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A Theoretical Model Design for Third Party Logistics Selection in Warehouse Receipt System Using Unascertained Mathematics

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Abstract: The third party logistics selection is one of the most important steps in a warehouse receipt implementation program and is critical to the system success. Due to inherent complexity of warehouse receipt system, selecting an appropriate third party logistics is a risky, difficult and time-consuming task for the system. In this research, a comprehensive hybrid multi-criteria decision making model is developed in two stages using unascertained mathematics to evaluate and rank the alternatives. The model combines the weight determined by experts and entropy weight to solve the index weight, which gives a comprehensive consideration of subjective and objective factors and the method can improve the accuracy of weight value and the reliability of evaluation results. The proposed model is practical and quite simple in real world problems of selecting the most appropriate third party logistics for the warehouse receipt systems.

Key words: Warehouse receipt system, unascertained measure, information entropy, analysis hierarchy process, multi-criteria decision-making

INTRODUCTION

The existing research suggests that warehouse receipt systems ease access to finance at all levels in the marketing chain, moderate seasonal price variability and promote instruments to mitigate prices (Coulter and Onumah, 2002). In the warehouse receipt systems, the warehouse operator as the agent of the depositors to hold the stored commodity by way of safe custody and provide the storage voucher to depositors, then the depositors can transfer the receipts to bank, where the stored commodity is pledged as security for a loan, the banks determine the lines of credit based on the receipts. Hence, there exists the principal-agent relationship between warehouse operators and depositors or between warehouse operators and banks. The warehouse receipts strength rely on the third party logistics enterprises, implying the supporting management and service of the third party logistics and being formed the three-party close corporation relationship among bank and the third party logistics enterprise and depositor (Li and Kuang, 2012). Therefore, the three-party agency relationship exists in warehouse receipt systems and in this system, the third party logistics enterprises play a very important role. Therefore the bank, during the construction process of the warehouse receipt system, should select the third party logistics as a partner carefully so as to ensure the stable operation of the whole system and lowered credit risk of the banks. Based on this point, this study is devoted to study the selection problem of logistics enterprise in setting up the warehouse receipt systems.

When selecting the third party logistics as a partner, this study employ both qualitative and quantitative indexes and take into account of the actual situation of warehouse receipt systems in china. Many researchers have studied the methods of selecting the third party logistics as a partner, including mathematical programming method, data envelopment analysis, analytic network process, ABC method, Analysis Hierarchy Process (AHP), Fuzzy Comprehensive Evaluation (FCE), neural network algorithm, genetic algorithm, gray situation decision method and so on. These research methods have provided very good analysis tools for logistics partner selection, but the methods have their own limitation. According to the characteristics of the selection indexes of logistics partner in the warehouse receipt systems, This study proposes here to use the unascertained measure method basing on information entropy and AHP method to set up comprehensive evaluation model.

MATERIALS AND METHODS

Setting $x_1, x_2,\ldots,x_n$ is n evaluation objects and evaluation object space is $X = \{ x_1, x_2,\ldots, x_n \}$. If $x_i \in X$ and $I_1, I_2,\ldots I_m$ are m assessment indexes, then index space is $I = \{I_1, I_2,\ldots I_m\}$. x_{ij} is observed value of object $x_{i,}$, $C = \{c_1, c_2,\ldots c_k\}$ is evaluation space and c_k ($1 \le k \le K$), is the kth remark rating.

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Unascertained measure of single index: When observed value of object x_i about index I_j is different, the remark rating of index x_i is different too. Setting the extent of x_{ij} belonging to remark rating c_k is $\mu_{ijk} = \mu(x_{ij} \in c_k)$, then μ_{ijk} is test results of extent. And μ is need to meet three conditions as follow (Lu *et al*., 2008; Shi *et al*., 2008; Liu and Pang, 2000):

$$\begin{aligned} &0 \le \mu(x_{ij} \in c_k) \le 1, && i=1,2,\cdots,n; j=1,2,\cdots,m; k=1,2,\cdots,K \\ &\mu(x_{ij} \in U) = 1, && i=1,2,\cdots,n; j=1,2,\cdots,m \\ &\mu\left(x_{ij} \in \bigcup_{k=1}^{K} c_k\right) = \sum_{k=1}^{K} \mu(x_{ij} \in c_k), && k=1,2,\cdots,K \end{aligned}$$

