

Research Article

Low Carbon Supply Chain's Performance Evaluation Based on Entropy Method and Fuzzy Comprehensive Evaluation Method

^{1,2}Xu Xu, ¹Liu Wei and ³Pei-hua Wang

¹Institute of Transportation, Shanghai Maritime University, Shanghai 201306, China

²Department of Logistics Management, Shanghai Dianji University, Shanghai 201306, China

³College of Information Technology, Shanghai Ocean University, Shanghai 201306, China

Abstract: This study constructed a performance evaluation index system of low carbon supply chain from the economic, resources and environment. This index system highlights the environmental value orientation and green culture technology evaluation. On this basis, uses entropy value method to definite the index system of index weigh and uses the fuzzy comprehensive evaluation method to establish the evaluation model. It overcomes the respective faults of the entropy value method and fuzzy comprehensive evaluation method and makes low carbon supply chain performance evaluation more scientific and accurate. Finally, the model was verified analysis.

Keywords: Entropy method, fuzzy comprehensive evaluation method, low carbon supply chain, performance evaluation

INTRODUCTION

Low carbon economy and circular economic development mode is also arises at the historic moment with severe challenges of global climate warming to human survival and development. Huang and Zhang (2010) with low carbon economy and circular economy development, low carbon supply chain researches also gradually become a hot spot. Low carbon supply chain (Qian, 2010) is the concept of green and environmental awareness into the entire supply chain management process, it operates based on green manufacturing theory and supply chain management technique and it manages and controls the whole supply chain process including design, procurement, production, packaging, transportation, sales, consumption and recycling, so that the whole supply chain of resource consumption and environmental impact of minimum, is to achieve social, business and the natural environment of common and sustainable development of a new strategic mode. This (Xu, 2011) can not only give enterprise to bring better economic benefit and can give the society brings the environmental benefits and to promote the enterprise in social image and status. The low carbon supply chain (Zhang, 2010) can help enterprises to improve production efficiency, enhance core competitiveness and can be that enterprise to reduce the environmental pollution and resource consumption, it (Guo, 2009) may be said is to realize the enterprise and social win-win. Low carbon supply chain (Zhang, 2006) in the cycle economy and low carbon economic development process, harmonizing environmental and economic

development and ensure the sustainable development of economy important role, so performance effective scientific and reasonable evaluation on low carbon supply chain management is one of the most important problems.

LOW CARBON SUPPLY CHAIN PERFORMANCE EVALUATION INDEX SYSTEM CONSTRUCTION

Low carbon supply chain performance evaluation index selection (Liu, 2008) mainly comes from the traditional supply chain performance evaluation index, many scholars only in traditional index system and a green index or environmental index (Liu and Jiao, 2011) no thinning. In order to highlight the green concept, in this study, the low carbon supply chain performance evaluation index system construction, from economy, resources and environment three into consideration, the low carbon supply chain is embodied in the green concept of the supply chain in each link. In addition to the traditional supply chain performance evaluation index outside, increase the environmental performance (Zhang, 2011) and will further refinement for resource utilization (Wen, 2011), environmental protection (Sarkis, 2003) green culture three aspects, by using factor analysis, the influence factors of low carbon supply chain screening, to determine the level of low carbon supply chain evaluation system structure (Nagel, 2003) five level index, subdivided into 29 secondary index, Specific as is shown in Table 1. One class index of low carbon supply chain integrated

Table 1: Green supply chain performance evaluation index system

One class index	Secondary indexes
Financial value(u1)	Supply chain cash turnover (u ₁₁)
	Supply chain profit growth (u ₁₂)
	Supply chain return on equity (u ₁₃)
	Safety delivery ratio (u ₂₁)
	Product quality percent of pass (u ₂₂)
Customer service (u ₂)	The customer approval green (u ₂₃)
	Customer complaints (u ₂₄)
	Order complete ratio (u ₂₅)
	Delivery accuracy (u ₂₆)
	Logistics cost (u ₃₁)
Cost management (u ₃)	Information cost (u ₃₂)
	Operation unit cost (u ₃₃)
	Recycling cost (u ₃₄)
	Pollutants processing cost (u ₃₅)
	Production flexibility (u ₄₁)
Business process (u ₄)	The product added value (u ₄₂)
	Product demand (u ₄₃)
	Product sales (u ₄₄)
	reaction time flexible (u ₄₅)
	Raw material and energy comprehensive utilization (u ₅₁)
Resource utilization (u ₅)	Resources using rate (u ₅₂)
	Product waste recovery (u ₅₃)
	Control pollutant level (u ₆₁)
Environmental protection (u ₆)	Environmental pollution level (u ₆₂)
	Environment recovery level (u ₆₃)
	Environmental value orientation (u ₇₁)
	Environmental consciousness (u ₇₂)
Green culture (u ₇)	Education degree (u ₇₃)
	Green culture technology (u ₇₄)

