Improvement of Green Suppliers' Efficiency under GSCM

Lirong CHEN, Qiang LI, Shanshan WANG *
School of Computer science, Inner Mongolia University, Hohhot, People's Republic of China

ABSTRACT: During the implementation and diffusion of the green supply chain management, researches were focused on the focal enterprises, e.g. how to select suitable green supplier, instead, our work is trying to pay attention to green suppliers on how to improve the relative efficiency under green supply chain management. Data envelope analysis is used to evaluate the efficiency. Output indicators are determined according to the requirement from the downstream. The evaluation process is detailed through an illustrative application. According to the result analysis, the enterprises are clear about their position in peer companies and the deficiency, and this will help enterprises to improve the environment performance as well as financial performance.

KEYWORD: Green supplier; Environmental management; Data envelope analysis; Green supply chain management

1 INTRODUCTION

It is well known that "green" principles and strategies have become vital for companies as the public awareness increased against the environmental degradation. In order to improve their competitiveness in the international market, Chinese enterprises have to strengthen environmental management, and green supply chain management (GSCM) is effective to achieve this goal. In recent years, many domestic and foreign scholars engaged in research in this area. Such as: Zhu Qinghua, Wang Nengmin, Sarkis, etc. A growing number of green supply chain management (GSCM) studies have dealt with: the drivers for GSCM [1-2]; its practices [3]; the relationships between GSCM and its operational and/or economic performance [4]; green manufacturing and supply chain design [5] ; vendor selection index system design and models [6-8]; recent studies focus on the adoption of GSCMs in the innovation diffusion [9-10]. However, these scholarly works have primarily focused on the focal or large-sized buying firms, especially, to give advice on how to choose the right supplier, including the design of the index system and methodology; while, they scarcely took into account the suppliers in green supply chain.

Then for the green suppliers, as we all know, they are very important for the focal enterprises, and they are much more important for the whole supply chain.

During the GSCM practice, some have experienced or felt higher pressure from the focal enterprises or international customers, some are reactive and only to meet the regulations [11]. Many suppliers want to and are willing to work with their customers in meeting the customer's environmental standards and establishing environmental leadership. After all, good environmental practices should increase efficiency and competitiveness, and save money. Commercial firms have had early success using green SCM principles. Texas instruments, Commonwealth Edison, pepsi-Cola, Dow Corning and so on. Furthermore, meeting customer requirements usually means continued business, but how to meet the requirements from customers while maintaining their profit. In fact, Chinese manufacturers are still in the early learning stage for GSCM [12]. GSCM has brought environmental performance improvement, but no significant improvement for both positive and negative financial performance [9]. So most of the suppliers are hesitate to take active practice and do not know how to implement GSCM while maintain reasonable profit. To achieve national or corporate environmental targets, the involvement of these green suppliers is vitally important [13]. This paper introduces data envelope analysis (DEA) to evaluate the efficiency of the green suppliers, and helps the suppliers to find the reasons for inefficiency.

The paper is organized as follows. In the next section, based on the definition of GSCM, the author describes connotation of green supplier. Following the next section, the research method, and explanation of the input and output. Then the author presents the process of evaluation on green suppliers through an illustrative application and highlights implications from the results. In the final section, the author addresses limitations of this study along with directions for future research.

2 GSCM AND GREEN SUPPLIERS

Before we go further about the green suppliers, we have to give it a clear definition. In [14], it denoted that: GSCM entails closing material cycles and preventing leakage of the materials in the chain. It takes the entire life cycle of a product into account, and it includes all the production and consumption processes, from the extraction of raw materials and the use of energy, to the dumping of waste. When integrated green SCM is realized, materials are reused or recycled, and no emissions and wastes should be generated. According to the idea of Life Cycle Analysis, all the entities that provide product and service for the downstream in the closed loop can be called suppliers. There are two kinds of enterprises: environmental reactivity who are typical of companies that only implement the minimal compulsory changes to meet regulations; environmental pro-activity who are typical of companies that voluntarily take measures to reduce their impact on the natural environment. No matter reactive or proactive suppliers, we all call them green suppliers, the difference lies in the extent of their greening practice. So the green suppliers can be farmers, production base, manufacturers, distributors, wholesalers, logistics and so on.

3 USING DEA TO EVALUATE RELATIVE EFFICIENCY OF THE GREEN SUPPLIERS

3.1 Methodology Introduction

There are many methods for assessment, and here we choose DEA model. DEA is an analytical procedure developed by Charnes et al. (1978) for measuring the relative efficiency of decision making units (DMUs) which perform similar activities involving multiple incommensurate inputs and outputs. DEA has its advantage in evaluation, for example: it is able to compare DMUs using different criteria, and the input and output do not need to have the same units of measurement, nor any predetermined functional relationship to each other. It identifies the efficient and inefficient units and provides targets for inefficient ones. So it is widely used when measuring the efficiency of multi-input and multi-output units [15-17].

3.2 Explanations of the Inputs and Outputs

Green suppliers have to meet the requirement of the customers with constrains of limited resources. So the requirements from the downstream can be the outputs, and resources that are used to supply the satisfied products and service are inputs. Lists are in the following tables.

Table 1. Input Indicators

Input indicators	Explanations
Total assets	All assets owned or controlled by the enterprise, it is the total items of assets in the corporate balance sheet.
Total working time	Equivalent employees working hours
Training cost	The investment used to train managers and employees
Environment investment	The investment on environment management, including investment on the new green technology, and the establishment of a specialized environmental management department.