The above principals are nonnegative and normalization and additivity, if μ satisfies all principals, μ is unascertained measure (Xiao *et al*., 2009):

$$(\mu_{ijk})_{m\times K} = \begin{bmatrix} \mu_{i11} & \mu_{i12} & \cdots & \mu_{i1K} \\ \mu_{i21} & \mu_{i22} & \cdots & \mu_{i2K} \\ \vdots & \vdots & \cdots & \vdots \\ \mu_{im1} & \mu_{im2} & \cdots & \mu_{imK} \end{bmatrix} i=1,2,\cdots,n \tag{1}$$

And matrix $(\mu_{ijk})_{m\times K}$ is evaluation matrix about single index of object x_i, μ^i_j $(1 \le j \le m)$ is unascertained measure about objective value x_{ij} belonging to remark rating.

Determining index weight: Traditional evaluation method of unascertained measure employs the information entropy method to determine the weight of index. But due to the obvious shortcomings in the nature and definition of entropy, the knowledge and experience of experts and the opinion of decision makers, very important factors in index weighting, are impossible to be captured by the information entropy method. Hence, the traditional evaluation method of unascertained measure generates more objective weight value and there often exists obvious deviation may between the weight generated by entropy and the actual degree of importance. It may even lead to completely incorrect weighting. However, the analytical hierarchy process can remedy this shortage (Xiao *et al*., 2007; Cao *et al*., 2006). Therefore, this study applies the analytical hierarchy process to modify the weight value by information entropy. Next, the concrete steps of the modified entropy method will be illustrated.

Categorization weight determined by information entropy method: Entropy is a kind of measure about uncertainty of system status, information entropy is mainly to solve the measure of the amount of information, that is the amount of information about the demand on grasping uncertainty which can be expressed by the extent on being solved of uncertainty. And entropy weight can be expressed by the coefficience of degree of relative fierce and the larger the variation degree is, then the smaller the value of information entropy, which shows the index provides larger information and the weight value is larger (Tseng and Lin, 2012; Li *et al*., 2004).

Steps of information entropy method is introduced as follow.

μ^i_j is unascertained measure of object x_i, which objective value x_{ij} about index I_j is belonging to c_1, c_2,... c_k, then:

$$\mu^i_j = (\mu_{ij1}, \mu_{ij2}, \cdots, \mu_{ijK}) \tag{2}$$

Index weight w^i_j is used to describe classification contribution about index I_j to object x_i and w^i_j depends on the extent of focus and scatter of every components of μ^i_j. the extent of focus and scatter of every components of μ^i_j has many methods, this paper uses entropy. Entropy H (j) is decided by measure μ_{ijk} and:

$$\begin{aligned} h(j) &= -\sum_{k=1}^{K} \mu_{ijk} \cdot \log \mu_{ijk} \\ g^i_j &= 1 - \frac{1}{\log K} h(j) = 1 + \frac{1}{\log K} \sum_{k=1}^{K} \mu_{ijk} \cdot \log \mu_{ijk} \end{aligned} \tag{3}$$

Setting:

$$v^i_j = \frac{g^i_j}{\sum_{j=1}^{m} g^i_j} \left(\text{obvious} 0 \le v^i_j \le 1 \text{and} \sum_{j=1}^{m} v^i_j = 1 \right) \tag{4}$$

According to nature of entropy: (1) If and only if

$$\mu_{ij1} = \mu_{ij2} = \cdots = \mu_{ijK} = \frac{1}{K}$$

g_j is equal to zero which is the minimum; (2) if and only if $\mu_{ijk0} = 1$ and other K-1 is zero all, g_j is equal to one which is the maximum; (3) if μ_{ijk} is focus more, g_j is near one more, on the contrary μ_{ijk} is scatter more, then g_j is near zero more.

