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Fourth-party Logistics Optimization Decision-making Based on Graph Model with Multi-dimensions

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Abstract: Based on practical project, this study proposes key steps of optimization and decision-making in the fourth-party logistics operation. First, we identified supplier evaluation indicators by using the fuzzy comprehensive evaluation method. A directed graph model with multi-dimensions was established based on four elements: price, time, logistics capacity and evaluation information of 3PL suppliers. After simplifying and transforming some restrictions, we solved the problem with Dijkstra algorithm.

Key words: Forth-party logistics, fuzzy evaluation, directed graph with multi-dimensions, Dijkstra algorithm

INTRODUCTION

Fourth-party logistics providers primarily manage and integrate on third party logistics suppliers and "industry best" is as the goal to offer better logistics services to customers. The main problem in the fourth party logistics operation is basically about the fourth party logistics management and integration of third-party logistics providers:

- The supplier basic information management refers to providing registration and basic information maintenance function online for 3PL providers. Basic information including scope of operations, providing operating tools, operational paths, the approximate operating time, etc.
- Optimization decisions (Dickson, 1966) means when the customers order is determined, based on the existing service of 3PL vendors, we should optimize decisions under the premise that meets customer requirements. It includes paths option, transport carrier choice and 3PL provider selection
- Supplier evaluation: the evaluation results will be used as a reference factors in 3PL vendor selection
- Interactive information management: including the available resources of logistics system of 3PL supplier, customer logistics service consultation and feedback, assigned the directive of the 3PL logistics business, 3PL suppliers directive implementation status and customer logistics business inquiries
- The financial management of logistics: including receivables management and payables management

From the above analysis, we know the essence of 4PL is integration. Integration is mainly reflected in the information sharing and process optimization (Open GIS Consortium Technology Office, 2000). Fourth party logistics provider integrating third party logistics provider, it must be on the basis of information collected and shared, as well as evaluation of the 3PL logistics business solutions for optimization and decision making, with the greatest benefit to provide logistics services (logistics services including transportation and storage). Optimize decision-making, mainly talking about here is based on the dynamic logistics resource available information as well as the history of the 3PL supplier evaluation information, finally to make an optimal solution and make decisions (Xiaolong and Ruchuan, 2008). To make optimize selection should be made a comprehensive analysis of path choice, transport carrier selection, 3PL suppliers selection issues.

FORMAT OF MANUSCRIPT

Based on the above analysis, many factors should be considered in order to choose the path which refers to the suppliers included a variety of information. Therefore, we use weights to express the information of suppliers. Of course, because of there is not only one relevant information, the weights should be a multi-dimensional data vector, with, i and j each represent the starting and suspension city. And then we should know how to determine contains of the data vector as well as the related information of suppliers (Zhiqiang and Jiafang, 2006). The author of the analysis drawn to literature, the main consideration factors in selecting suppliers including: the price of 3PL provided, delivery time, logistics capability and supplier evaluation index. Therefore, taking the four factors as the contents of the data contained in the vector. Defined as (C, T, P, E).

Indicator system: C represents the price information (price, units, measurement, standards), T represents the time information (departure time, delivery time, arrival time), P represents the logistics capability (the way of transportation, carrier load) and E represents the supplier evaluation information (storage capacity, the distribution function, customer satisfaction levels, information levels, corporate cohesion):

- **Price:** Unit price of each third party logistics providers can offer, generally speaking, assume other conditions is almost the same, the lower the price, the lower the cost which can be used as the indicators in selecting 3PL suppliers
- **Time:** Time information mainly includes start time, arrival time and delivery time
- **Logistics capabilities:** Logistics capability mainly refers to the transport capacity of the 3PL suppliers, including the use of the mode of transport: air transportation, land transportation and sea shipping or other
- **3PL supplier evaluation information:** Supplier evaluation information includes the followings: storage capacity, payment terms, the goods in good condition, the distribution function, the information level, the level of customer satisfaction, corporate cohesion and so on. Show the above indicators in the hierarchy

