center by centroid method, considering there were some problems in original centroid method. They applied the circulation cost partial differential equation to improve original calculating formulas.

Zhou Meihua [9] employed the advantages of centroid method and differential method in the location selection of self-use distribution center of Xuzhou Mine Group. As a result, a good effect was achieved.

Yun Qingli *et. al*. [10] applied the GA global search optimization technique in the location selection of distribution center. The algorithm design was done by establishing the GA model of location selection, and analytical comparison was made with traditional mixing integer programming method.

Li Qingsong *et. al.*, [11] studied the optimal inventory strategy, working out the non-linear relation of optimal inventory cost and demand quantity, as well as the square-root simulating expression of total inventory cost and the number of distribution centers in a certain total demand. They proposed the location selection model of inventory cost based on transport costs, and inventory cost and construction cost of distribution center.

The logistics started to be studied in the later period in China. In the field of logistics distribution center location selection, some foreign research results were used mostly, and the site selection decision making in reality mainly depended on Delphi method and experts' "brainstorming" or the optimal decisions were made by the close degree calculation by some quantitative methods such as analytic hierarchy process and fuzzy mathematics. China's logistics distribution center location selection will be further studied deeply due to its big objective conditions in such a vast territory.

2. The Process of Location Selection of Logistics Distribution Center

The general process of location selection of logistics distribution center is shown as follows by literature analysis:

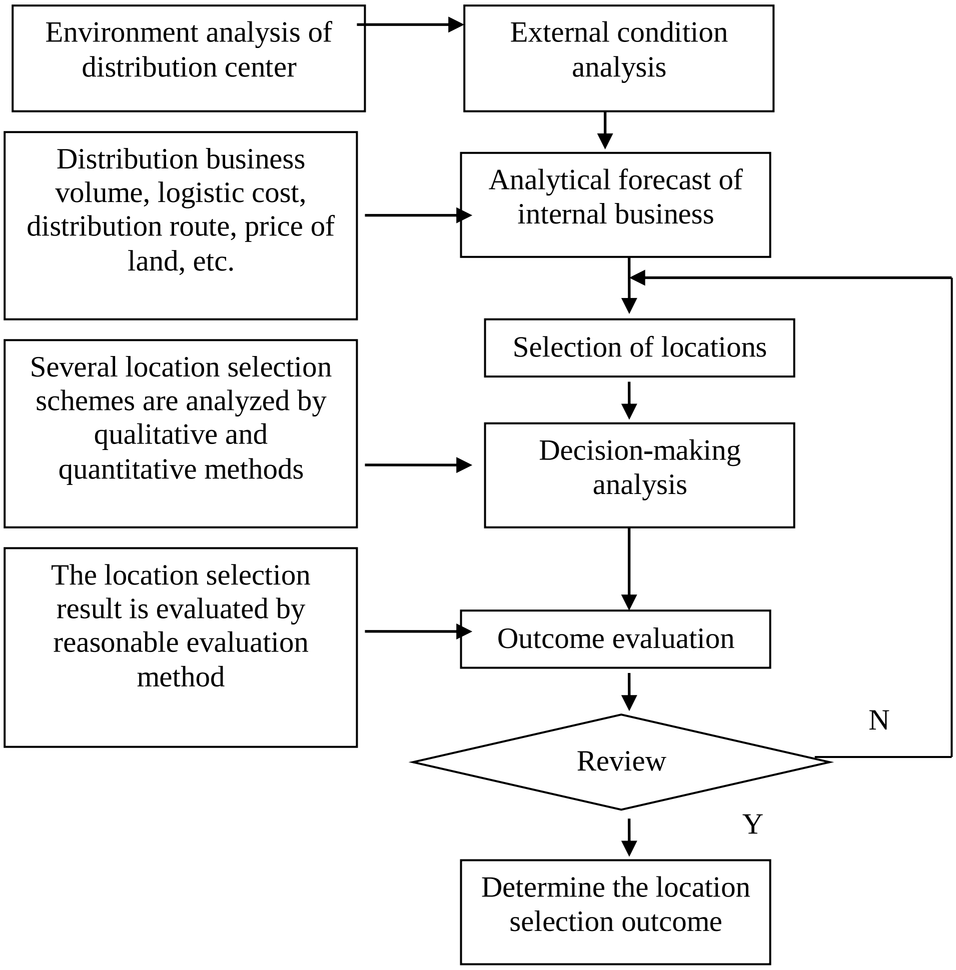

Figure 1. The Process of Logistics Distribution Center Location Selection

The decisive influencing factors for the logistics distribution center location selection are work amount and cost.

