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Research on Performance Measurement of Green Supply Chain Management

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Abstract. In this paper, using SCOR model as a framework of green supply chain, the authors establish the indicator system of overall performance evaluation on the green supply chain from the finance, operations and environment of the supply chain. According to the characteristics of the multi-level performance evaluation system and the fuzzy comprehensive evaluation method, the authors build the enterprise performance evaluation model on the green supply chain management. Using the implementation of the green supply chain on the Wilsonart Company as a case, the authors analyze and test that the green supply chain management can improve the overall performance of enterprises.

Keywords: green supply chain, performance evaluation, multi-objective evaluation, fuzzy comprehensive evaluation

1. Introduction

In recent years, the green supply chain management is increasingly becoming an important strategy for the sustainable development of the enterprises, which is the enterprise to obtain and enhance the international competitiveness in an effective manner. The green supply chain is a kind of modern management mode which is integrated the thoughts of the environmental protection.

2. The SCOR model of the green supply chain

The full name of the SCOR model was the Supply-Chain Operation Reference, which was proposed by the National Supply Chain Council in 1997. The SCOR model is able to measure and improve the internal and external business processes of the corporate, and it also guides the strategic management of the enterprises. Therefore, in the study of the performance evaluation of the the green supply chain the enterprises will inevitably have to refer to the mind and analysis of the mechanism of the SCOR model. Based on the SCOR model of the original supply chain the SCOR model is nested the green manufacturing ideas. It requires the design staff of the supply chain consider fully the whole life cycle of the product in the beginning design, from all the factors of the conception to the product scrap, which includes the quality, cost, schedule, user requirements, optimal use of the resources, waste generation and the recovery of materials and so on. The entire supply chain is divided into the purchasing, the manufacturing, the marketing and the recycling links, each link following the requirements of the green manufacturing (see Figure 1).

3. The introduction of the Wilsonart Company

The Wilsonart Company was founded in 1912, whose headquarter lied in Chicago. It had more than 700 operators and 50,000 employees in 48 countries, whose annual sales were beyond 10 billion dollars. It is the key that the Wilsonart Company kept in close contact and the long-term cooperation with its suppliers. From the suppliers to the customers as a throughout process, the work of the Wilsonart Company is the direct, cost savings and environmental protection. In 1996, the Wilsonart Company built its Asia headquarters in China.

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Today, the Wilsonart Company produces tens of thousands fireproof boards on a daily to the world on a daily for the supply to the whole world. In addition, the Wilsonart Company has been obtained the factory certificate of the Chinese class and Chinese symbol certificates of the green materials.

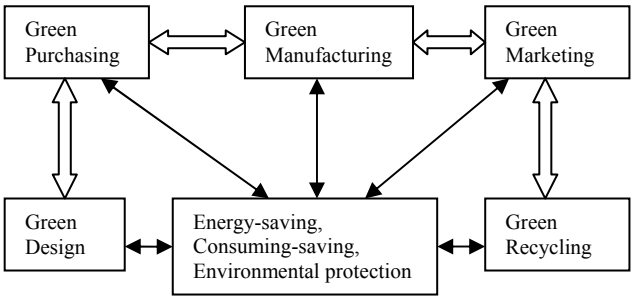

Fig. 1: The SCOR model diagram of the green supply chain

4. The model of the comprehensive performance evaluation

4.1. Establishing the set of the evaluation index

The authors consider the comprehensive performance is made up of the accounts performance, the operating performance and the environmental performance. The target layer is divided into two-layer for the first-level indicator and the second-level indicator, therefore, this paper uses the two-level fuzzy comprehensive evaluation method (see Table 1). Based on the indicator system, the authors suppose the first indicator set is "$A=\{A: A_1, A_2, A_3\}$". Setting up the first-level indicator, $A_i\ (i=1,2,3)$, its each index includes G_i the second-level indicators ,which are recorded $A_i=\{A_{i1}, A_{i2}, \cdots, A_{Gi}\}\ (i=1,2,3)$. One of them A_{ij} is said that j the second-level indicators of the first-level indicator A_i. The set of the second-level indicator is $A_1=\{A_{11}, A_{12}, A_{13}, A_{14}, A_{15}, A_{16}, A_{17}, A_{18}, A_{19}\}$. As a result, we can write A_2, A_3.

4.2. Establishing the weight coefficient matrix

Supposing weight for $W\ (i=1,2,3)$, then the first-level weight set is $W=\{W_1, W_2, W_3\}\ (0<W<1)$. Supposing the weight coefficient of the second-level indictor A_{ij} is $w_{ij}=\{w_{ij}\,|\,i=1,2,3; j=1,2\cdots G_i; 0<W<1\}$.

We can record： $W_1=\{w_{11}, w_{12}, w_{13}, w_{14}, w_{15}, w_{16}, w_{17}, w_{18}, w_{19}\}$. As a result, similarly W_2, W_3.