Table 2. Output Indicators

Output indicators	Explanations
Quality	Measured by the rate of qualified products
Price	The advantage in price
Service	Level of service, mainly refers to the date of delivery
Environment performance	Waste emissions and energy consumption

For every enterprise, they want to gain larger outputs with fewer inputs, so generally, the inputs should be the indicators that are "the smaller the better". The input indicators are determined with careful consideration. For example, we use working hours of the workforce instead of number of employees, because overtime working should be considered. Whereas, output should be the indicators that are "the larger the better". Here it is different from that in the situation of selecting green suppliers by the downstream. For example, the customers hope the procurement price to be as low as possible, while for the suppliers, they want the price of the product or service to be higher, in this way, they can grab profit, and at the same time to maintain competence in the market. So here we make a little change on the indicator, take price for example, calculate the advantage of the price which equals to the maximum of price in the market minus the price of enterprise i.

$$p_i^{'} = \max\{p_i\} - p_i, i = 1, 2...n$$

The indicator of "service" is used the same method for processing. Denote D_i to be the date of delivery, $\max D = \max\{D_i, i = 1,2,...,n\}$, and the advantage is $D_i' = \max D - D_i$. For the indicator of environment performance we take the method in [16]. The performance is measured by "three wastes" emissions and energy consumption per unit of output. That is,

$$E_i' = \alpha_1 \cdot A + \alpha_2 \cdot W + \alpha_3 S + \alpha_4 \cdot E$$

Have $a_i, i = \{1,2,3,4\}$ is the weight of each items based on the local market conditions; A, W, S, E respectively, expresses waste gas, waste water, solid waste and energy consumption per unit of production value .Here we think it is better to take the production value into account, for our goal is to decrease the emission and energy consumption per unit production value. With the same reason as the above two indicators, we take the reciprocal of E_i at the same time, whether the supplier have been ISO14000 certified is an important factor during the customers' selection, denote C_i as the value of certification, if certified, then it is assigned 1, or else 0. So we combine C_i into this indicator. Then the value of environment performance is obtained by:

$$E_i = \frac{1}{E_i'} + C_i$$

4 AN ILLUSTRATIVE EXAMPLE

4.1 *DEA Assessment Simulation*

To detail the proposed DEA model, we provide an illustrative example. Although the illustrative example is not an actual application of a real world situation, it can tell the company how to evaluate the efficiency and how to analyze the result to get useful information for decision. Suppose a group company has several sub-companies. There are 18 DMUS, here are the inputs and outputs:

X=[650   750   600   350   600   800   700 1000   2000   1500   1300   1100   450   580 800   1400   1100   350; 1000   800   600   400 700   1000   900   1100   1500   2000   1500 1300   800   700   1000   1800   1300   400; 70 60   50   40   45   60   80   40   70   65   55   60 44   70   60   65 60   40; 80   70   60   50   80 90   70   100   110 120   120   120   68   80 90   120   120   50];

Y=[0.98   0.99   0.96   0.97   0.96   0.97 0.96   0.95   0.96   0.98   0.97   0.96   0.95   0.98

0.95   0.97   0.98 0.99;   0.1   0.3   0.2   0.3   0.4 0.2   0.1   0.09   0.08   0.5   0.15   0.1   0.15 0.18   0.09   0.15   0.18   0.4;   2   3   1   5   4 3   1   5   7   6   2   9   3   4   5   2   4   7;   0.9 1.2   0.7   0.8   0.9   1.5   1.6   1.85   1.95   1.7 0.8   0.7   1.5   1.6   1.85   0.8   1.75   1.9];

Here C^2R model is used to do the evaluation with Matlab for the calculation.

4.2 *Data Analysis*

According to the rules in [16-17], we can know DMU18 is efficient both in scale and in technology and the others are inefficien In fact, DMU18 is the unit we construct for purpose, which has the smallest inputs and the largest outputs, and it is to be the most efficient one. Compared to it, analysis of each unit's relative efficiency scores provides further insight into its deficiency, we can calculate the target for every inefficient unit, take unit1 as an example, $x_1' = \theta_1 x_1 - s_1^- = 0.6187*650 - 0.0557*103 = 346.46$, $x_2' = 396.43$, $x_3' = 39.609$, $x_4' = 49.5$ and $y_1' = y_1 + s_1^+ = 0.98$, $y_2' = 0.3960$, $y_3' = 6.9393$, $y_4' = 1.8808$, so we say, if the inputs and outputs reach the target, then unit 1 is efficient.

DMU1,3,4,6,7,8,11,13,14,15,16 are operating at increasing returns to scale, in this stage, if the input doubled, the output is greater than doubled, so the company can increase its input to get more output; while DMU2,5,18 are operating constant returns to scale, it means that the company doubles its input, then its output will be doubled; DMU9,10,13 are operating at decreasing returns to scale, in this situation, it is not wise to increase its input.

5 SUMMARY AND CONCLUSION

Helping the green supplier to be more efficient is very important in green supply chain management. A supplier management process model using DEA has been proposed in this paper. The outputs of the DMU are chosen from the index system for selecting good green suppliers, and the inputs are determined by requirement of the decision makers. So if the input indicators change, the relative efficiency of DMU will be changed. Detail data analysis was given here, enterprise knows where it is among their peers, and knows how to improve it. This will promote voluntary actions by companies to achieve their environmental goals. In addition, through the comparison, companies know their improvement direction and see the positive relationship between the environment practice and the financial performance and will go on a virtuous circle.

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