Determination of supplier evaluation information: In the above four indicators, the first three indicators can be quantified which means the data can be compared directly, but the supplier evaluation belongs to the subjectivity of indicators which can not be directly expressed through the data, it needs other models to make sure the 3PL supplier evaluation information. This passage we should use the fuzzy comprehensive evaluation model. Fuzzy comprehensive evaluation (Jianjie *et al*., 2003) involves four elements: factor set U, review set V, single factor evaluation matrix R, weight vector W. Steps are follows:

- **Step 1**: Making sure the supplier evaluation index set U

Through the collection of information and expert advice to determine the evaluation of suppliers set U, diving p to u, it is divided into n subsets U_1, U_2,···U_n to meet:

$$\bigcup_{1}^{n} U_1 = U, U_i \cap U_j = \phi, i \neq j \tag{1}$$

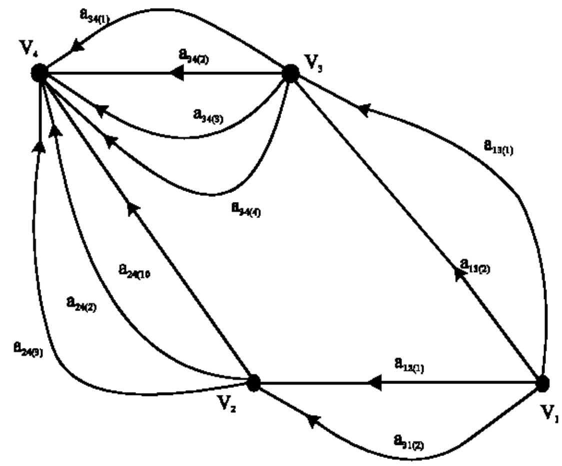

Fig. 1: Maintenance of initial digraph

Then you can get a second-tier collections of elements U/P = U_1, U_2,···U_n, specific indicators shown in Fig. 1 and 2 which n = 7.

- **Step 2:** Determining weight set w

For supplier assessment indicator system, using analytic hierarchy process to determine matrix which is:

$$W = (w_1, w_2......, w_n) \sum_{1}^{n} w_i = 1 \tag{2}$$

$$W = (w_{i1}, w_{i2}......, w_{im}) \sum_{j=1}^{m} w_j = 1 \tag{3}$$

where, i = 4, 5, 6, 7; w_{ij} represent the weight of U_{ij} in the condition of U_i subset; m represent the number of secondary indicators.

- **Step 3:** Establishing a comment set V and score set F

Assumptions to establish the set of a five-tier vendor reviews:

V = (good, better, average, poor, worse), the corresponding scores F = (0.8, 0.6, 0.4, 0.2)

- **Step 4:** Making single factor evaluation for each factor of U_i can get the fuzzy evaluation matrix R_i:

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1k} \\ r_{i21} & r_{i22} & \cdots & r_{i2k} \\ \cdots & \cdots & \cdots & \cdots \\ r_{im1} & r_{im2} & \cdots & r_{imk} \end{bmatrix} \tag{4}$$

Among them, k represents the series of review sets. R_{imj} (I = 4, 5, 6, 7; j = 1, 2,⋯,5) indicates that U_{im} is belonging to which number of the degree of membership of the comment v_i.

On the comprehensive evaluation, you can get:

$$B_i = W_i \bullet R_i = W_i \bullet \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1k} \\ r_{i21} & r_{i22} & \cdots & r_{i2k} \\ \cdots & \cdots & \cdots & \cdots \\ r_{im1} & r_{im2} & \cdots & r_{imk} \end{bmatrix} = (b_{i1}, b_{i2}, \ldots, n = b_{ik}) \quad (5)$$

Normalized B_i will take B_i', similarly, comprehensive evaluation of several factors of u/p, will take the total evaluation matrix B:

$$B = (B_1', B_2', \cdots B_n') \quad (6)$$

- **Step 5:** Fuzzy comprehensive evaluation of U

Suppose the result of the first degree fuzzy comprehensive evaluation of U/P is Z:

$$Z = W \bullet B = W \bullet (B_1', B_2', \cdots B_n')^T = (z_1, z_2, \cdots z_m) \quad (7)$$

$z_i(i = 1, 2, \cdots m)$, then will get the composite score of suppliers C $C = ZF^T$ (8)

- **Step 6:** Preferred

According to step 1-5, then calculate each suppliers $C(C \le 1)$ value, for comparison, we stipulate the value of C is more than 0.75% of vendors can meet the requirements.

