Application of Entropy-AHP-TOPSIS methods to Select Food Suppliers

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Abstract. In this paper, we give a framework to select food suppliers. The proposed framework is divided into three stages. During the first stage, we construct an index system that include quality, ability, management, service and R&D. In the second stage, we use entropy and Analytic Hierarchy Process(AHP) to determine weights. The third stage is associated with the application of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank food suppliers and select the best one. In the end, we give an example to prove the method is validity and fessibility.

Introduction

In recent years, more and more food safety incidents have been payed people more attention in the word. And those incidents are related with food suppliers. In China, there are more contaminated pork, rice, and milk powder. Suppliers are the source of the supply chain. Effective selection on the food suppliers, which are safe and reliable, is to prevent from food safety incidents.

In food supply chain research, Hamprecht et al. (2005)[1] reported on how a global food manufacturer made use of control points of the food safety systems to trace back material flows to agricultural production. The increased transparency gave the food manufacturer the opportunity to evaluate risky suppliers concerning their sustainability performance. In the food supply chain research tool development such as benchmarking tools for multiple of sustainable food supply chain stages has been addressed in Yakovleva et al.(2012)[2]. They focused on various partners in the supply chain including growers, processors, distributors, and retailers. The focus on multiple dimensions of sustainability, organizational types, and industries make it difficult for benchmarking and management effort. Risk management plays a significant role in the food supply chain and its sub-suppliers, especially for social sustainability issues such as health and human risks (Diabat et al., 2011)[3]. The focus of this previous research has been on descriptive and planning issues, with very little focus on direct issues of supplier management (Mena et al., 2013)[4].

In this paper, we focus on supplier management and try to establish a comprehensive evaluation index system for food suppliers. Then we use AHP-entropy-TOPSIS method to construct supplier evaluation model, which can provide decision support for the food enterprises to choose the suppliers. Evaluation model can be shown in Figure 1.

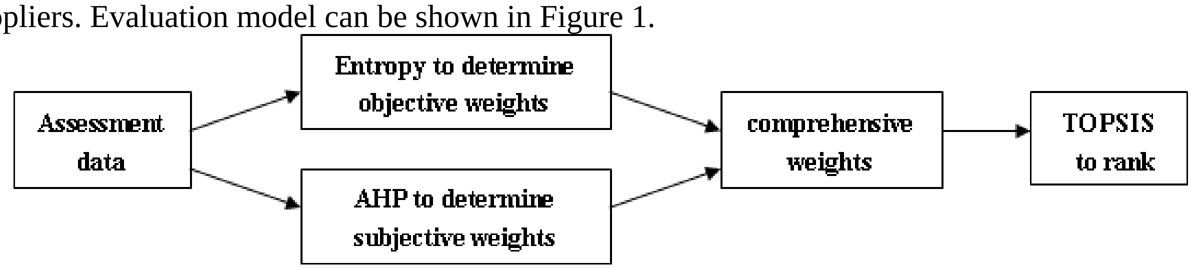

Figure. 1 evaluation model

Construction of index system

We analyze on every key point of food supply chain and consider the factors of influence on every aspect of food supplier, and then we establish the evaluation index system of food supplier.

The evaluation index system consists of 3 hierarchy, 5 sub-system and 18 indicators(Table1). These indicators were got by literature polymerization[5-7].The first is system-level, namely evaluation system of food supplier. Second is target-level, Third is concrete evaluation index of every target-level.

We divide these indicators into five categories: Quality (B_1), Ability(B_2), Management (B3), Service (B_4), R&D (B_5). They together evaluate food supplier (A). Quality includes: Food safety and health (X_{11}), food quality (X_{12}), Food reliablity(X_{13}). Ability includes: Order fulfillment rate (X_{21}), Timely delivery rate (X_{22}), Transportation safety (X_{23}). Management includes: GSM system implementation rate (X_{31}), SSOP implementation rate (X_{32}), HACCP implementation rate (X_{33}), ISO9000 implementation rate(X_{34}). Service includes: Order fill rate (X_{41}), Customer complaint rate (X_{42}), Food traceability rate (X_{43}), Recall system setting rate (X_{44}). R&D includes: R&D personnel ratio (X_{51}), Ability index of R&D personnel (X_{52}), R&D personnel flow rate (X_{53}), R&D funding ratio (X_{54}).

