Original Research

Identification and Assessment of Logistical Factors to Evaluate a Green Supplier Using the Fuzzy Logic DEMATEL Method

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Received: 4 June 2012
Accepted: 14 September 2012

Abstract

Increasing pressures and stringent environmental regulations and increased public awareness against environmental impacts in developing countries have caused companies to try increasing environmental sustainability activities and forced them to choose suitable suppliers to reduce environmental risks in supply chain management. Many management practices that contribute to improving a firm's environmental performance are developed in the area of logistics. According to high impacts of logistics management, the aim of this paper is using the fuzzy DEMATEL method to examine the influential logistical criteria of green supply chains, because the nature of supplier selection in green supply chains is a complex multi-criteria problem. Logistics factors in GSCM are categorized in 5 main criteria as: procurement logistics, production logistics, distribution logistics, disposal logistics, and reverse logistics.

Results show that environmentally friendly packaging (a distribution logistic factor) is more influential than other factors.

Keywords: green supply chain management, supplier assessment, logistics, fuzzy set theory, decision making trial and evaluation laboratory (DEMATEL)

Introduction

Many countries are moving toward globalization of their economies in order to lower production costs and services. This trend will be seen mostly in status of global production in Asia and developing countries in the following years [1]. Increasing the tendency for industrialization and globalization in developing countries has provided more opportunities for productive industries. But these factors have influenced the environment and increased environmental pressures [2]. With increasing environmental concerns over the past decade, we have enhanced environmental issues related to environmental pollution in the operational process of supply chain management, thus helping the initiative of green supply chain management (GSCM). All solutions, including logistics management for product lifecycle management, should be considered in a more comprehensive way [3, 4]. Hence, GSCM has emerged as an important approach to reducing environmental risks and environmental burdens in manufacturing and disposal, as well as enhancing profit and competitive advantages [5]. Firms adopt GSCM to improve competitive advantages and profits [6-9]. It is critically considered as a new concept that integrates environmental factors into supply chain manage-

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ment through production, procurement, distribution, and reverse and disposal logistics [5, 7, 10]. Environmental impact (e.g. air emissions) occurs at all stages of a product lifecycle from resource extraction to manufacture, use, reuse, recycle, and disposal [11]. Firms have applied green supply chain management in green manufacturing practices which include green design, green purchasing, product recovery and reuse, green product standards [12, 13], green purchasing, green distribution and reverse logistics refer to the involvement of environmental thinking into the supply chain management from the extraction of raw materials to product design, manufacturing processes, delivery of the final products to the consumers and end-of life management [7]. In the process of GSCM, the selection of a green supplier is always encountered, the multi-criteria decision making (MCDM) tools are always proposed to be applied in the process [7, 14-17]. There are many mathematical approach for evaluation of suppliers, such as analytic hierarchy process (AHP) [18], fuzzy AHP [19, 20], fuzzy analytic network process (ANP) [21, 22], fuzzy TOPSIS [23-25] fuzzy DEMATEL [9, 26, 27], etc. The objective of this study is to investigate logistical factors and evaluate them in GSCM and study the influence of these most important criteria for supplier assessment using the fuzzy DEMATEL method. The structure of this study is as follows: Section 1 introduces the background and motivation. A review of literature related to GSCM is mentioned in Section 2. The fuzzy set theory and DEMATEL method is described in Section 3. The application procedures of fuzzy DEMATEL and results are presented in Section 4. Section 5 discusses the results with some managerial and theoretical implications. Finally, conclusion and implications are presented in Section 6.

Literature Review

In order to provide sufficient understanding of the relationships among proposed GSCM criteria, this chapter clearly presents the literature related to green supply chain management, logistics, and its factors.

Green supply chain management is the process of incorporating environmental concerns into business activities. There are three common aspects of green supply chain management known as environment, strategy, and logistics [28].

There are various activities involving GSCM such as reuse, remanufacturing, and recycling, which are embedded in green design, green procurement practices, total quality environmental management, environmentally friendly packaging, transportation, and various product end-of-life practices [29]. The success of GSCM initiatives depends on proactivity and coordination among supply chain members to ensure the environmental impact minimization of the manufacturing and delivery of products and services [7, 29-34].

Green Logistics

We can find some concepts and elements that can serve as the foundation for a decision framework for prioritizing or selecting systems by the organization that would aid in selecting green suppliers. These are summarized as follows (and Table 1).

Green logistics dimension: A more tactical set of organizational elements that will influence how the supply chain is to be managed, either internally or externally, can be described by green logistics dimension of an organization. Major elements of the green logistics dimension will typically include procurement, production, distribution, reverse logistics, and disposal [6, 8, 11, 14, 20, 35-38].

Procurement Logistics

In an environmentally friendly chain the first step is procurement and vendor selection. The integration of suppliers begins with green purchasing of raw material [7, 39, 40]. This green purchasing can lead to environmentally friendly raw material and substitution for environmentally questionable raw materials [20, 29]. Some programs like guiding suppliers to establish their own environmental programs [20], which can improve reduction of solid/liquid wastes, reduction of emissions, resource reduction, decreasing consumption of hazardous/harmful/toxic materials [41].

Production Logistics

Production influences the green supply chain with design and the production process. Within this function, environmental issues such as total quality environmental management make some form of value-adding contribution [37]. For instance a well-designed product should avoid the need for using hazardous or restricted materials during the manufacturing process and should minimize waste during the manufacturing process with a green technology [42-44].

Distribution Logistics

Distribution is another operation that effects the green supply chain. Environmentally friendly packaging, environmentally friendly transportation, and the type of carrier uses are some items that affect the performance of the green distribution [7].