According to above natures of g_j, v^i_j is classification weight of index I_j about x_i,then

$$v^i = (v^i_1, v^i_2, \cdots, v^i_m) \tag{5}$$

Index weight determined by analytic hierarchy process: The steps of analysis hierarchy process to determine index weight can be approximately dived into two stages. Firstly, Expert opinion method is utilized to solve the important ranking of every index and the weight value of index in the every hierarchy can be calculated. Secondly, it is necessary to check consistency test and consistency test of judgment matrices meets requirements if consistency ratio is less than 0.1, it is need to notices that all judgment matrices are required to meet consistency test. The detailed description of AHP can has been found in many literatures (Zhang and Fu, 2012; Yu, 2012; Liu *et al*., 2012), so the concrete steps of AHP is not being illustrated in detail. The classification weight of index I_j about x_i is denoted by μ^i_j, then $u^i = (u^i_{,1}, u^i_{,2}, \ldots, u^i_{,m})$ is the classification weight vector of indexes $I_1, I_2, \ldots I_m$ about x_i.

Comprehensive weight determined by modified entropy method: According to the calculation results of index weight by entropy and AHP, the index weight of modified entropy can be determine and denoted as w_j. Then:

$$w_j = \frac{u_j v_j}{\sum_{j=1}^{m} u_j v_j} \tag{6}$$

Comprehensive evaluation system: If $w^i_j = 0$, μ_{ijk} is rewrote to $w_j \mu_{ijk} = w^i_j . \mu_{ijk} + (1 - w^i_j) . \mu_{ijk}$ and $w^i_j . \mu_{ijk} = 0$; if $w^i_j > 0$, notice following:

$$\begin{gathered} 0 \le \sum_{j=1}^{m} w^i_j \cdot \mu_{ijk} \le 1 \\ \sum_{k=1}^{K}\left[\sum_{j=1}^{m} w^i_j \cdot \mu_{ijk}\right] = \sum_{j=1}^{m}\left[w^i_j \sum_{k=1}^{K} \mu_{ijk}\right] = \sum_{j=1}^{m} w^i_j = 1 \end{gathered} \tag{7}$$

Then:

$$\sum_{j=1}^{m} w^i_j \cdot \mu_{ijk}$$

is unascertained measure for x_i belonging to kth remark rating.

Setting:

$$\mu^i = W^i \cdot (\mu_{ijk})_{m \times K} = (w^i_1, w^i_2, \cdots, w^i_m)\begin{bmatrix} \mu_{i11} & \mu_{i12} & \cdots & \mu_{i1K} \\ \mu_{i21} & \mu_{i22} & \cdots & \mu_{i2K} \\ \vdots & \vdots & \cdots & \vdots \\ \mu_{im1} & \mu_{im2} & \cdots & \mu_{imK} \end{bmatrix} \tag{8}$$

$$\mu^i = (\mu_{i1}, \mu_{i2}, \cdots, \mu_{ik})$$

Then, μ^i is evaluation vector of x_i.

Evaluation criteria: Remark rating is ordered, the kth remark rating c_k is better than k+1th remark rating c_{k+1}, So, recognition criteria about greatest measure is inappropriate, recognition criteria about confidence level is introduced.

If $\{c_1, c_2, \ldots, c_k\}$ satisfies that $c_i > c_{i+1}$ (i = 1,2,...,k-1), setting λ ($0.5 < \lambda < 1$) is confidence level, usually λ is 0.6 or 0.7 and:

$$k_0 = \min_k \left[\left(\sum_{l=1}^{k} \mu_{il}\right) \ge \lambda, k = 1, 2, \cdots, K\right] \tag{9}$$

Then, x_i belongs to k_0th remark rating c_{k0}.

Case study: To demonstrate the performance of the proposed method for selecting the third party logistics in warehouse receipt system, a case study is given in this section.

Indexes system: According to the actual situation of warehouse receipts business in china and reference to the existing research results, this paper build up the indexes system of logistics partner selection in warehouse receipt systems from different aspects, which follow the principles of the establishment of indexes system (Table1).

Firstly, the experts score for every evaluation factor by evaluation rank, the evaluation ranks have been divided into 6 and can been marked as $C = \{c_1, c_2, \ldots, c_s\} = \{5A, 4A, 3A, 2A, A, none\}$.

Grade standard of some appraisal indexes in logistics enterprises is showed as Table 2.