performance evaluation system mainly includes: financial value (Horse *et al.*, 2011). customer service (Sun, 2007) cost management (Li, 2011) business process (Chen and Shi, 2006) resource utilization (Xu, 2011) environmental protection (Ma, 2009) green culture (Xu, 2011).

Low carbon supply chain performance evaluation index system includes not only the basis of evaluation index and considering the environmental value orientation, green culture technology and a lot of environmental protection input use condition, increased the environmental protection and green culture index, not only emphasized the supply chain performance evaluation of the main quantitative index, but also further strengthen the green evaluation of quantitative and qualitative analysis.

Entropy value method to definite index weight:

Constructing evaluation information matrix: With m level evaluation index, a level of evaluation index has n two level of evaluation index, there gets the original evaluation information matrix :

$$A = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \dots & \dots & \dots & \dots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix}$$

Two level indexes can be divided into larger enterprises more favorable benefit index, such as supply chain profit growth rate, net asset profit rate, safe delivery rate; there are divided into smaller enterprises more adverse cost index, such as the logistics cost, information cost, customer complaint rate.

Degree index quantification and entropy value: Due to the different index measure is differ, so need to evaluation indexes and quantitative degrees. Unison quantitative method is as follows:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}}$$

For efficiency index as follows:

$$P_{ij} = \frac{X_{ij}}{\sum_{j=1}^n X_{ij}}$$

For cost type index, is not quite same, in order to make its base and consistent efficiency index, then the following treatment:

$$P_{ij} = \frac{1/x_{ij}}{\sum_{i=1}^m (1/x_{ij})}$$

It can be concluded that decision matrix, are as follows:

$$A = \begin{bmatrix} P_{11} & P_{12} & \dots & P_{1n} \\ P_{21} & P_{22} & \dots & P_{2n} \\ \dots & \dots & \dots & \dots \\ P_{m1} & P_{m2} & \dots & P_{mn} \end{bmatrix}$$

Thus, computing the first j indexes of entropy value is:

$$e_j = -k \sum_{i=1}^m P_{ij} \ln P_{ij}$$

$$k = \frac{1}{\ln m}, m \text{ for enterprise's number.}$$

Calculation index weight: In the calculation of the index weight, the need to identify the j index of difference coefficient g_j . For a given J, x_{ij} difference is small, then the more. When x_{ij} are all equal, the $e_j = e_{max} = 1$, at this time the plan comparison, index x_{ij} are no effect. When the scheme is larger when the index value, the smaller e_j , shows the indicators for the

comparison are more greater roles, the define difference coefficient g_j , $g_j = 1 - e_j$, The greater the g_j , index is important. At this time difference coefficient vector $G = (g_1, g_2, g_m)$. Have the above foundation, the index weight is determined as:

$$W_j = \frac{g_j}{\sum_{j=1}^n g_j}, (j = 1, 2, 3, \dots, n)$$

PERFORMANCE EVALUATION

To establish fuzzy comprehensive evaluation factor set and evaluation set: According to the evaluation index system, the establishment of three layer evaluation object factors set, the $U_1, U_2, U_3, U_4, U_5, U_6, U_7$, are the behalf of the financial value, customer service, cost management, business process, resource utilization and environmental protection, green culture:

$$\begin{aligned} u &= \{u_1, u_2, u_3, u_4, u_5, u_6, u_7\} \\ u_1 &= \{u_{11}, u_{12}, u_{13}\} \\ u_2 &= \{u_{21}, u_{22}, u_{23}, u_{24}, u_{25}, u_{26}\} \\ u_3 &= \{u_{31}, u_{32}, u_{33}, u_{34}, u_{35}\} \\ u_4 &= \{u_{41}, u_{42}, u_{43}, u_{44}, u_{45}\} \\ u_5 &= \{u_{51}, u_{52}, u_{53}\} \\ u_6 &= \{u_{61}, u_{62}, u_{63}\} \\ u_7 &= \{u_{71}, u_{72}, u_{73}, u_{74}\} \end{aligned}$$