Reverse Logistics

A significant trend in GSCM has been recognition of the strategic importance of reverse logistics. The definition of reverse logistics from an environmental perspective focuses primarily on the return of recyclable or reusable products and materials into the forward supply chain [7]. Reverse logistics is "closing the loop" of the supply chain. The company can achieve both the cost and competitive advantage of recycling, refurbishing, and re-manufacturing [20, 29, 40, 45]. Supplier advances in providing environmentally friendly packages and taking them back after selling, re-using, disassembly, or re-engineering [46] are important for competition and save costs at this section.

Disposal Logistics

Recycling is the process by which products otherwise destined for disposal are processed to recover base materi-

Table 1. Criteria and sub criteria of supplier selection.

Purpose		Criteria	References	Sub Criteria	Refrences
Green Supply Chain Mnagement (GSCM)	*Logistics*	*Procurement Logistics*	[40, 50, 51]	Green purchasing strategies	[7, 14, 20, 40, 46, 51-53]
				Guiding suppliers to setup their own environmental programs	[20, 51, 54, 55]
				Integration of supplier into environmental management processes	[51, 56]
				Decrease of consumption for hazardous/harmful/toxic materials and/or their manufacturing process	[41, 57, 58]
		Production Logistics	[14, 40, 50, 51]	Green design	[13, 15, 40, 47, 52, 53, 59, 60]
				Green process and technology	[35, 42-44, 53, 58]
				Incorporating environmental total quality management	[8, 15, 20, 37, 58]
		Reverse Logistics	[50, 51, 61]	Remanufacturing and refurbishing activities	[51, 52, 62]
				Re-use, disassembly, re-engineering, and recycling of products and materials	[13, 40, 52, 63, 64]
				Taking back packaging	[51, 65]
		Distribution Logistics	[50, 51, 61]	Environmentally friendly packaging	[50, 51, 65, 66]
				Environmentally friendly transportation	[7, 51]
				Type of carrier	[50, 62, 63]
		Disposal Logistics	[50, 65]	Enhanced services	[29, 69-71]
				Saving natural resources	[72, 73]

als, for example precious metals from computer chips. For minimization of environmental impact the ideal scenario would be maximum possible reuse and disposal in a landfill only when it cannot be reused or recycled. Reuse will be preferred only if it is economically more attractive than recycling, and recycling would be continued only if it is economically more attractive than disposal in a landfill. Disposal logistics is the final important criteria in logistics for supplier selection, and suppliers should use it in special circumstances to enhance services and save natural resources [6, 14, 20, 35, 38, 47-49].

Method

In previous research some researchers offered several techniques for selecting suppliers, such as Tseng [74], who explored a set of qualitative and quantitative measurements of environmental practice in knowledge management capability by a novel hybrid multi-criteria decision-making model to address the dependence relationships of criteria with the integration of the analytical network process and DEMATEL. Another, Kannan et al. [67], applied an integrated model that analyzes and selects green suppliers based on their environmental performance using the interpretive structural modeling (ISM) and analytic hierarchy process (AHP). The fuzzy set theory has been utilized to classify geographic entities due to vague class definition since the beginning of the 1970s [75]. According to Tseng et al. [17], all conventional SCM criteria need be incorporated together with environmental criteria to find the most suitable supplier in a comprehensive model. However, few methods and studies are capable of demonstrating the relationship between factors that might affect SCM performance. With the combination of fuzzy set theory, this examination will solve the distortion and loss of information of human judgments by converting linguistic preferences to fuzzy numbers. Supplier selection is a multi-criteria decision problem [76-78].

The study obtains direct and indirect influence among criteria using the DEMATEL technique, and computes the causal relationship and strength among criteria. The DEMATEL technique does not need large amounts of data and is capable of revealing the relationship among these factors influencing other factors in the supplier selection [75]. This method is used to fill the gaps between the interactive relations of those criteria [75, 79-81]. Therefore, this research applied a fuzzy DEMATEL to evaluate the problem and develop GSCM performance through good supplier selection.

Methodology

Many organizations have adopted group decisions to find a satisfactory solution in real decision-making problems. Some important definitions and notations of fuzzy set theory from Chang et al. [75] were reviewed.

Fuzzy Set Theory

The fuzzy aggregation method always needs to contain a defuzzification method because the results of human judgments with fuzzy linguistic variables are fuzzy numbers.

The group decision is to get an agreement through interactions of many experts, and then an acceptable determination can be obtained [82]. In achieving a favorable solution, group decision making is usually important to any organization. But in decision-making problems related to complicated systems, the evaluation given by experts or decision makers on qualitative criteria of a certain object is always expressed in linguistic expressions instead of crisp values, based on experience and expertise. Such linguistic evaluations are vague, which makes further analysis hard to compute. Hence, fuzzy set theory can be implemented to measure ambiguous concepts associated with human subjective judgments.

In fuzzy logic, each number between 0 and 1 indicates a partial truth, whereas crisp sets correspond to binary logic [0,1]. Some important definitions and notations of fuzzy set theory from Cheng and Lim [82] were reviewed.

Let X be the universe of discourse,

$$X = \{x_1, x_2, x_3 \ldots, x_n\}.$$

A fuzzy set Ã of X is a set of order pairs

$$\{(x_1, f_{\tilde{A}}(x_1)), (x_2, f_{\tilde{A}}(x_2)), \ldots, (x_n, f_{\tilde{A}}(x_n))\}$$

...where $f_{\tilde{A}}$: X→[0, 1] is the membership function of Ã and $f_{\tilde{A}}(x_i)$ stands for the membership degree of x_i in Ã. To deal with the research problems in uncertainty, an effective fuzzy aggregation method is required [52, 83].