Algorithm: In this section, the study implied the algorithm introduced by section 2 and the indexes system established by section 3 to select the logistics partners for commercial bank. According to statistical data and evaluation grade from experts, the measure matrix of single index is calculated by unascertained measure function and is showed as following:

$$\mu^1_{1jk} = \begin{bmatrix} 0 & 0 & 0.2 & 0.8 & 0 & 0 \\ 0 & 0.35 & 0.65 & 0 & 0 & 0 \\ 0.375 & 0.625 & 0 & 0 & 0 & 0 \\ 0 & 0.5 & 0.2 & 0.3 & 0 & 0 \\ 0.1 & 0.3 & 0.3 & 0.2 & 0.1 & 0 \end{bmatrix}$$

$$\mu^1_{2jk} = \begin{bmatrix} 0.1 & 0.1 & 0.6 & 0.1 & 0.1 & 0 \\ 0.2 & 0.1 & 0.4 & 0.3 & 0 & 0 \\ 0 & 0.786 & 0.114 & 0 & 0 & 0 \\ 0.081 & 0.919 & 0 & 0 & 0 & 0 \\ 0 & 0.6 & 0.3 & 0.1 & 0 & 0 \\ 0.1 & 0.7 & 0.2 & 0 & 0 & 0 \\ 0 & 0.4 & 0.3 & 0.2 & 0.1 & 0 \\ 0.157 & 0 & 0.843 & 0 & 0 & 0 \\ 0.215 & 0.785 & 0 & 0 & 0 & 0 \\ 0.3 & 0.2 & 0.2 & 0.3 & 0 & 0 \end{bmatrix}$$

Table 1. The indexes system of logistics partner selection in warehouse receipt systems

Target layer	Rule layer	Index layer	Remark
Comprehensive quality of logistics partner in warehouse receipt systems	Resource status of logistics enterprise	The logistics enterprise's private warehousing and storage area	Units: Square meter
		Distribution sites	Units: Number
		The total assets of the logistics enterprise	Units: Yuan
		Staff quality	Staff proportion who have educated in junior college or higher school level or have achieved the logistics professional qualification authentication
		Credit records	Expert evaluation
	Logistics enterprise competence	Standardization degree of business operation	Whether the business operation has implement the standardization
		Commodity intact rate	Commodity intact rate is equal to the number of commodity which has none any value lost is divided by the total number of commodity
		Inventory turnover	Inventory turnover is equal to cargo throughput is divided by average stock in report period
		Logistics market share	Logistics market share is equal to the logistics enterprise's operating income is divided by the operating income of the same industry in report period
		Automation	Expert evaluation
		Integration ability of external resource	Expert evaluation
		The ability of providing and implementing logistics service schemes	Expert evaluation
		Business scope	International, national, trans-province, or inter-province
		Customer satisfaction	The investigation and statistics on customer satisfaction situation every year
		Informatization degree	The proportion of business information realizing informatization management
	The management state of logistics enterprise	The operating income of warehousing and storage every year	The income from enterprise finishing warehousing and storage or distribution
		Logistics enterprise business hours	Units: Year
		Total assets turnover ratio	Total assets turnover ratio is equal to total liabilities are divided by total assets
		Asset-liability ratio	Asset-liability ratio is equal to total liabilities are divided by total assets
		Service increasing ratio	Service increasing ratio is equal to income increase in current year is divided by total income in previous year
		Impact index of the logistics enterprise	Expert evaluation
		Internationalization degree	Expert evaluation
	Corporative state	Corporative time	Unit: Year
		Corporation the perfection	Expert evaluation
		Information communication	Expert evaluation
		Information system compatibility	Expert evaluation

$$\mu_{3jk}^{1}=\begin{bmatrix} 0.375 & 0.625 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0.106 & 0.894 & 0 & 0 & 0 & 0 \\ 0 & 0.091 & 0 & 0.909 & 0 & 0 \\ 0 & 0.217 & 0.783 & 0 & 0 & 0 \\ 0.3 & 0.2 & 0.4 & 0.1 & 0 & 0 \\ 0.2 & 0.2 & 0.5 & 0.1 & 0 & 0 \end{bmatrix}$$