(1) Work amount

The work amount for logistics distribution center is decided by such variables as transport amount and capacity, and delivery amount to users from goods-supply sites to the distribution center.

Above data are different in different seasons, months and periods of time. In determining the work amount of a logistics distribution center, it is involved in not only current data but also the predicted values after facility operations.

(2) Expenses

The expenses related to the location selection of a logistics distribution center mainly include: transport cost from the goods-supply site to the logistics distribution center, transport cost for goods delivered to users, charges for facilities and land for business, relevant staff cost, and operating expenses.

3. Establishment of Index System for Logistics Distribution Center Location Selection

The location selection of a logistics distribution center plays a decisive role in the competitiveness of supply chain. The right location selection can result in cost reduction of supply chain and improvement of goods supply quality and efficiency. However, there are many factors influencing the location selection, which is involved in natural environment, social environment and operating environment. Its main influencing factors are summed up as follows:

(1) Natural environment

① Weather conditions

② Geological conditions

③ Hydrologic conditions

④ Topographic condition

(2) Social and economic factors

① Traffic and transport conditions

② Layout of regional industries

③ Flow of goods

④ Human resources

⑤ Urban planning and development

⑥ Policies and regulations。

⑦ Social influences

Besides above two important factors, other factors are summed up as follows that influence logistics distribution center location selection:

(1) Land Purchasing Cost

There is a more fluctuation in the price of land in different areas even in one city. One corporate distribution center takes up a larger area of less than 20 mu or more than 100 mu. The price change of land can affect construction cost of the distribution center greatly. The calculation formula for the cost of land purchasing is as follows:

$$C_L = P_L \times L$$

Where, C_L is land purchasing cost, P_L is the price of land per unit area, and L is the area covered by the distribution center.

(2) Transport Cost

The enterprise goods transport generally goes by railway and highway transports. The transport cost mainly refers to the fuel consumption fee for goods that is delivered to retailers by vehicles of a distribution center. The vehicle fuel consumption is directly proportional to the distance that the vehicles run regardless of vehicle jamming time and the driver’s driving habits. In the same way, the price change of fuel is also ignored, and the current fuel price is available in calculation when the fuel consumption fee is calculated based on fuel consumption.

The formula for transport cost is:

$$C_T = P_O \times O_T \times T$$

Where, C_T is transport cost, P_O is unit price of fuel, O_T is fuel consumption of unit mileage, T is total mileage of vehicle running. P_O and O_T may be known, while T is unknown. By this way, the calculation of transport cost is converted into the estimation of vehicle running mileages.

(3) Properties of Goods

The logistics distribution centers operating different kinds of goods are laid out in different regions respectively. For example, the industrial structure, product structure and industrial layout should be considered for the location selection of productive logistics distribution centers.

4. Methodology

The spider chart was proposed by Prof. Sun Banjun of Shijiazhuang Institute of Economics in his study on the evaluation of competitiveness of group companies. According to the principle of the spider predation by web, an enterprise, just like a big spider, knits its own web by itself, and earns the profit and gains customers' trust by the web. A full, dense and good web indicates the group company can earn the profit, and has the stronger ability to win customers, *i.e.*, stronger competitiveness. This web is knitted based on the evaluation index system of the group company's competitiveness and evaluation values and weight of indexes, then, some approaches in fuzzy overall evaluation techniques are combined with the pie charts in Excel to form several small sectors taking up different areas. Total sum of areas of these sectors represents the competitiveness of the group company.

This method is named as the "spider chart method" because the final diagram is similar to the spider web chart.

As show in Figure 2, the drawing procedures for the spider chart are stated as follows:

(1) Draw the pie chart based on the first-level classification and weight of the enterprise competitiveness.

(2) Supposing the second-level indexes and their weight are set in the first indexes; the pie charts in Article 1 are subdivided based on the second-level classification and their weight in corporate competitiveness evaluation index system, and then the new pie charts are drawn.

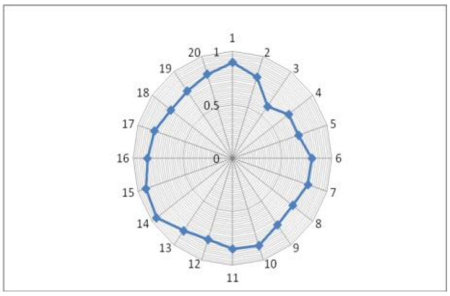

Figure 2. The Spider Chart Principle

(3) The index values are non-dimensionalized (or called the fixed value conversion) based on properties and numerical values of the third-level evaluation indexes, so as to solve the dimensionless index values (index evaluation values) after conversion.