Definition 1: When X is a continuous rather than a countable or finite set, fuzzy set Ã is denoted as:

$$\tilde{A} = f_{\tilde{A}}(x_i)/(x), \text{ where } x \in X.$$

Definition 2: When X is a countable or finite set, the fuzzy set Ã is represented as:

$$\tilde{A}=\sum i\ f_{\tilde{A}}(x_i)/(x) \text{ where } x_i \in X.$$

Definition 3: Fuzzy set Ã of the universe of discourse X is normal when its membership function $f_{\tilde{A}}(x)$ satisfies max $f_{\tilde{A}}(x) = 1$.

Definition 4: A fuzzy number is a fuzzy subset in the universe of discourse X that is not convex but also normal.

Definition 5: The fuzzy α-cut Ãα and strong α-cut Ãα+ of the fuzzy set Ã in the universe of discourse X is defined by:

$$\begin{aligned} &\tilde{A}\alpha=\{x_i|f_{\tilde{A}}(x_i)\} \geq \alpha, x_i \in X\}, \text{ where } \alpha \in [0,1] \\ &\tilde{A}\alpha+=\{x_i|f_{\tilde{A}}(x_i)\} \geq \alpha, x_i \in X\}, \text{ where } \alpha \in [0,1] \end{aligned} \quad (1)$$

Definition 6: A fuzzy set Ã of the universe of discourse X is convex if and only if every Ãα is convex, that is Ãα is a close interval of R. It can be written as:

$$\tilde{A}\alpha=[P_1(\alpha), P_2(\alpha)], \text{ where } \alpha \in [0,1] \quad (2)$$

Definition 7: A triangular fuzzy number (TFN) can be defined as a triplet (a_1, a_2, a_3); the membership function of the fuzzy number Ã is defined.

$$f_{\tilde{A}}(X) = \begin{Bmatrix} 0 & , & x < 1 \\ \dfrac{(x-a_1)}{a_2-a_1} & , & a_1 \leq x \leq a_2 \\ \dfrac{(x-a_1)}{a_2-a_1} & , & a_1 \leq x \leq a_2 \\ 0 & , & x > a_3 \end{Bmatrix} \quad (3)$$

Let Ã and B̃ be two TFN parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively, then the operational laws of these two TFNs are as follows:

$$\begin{aligned} &\tilde{A}+\tilde{B} = (a_1,a_2,a_3)+(b_1,b_2,b_3) = \\ &= (a_1+b_1, a_2+b_2, a_3+b_3) \\ &\tilde{A}-\tilde{B} = (a_1,a_2,a_3)-(b_1,b_2,b_3) = \\ &= (a_1-b_1, a_2-b_2, a_3-b_3) \\ &(\tilde{A}\times\tilde{B} = (a_1,a_2,a_3)\times(b_1,b_2,b_3) = \\ &= (a_1\times b_1, a_2\times b_2, a_3\times b_3) \\ &A^{\sim}/B^{\sim} = ((a_1,a_2,a_3))/((b_1,b_2,b_3)) = \\ &= (a_1/b_1, a_2/b_2, a_3/b_3) \end{aligned} \quad (4)$$

...where a_1, a_2, and a_3 are real numbers and $a_1 < a_2 < a_3$.

In achieving a favorable solution, group decision-making is important. Because the process of arriving at a consensus is based on the reaction of multiple individuals, an acceptable judgment may be gained. To cope with the uncertainty of the research, fuzzy aggregation is required, which contains a defuzzification method because the human being's judgments with fuzzy linguistic variables are fuzzy numbers. Defuzzification refers to the selection of a specific crisp element based on the output fuzzy set, which converts fuzzy numbers into a crisp score. This study applies the converting fuzzy data into crisp scores developed by Opricovic and Tzeng [84], the main procedure of determining the left and right scores by fuzzy minimum and maximum; the total score is determined as a weighted average according to the membership functions. Let $\tilde{w}_{ij}^k = (a_{1ij}^k, a_{2ij}^k, a_{3ij}^k)$ means the degree of criterion *i* that affects criterion *j* and fuzzy questionnaires *k*(*k*=1,2,... .,*k*).

Normalization

$$\begin{aligned} xa_{1ij}^k &= (a_{1ij}^k - \min_{1\le k\le k} a_{1ij}^k)/\Delta_{min}^{max} \\ xa_{2ij}^k &= (a_{2ij}^k - \min_{1\le k\le k} a_{2ij}^k)/\Delta_{min}^{max} \\ xa_{3ij}^k &= (a_{3ij}^k - \min_{1\le k\le k} a_{3ij}^k)/\Delta_{min}^{max} \end{aligned} \quad (5)$$

...where: $\Delta_{min}^{max} = \max a_{3ij}^k - \min a_{1ij}^k$

Compute right (rs) and left (ls) normalized values:

$$\begin{aligned} xls_{ij}^k &= xa_{2ij}^k/(1+xa_{2ij}^k - xa_{1ij}^k) \\ xrs_{ij}^k &= xa_{3ij}^k/(1+xa_{3ij}^k - xa_{2ij}^k) \end{aligned} \quad (6)$$

Compute total normalized crisp values:

$$x_{ij}^{k} = \frac{\left[xls_{ij}^{k}\left(1-xls_{ij}^{k}\right)+xrs_{ij}^{k}\times xrs_{ij}^{k}\right]}{1-xls_{ij}^{k}+xrs_{ij}^{k}} \quad (7)$$

Compute total normalized crisp values:

$$\widetilde{w}_{ij}^{k} = \min a_{1ij}^{k} + x_{ij}^{k}\Delta_{min}^{max} \quad (8)$$