Table.1 Evaluation system of food supplier

System	Targets	Indexes
Evaluation system of food supplier (A)	Quility (B_1)	Food safety and health (X_{11})
		Food quality (X_{12})
		Food reliability (X_{13})
	Ability (B_2)	Order fulfillment rate (X_{21})
		Timely delivery rate (X_{22})
		Transportation safety (X_{23})
	Management (B_3)	GSM system implementation rate (X_{31})
		SSOP implementation rate (X_{32})
		HACCP implementation rate (X_{33})
		ISO9000 implementation rate(X_{34})
	Service (B_4)	Order fill rate (X_{41})
		Customer complaint rate (X_{42})
		Food traceability rate (X_{43})
		Recall system setting rate (X_{44})
	R&D (B_5)	R&D personnel ratio (X_{51})
		Ability index of R & D personnel (X_{52})
		R&D personnel flow rate (X_{53})
		R&D funding ratio (X_{54})

Determine weights

AHP is subjective methord to get weights and has its own shortcomings, such as individual deviations, resulting in extreme values, etc. We use entropy weight to compensate for its shortcomings

Use AHP to determine subjective weights.

The AHP has become one of the most widely used multiple-criteria decision-making (MCDM) methods. The AHP method provides a structured framework for setting priorities on each level of the hierarchy using pairwise comparisons that are quantified using 1–9 scales [8].

Let $X_1, \cdots X_m$ be m performance factors and $W = (w_1 \cdots w_m)$ be their normalized relative importance weight vector which is to be determined by using pairwise comparisons and satisfies the normalization condition:

$$\sum_{j=1}^{m} w_j = 1 \quad \text{with} \quad w_j \geq 0 \quad \text{for } j=1,\ldots,m.$$

The pairwise comparisons between the m decision factors can be conducted on scale (1–9) by asking questions to experts or decision makers like, which criterion is more important with regards to the decision goal. The answers to these questions form an $m \times m$ pairwise comparison matrix $A = (a_{ij})_{m \times m}$. where a_{ij} represents a quantified judgment on w_i / w_j with a_{ii}=1 and $a_{ij}=1/a_{ji}$ for i, j =1, ..., m.

If the pairwise comparison matrix $A=(a_{ij})_{m\times m}$ satisfies $a_{ij}=a_{ik}a_{kj}$ for any *i*, *j*, *k* = 1, ..., m , then *A* is said to be perfectly consistent; otherwise it is said to be inconsistent. Form the pairwise comparison matrix *A*, the weight vector W can be determined by solving the following characteristic equation: $AW=\lambda_{\max}W$. Where $\lambda_{\max}$ is the maximum eigenvalue of A. Such a method for determining the weight vector of a pairwise comparison matrix is referred to as the principal right eigenvector method (Saaty, 1980). The pairwise comparison matrix A should have an acceptable consistency, which can be checked by the following consistency ratio: $CR=[(\lambda_{\max}-n)/(n-1)]/RI$

If $CR\le 0.1$, the pairwise comparison matrix is considered to have an acceptable consistency; otherwise, it required to be revised.

Entropy to determine objective weights.

The entropy by Shannon[9] can be used to determine the disorder degree and its utility in system information. The smaller the entropy value is, the smaller the disorder degree of the system is. Supposing there are m food suppliers and n pieces of indexes in the index system, x_{ij} is the *j*th index's value in the *i*th food supplier. In order to eliminate the influence of index dimension on incommensurability, it is necessary to standardize indexes using the equations of relative optimum membership degree.