(4) The evaluation values of the second and first-level indexes are solved based on dimensionless index values of the third-level indexes. On the basis of that, total value of corporate competitiveness evaluation (score) is calculated. All index evaluation values as radiuses are marked by the arc or point form in the corresponding areas of the pie chart. Many formed sectors make up a spider chart.

In this paper, the spider chart principle for evaluation of corporate competitiveness is applied for the location selection of enterprise logistics distribution center. It mainly applies such indexes as transport cost to judge advantages and disadvantages of alternative schemes, so that the best logistics distribution center location can be selected from the alternative scheme. The specific process is stated as follows:

(1) All indexes are reclassified first in order to be fit for features of different evaluation objects and easy to analysis of the features. The specific classification methods are different.

(2) Determine the standard values of single indexes.

(3) Calculate the actual enterprise index values.

(4) Plot the spider analysis chart.

(5) All schemes are analyzed based on actual position and distribution of broken lines in spider charts.

5. Model Construction

At first, the index weight is determined for the location selection evaluation system. The analytic hierarchy process (AHP) is a quantitative analysis on the basis of qualitative analysis, and it is generally applied in multi-objective decision in lack of necessary data information, where, a great number of expert consultations and sufficient argumentation are needed. It is more accurate by the multi-objective programming method in the operational research for the multi-objective decision problems with sufficient data. The AHP method is a pro forma expression, handling and objective description for people’s subjective judgments. After the relative weight is calculated by judgment matrix, the consistency test of judgment matrix amount is done to overcome the shortage of pairwise comparisons. The AHP method can be applied widely for multi-objective decision making in resource distribution, conflict analysis and scheme comparison. To sum up, this paper applies the analytic hierarchy process (AHP) to determine index weights according to research objects and data information.

The indexation system is shown in Table 2.

Table 2. Index System of Logistics Distribution Center Location Selection

Objective level	Index system of corporate logistics distribution center location selection															
Standard	Land purchasing cost			Transport cost			Product property			Development strategy		Social environment			Operating environment	
Index	Unit are of land	Price per unit land	Area of logistics center	Unit cost for railway transport	Unit cost for highway transport	Unit cost for other transports	Product life cycle	Product quality density	Productivity of finished products	Planning period	Brand awareness	Policy support	Conformity of regional industries	Contribution to employment	Scale of total assets	Market outlook

6. Plotting of Spider Chart and Evaluation of Logistics Distribution Center Location Selection

(1) The first-level index pie chart is plotted based on the weights and indexes in above table.

(2) The pie chart is plotted based on the second-level indexes.

After the spider chart is plotted successfully, the schemes to be selected are evaluated and analyzed. The evaluation on logistics distribution center covers the sum of all sectorial areas within the spider chart. The sectorial area is calculated by the following formula:

$$S=\sum_{i=1}^{n}\frac{1}{2}r_i^2\theta_i \text{, or } S=\sum_{i=1}^{n}\frac{1}{2}\times r_i^2\times 2\pi\times q_i$$

Where, S stands for the sum of all sectorial areas, *i.e.*, the evaluation value of the logistics distribution center to be select; r represents the side length of the i-th sectors (equivalent to the radius of a circle); θ is the included angle of two sides of the i-th sector (unit: Radian); q is the weight of evaluation index; n is number of sectors, that is, number of evaluation indexes.

Total area S can directly indicate the evaluation value of the logistics distribution centers to be selected, and they are sequenced by the evaluation value. In the other hand, the better the small sector is fitted with the corresponding parts of the spider chart, the better the indexes represented by the small sector are, or the bigger proportion of the area all evaluation indexes cover in total area, the better the logistics distribution center is. Conversely, the bigger the gap is, the poor the index is. In addition, the information is obtained that indexes represented by the bigger gap are just the disadvantages of logistics distribution center. So the newly-built logistics distribution center is substituted or abandoned, while the existing logistics distribution center is improved further.

7. Case Analysis

Taking an example of one company's product logistics distribution center in A city, we carry out analysis on the logistics distribution center location selection by the spider chart. The company needs to build a product logistics distribution center, where the products manufactured are not only delivered to users through the center but also the semi-finished products are delivered to the operating sites for further processing. In order to save construction and transport costs, guarantee the effective delivery and improve competitiveness of supply chain and the company, the company decides to invest labor power and material resources in the location selection of the logistics distribution center.