Integrate crisp values from different opinions of *k* respondents:

$$\widetilde{w}_{ij}^{k} = (1/k)(\widetilde{w}_{ij}^{1} + \widetilde{w}_{ij}^{2} + \cdots + \widetilde{w}_{ij}^{k}) \quad (9)$$

The DEMATEL Method

The DEMATEL method is based on digraphs, which separate involved factors into cause group and effect group. Directed graphs, known as digraphs, are more useful than directionless graphs because digraphs demonstrate the directed relationships of sub-systems. The digraph may portray a basic concept of contextual relations among elements of a system in which the values represent the strength of influence. Hence, the DEMATEL can convert the relationship between cause and effect factors into an intelligible structural model of the system. The DEMATEL can propose the most important criteria which affects other criteria [85]. This structural modeling approach adopts the form of a directed graph, a casual effect diagram, to present the interdependence relationships and the values of influential effect between factors [27]. Hence, the DEMATEL method can, through analysis of visual relationships of levels among system factors, divide all elements into causal group and effected group and the relationship between the causes and effects of criteria into an intelligible structural model of the system. This can provide researchers with a better understanding of the structural relationship between system elements, and find ways to solve complicated system problems [86-93].

The essentials of the DEMATEL method suppose that a system contains a set of criteria $C=\{C_1,C_2\ldots,C_n\}$, and the particular pairwise relations are determined for modeling with respect to a mathematical relationship.

The solving steps are as follows:

1. Generating the direct relationship matrix. Measuring the relationship between criteria requires that the comparison scale be designed into four levels:
   0 (no influence)
   1 (very low influence)
   2 (low influence)
   3 (high influence)
   4 (very high influence)
   An initial direct relation matrix A is a *n*×*n* matrix obtained by pair-wise comparisons, in which T_{ij} is denoted as the degree to which criterion i affects criterion j, i.e., $T = [t_{ij}]_{n\times n}$
2. Normalizing the direct relation matrix. On the basis of the direct relation to matrix A, the normalized direct relation to matrix I can be obtained through the equation:

$$S = K \times A \quad (10)$$

$$K = 1/\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij} \quad (11)$$

3. Attaining the total relation matrix. Once the normalized direct relation to matrix S is obtained, the total relation to matrix I is denoted as the identity matrix.

$$T = S\,(I - S)^{-1} \quad (12)$$

4. Producing a causal diagram. The sum of rows and the sum of columns are separately denoted as vectors D and R within the total relation matrix M. A cause and effect graph can be acquired by mapping the dataset of (D+R, D-R). The horizontal axis vector (D+R), named "Prominence," is made by adding D to R, which reveals how important the criterion is. Similarly, the vertical axis (D-R) named "Relation" is made by subtracting D from R, which may group criteria into a cause group. Or, if the (D-R) is negative, the criterion is grouped into the effect group.

$$T = [t_{ij}]_{n\times n},\ i,j= \quad 1,2,\ldots,n \quad (13)$$

$$D = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = \left[t_j\right]_{1\times n} \quad (14)$$

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = \left[t_i\right]_{n\times 1} \quad (15)$$

5. Obtaining the inner dependence matrix. In this step, the sum of each column in total relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired [77, 94].

The Application Procedures of Fuzzy DEMATEL and Results

This study applies the fuzzy DEMATEL using 15 evaluation criteria and symbols as follows:

- green purchasing strategies C1;
- guiding suppliers to set up their own environmental programs C2;
- integrating suppliers into environmental management processes C3;
- decreasing consumption for hazardous/harmful/toxic materials and/or their manufacturing process C4;
- green design C5;
- green process and technology C6;
- incorporating environmental total quality management C7;
- remanufacturing and refurbishing activities C8;
- re-use, disassembly, re-engineering, and recycling of products and material C9;
- taking back packaging C10;
- environmentally friendly packaging C11;
- environmentally friendly transportation C12;
- carrier type C13;
- enhanced services C14;
- saving natural resources C15.

This study is designed to estimate the influence of each criterion in supplier selection and to compare the importance of each criterion to represent the degree of significance.

Table 2. The fuzzy linguistic scale.

Linguistic variable	Influence score	Corresponding triangular fuzzy numbers (TFNs)
No influence	0	(0, 0, 0.25)
Very low influence	1	(0, 0.25, 0.5)
Low influence	2	(0.25, 0.5, 0.75)
High influence	3	(0.5, 0.75, 1)
Very high influence	4	(0.75, 1, 1)

This study applies the fuzzy DEMATEL to GSCM performance in order to build a cause-and-effect model for GSCM supplier selection for manufacturer enterprises. This research conducts four proposed steps as follows:

Step 1: Identifying decision goals – gathering the relevant information to evaluate the advantages and disadvantages and monitor results to ensure the goals are achieved. This is necessary to form two expert committees for group knowledge to achieve the goals.

Fifteen GSCM performance criteria to study the interrelationships of criteria in uncertainty.

Step 2: Developing evaluation criteria and survey instruments – this is important for establishing a set of criteria for evaluation. However, the criteria have the nature of complicated relationships within the cluster of criteria. To gain a structural model dividing evaluation criteria into the cause-and-effect groups, the DAMATEL is appropriate to be applied in this study. Acquiring the responding instrument – to ensure the relationships among the evaluation criteria, it is necessary to consult two groups of experts to confirm reliable information of criteria influence and direction.