Model and analysis: After the analysis and identification of indicators, we optimized the fourth party logistics decision problems into the following models:

$$\begin{cases} V = \{v_1, v_2, \ldots v_i, \ldots\ldots\} \\ A = \{a_{12(1)}, a_{12(2)}, \ldots, a_{ij(k)}, \ldots\} \\ \min Z = F(V, A) \\ f_i \ge 0 \end{cases}$$

V is the city (sent, destination, possible transit) set, A is the urban logistics providers(related information) set; $a_{ij(k)}$ is (C, T, P, E), the i and j of $a_{ij(k)}$ is departure city and termination city. K means the order numbers of different suppliers between the city i and city j. Z represents the optimization objective function; f_i represents the constraint. Figure 2 and 3 are given multi-rights with multiple arc directed graph.

In Fig. 2 and 3, v_1, v_2, v_3, v_4 means four cities, v_1 is sent, v_4 is destination, v_2, v_3 is possible transit; $a_{12(1)}$, $a_{12(2)}$, $a_{12(3)}$, $a_{24(1)}$, $a_{24(2)}$ $a_{13(b)}$ $a_{13(2)}$ $a_{34(b)}$ $a_{34(2)}$ $a_{34(3)}$ represent the 3PL suppliers among cities, the subscript in parentheses numbers indicates the sequence number of different logistics providers in the same two cities, such as there are three 3PL suppliers between v_1 and v_2. Also there are two suppliers between v_2 and v_4.

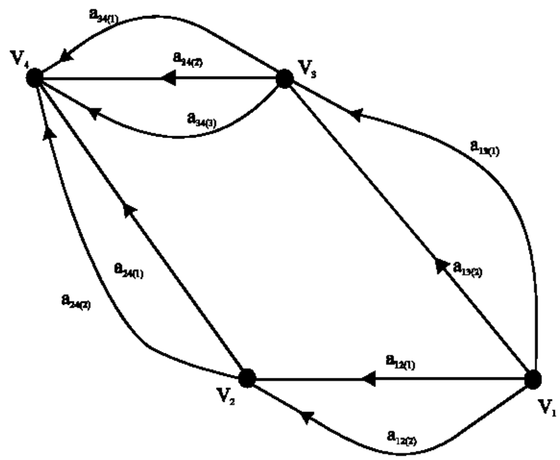

Fig. 2: Removed directed graph that inconsistent with logistics capability

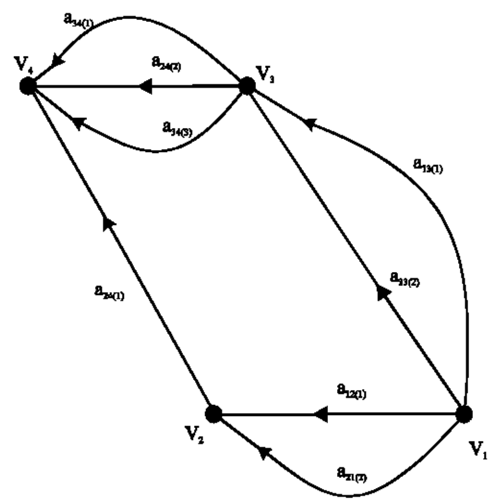

Fig. 3: Removed directed graph that does not comply with constraints

In the model mentioned above, each path corresponds to an alternative solution of the logistics business, thus the above optimization of selecting the path simplified the problem of optimization to selecting the path in the problems of logistics providers. It is noticing that the weight here is multi-weights. The corresponding calculation criteria must be calculated. As for the algorithm, scholars commonly used Dikstra and genetic algorithms and so on. In this passage, the author considers taking the method which is the same as solving the shortest path by Dijkstra algorithm into solving directed graph with multi-dimensions model.

