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# Evaluation of Green Supply Chain Management Practices Under Uncertainty Environment: Case Study in The Company for Batteries Industry

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**Abstract.** This work used a model of integrated the fuzzy set theory and Decision-Making Trial and Evaluation Laboratory to evaluate the green practices that can affect the green supply chain implementation in battery industry. The integrated fuzzy MCDM model is used to assess the GSCM performance in company based on green terms: green purchasing, green manufacturing, reverse logistic. Therefore, using fuzzy DEMATEL method to exploring the relationship between criteria and factors which affect other factors in GSCM. The hybrid approach presented an empirical analysis under linguistic preferences for the firm to find the critical practices that affected the GSCM performance and green practice implementation. The results showed that the economic performance and the revers logistic are the cause of the low environmental performance of the company and located in the cause group.

## 1. Introduction

In general, the industrial companies are under pressures and challenges to enhancing environment performance, so it tries to face these pressures by implement green activities to improve the competitive advantage. In recent years, the interest increases of industrial companies to applied GSCM practices in order to improve economic and environmental performance, it is necessary to achieve an evaluation to green practices in firms to find the weak and strong area in firm performance. Green supply chain management is approach that used to minimize or eliminate the negative effects of operations in firms on environment<sup>[1]</sup>. The green practices have become strong approach that applied to decrease the negative level of environmental impacts<sup>[2]</sup>. The negative impact on environment appears at production stages of product start from raw material extraction to final product (manufacturing, use, reuse, remanufacturing and disposal)<sup>[1]</sup>. There is a lot of concern among companies when implementing the GSCM, including lack of environmental knowledge, cost to replace new system, eco-technology, no government support and fear of failure. GSCM performance can be classify to main aspect and include operational, environmental and economic performance<sup>[3-6]</sup>. Integrating the environmental concept into supply chain activates change it into a green supply chain<sup>[7]</sup>. Therefore, achieve of appropriate green practices can improve economic and environmental performance and lead to a more sustainable industry. Many solutions have been proposed to enhance the environment al performance of the firms. Most of methods that are used to evaluate GSCM and its implication are empirical study based on a questionnaire distributed to respondents' experts and decision makers. An integrated fuzzy MCDM approaches is presented by Ozer Uygun and Ayse Dede for assessing and ranking the GSCM performance based on fuzzy (DEMATEL, ANP and TOPSIS) methods<sup>[8]</sup>. Ru-Jen Lin proposed a study based on fuzzy DEMATEL method to evaluated eight criteria of three major green concepts represented by external pressures, performance and practices<sup>[9]</sup>. Bukukozaan and Cifici proposed an integration method based



on DEMATEL, ANP and TOPSIS in fuzzy environment to evaluate green supplier <sup>[10]</sup>. Xiaojun Wang and Hing Kai Chan Proposed a hierarchical fuzzy TOPSIS approach to evaluate the green practices to enhance the performance when applied green practices in the supply chain <sup>[11]</sup>. A fuzzy-GRA method is proposed by Tseng and Chiu to select the green suppliers when evaluated GSCP <sup>[12]</sup>. In addition, Wu et al. assessed GSCP by using fuzzy DEMATEL to find the influence of green criteria on GSCM <sup>[13]</sup>, also Kusi-Sarpong et al. applied fuzzy-DEMATEL and ANP to determine the influence of GSCP on sustainable performance <sup>[14]</sup>.

Hence, implementing green concepts into batteries industry is essential to reduce environmental impacts and enhance market competition. The contribution of this study is to help managers in the company for batteries industry to improve their environmental images and enhance competitive position. The main aim of study is to explore the relationship between GSCM practices and their impact on the expected performance of company. Using fuzzy DEMATEL method to determine the interrelationship between the dimensions by use the triangular fuzzy numbers to express the linguistic values of experts' opinion in their responses to the questionnaire and integrated with dematel method to find the effect and cause interrelationship between GSCM practices.

## **2. Green supply chain management**

Green supply chain management is merge of green considerations in whole supply chain to improve the environmental performance. The concept of GSCM emerged in the early 1990s, but the interest of researchers in this concept increased after 2000 <sup>[4,15]</sup>. In reviewing the previous literature, there are several definitions of GSCM presented by researchers <sup>[16-22]</sup>. Referring to previous literature, the researchers determine the dimensions of the supply chain with different criteria suitable for the selected firms. There are many strategies that can be applied to improve the relationship between firms and environmental performance such as; eco-design, ISO 14000 standards, life cycle product analysis, GSCM <sup>[23, 24]</sup>

Green practices can be including several aspects such as green design, green purchasing, green manufacturing, green packaging, green logistic, reverse logistic, etc. GSCP attributes commonly expressed in a qualitative style which needs to human subjective perceptions. So, linguistic values always reflect fuzzy judgment of human <sup>[25]</sup>. One of the most important issues in GSCM is the process of evaluation and selection of important practices that improve the firm's performance and require increased attention.