Fifteen criteria are evaluated, including: (C1), (C2), …, (C15). The fuzzy DEMATEL method is also used to test the influence of each criterion. Then, the respondents were asked to evaluate the interrelationship of each criterion using four scores in linguistic terms: 0 (no influence), 1 (very low influence), 2 (low influence), 3 (high influence), and 4 (very high influence). To ensure the relationships among the evaluation criteria, it is necessary to consult the experts to confirm reliable information of the criteria influences and directions using a survey instrument. In this paper our questioners were 15 managers in maintenance, operation, production, quality, and logistical areas, and 5 questioners were university professors (Tables 2 and 3).

Step 3: Interpret the linguistic information into fuzzy linguistic scale – using linguistic information to convert fuzzy numbers into a crisp score, the fuzzy assessments applying in Eqs. (5-9) are defuzziffied and aggregated as a crisp value $\widetilde{W}_{ij}^{k}$.

The empirical data is obtained from each individual expert assessment using Eq. (5) to normalize the assessment data. The linguistic information converts the TFNs into crisp value by using Eqs. (6-8); $\widetilde{W}_{ij}^{k}$ is the computed crisp value. Eqs. (5-9) obtain the DEMATEL initial direct relation matrix.

Step 4: Analyze the criteria into causal and effect diagram – the crisp value is composed of the initial direct relation matrix. The normalized direct relation matrix can be obtained through Eq. (10). According to Eqs. (11-15), a causal and effect diagram can be constructed [52, 83].

Table 3. Direct relation matrix T.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	1	1	1	3	2	3	2	1	3	2	2	1	1	2	4
C2	3	2	3	4	3	3	2	2	3	2	3	3	1	2	4
C3	2	3	1	3	2	2	3	2	2	1	2	3	0	2	3
C4	1	3	1	1	0	1	2	0	2	1	2	2	0	3	4
C5	2	2	3	3	1	3	2	2	4	2	3	2	1	3	3
C6	1	3	3	3	1	1	2	2	4	2	3	3	1	3	4
C7	3	3	3	3	2	1	1	2	3	2	2	2	0	4	3
C8	3	2	2	4	3	4	2	1	4	1	2	3	1	3	4
C9	3	3	2	4	2	2	2	2	1	1	2	3	0	3	4
C10	2	1	1	2	1	1	1	2	2	2	1	2	1	3	2
C11	2	2	1	4	2	1	0	1	3	2	1	1	1	2	4
C12	2	3	3	3	2	2	2	1	3	1	2	2	1	3	4
C13	1	1	3	2	2	3	1	2	3	1	2	2	1	2	1
C14	2	1	1	2	1	1	0	1	1	1	1	1	3	2	1
C15	1	1	2	4	3	2	2	1	2	3	1	2	2	1	4

Table 4. Total DEMATEL relation matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0.25	0.44	0.62	0.68	0.68	0.68	0.79	0.56	0.85	0.38	0.44	0.44	0.44	0.44	0.79
C2	0.80	0.38	0.68	0.74	0.74	0.80	0.63	0.79	0.62	0.79	0.62	0.44	0.33	0.38	0.56
C3	0.68	0.68	0.32	0.85	0.74	0.63	0.74	0.78	0.56	0.33	0.44	0.44	0.38	0.44	0.44
C4	0.73	0.68	0.38	0.38	0.38	0.38	0.57	0.50	0.44	0.50	0.38	0.44	0.21	0.44	0.56
C5	0.79	0.50	0.50	0.85	0.44	0.80	0.79	0.50	0.74	0.79	0.44	0.38	0.38	0.50	0.50
C6	0.68	0.63	0.50	0.85	0.79	0.44	0.50	0.79	0.85	0.44	0.50	0.44	0.33	0.50	0.56
C7	0.80	0.80	0.68	0.85	0.68	0.62	0.38	0.85	0.74	0.56	0.38	0.44	0.21	0.44	0.38
C8	0.68	0.44	0.38	0.85	0.80	0.74	0.63	0.44	0.90	0.62	0.50	0.38	0.27	0.5	0.50
C9	0.74	0.44	0.38	0.85	0.74	0.63	0.63	0.74	0.26	0.56	0.63	0.62	0.33	0.5	0.50
C10	0.56	0.33	0.33	0.68	0.56	0.38	0.38	0.56	0.50	0.44	0.79	0.74	0.62	0.68	0.50
C11	0.63	0.44	0.33	0.85	0.68	0.50	0.50	0.32	0.79	0.74	0.44	0.62	0.62	0.68	0.85
C12	0.50	0.68	0.68	0.85	0.32	0.50	0.50	0.33	0.44	0.33	0.38	0.56	0.62	0.74	0.85
C13	0.33	0.50	0.63	0.68	0.44	0.44	0.33	0.33	0.38	0.33	0.38	0.79	0.26	0.79	0.79
C14	0.44	0.44	0.38	0.56	0.50	0.44	0.44	0.44	0.44	0.50	0.38	0.56	0.44	0.56	0.79
C15	0.62	0.44	0.50	0.85	0.74	0.68	0.63	0.68	0.74	0.75	0.73	0.74	0.56	0.44	0.73

The normalized direct relation matrix can be obtained through Eqs. (10) and (12). Following Eq. (13), the total relation matrix can be acquired, and is presented in Table 4.

Then use Eqs. (14-15), the horizontal axis vector (D+R) named "Prominence" is made by adding D to R, which reveals the importance of criterion. Similarly, the vertical axis (D-R) named "Relation" is made by subtracting D from R, which may move criteria into a cause group (Table 5). If the (D-R) is negative, the criteria are grouped into the effect group. Therefore, the cause-and-effect diagram can be acquired by mapping the dataset of the (D+R, D-R), providing valuable insight for problem solving. Recognizing the position of each factor in the whole system, this study can find out the ones that have more effect on the system and the efficiency of the system is attended to great improvement [52, 83]. Study findings from the causal diagram are described in Table 5.