To the benefit indexes, the attribute value of the *j*th index in the *i*th food supplier can be transformed by: $r_{ij}^{'}=(x_{ij}-\min_j x_{ij})\Big/(\max_j x_{ij}-\min_j x_{ij})$, $(i=1,\cdots,m;\ j=1,\cdots,n)$

To the cost indexes, the attribute value of the *j*th index in the *i*th food supplier can be transformed by: $r_{ij}^{'}=r_{ij}^{'}=(\max_j x_{ij}-x_{ij})\Big/(\max_j x_{ij}-\min_j x_{ij}),\ x_{ij}\neq 0$, $(i=1,\cdots,m;\ j=1,\cdots,n)$

After standardization of indexes, the standardized index matrix is $R^{'}=[r'_{ij}]_{m\times n}$

According to the definition of entropy, entropy of the jth index is determined by:

$$H_j=\sum_{i=1}^{m}f_{ij}\ln f_{ij}\Big/\ln m,\quad (i=1,\cdots,m;\ j=1,\cdots,n)$$

Where $f_{ij}=r_{ij}\Big/\sum_{i=1}^{m}r_{ij}$, $(i=1,\cdots,m;\ j=1,\cdots,n)$

Entropy weight of the *j*th index is determined by:

$$w_j^{'}=(1-H_j)\Big/(n-\sum_{j=1}^{n}H_i),\ \sum_{i=1}^{n}w_i=1,\quad (j=1,\cdots,n)$$

Determine comprehensive weights.

Comprehensive weights can be given:

$$\theta_j=w_j\times w_j^{'}\Big/\sum_{j=1}^{m}w_j\times w_j^{'}$$

TOPSIS method

TOPSIS method is appropriate method in System Decision Analysis[10-11]. The basic idea is: Define the positive ideal solution and negative ideal solution about decision problem; Positive ideal solution is generally optimal solution and Negative ideal solution is to assume the worst solution. The decision rule is that every program was compared with the ideal solution and negative ideal solution. Satisfactory solution is the closest to the positive ideal solution and the farthest to the negative ideal solution. The concrete steps are as follows:

Step 1: Construct normalized decision matrix $Y=(y_{ij})_{n\times m}$. Suppose *n* options, *m* evaluation indicators, and then decision matrix is Y and Construct normalization decision matrix $Z=(z_{ij})_{n\times m}$.

Where y_{ij} means index value about the ith options and the jth evaluation indicators. i=1, 2,…, n, j=1, 2,…, m.

Where $z_{ij} = y_{ij} \Big/ \sqrt{\sum_{i=1}^{m} y_{ij}^2}$, i=1, 2,…, n, j=1, 2,…, m.

Step 2: construct weighted normalization decision matrix $V = (v_{ij})_{n\times m}$. Where $x_{ij} = w_j z_{ij}$, i=1, 2,…, n, j=1, 2,…, m. w_j is the weight of the j th indicators.

Step 3: determine the positive ideal solution x^+, which means each indicator value reaches the best values in the various options. Determine the negative ideal solution x^-, which means each indicator value reaches the worst values in the various options.

Step 4: Calculate the distance from every option to the positive ideal solution and calculating the distance from every option to the negative ideal solution. The distance usually measured by the Euclidean distance.

Distance from each option to the ideal solution x^+:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (x_{ij} - x_j^+)^2}\ ,\ i=1,\ 2,\ldots,\ n. \tag{1}$$

Distance from each option to the negative ideal solution x^-:

$$d_i^- = \sqrt{\sum_{j=1}^{m} (x_{ij} - x_j^-)^2}\ ,\ i=1,\ 2,\ldots,\ n. \tag{2}$$

Step 5: Calculate Comprehensive evaluation index for each option:

$$C_i^* = d_i^- / (d_i^+ + d_i^-)\ , i=1,\ 2,\ldots,\ n. \tag{3}$$

Step 6: Rank from the best to the worst based on C_i^* value, which the more value is, the worse the option is. That C_i^* is closer to 1 means that the ith option is more close to the optimal level.

A case study

A supermarket want to choose partners from 4 food suppliers. Evaluation index systerm is given as Table 1. Now, we rank the four food suppliers to help managers detemine which one is worth to be parnter.

Caculate objective weights.