APPLICATION OF DIRECTED GRAPH WITH MULTI-DIMENSIONS

Model application background: Company L recently designs a transportation program for Harbin linen, Ltd. Harbin linen, Ltd has a number of linens to export to European countries. The quantity is about 70~80 tons. According to the characters of goods and other factors, the linen company hope to adopt international air charter transport. In addition, according to the requirement of delivery, goods shall arrive on September 9~10. At the same time, customers want to achieve the minimum logistics costs under the condition of meeting all the terms and the linen company hopes the historical of the third party logistics providers is better. The linen company needs the L logistics company to provide him with the best transportation program. Analysis of customer requirements, author and L logistics company supplier decided to take multi-dimensions to optimize the transportation program, in order to determine the final transport path and 3PL suppliers.

Application of the model and analysis: According to the needs of the customers, company L began to design transportation programs to select the best path and suppliers. First, we must consider the following questions:

How to determine the transit: Choose the possible transit according to the experience and the information of logistics resource. Because Harbin is an inland city, the best option (Smirnov *et al.*, 2003) is to export through the international airport and our domestic international airports are located in four cities: Beijing, Shanghai, Guangzhou and Hong Kong. Due to the location of Harbin, Guangzhou and Hong Kong are far away, initially scheduled Beijing, Shanghai as a transfer point.

How to select the mode of transport: In fact, the different modes of transport can also be used as the criteria of 4PL suppliers (Lee and Dong, 2009). However, it always shipped by train to the transit while export from the mainland, then installed in the transit and shipped abroad. But, different mode of air transportation has a great impact on transportation cost. Generally, the modes of air are air transport, charter transportation, consolidation and other means. In this case, customers need for a charter flight to lower the cost of transport.

How to extract the underlying data: Structure data (Lu, 2003) extracted from the database of the company are as follows: $a_{ij}(k)$ = (C(freight: yuan/t), T(time of departure: month: day, time required), P(by air and tonnage), E(historical evaluation value of 3PL supplier).

Description: (1) domestic transportation, the transport time from Harbin to Beijing and Shanghai arranges flexible and has no problems. There is no difference in the mode of transport, (2) The main constraint conditions are from the conditions of international air business and (3) The value of E obtained by the analytic in section 4.2.2, will not repeat and only give the resulting value.

According to the above analysis, establish the directed graph with multi-dimensions, as shown in Fig. 3, v_1, v_2, v_3 and v_4 each respects Beijing, Shanghai, Harbin and European country.

Analysis: According to survey of company L, we can find: (1) there are many 3PL suppliers from Harbin to Beijing or Shanghai, we exclude by the value E. In the case, customers hope the historical evaluation of the supplier is to be good. In view of this, we require the suppliers which E≤0.7.5 can not as a consideration. After screening: there are each two 3PL suppliers can be chosen from Harbin to Beijing of Shanghai. They are: China railway united logistics Ltd Harbin branch $a_{12(1)}$, Yuanzheng logistics group Harbin branch $a_{12(2)}$, Harbin xianghe transportation Ltd., $a_{13(1)}$, Harbin branch company of Shanghai wanxing log istics $a_{13(2)}$. They formed the following weights:

Harbin-Beijing: $a_{12(1)}$ = (C(110), T, P, E (0.823)),
$a_{12(2)}$ = (C(110, T, P, E (0.780))

Harbin-Shanghai: $a_{13(1)}$ = (C(140), T, P, E (0.801)),
$a_{12(1)}$ = (C(120), T, P, E (0.792))

(2) there are three logistics companies which can provide international air freight from Beijing to European. According to the data collected by company L: Beijing Guanghua Transport $a_{24(1)}$ would provide charter transportation (85 tons), departing from September 8, sailing 1 day, the cost of transportation is 1070 yuan per ton. Similarly, there are two similar companies which are Beijing Jinkai logistics Ltd., $a_{24(2)}$and Beijing Baifu eastern international logistics Ltd., $a_{24(3)}$. They formed the following weights:

$a_{24(1)}$ = (C(1070), T(9:8,1), P(charter 85 ton), E(0.780))
$a_{24(2)}$ = (C(990), T(9:10,1), P(charter 85 ton), E(0.820))
$a_{24(3)}$ = (C(1215), T(9:9,1), P(charter 40 ton), E(0.853))