Managerial Implication

This study plans to improve GSCM implementation through 15 criteria. According to the findings, several managerial implications are derived. It would be essential to focus on the cause group criteria in advance due to their influence on the effect group criteria [85]. Based on the results of the total relation matrix in Table 4, this study finds evaluation criteria of causal relationships among GSCM supplier selection from the fuzzy DEMATEL method to

Table 5. The prominence and relation axis for cause-and-effect group.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
D	6.7	7.3	6.7	5.5	7.0	6.9	6.9	6.8	6.7	6.3	7.3	6.5	5.8	5.7	7.8
R	7.3	6.2	5.7	8.9	7.3	6.8	6.7	7.0	7.3	6.5	5.9	6.2	4.6	6.2	7.3
D-R	-0.6	1.1	1	-3.4	-0.3	0.1	0.2	-0.2	-0.6	-0.2	1.4	0.3	1.2	-0.5	0.5
D+R	14	13.5	12.4	14.4	14.3	13.7	13.6	13.8	14.0	12.8	13.2	12.7	10.4	11.9	12.1

Green purchasing strategies: C1; guiding suppliers to setup their own environmental programs: C2; integration of supplier into environmental management processes: C3; decrease of consumption for hazardous/harmful/toxic materials and/or their manufacturing process: C4; green design: C5; green process and technology: C6; incorporating environmental total quality management: C7; remanufacturing and refurbishing activities: C8; re-use, disassembly, re-engineering and recycling of products and material: C9; taking back packaging: C10; environmentally friendly packaging: C11; environmentally friendly transportation: C12; carrier type: C13; enhance services: C14; save natural resources: C15.

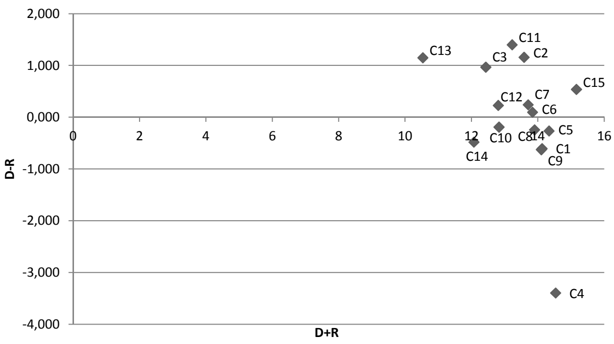

Fig. 1. Cause-and-effect diagram.

depict GSCM implementation. According to Fig. 1, the research can acquire valuation cues for making accurate decisions. The company knows that the influence degrees among criteria are different to finding the key criterion for improving performance in GSCM based on the results of total matrix (Table 4). The study finds the causal diagrams are as follows. First, if the enterprise wants to obtain high performance in the effect criteria, it would control and pay more attention to the "cause criteria" beforehand [53]. The criteria (C2, C3, C6, C7, C11, C12, C13, and C15) influence dispatching evaluation criteria. These criteria influence C1, C4, C5, C8, C9, C10, and C14). If the company wanted to improve the effectiveness of a specific criterion (e.g., C1, C4, C5, C8, C9, C10, and C14), it would be necessary to pay attention to (C2, C3, C6, C7, C11, C12, C13, and C15). This is because (C2), (C3), (C6), (C7), (C11), (C12), (C13), and (C15) are the influencing criteria and can be improved, while (C1), (C4), (C5), (C8), (C9), (C10), and (C14) are influence criteria and can arrive at the effect criteria. Then, it is easier for a company to find the performance of the appropriate suppliers by using the results [83, 95]. Secondly, the most important criterion that influences GSCM is saving natural resources (C15). Hence, in order to maintain and promote GSCM performance, it is necessary for managers to stress requirements of savings natural resources to achieve higher levels of environmental performance. On the other hand, from the cause diagram the results imply that environmentally friendly packaging (C11) is the central criterion for evaluating indirectly the criterion of C1, C2, C3, C4, C5, C6, C7, C8, C9,C10, C12, C13, C14, and C15.

Obviously, the result shows that environmentally friendly packaging (C11) is the most important and most influencing the criterion because its position has the highest intensity of relationships to other criteria. This implies that managers should conduct a number of strategies, such as packaging that can be absorbed by the environment, packaging with multiple applications, packaging with reusability, etc. The major objective in such cases is to achieve environmentally friendly packaging. Third, the study indicated that high-value criteria have large influences on others criteria that are opposite. Moreover, the framework can be applied as an analytical tool to evaluate the GSCM supplier selection. Thus, the evaluators are most concerned about performance when selecting the appropriate green suppliers to GSCM activities. Among those, C4 and C15 would to be taken into deeper consideration. The fuzzy DEMATEL method is comprehensive and applicable to all companies facing problems that require group decision making in a fuzzy environment. Nonetheless, this study contains some limitations. First, the shortage of respondents to ensure the validity of the research, future research should conduct questionnaires to achieve better exploration. Second, since no case study or empirical study has been used to investigate how factors influence GSCM implementation, future research should conduct empirical study in a specific industry [52, 83].

Conclusions

This study used the fuzzy DEMATEL method to evaluate the logistics factors of GSCM implementation. The results of this study can help a company evaluate and analyze suitable suppliers. The results show that environmentally friendly packaging criteria has the greatest influence among the criteria for selecting suppliers. This research suggests that the manufacturer wanting to evaluate or select suppliers should note environmentally friendly packaging, since this evaluation criterion highly affects other factors. In addition, the manufacturing industry frequently pays attention to decreases of consumption for hazardous/harmful/toxic materials and/or their manufacturing process, re-use, disassembly, re-engineering, and recycling of products and materials and the number of patents. However, it was not the exact factor to value the evaluation of significance, it still can effectually help enterprises choose a GSCM supplier. According to analysis results, environmentally friendly packaging criteria could directly or indirectly influence many other factors in logistical criteria. Furthermore, the company could pay attention to guiding suppliers to set up their own environmental programs, integrate suppliers into environmental management processes, green process and technology, incorporating environmental total quality management, environmentally friendly packaging, environmentally friendly transportation, type of carrier, and save natural resources.