Table 1: The evaluation indicators factors about the Green supply chain performance

Target layer	*The first-level indicator*	*The second-level indicator*
The comprehensive performance of the green supply chain A	The accounts performance of the supply chain A_1	1. Amount of environmental investment A_{11}; 2. Green operating costs A_{12}; 3. Training costs A_{13}; 4. Procurement costs of the green material A_{14}; 5. Proceeds of the recycled materials to be used A_{15}; 6. Energy consumption costs A_{16}; 7. Waste disposal costs A_{17}; 8. Waste discharge fees A_{18}; 9. Costs of the environmental accidents to be punished A_{19}.
	The operating performance of the supply chain A_2	1. Timely supply capacity of the products A_{21}; 2. Inventory efficiency A_{22}; 3.Corner material A_{23}; 4.Product quality A_{24}; 5.Efficiency of the production lines A_{25}; 6.Production capacity A_{26}; 7.Rate of the sales growth A_{27}; 8.Rate of the new Products Development A_{28}.
	The environmental performance of the supply chain A_3	1.Exhaust emissions A_{31}; 2.Wastewater discharge A_{32}; 3.Solid waste disposal A_{33}; 4.Use of dangerous, toxic, hazardous materials A_{34}; 5.Degree of the enterprises environmental conditions to be improved A_{35}; 6.Rate of the energy consumption A_{36}; 7.Environmental violations ratio A_{37}; 8.Recycling efficiency of the abandoned materials A_{38}.

4.3. The steps of the fuzzy comprehensive evaluation

- Determining the reviews set

The evaluation results of every indicators of the environmental performance evaluation system of the green supply chain is divided into 5 grades, which are excellent, good, medium, qualified, and poor. Using 100 points is said excellent, successive declining, and 20 points is considered bad. The reviews set are: $S=\{excellent, good, medium, qualified, poor\}=\{100,80,60,40,20\}$.

- Finding the evaluation matrix

The results Y_{ij} of each single factor of the fuzzy comprehensive assessment constitute together a high-level evaluation matrix R_i. Using the same method, R_i will be multiplied by the weight coefficient matrix W_i, finding the results Y_i of the comprehensive assessment of the evaluation factors set of the order i, using Y_i to constitute a higher-level matrix R, the last to seek a comprehensive evaluation matrix, Y and the matrix is the results of the comprehensive evaluation, that is, $Y = W \cdot R = \{Y_1, Y_2, \cdots, Y_g\}$.

Finally, calculating a composite score $M = Y \cdot S^T$, M is the comprehensive performance score, and Y is the final comprehensive evaluation matrix, and S is to the row vector of the evaluate grade-point, and S^T is the transfer matrices about S. The overall performance score of every level index can be also derived, as follows: $M_k = Y_k \cdot S^T$. The value M reflects the strengths and weaknesses of the different evaluation indicators, which provides a scientific basis for the environmental performance assessment of the green supply chain.

4.4. Analyzing the assess results

Using this method can calculate the comprehensive performance of the enterprises and all levels performance of the green supply chain. (1) If $M / M' > 1.1$, the implementation of the green supply chain management improves the enterprise performance. (2) If $M/M' \leq 1.1$, the implementation of the green supply chain management does not increase the overall enterprise performance.

5. The performance evaluation of the Wilsonart Company

5.1. Writing the fuzzy relationship matrix

Investigating the top 45 persons in the company management and the technical staff, 45 questionnaires are returned, but the authors obtain 40 valid questionnaires. In 40 valid questionnaires, 16, 12, 8, 4and 0 questionnaires respectively play very good, better, ordinary, poor and very poor. Then the fuzzy membership degree of all reviews set are 16/40 = 0.40, 12 / 40 = 0.30, 8 / 40 = 0.20, 4 / 40 = 0.10, 0 / 40 = 0. We can write $R_{11} = (0.40, 0.30, 0.20, 0.10, 0)$. According to this way, we can also obtain R_{12}, R_{13}, R_{14}, R_{15}, R_{16}, R_{17}, R_{18}, R_{19}. Therefore the fuzzy relation matrix of the financial performance may be recorded R_1. Similarly, we can also write the fuzzy relationship matrix of the operation performance and the environmental performance.