Table 2: Grade standard of some appraisal indexes

	Grades					
Evaluation indexes	5A (c1)	4A (c2)	3A (c3)	2A (c4)	1A (c5)	None (c6)
Logistics enterprise's private warehousing and storage area (Units: Square meter)	More than 200,000	More than 80,000	More than 30,000	More than 4,000	More than 4,000	Less than 4,000
Distribution sites(Units: Number)	More than 400	More than 300	More than 200	More than 100	More than 50	
The total assets of the logistics enterprise (Units: Yuan)	More than 1 billion	More than 200 million	More than 40 million	More than 8 million	More than 2 million	
Customer satisfaction	More than or equal 98%	More than or equal 95%	More than or equal 90%			
The operating income of warehousing and storage every year (Units: Yuan)	More than 600 million	More than 120 million	More than 25 million	More than 5 million	More than 2 million	Less thanc 2 million
Logistics enterprise business hours (Units: Year)	More than 3 years	More than 2 years	More than 1 year	Less than 1 year		
Asset-liability ratio	No more than 70%	more than and equal 70%				

$$\mu^{1}_{4jk} = \begin{bmatrix} 0 & 0 & 0.416 & 0.584 & 0 & 0 \\ 0 & 0.4 & 0.4 & 0.2 & 0 & 0 \\ 0.5 & 0.3 & 0.2 & 0 & 0 & 0 \\ 0.1 & 0.3 & 0.3 & 0.2 & 0.1 & 0 \end{bmatrix}$$

According to 4-6, the weight vector of index classification can be calculated by the modified entropy, corresponding results of every steps are:

v = (0.0514, 0.0456, 0.0450, 0.0303, 0.0114, 0.0225, 0.0204, 0.0539, 0.0601, 0.0356, 0.0394, 0.0204, 0.0540, 0.0506, 0.0169, 0.0450, 0.0713, 0.0579, 0.0592, 0.0505, 0.0204, 0.0227, 0.0443, 0.0293, 0.0303, 0.0114)

u = (0.061, 0.023, 0.038, 0.041, 0.069, 0.017, 0.014, 0.036, 0.05, 0.02, 0.019, 0.032, 0.057, 0.079, 0.025, 0.047, 0.054, 0.043, 0.072, 0.03, 0.026, 0.015, 0.033, 0.035, 0.046, 0.018)

w_j = (0.0741, 0.0247, 0.0404, 0.0294, 0.0186, 0.009, 0.0067, 0.0459, 0.071, 0.0168, 0.0177, 0.0154, 0.0727, 0.0944, 0.0100, 0, 0499, 0.0910, 0.0588, 0.1006, 0.3578, 0.1251, 0, 0081, 0.0345, 0.0242, 0.033, 0.0049)

Then, evaluation vector of the logistics computed by 8 is:

$$\mu = w_j \times \mu_{ijk} = (0.1997, 0.3876, 0.2013, 0.2020, 0.0048, 0)$$

Setting $\lambda = 0.7$ and according to (9), if k0 = 3, 0.1997+0.3876+0.2013=0.7886>0.7. So, the comprehensive evaluation result of the logistics enterprise is good and the confidence level is no less than 70%, which illustrates that the commercial bank can choose this logistics enterprise as their partner.

According to the above-mentioned result and combining the actual situation in this logistics enterprise, this study finds that the private warehousing and storage area of this logistics enterprise is not formed into the large scale, which cause to lower the company's comprehensive evaluation result, so the logistics enterprise should expanse the private warehousing and storage area in the future development to enhance the core competence. Overall, this logistics enterprise has stronger advantage, that is the company has the large percentage total assets, rapid inventory turnover, larger logistics market share, higher customer satisfaction, good operating income of warehousing and storage every year and rapid total assets turnover ratio.

CONCLUSION

The unascertained measure model is based on order of evaluation space and uncertainty of information, gives reasonable confidence criteria and ranking scores criteria, which makes the result is more reasonable and identifiable. And the model can process the quantitative indicators and qualitative indicators existing in one model simultaneously. In addition, unascertained measure model can give order of quality and also give grade estimation. Therefore, the unascertained model provides a good method to evaluation field. But traditional unascertained model utilized the entropy to solve the weight, which has some shortcoming. It is well known that the weight value has great influence on evaluation result in assessment model, so it is important to determine the weight scientifically, For shortcoming of the weight value by entropy in traditional model being more objective, this study established unascertained comprehensive evaluation model basing on modified entropy, the model combines the advantages of the entropy method and the AHP to determine the index weight, which makes the evaluate result to be more scientific and reasonable.

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