Refrences

1. LIN R.J., CHEN R.H., NGUYEN T.H. Green supply chain management performance in automobile manufacturing industry under uncertainty. Procedia - Social and Behavioral Sciences. **25**, 233, **2011**.
2. RAO P. Greening the supply chain: a new initiative in South East Asia, Int. J. Oper. Prod. Man. **21**, (6), 632, **2002**.
3. FLEISHMANN M., KRIKKE H.R., DEKKER R., FLAPPER S.D.P. A characterization of logistics networks for product recovery. Omega. **28**, 653, **2000**.
4. ROBESON J.F., COPACINO W.C., HOWE R.E. The Logistics Handbook. Macmillan, Inc. New York. **1992**.
5. VAN HOEK R.I., ERASMUS. From reversed logistics to green supply chains. Logistics Solutions. **2**, 28, **2000**.
6. SARKIS J. A strategic framework for green supply chain management, Journal of Cleaner Production, **11**, (4), 397, **2003**.

7. SRIVASTAVA S.K. Green supply-chain management: a state-of-the-art literature review. International Journal of Management Reviews. **9**, (1), 53, **2007**.
8. ZHU Q., SARKIS J., LAI K.H. Green supply chain management implications for closing the loop. Transportation Research Part E: Logist. Transport. Rev. **44**, (1), 1, **2008**.
9. TSENG M.L. A causal and effect decision making model of service quality expectation using grey-fuzzy DEMATEL approach. Expert. Syst. Appl. **36**, 7738, **2009**.
10. GREEN K., MORTON B., NEW S. Purchasing and environmental management: interaction, policies and opportunities. Business Strategy and the Environment. **5**, 188, **1996**.
11. ZHU Q., SARKIS J., LAI K.H. Green supply chain management: pressures, practices and performance within the Chinese automobile industry. Journal of Cleaner Production. **15**, (11-12), 1041, **2007**.
12. LI S., RAGU-NATHAN B., RAGU-NATHAN T.S., RAO S.S. The impact of supply chain management practices on competitive advantage and organizational performance. Omega. **34**, 107, **2006**.
13. CHIEN M.K., SHIH L.H. An empirical study of the implementation of green supply chain management practices in the electrical and electronic industry and their relation to organizational performances. International Journal of Environment Science Technology. **4**, (3), 383, **2007**.
14. LEE A.H.I., KANG Y., HSU H.C.F., HUNG H.C. A green supplier selection model for high-tech industry. Expert. Syst. Appl. **36**, 7917, **2009**.
15. ZHU Q., SARKIS J., LAI K.H. Confirmation of a measurement model for green supply chain management practices implementation. Int. J. Prod. Econ. **111**, 263, **2008**.
16. TSENG M.L., LIN Y.H., CHIU A.S.F., LIAO C.H. Using FANP approach on selection of competitive priorities based on cleaner production implementation: A case study in PCB manufacturer Taiwan. Clean Technology and Environmental Policy. **10**, (1), 17, **2008**.
17. TSENG M.L., CHIANG J.H., LAN L.W. Selection of optimal supplier in supply chain management strategy with analytic network process and choquet integral. Computers & Industrial Engineering. **57**, (1), 330, **2009**.
18. SEVKLI M., KOH S.C.L., ZAIM S., DEMIRBAG M., TATOGLU E. An application of data envelopment analytic hierarchy process for supplier selection: A case study of BEKO in Turkey. Int. J. Prod. Res. **45**, 1973, **2007**.
19. CHAN F.T.S., KUMAR N. Global supplier development considering risk factors using fuzzy extended AHP-based approach. Omega. **35**, 417, **2007**.
20. RAO P., HOLT D. Do green supply chains lead to competitiveness and economic performance?. Int. J. Oper. Prod. Man. **25**, (9), 898, **2005**.
21. LIN R.H. An integrated FANP-MOLP for supplier evaluation and order allocation. Applied Mathematical Modelling. **33**, 2730, **2009**.
22. TUZKAYA U.R., ÖNUTO S. A fuzzy analytic network process based approach to transportation-mode selection between Turkey and Germany: A case study. Information Sciences. **178**, 3133, **2008**.
23. SALEHI M., TAVAKKOLI-MOGHADDAM R. Project selection by using a fuzzy TOPSIS technique. World Academy of Science, Engineering and Technology. **40**, 85, **2008**.
24. YONG D. Plant location selection based on fuzzy TOPSIS. International Journal of Advanced Manufacturing Technology. **28**, 839, **2006**.
25. IÇ Y.T., YURDAKUL M., Development of a quick credibility scoring decision support system using fuzzy TOPSIS. Expert. Syst. Appl. **37**, 567, **2010**.
26. CHEN C.C., TSENG M.L., LIN Y.H. Using fuzzy DEMATEL to develop a causal and effect model of hot spring service quality expectation. In IEEE international conference on industrial engineering and engineering management. 1004, **2008**.
27. WU W.W., LEE Y.T. Developing global managers' competencies using the fuzzy DEMATEL method. Expert. Syst. Appl. **32**, 499, **2007**.
28. GILBERT S. Greening supply chain: Enhancing competitiveness through green productivity. Taipei, Taiwan, 1, **2001**.
29. HERVANI A.A., HELMS M.M., SARKIS J. Performance measurement for green supply chain management. Benchmarking: An International Journal. **12**, (4), 330, **2005**.
30. LINTON J.D., KLASSEN R., JAYARAMAN V. Sustainable supply chains: an introduction. J. Oper. Manag. **25**, (6), 1075, **2007**.
31. ZHU Q., SARKIS J. An inter-sectoral comparison of green supply chain management in China: drivers and practices. Journal of Cleaner Production. **14**, (5), 472, **2006**.
32. VACHON S., KLASSEN R.D. Environmental management and manufacturing performance: the role of collaboration in the supply chain. Int. J. Prod. Econ. **111**, 299, **2008**.
33. SARMIENTO E. Identifying improvement areas when implementing green initiatives using a multitier AHP approach. An International Journal. **17**, (3), 452, **2010**.
34. WALKER H., DI SISTO L., MCBAIN D. Drivers and barriers to environmental supply chain management practices: lessons from the public and private sectors. Journal of Purchasing and Supply Management. **14**, (1), 69, **2008**.
35. AWASHTI A., CHAUHAN S.S., GOYAL S.K. A fuzzy multicriteria approach for evaluating environmental performance of suppliers. Int. J. Prod. Econ. **126**, (2), 370, **2010**.
36. PUNNIYAMOORTHY M., MATHIYALAGAN P., PARTHIBAN P. A strategic model using structural equation modeling and fuzzy logic in supplier selection. Expert. Syst. Appl. **38**, (1), 458, **2011**.
37. SARKIS J., MEADE L.M., TALLURI S. E-logistics and the natural environment. Supply Chain Management: An International Journal. **9**, (4), 303, **2004**.
38. TUZKAYA G., OZGEN A., OZGEN D., TUZKAYA U.R. Environmental performance evaluation of suppliers: A hybrid fuzzy multi-criteria decision approach. International Journal of Environmental Science and Technology. **6**, 477, **2009**.
39. ZHU Q., GENG Y. Integrating Environmental Issues into Supplier Selection and anagement: A Study of Large and Medium-Sized State-Owned Enterprises in China. Greener Management International. (**35**), 27, **2001**.
40. ZHU Q., GENG Y., FUJITA T., HASHIMOTO S. Green supply chain management in leading manufacturers Case studies in Japanese large companies. Management Research Review. **33**, (4), 380, **2010**.
41. ELTAYEB T.K., ZAILANI S. RAMAYAH T. Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes. Resource Conservation and Recycling. **55**, (5), 495, **2011**.
42. JABBOUR A.B.L.S., JABBOUR C.J.C. Are supplier selection criteria going green? Case studies of companies in Brazil. Ind. Manage. Data Syst. **109**, 477, **2009**.
43. KUBOKAWA S., SAITO I. Manufacturing management strategies for environmental protection: Toward the environ-