To establish evaluation set $v = \{v_1, v_2, \dots, v_n\}$. Here use {optimal, good, good, in general, the difference} four ranks, general evaluation grade matrix for [100, 80, 60 and 40].

Fuzzy evaluation method: Fuzzy evaluation method mainly divided into single factor fuzzy evaluation and multi-factor comprehensive evaluation, including single factor fuzzy evaluation:

$$f : U \rightarrow \phi(V) : u_i \mapsto f(u_i) = (r_1, r_2, \dots, r_m) \in \phi(V)$$

For weight $A = (a_1, a_2, \dots, a_n)$, according to the fuzzy mathematical evaluation model formula: $A * R = B$, carries on the fuzzy overall assessment operation. Here the given $B = (b_1, b_2, \dots, b_n)$ is a general assessment results. Then according to the maximum membership principle, b_j of numerical biggest b_j max of the corresponding level V_j is the comprehensive evaluation results and evaluation object of low carbon supply chain performance level.

The empirical analysis: This study selects a low carbon supply chain enterprise member, the experts

Table 2: The index weight by entropy value method

	weight	Membership degree R_i			
		Optimal	Good	General	Poor
u ₁₁	0.3442	0.1	0.3	0.4	0.2
u ₁₂	0.3396	0.3	0.2	0.3	0.2
u ₁₃	0.3162	0.15	0.3	0.35	0.2
u ₂₁	0.1672	0.3	0.3	0.2	0.2
u ₂₂	0.6306	0.3	0.4	0.2	0.1
u ₂₃	0.0216	0.5	0.2	0.2	0.1
u ₂₄	0.0358	0.2	0.3	0.3	0.2
u ₂₅	0.0575	0.3	0.3	0.2	0.2
u ₂₆	0.0873	0.3	0.3	0.2	0.2
u ₃₁	0.5017	0.3	0.2	0.3	0.2
u ₃₂	0.2598	0.4	0.3	0.2	0.1
u ₃₃	0.1062	0.4	0.3	0.1	0.2
u ₃₄	0.0858	0.4	0.3	0.2	0.1
u ₃₅	0.0465	0.4	0.3	0.2	0.1
u ₄₁	0.0542	0.3	0.3	0.2	0.2
u ₄₂	0.0859	0.4	0.3	0.2	0.1
u ₄₃	0.3871	0.2	0.4	0.2	0.2
u ₄₄	0.3765	0.3	0.3	0.4	0.4
u ₄₅	0.0963	0.3	0.3	0.2	0.2
u ₅₁	0.4789	0.4	0.3	0.2	0.1
u ₅₂	0.4651	0.4	0.4	0.3	0.1
u ₅₃	0.0560	0.3	0.3	0.3	0.1
u ₆₁	0.6361	0.4	0.3	0.2	0.1
u ₆₂	0.3271	0.4	0.3	0.3	0.1
u ₆₃	0.0368	0.4	0.3	0.2	0.2
u ₇₁	0.2378	0.4	0.4	0.2	0.2
u ₇₂	0.2291	0.4	0.2	0.4	0.1
u ₇₃	0.3961	0.4	0.4	0.1	0.1
u ₇₄	0.1370	0.3	0.4	0.2	0.1

marking method, for establishing green supply chain performance evaluation indexes of the score. The whole of low carbon supply chain performance evaluation level is divided into four levels: optimal (v_1), good (v_2), general (v_3), poor (v_4). Using the entropy value method and fuzzy comprehensive evaluation method evaluates the green supply chain.

To establish the weight set: In order to overcome the analytic hierarchy process and entropy value method shortcomings, making the determination of weight is more reasonable and reliable. Comprehensive entropy value method and analytic hierarchy process to determine the index measure layer, criterion layer index weights and fuzzy evaluation matrix R_i . Use above calculation method, to determine the weights of the Table 2.