## **3. GSCM practices**

Based on the previous literature and expert's opinions and field of selected company to conduct this study, three main criteria are determined as green purchasing, green manufacturing, reverse logistic and their impact on economic and environmental performance of the firm. All these criteria and sub criteria were used in evaluation process are shown in Table 1.

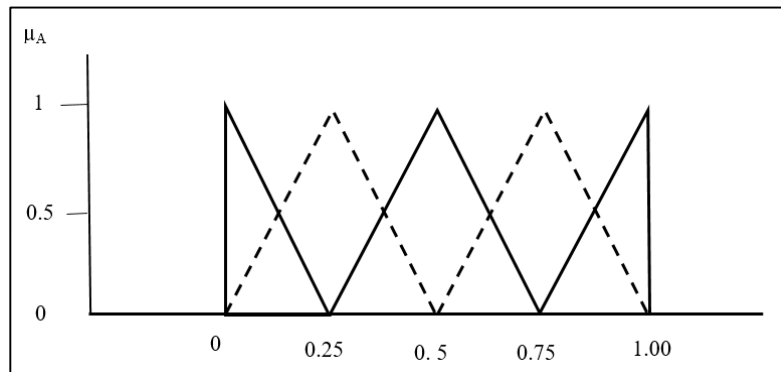
**Table 1.** GSCM practices.

GSCM	CODE	Practices	Reference
Green purchasing	D1	C1 Use of environmentally friendly technology C2 Supplier-Customer Collaboration C3 Suppliers' ISO14000 certification C4 Use environmentally friendly technique C5 Environmentally friendly transportation.	[8,26,27,28,29]
Green manufacturing	D2	C6 Cleaner production C7 Does not use hazardous materials and Minimize waste during production. C8 Use recycling material C9 Use of environmentally friendly technology for re-manufacturing C10 Recycle waste to produce environmentally-friendly products	[6,25,30]
Reverse logistic	D3	C11 Reuse of used parts or components. C12 Recondition and refurbishing of used parts or components. C13 Employee health and safety concerns while Transportation. C14 Using green fuels (liquid natural gas).	[6,8,10,29]
Economic performance	D4	C15 Reduce pollution sources and emissions C16 Reduce the use of hazardous and harmful material C17 Reduce environmental accidents C18 The company seeks to improve environmental performance C19 Use environmentally friendly techniques	[33,34]
Environmental performance	D5	C20 Reduced cost of purchasing material C21 Reduce cost of energy consumption C22 Reduce cost of data processing C23 Reduce cost of transportation and storage C24 Reduce fines for environmental accidents	[33,34]

#### 4. Fuzzy set theory

Fuzzy set theory is a method used to describe elements within a certain range between 0 and 1 by degree of membership [35]. It was proposed by Zadeh in 1965 to solve some of the problems facing decision makers, especially in fuzzy situations. Experts are exposed to issues that depend on human opinion, so there is uncertainty in the answer. A linguistic term will be used like "good", "bad" "very weak" to express the status of problem. Also, convert linguistic variable to fuzzy number to assess the case. A triangular fuzzy number is a common and easy method to help decision makers to describe the uncertainty situation and complete the calculation. Fuzzy set can be presented as  $M = (l, m, u)$  where  $l$ : lower,  $m$ : medium and  $u$ : upper boundaries. Fuzzy membership function is shown in figure 1.

$$\mu_A = \begin{cases} 0 & x < l \\ \frac{x-l}{m-l} & l \leq x \leq m \\ \frac{m-l}{u-x} & m \leq x \leq u \\ 0 & x > u \end{cases}$$



**Figure 1.** fuzzy membership functions for linguistic value.

### 5. Fuzzy DEMETAL method

The DEMATEL method was developed by Geneva Research Centre to solve complex problem for analysis the cause and effect relationships between factors of the system and find critical factors effect of complex system [31]. When dealing with inaccurate or ambiguous data, fuzzy DEMATEL method gives the best decision making under an uncertain environment. The steps of fuzzy DEMATEL are explained as follows:

1. Determine of evaluation criteria and building the linguistic scale as shown in Table 1.

**Table2.** The fuzzy linguistic scale

Linguistic Terms	Score	Triangular Fuzzy Numbers
No influence (N)	0	(0,0,0.25)
Very low influence (VL)	1	(0,0.25,0.50)
Low influence (L)	2	(0.25,0.50,0.75)
High influence (H)	3	(0.50,0.75,1.00)
Very high influence (VH)	4	(0.75,1.00,100)

2. Pair-wise comparisons were established based on set of expert decision making  $\tilde{Z}$  in the firm.

Where N number of experts.

$$\tilde{Z} = \frac{\tilde{z}^1 + \tilde{z}^2 + \dots + \tilde{z}^n}{N} \quad (1)$$

The initial direct-relation fuzzy matrix  $\tilde{Z}$  is take this form

$$\tilde{Z} = \begin{bmatrix} 0 & \tilde{z}_{12} & \dots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \dots & \tilde{z}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \dots & 0 \end{bmatrix}$$

3. Normalizing the initial direct-relation fuzzy matrix by calculate:

$$\tilde{X} = \begin{bmatrix} 0 & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & 0 & \dots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \dots & 0 \end{bmatrix}$$

where

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left( \frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r} \right) \quad (2)$$

And

$$r = \max_{1 \leq i \leq n} (\sum_{j=1}^n u_{ij}) \quad (3)$$

4. Finding the total-relation fuzzy matrix by define three crisp matrices.

$$X_l = \begin{bmatrix} 0 & \acute{l}_{12} & \cdots & \acute{l}_{1n} \\ \acute{l}_{21} & 0 & \cdots & \acute{l}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \acute{l}_{n1} & \acute{l}_{n2} & \cdots & 0 \end{bmatrix}$$

$$X_m = \begin{bmatrix} 0 & \acute{m}_{12} & \cdots & \acute{m}_{1n} \\ \acute{m}_{21} & 0 & \cdots & \acute{m}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \acute{m}_{n1} & \acute{m}_{n2} & \cdots & 0 \end{bmatrix}$$

$$X_u = \begin{bmatrix} 0 & \acute{u}_{12} & \cdots & \acute{u}_{1n} \\ \acute{u}_{21} & 0 & \cdots & \acute{u}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \acute{u}_{n1} & \acute{u}_{n2} & \cdots & 0 \end{bmatrix}$$

5. The total-relation fuzzy matrix can be calculated as:

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{z}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & 0 \end{bmatrix}$$

where

$$[l''_{ij}] = X_l \times (I - X_l)^{-1} \quad (4)$$

$$[m''_{ij}] = X_m \times (I - X_m)^{-1} \quad (5)$$

$$[u''_{ij}] = X_u \times (I - X_u)^{-1} \quad (6)$$

6. Find  $(\tilde{D}_i + \tilde{R}_i)^{def}$  and  $(\tilde{D}_i - \tilde{R}_i)^{def}$  values

$$\tilde{T}^{def} = \begin{bmatrix} \tilde{t}^{def}_{11} & \tilde{t}^{def}_{12} & \cdots & \tilde{t}^{def}_{1n} \\ \tilde{t}^{def}_{21} & \tilde{t}^{def}_{22} & \cdots & \tilde{t}^{def}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}^{def}_{n1} & \tilde{t}^{def}_{n2} & \cdots & 0 \end{bmatrix} \text{ where } \tilde{t}^{def}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij})$$

## 6. CFCS defuzzification method

There are many defuzzification techniques. The most common method is the Centre of gravity method but CFCS defuzzification method is employed to give a better crisp value than the Centroid method. Opricovic and Tzeng proposed a CFCS method for multi-criteria decision making which can distinguish two symmetrical TFN with the same mean, whereas the other methods do not distinguish between two such fuzzy numbers [32]

Steps of CFCS defuzzification method:

### 1. Normalization

$$R = \max_j u_{ij}, L = \min_j l_{ij} \text{ and } \Delta = R - L \quad (7)$$

$$x_{lj} = \frac{(l_{ij} - L)}{\Delta}, x_{mj} = \frac{(m_{ij} - L)}{\Delta}, x_{uj} = \frac{(u_{ij} - L)}{\Delta} \quad (8)$$

### 2. Find the left score (ls) & right score (rs) to normalized value:

$$x_j^{ls} = \frac{x_{mj}}{(1 + x_{mj} - x_{lj})} \text{ and } x_j^{rs} = \frac{x_{uj}}{(1 + x_{uj} - x_{mj})} \quad (9)$$

### 3. The total normalized crisp value can be finding as below:

$$x_j^{crisp} = \frac{[x_j^{ls} \times (1 - x_j^{ls}) + x_j^{rs} \times x_j^{rs}]}{[1 - x_j^{ls} + x_j^{rs}]} \quad (10)$$