Similarly, there are four logistics companies which can provide international air transport service. they are: Shanghai Changfa international freight Ltd., $a_{34(1)}$, Shanghai Donghuan international freight Ltd., $a_{34(2)}$, Shanghai Fengyu logistics Ltd., $a_{34(3)}$ and Shanghai Dapeng air transport $a_{34(4)}$, according to the data of company L, They formed the following weights:

$a_{34(1)}$ = (C(990), T(9:8,1), P(charter 85 ton), E(0.832))
$a_{34(2)}$ = (C(880), T(9:9,1), P(charter 90 ton), E(0.77))
$a_{34(3)}$ = (C(940), T(9:8,1), P(charter 40 ton), E(0.850))
$a_{34(4)}$ = (C(960), T(9:8,1), P(charter 85 ton), E(0.850))

The whole question is described below:

$$A = \{a_{12(1)}, a_{12(2)}, a_{13(1)}, a_{13(2)}, a_{24(1)}, a_{24(2)}, a_{24(3)}, a_{34(1)}, a_{34\,(2)}, a_{34(3)}, a_{34(4)}\}\ \min Zcost = |a_{1i(j)}:C|+|a_{1i4(k)}:C\times P|$$

$$\left|T_{抵达时间}\right| \le \left|9:9\sim 10\right|$$

P is charter transportation.

"$a_{ij(k)}$" represents the components of multi-dimensions, $|a_{1i(j)}:C|,|a_{i4(k)}:C\times P|$ represents the cost of component. Here, it represents by the data of chartered transport tonnage values. Data takes the order number from 1-365 days.

Operation: According to the requirements of customer, we have to choose charter transportation constraints and remove the arc that inconsistent the conditions. As shown in Fig. 2 and 3.

Then remove the arc that inconsistent the time according to the time constraints (September 9-10 arrival) as shown in Fig. 3.

According to the aforementioned process of solution (Woudsma *et al*., 2008), choose the optimal arc between two cities. For example, there are two suppliers between point 1 and point 2, removing the second supplier according to the value of E. Similarly, between point 1 and point 3, according to the price first and discard the first supplier naturally. Point 3 and point 4 can not only according to the unit price, but also needs to account cost to meeting the requirements of value E, namely rice×tonnage, in the cases 880×90<990×85<940×100, so remove the first and third suppliers. After above process, it can gain the optimal arc shown as the Fig. 3-4.

Transfer the weight (Liu and Wang, 2009) which shown in the Fig. 3-4 to the one-dimensional weight and its goal is to make the logistics cost minimum. We can take the price in multi-dimensions multiply by tonnage as the calculation of the corresponding arc and form the simple directed graph. Using Dijkstra to solve the graph, get the shortest path $v_1 \to v_3 \to v_4$. Back to the original question, that is while transfer to Shanghai, select the number 2 3PL supplier between Harbin and Shanghai, namely Harbin branch company of Shanghai Wanxing logistics company. Select the No. 2, 3PL supplier while ship from Shanghai to European country, namely Shanghai Donghuan international freight Ltd.

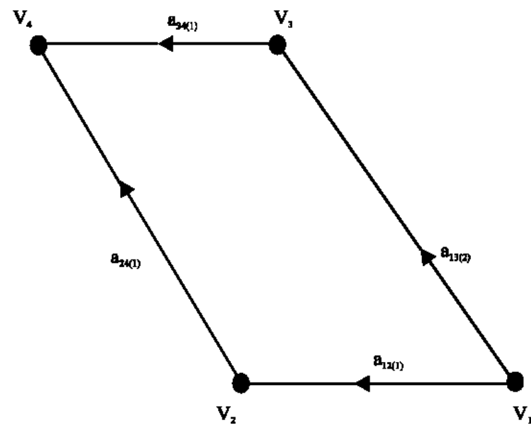

Fig. 4: Selected optimal arc of directed graph between two points

Thus, company L successfully designs a transport program for linen company and chooses the most suitable transport paths and the third party logistics providers for linen company.

Summary: It successfully solved the problems of route optimization and supplier selections by using directed graph with multi-dimensions. The above model and solution algorithm is slightly rough and there is no comparison with other algorithms, thus it needs further improvement. But it is very effective in solving practical problems, L logistics operation already certified.

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