$$R_1 = \begin{pmatrix} 0.40 & 0.30 & 0.20 & 0.10 & 0 \\ 0.50 & 0.15 & 0.30 & 0.05 & 0 \\ 0.10 & 0.20 & 0.15 & 0.40 & 0.15 \\ 0.25 & 0.15 & 0.20 & 0.35 & 0.05 \\ 0.35 & 0.40 & 0.05 & 0.20 & 0 \\ 0.30 & 0.45 & 0.15 & 0.05 & 0.05 \\ 0.10 & 0.15 & 0.45 & 0.20 & 0.10 \\ 0.50 & 0.30 & 0.10 & 0.10 & 0 \\ 0.70 & 0.10 & 0.10 & 0.10 & 0 \end{pmatrix} \quad R_2 = \begin{pmatrix} 0.30 & 0.40 & 0.20 & 0.10 & 0 \\ 0.40 & 0.45 & 0.10 & 0.05 & 0 \\ 0.30 & 0.25 & 0.30 & 0.10 & 0.05 \\ 0.70 & 0.10 & 0.10 & 0 & 0.10 \\ 0.20 & 0.40 & 0.30 & 0.10 & 0 \\ 0.25 & 0.35 & 0.20 & 0.10 & 0.10 \\ 0.60 & 0.20 & 0.10 & 0 & 0.10 \\ 0.55 & 0.30 & 0.15 & 0 & 0 \end{pmatrix} \quad R_3 = \begin{pmatrix} 0.75 & 0 & 0.20 & 0.05 & 0 \\ 0.50 & 0.30 & 0.15 & 0.05 & 0 \\ 0.40 & 0.35 & 0.15 & 0.05 & 0.05 \\ 0.80 & 0.10 & 0 & 0.10 & 0 \\ 0.50 & 0.20 & 0.20 & 0 & 0.10 \\ 0.70 & 0.20 & 0.10 & 0 & 0 \\ 0.90 & 0.10 & 0 & 0 & 0 \\ 0.65 & 0.10 & 0.10 & 0.05 & 0.10 \end{pmatrix}$$

5.2. Calculating each weight factor of the second-level indicator

$$W_1 = (0.12 \quad 0.19 \quad 0.04 \quad 0.24 \quad 0.09 \quad 0.13 \quad 0.05 \quad 0.06 \quad 0.08)$$

$$W_2 = (0.16 \quad 0.06 \quad 0.04 \quad 0.20 \quad 0.13 \quad 0.15 \quad 0.14 \quad 0.12)$$

$$W_3 = (0.14 \quad 0.09 \quad 0.04 \quad 0.24 \quad 0.07 \quad 0.18 \quad 0.06 \quad 0.18)$$

The weight factor of the first-level indicator of the overall performance evaluation of the Wilsonart Company may be defined $W = (0.30 \quad 0.40 \quad 0.30)$.

5.3. Determining the matrix of the reviews set

$$S = (100 \quad 80 \quad 60 \quad 40 \quad 20)$$

5.4. Finding the evaluation matrix

$Y_k = W_k \cdot R_k, (k = 1,2,3)$ .We can obtain $Y_1 = W_1 \cdot R_1 = (0.369 \quad 0.237 \quad 0.196 \quad 0.169 \quad 0.029)$. Similarly, we can obtain Y_2, Y_3 in turn.

The total membership matrix is $R = \begin{pmatrix} 0.369 & 0.237 & 0.196 & 0.169 & 0.029 \\ 0.438 & 0.290 & 0.171 & 0.051 & 0.050 \\ 0.689 & 0.139 & 0.098 & 0.047 & 0.027 \end{pmatrix}$

The weight coefficient matrix of the first-level indicator is W . $W = (0.30 \quad 0.40 \quad 0.30)$.We can also write the comprehensive evaluation matrix. $Y = W \cdot R = (0.493 \quad 0.229 \quad 0.157 \quad 0.085 \quad 0.037)$.

5.5. Calculating the comprehensive performance score

Finally the comprehensive performance score is calculated. $M = Y \cdot S^T = 81.18$. The comprehensive performance score of every-level are respectively the accounts performance $M_1 = Y_1 \cdot S^T = 74.96$, the operating performance $M_2 = Y_2 \cdot S^T = 80.30$ and the environmental performance $M_3 = Y_3 \cdot S^T = 88.32$. The performance evaluation of the green supply chain is 81.18 points, whose basic assessment is good. The financial performance score, the operating performance score and the environmental performance score are respectively 74.96, 80.30 and 88.32. Namely, the Wilsonart Company's financial performance is lower, which need improve the financial performance by applicating the green supply chain management. However, its operating performance is very outstanding, and the environmental performance is very good. Sum up the Wilsonart Company's comprehensive performance is more excellent, but its performance is still inadequate.

5.6. Comparing the comprehensive performance before and after the implementation of the green supply chain

In this way, we can calculate the comprehensive performance and every-level performance before the implementation of the green supply chain. The comprehensive performance, the accounts performance, the operating performance and the environmental performance before the implementation is respectively $M' = 71.32$, $M_1' = 80.27$, $M_2' = 79.63$ and $M_3' = 52.97$. Using the benchmarking method, according to M and M' , we can calculate their ratio, whose result is $M / M' = 1.14 > 1.1$. The enterprise performance has markedly improved after the implementation of the green supply chain management, namely the Green supply chain management can improve the enterprise performance.

By the comparison of the performance indicators, we easily find the financial performance is a slight decrease after the implementation of the green supply chain, which explains the implementation increases the enterprise's costs. The operating performance declines slightly, which indicates the green supply chain little effect on the operating performance. The environmental performance substantially increase, which indicates the implementation of the green supply chain significantly enhances the level of the enterprise's environmental performance.

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