### 4. Finding crisp value:

$$\tilde{f}_{ij}^{crisp} = L + x_j^{crisp} \times \Delta \quad (11)$$

## 7. Case study

A survey was conducted through the distribution of a questionnaire among four experts of the state company of batteries industry; the decision makers were an operations manager (DM1), a purchasing manager (DM2), recycling managers (DM3), and an environmental manager (DM4). The respondents were asked to assign a score to each criterion to determine its importance and also to rank practices based on various criteria independently. The five dimensions were green purchasing (D1), green manufacturing (D2), reverse logistic (D3) and their impact on economic (D4) and environmental performance (D5). The experts gave their opinion on the relationship between the various criteria and create a pairwise comparison matrix to determine the interrelationships between the practices. the initial direct-relation fuzzy matrix is shown in Table 2. The normalizing the initial direct-relation fuzzy matrix can be calculated by Eqs. (2) and (3) and shown in Table 3. The total-relation fuzzy matrix can be calculated by Eqs. (4)-(6) and shown in Table 4.

**Table 2.** The initial direct-relation fuzzy matrix.

	D1			D2			D3			D4			D5		
D1	0.00	0.00	0.25	0.50	0.75	0.88	0.31	0.56	0.81	0.44	0.56	0.81	0.63	0.88	0.81
D2	0.38	0.63	0.81	0.00	0.00	0.25	0.25	0.50	0.75	0.63	0.81	0.94	0.63	0.88	0.94
D3	0.38	0.63	0.81	0.44	0.69	0.94	0.00	0.00	0.25	0.44	0.63	0.81	0.75	1.00	0.81
D4	0.44	0.69	0.94	0.31	0.56	0.75	0.13	0.38	0.63	0.00	0.00	0.25	0.63	0.88	0.25
D5	0.75	1.00	1.00	0.63	0.88	0.94	0.44	0.69	0.88	0.56	0.81	0.94	0.00	0.00	0.94

**Table 3.** The normalizing the initial direct-relation fuzzy matrix.

	D1			D2			D3			D4			D5		
D1	0.00	0.00	0.05	0.11	0.16	0.19	0.07	0.12	0.17	0.09	0.12	0.17	0.13	0.19	0.17
D2	0.08	0.13	0.17	0.00	0.00	0.05	0.05	0.11	0.16	0.13	0.17	0.20	0.13	0.19	0.20
D3	0.08	0.13	0.17	0.09	0.15	0.20	0.00	0.00	0.05	0.09	0.13	0.17	0.16	0.21	0.17
D4	0.09	0.15	0.20	0.07	0.12	0.16	0.03	0.08	0.13	0.00	0.00	0.05	0.13	0.19	0.05
D5	0.16	0.21	0.21	0.13	0.19	0.20	0.09	0.15	0.19	0.12	0.17	0.20	0.00	0.00	0.20

**Table 4.** The total-relation fuzzy matrix

	D1			D2			D3			D4			D5		
D1	0.07	0.21	0.64	0.16	0.35	0.75	0.10	0.27	0.68	0.15	0.31	0.74	0.20	0.41	0.74
D2	0.14	0.34	0.77	0.06	0.21	0.65	0.09	0.26	0.68	0.19	0.36	0.78	0.20	0.41	0.78
D3	0.15	0.35	0.75	0.15	0.35	0.77	0.04	0.17	0.58	0.16	0.33	0.75	0.23	0.44	0.75
D4	0.14	0.33	0.64	0.12	0.30	0.60	0.06	0.22	0.53	0.06	0.19	0.50	0.19	0.39	0.50
D5	0.22	0.43	0.96	0.20	0.40	0.94	0.13	0.32	0.85	0.19	0.39	0.94	0.10	0.30	0.94

The total DEMATEL relation matrix is calculated by Eqs. (7)-(11) and shown in Table 5. The causal and effect diagram is configured to finding out cause and effect group. The horizontal axis represents the importance and called “prominence” that can calculate by  $(D + R)$  and the vertical axis that represents the “relation” and can calculated by  $(D - R)$ . the negative values on the diagram represents the effect group. The prominence and relation of each criteria for cause and effect group listed in Table 6. And drawing in Figure 2.