Table 3. The Index System of Scheme I

Objective level	Standard level			Index level		
	Standard	Weight	Index value	index	Weight	Index value
Location selection index system of the company's logistics distribution center	B_1 land purchasing cost	0.172	0.87	C_{11} unit land area	0.059	0.78
				C_{12} Price of unit land	0.071	0.98
				C_{13} area of the logistics center	0.042	0.83
	B_2 transport cost	0.219	0.76	C_{21} unit cost of railway transport	0.058	0.89
				C_{22} unit cost of highway transport	0.068	0.81
				C_{23} unit cost of other transports	0.093	0.65
	B_3 product property	0.154	0.91	C_{31} product life period	0.065	0.88
				C_{32} product mass density	0.035	0.94
				C_{33} finished product productivity	0.055	0.91
	B_4 development strategy	0.143	0.70	C_{41} planning duration	0.096	0.64
				C_{42} brand awareness	0.047	0.82
	B_5 social environment	0.163	0.91	C_{51} policy support	0.040	0.87
				C_{52} Conformity of regional industry	0.060	0.94
				C_{53} contribution degree to employment	0.063	0.91
	B_6 operating environment	0.149	0.90	C_{62} total assets size	0.084	0.96
				C_{63} market outlook	0.065	0.81

The actual circumstances are stated as follows: The Company has 6 operating sites in A city, considering the users in seven areas in A city. Three schemes are worked out preliminarily as follows:

Scheme I: Build the logistics distribution center near the biggest of six operating sites.

Scheme II: Build the center at the area where there is a largest demand in seven user areas.

Scheme III: Build the center in the center of six operating sites, that is, the average distance to each operating site is shortest.

Taking an example of Scheme I, we carry out the evaluation analysis on the logistics distribution center. After the sites are determined for the logistics distribution center, all index values of the aforesaid system are obtained, and weight is given to all indexes by the analytic hierarchy process so as to gain the weights of index system and the values of index evaluation (Table 3).

(1) Plotting the First-Level Index Spider Chart

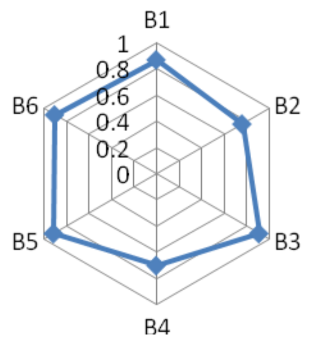

Figure 3. The First-Level Index Spider Chart

(2) Plotting the Second-Level Index Spider Chart

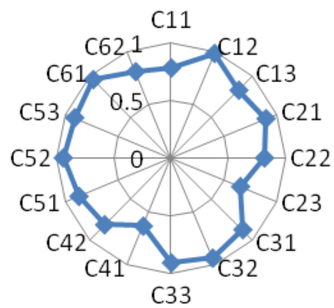

Figure 4. Second-Level Index Spider Chart

(3) Evaluation of Logistics Distribution Center Location Selection

① Evaluation of first-level indexes

$$S = \sum_{i=1}^{6} \frac{1}{2} \times r_i^2 \times 2\pi \times q_i = \sum_{i=1}^{6} r_i^2 \times \pi \times q_i$$
$$= 3.14 \times [0.87^2 \times 0.172 + \cdots + 0.90^2 \times 0.149] = 2.23$$

② Evaluation of second-level indexes

$$S=\sum_{i=1}^{16}\frac{1}{2}\times r_i^2\times 2\pi\times q_i=\sum_{i=1}^{18} r_i^2\times\pi\times q_i$$
$$=3.14\times[0.78^2\times 0.059+\cdots+0.81^2\times 0.065]=1.96$$

As shown by the spider chart, total evaluation value is the area of circle, *i.e.*, 3.14. The first-level index evaluation value is 2.23 by calculation, accounting for 71.0% of total area; the cover area for the second-level indexes is 1.96, making up 62.4% of total area. It is seen that this logistics distribution center stands at the upper level in the first-level indexes, but the second-level indexes are at a lower level, such indexes as more expensive in price of land, and higher cost for railway transport. So, the company should deliberate the two factors in selection of schemes. By calculation and comparison, if difficulties in the second-level indexes of Scheme I can't be overcome, relevant index values of alternative Schemes II and III are calculated in a similar way, and the logistics distribution center location is obtained by the comprehensive comparison.

7. Conclusion

By the spider chart principle, the paper:

(1) Establish the model of location selection of enterprise logistics distribution center, where six first-level indexes are used as the standards to evaluate logistics distribution center location selection, including land purchasing cost, transport cost, product properties, social environment and operating environment.

(2) Propose the evaluation system of logistics distribution center location selection, and figure out the evaluation values for each alternative scheme. This method is not only applicable for the location selection of new logistics distribution centers, but also for the evaluation and comparison to existing logistics distribution centers, so as to find out their disadvantages and improve the logistics distribution centers.

In the end of this paper, an example is taken to state the feasibility and reasonability of the method, which can provide the feasible way for the location selection of enterprise logistics distribution centers.

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