MODEL OPERATION

According to the applied mathematics model:

$$A_i * R_i = B_i$$

$$(a_{i1}, a_{i2}, a_{i3}, \dots, a_{ij}) \begin{bmatrix} r_{i11} & r_{i12} & r_{i13} & r_{i14} \\ r_{i21} & r_{i22} & r_{i23} & r_{i24} \\ \dots & \dots & \dots & \dots \\ r_{ik1} & r_{ik2} & r_{ik3} & r_{ik4} \end{bmatrix} = (b_{i1}, b_{i2}, b_{i3}, b_{i4})$$

Fuzzy subset $B_i = (b_{i1}, b_{i2}, b_{i3}, b_{i4})$ ($i = 1, 2, 3, 4, 5, 6, 7$), $b_{ij} \in [0,1]$ is the first level of comprehensive evaluation results, says the U_i ($i = 1, 2, 3, 4, 5, 6, 7$) range each one class index in the optimal, good, in general, the difference of the membership. Then:

$$R = \begin{matrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \\ B_7 \end{matrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \\ b_{51} & b_{52} & b_{53} & b_{54} \\ b_{61} & b_{62} & b_{63} & b_{64} \\ b_{71} & b_{72} & b_{73} & b_{74} \end{bmatrix} = \begin{bmatrix} 0.18 & 0.27 & 0.35 & 0.20 \\ 0.30 & 0.35 & 0.20 & 0.13 \\ 0.35 & 0.25 & 0.24 & 0.16 \\ 0.27 & 0.34 & 0.28 & 0.27 \\ 0.39 & 0.35 & 0.88 & 0.10 \\ 0.40 & 0.30 & 0.23 & 0.10 \\ 0.39 & 0.35 & 0.21 & 0.12 \end{bmatrix}$$

Weight vector $A = (a_1, a_2, a_3, a_4, a_6, a_7)$, According to the fuzzy mathematical evaluation model formula, $A * R = B$, then to the second level of fuzzy comprehensive evaluation arithmetic:

$$\begin{matrix} (a_{i1}, a_{i2}, a_{i3}, a_{i4}, a_{i5}) \end{matrix} \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ \dots & \dots & \dots & \dots \\ b_{71} & b_{72} & b_{73} & b_{74} \end{bmatrix}$$

$$= (0.2890, 0.1920, 0.2405, 0.1031, 0.0832, 0.0473, 0.0449)$$

$$* \begin{bmatrix} 0.18 & 0.27 & 0.35 & 0.20 \\ 0.30 & 0.35 & 0.20 & 0.13 \\ 0.35 & 0.25 & 0.24 & 0.16 \\ 0.27 & 0.34 & 0.28 & 0.27 \\ 0.39 & 0.35 & 0.88 & 0.10 \\ 0.40 & 0.30 & 0.23 & 0.10 \\ 0.39 & 0.35 & 0.21 & 0.12 \end{bmatrix}$$

$$= (b_1, b_2, b_3, b_4) = (0.29, 0.30, 0.32, 0.17)$$

The $B = (b_1, b_2, b_3, b_4)$ is the overall evaluation result. According to the principle of maximum membership, b_j of numerical biggest b_j max of the corresponding level V_j namely for this enterprise risk level.

From the calculate result can see, matrix B of the maximum membership degree is 0.32, this enterprise low carbon supply chain performance in the poor level.

CONCLUSION

On the basis of previous research, build up the green supply chain performance evaluation index system and the entropy method and fuzzy comprehensive evaluation method to the evaluation of combination of system analysis, to overcome the entropy method and fuzzy comprehensive evaluation of the shortcoming of the method, the green supply chain performance evaluation more scientific and accurate. But in this study, the selected indices need to be further validated in practice, to keep pace with the times, green

supply chain in the development of practical experience, some of these evaluation indicators of adjustment and development, so that in the green supply chain evaluation is more general and practical. At the same time, this study selected the method may have certain flaws, this also required in later practice in continuous verification, best to introduce some other research methods or the method introduced in this study the combination, the green supply chain performance to evaluate a system more perfect, scientific, accurate, so as to get a more substantial development.

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