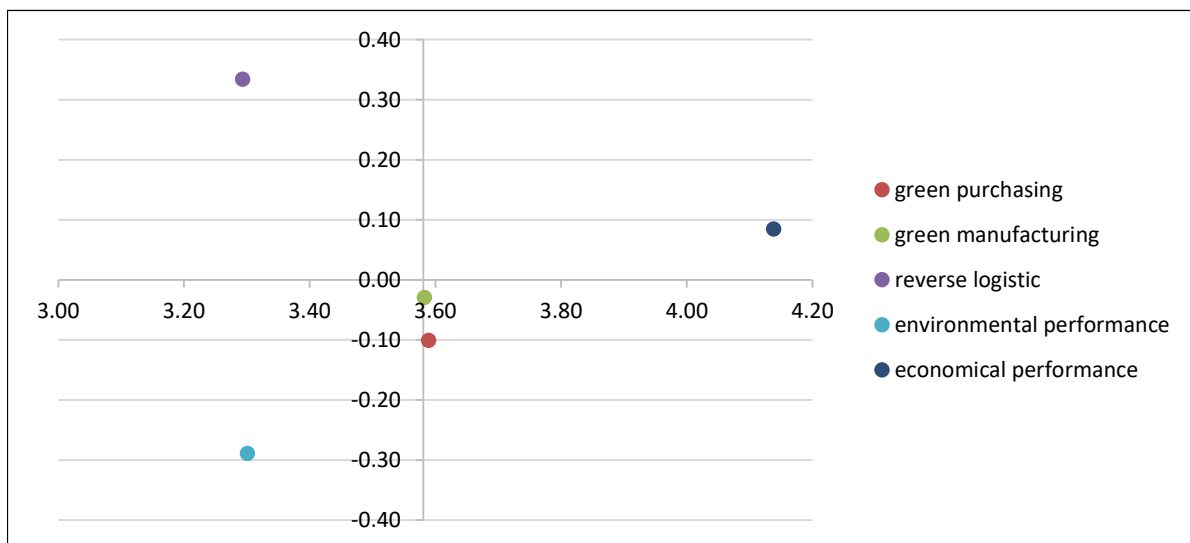
**Table 5.** The total DEMATEL relation matrix.

	D1	D2	D3	D4	D5
D1	0.270	0.382	0.314	0.359	0.420
D2	0.376	0.269	0.308	0.396	0.429
D3	0.381	0.386	0.227	0.374	0.445
D4	0.347	0.320	0.254	0.226	0.359
D5	0.471	0.450	0.376	0.440	0.374



**Table 6.** The prominence and relation of each criteria for cause and effect group.

<i>Criteria</i>	<i>D</i>	<i>R</i>	<i>D + R</i>	<i>D - R</i>
Green Purchasing	1.74	1.84	3.59	-0.10
Green Manufacturing	1.78	1.81	3.58	-0.03
Reverse Logistic	1.81	1.48	3.29	0.33
Environmental Performance	1.51	1.79	3.30	-0.29
Economic Performance	2.11	2.03	4.14	0.08

**Figure 2.** Cause and effect diagram

## 8. Results and discussions

From the result that found from the analysis process using fuzzy DEMATEL method, it was found that economic performance (D4) occurred in the first quarter of the causal and effect diagram. it represents factor of the cause group where it is one of the driving factors of the green supply chain that must be given extra attention to solve problems in the company. The main problem of company is financial problem related to self-financing. In addition to the obstacles facing the view of the company to improve its performance and increase profits in the presence of competitors. Economic performance has the highest value of  $(D + R)$  and this makes it a great ability to improve the system and has a great influence on other criteria.

The reverse logistic criteria (D3) occurred in the second quarter and was classified as one of the cause group. Reverse logistic has the greatest  $(D - R)$ , therefore has a significant impact on the system. in addition to, it is of high importance and little performance so must be given great importance and attention by the managers. Environmental performance (D5) appeared in the third quarter and this classifies the criteria of effect group and is a major problem experienced by the company in its transition to a green supply chain.

In the fourth quarter, both green purchasing (D1) and green manufacturing (D2) and it is belonging to effect group and independent factors affected by some other criteria with low degree of influence. These criteria are linked to the cause group where improved and increased attention to causal criteria, the performance of these criteria improve significantly.

## 9. Conclusion

The dimensions and criteria associated with GSCM have been determined. The interrelationship between the dimensions was found using fuzzy DEMATEL method. Also, finding the impact of each criterion on others. Based on result, the cause and effect groups were determined. The economic performance of company and the reverse logistic are among the most important factors affecting the performance of company. The cause group need more attention from the company in order to improve its performance in addition to reduce the environmental impact and increase its economic performance. The fuzzy DEMTAL approach used in this study proved effective in analysing the actual reality of the company. In addition, a clear image was given to the decision makers in the company to improve performance, which will affect the competitive advantage of the company.

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