We get the data from 4 food suppliers: C, D, F and E. some data came from historical records, other data came from experts scoring. Then normalized matrix as follows (Table 2)

Table.2 Normalized matrix

Indicators	C	D	F	E
X_{11}	0.2459	0.2629	0.2395	0.2517
X_{12}	0.1984	0.2949	0.2906	0.2161
X_{13}	0.2614	0.3139	0.2473	0.1774
X_{21}	0.1902	0.2565	0.2938	0.2594
X_{22}	0.1752	0.2817	0.2709	0.2722
X_{23}	0.2372	0.3213	0.2010	0.2405
X_{31}	0.1829	0.2783	0.2945	0.2442
X_{32}	0.2191	0.3088	0.2774	0.1946
X_{33}	0.2338	0.1792	0.3017	0.2853
X_{34}	0.2436	0.2805	0.2902	0.1857
X_{41}	0.2530	0.3080	0.1988	0.2401
X_{42}	0.2012	0.2605	0.2970	0.2414
X_{43}	0.2251	0.3617	0.2451	0.1681
X_{44}	0.2361	0.2999	0.2488	0.2152
X_{51}	0.2594	0.3280	0.2469	0.1657
X_{52}	0.4211	0.1053	0.0526	0.4211
X_{53}	0.4737	0.3158	0.1579	0.0526
X_{54}	0.3887	0.1141	0.3073	0.1899

Use entropy method, we can get objective weights:

W'={0.0539,0.0545,0.0546,0.0543,0.0545,0.0545,0.0545,0.0545,0.0546,0.0544,0.0544,0.0543,0.0553,0.0542,0.0549,0.0635,0.0619,0.0573}

Caculate subjective weights.

With the help ot some experts, we construct fuzzy comprehensive evaluation matrices. Then we count max Eigen value and eigenvectors, and normalized eigenvectors. In the end, we get weights

W={0.0877,0.0335,0.0383,0.0281,0.0155,0.0085,0.0384,0.0119,0.0187,0.0425,0.1661,0.1062,0.0570,0.0631,0.1189,0.0639,0.0310,0.0707}

Caculate comprehensive weights.

We can caculate comprehensive weights:

θ={0.0853,0.0329,0.0377,0.0275,0.0152,0.0083,0.0377,0.0117,0.0184,0.0417,0.1628,0.1039,0.0568,0.0616,0.1177,0.0731,0.0346,0.0730}

TOPSIS to rank.

With comprehensive weights, We can construct comprehensive weighted normalizing matrix and caculate positive ideal solutions, negative ideal solutions:

X^+ = {0.002854, 0.001152, 0.001502, 0.000836, 0.000500, 0.000331, 0.001230, 0.000437, 0.000498, 0.001460, 0.006346, 0.003243, 0.002436, 0.002304, 0.004837, 0.002794, 0.001702, 0.002899}

X^- = {0.001456, 0.000510, 0.000412, 0.000555, 0.000292, 0.000125, 0.000698, 0.000153, 0.000405, 0.000527, 0.002422, 0.001904, 0.000588, 0.000867, 0.001186, 0.000290, 0.000084, 0.000961}

Evaluation.

Using formula given in (1), (2) and (3), we can get d+, d- and C* as follow (Table.3) about four food supplier. Based on C* values, the ranking of the alternatives in descending order is C D F E. The results indicate that C and D are better alternative with C* value of 0.8771, 0.7173. other C* values were lower. It indicates that C and D have their obvious advantages and others have larger gap compare to C, D.

Table.3 Related indexes and ranking

Supermarket	d^+	d^-	C^*	*Ranking*
D	*9.42E-06*	*2.39E-05*	*0.7173*	*2*
C	*6.18E-06*	*4.41E-05*	*0.8771*	*1*
F	*2.83E-05*	*7.20E-06*	*0.2030*	*3*
E	*4.80E-05*	*2.92E-06*	*0.0574*	*4*

Conclusion

Evaluating food supplier is difficult, because it has many characteristics that set it apart from other performance. This paper has attempted to present a framework that simplifies and reduces the complexities of food supplier evaluation so that the manager can easily judge the performance of food supplier. In this paper, we mainly focused on the use of multi-criteria decision making framework for composite index research in the context of food supplier. In doing so, the entropy and AHP method were used to determine weight of each indicator, and TOPSIS method was proved valuable for food supplier performance evaluation. Comparing with other evaluation methods, the Entropy-AHP-TOPSIS method is simple, clear and reasonable. Therefore, the method should be widely used to the food supplier evaluation.

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