mental upgrading of management and manufacturing systems to cope with environmental laws. Prod. Plan. Control. **11**, (2), 107, **2000**.
44. KURK F., EAGAN P. The value of adding design-for the-environment to pollution prevention assistance options. Journal of Cleaner Production. **16**, (6), 722, **2008**.
45. TSAIA W.H., HUNG S.J. A fuzzy goal programming approach for green supply chain optimisation under activity-based costing and performance evaluation with a value-chain structure. Int. J. Prod. Res. **47**, (18), 4991, **2009**.
46. HSU C.W., HU A.H. Green supply chain management in the electronic industry. International Journal of Environmental Science and Technology. **5**, (2), 205, **2008**.
47. HUMPHREYS P.K., WONG Y.K., CHAN F.T.S. Integrating environmental criteria into the supplier selection process. J. Mater. Process. Tech. **138**, 349, **2003**.
48. MEADE L., SARKIS J. A conceptual model for selecting and evaluating third-party reverse logistics providers. Supply Chain Management: An International Journal. **7**, (5), 283, **2002**.
49. SIMPSON D.F., POWER D.J. Use the supply relationship to develop lean and green suppliers. Supply Chain Management: An International Journal. **10**, 60, **2005**.
50. BUYUKOZKAN G., ÇIFCI G. A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. Expert. Syst. Appl. **39**, (3), 3000, **2012**.
51. CHOUDHARY M., SETH N. Integration of Green Practices in Supply Chain Environment The practices of Inbound, Operational, Outbound and Reverse logistics. International Journal of Engineering Science and Technology. **3**, (6), 4985, **2011**.
52. LIN R.J. Using fuzzy DEMATEL to evaluate the green supply chain management practices. Journal of Cleaner Production. In Press, Corrected Proof, Available online. **1**, **2011**.
53. TSENG M.L. Green supply chain management with linguistic preferences and incomplete information. Applied Soft Computing. **11**, (8), 4894, **2011**.
54. KOLK A., PINKSE J. Market strategies for climate change. Eur. Manage. J. **22**, (3), 304, **2004**.
55. COGAN D., GOOD M., KANTOR G., MCATEER E. Corporate Governance and Climate Change: Consumer and Technology Companies. Ceres commissioned, **1**, **2008**.
56. WALTON S.V., HANDFIELD R.B., MELNYK S.A. The green supply chain: integrating suppliers into environmental management process. International Journal of Purchasing and Materials Management. **34**, (2), 2, **1998**.
57. ZHU Q., SARKIS J., LAI K.H. Green supply chain management innovation diffusion and its relationship to organizational improvement: An ecological modernization perspective. J. Eng. Technol. Manage. **29**, (1), 168, **2012**.
58. ZHU Q., SARKIS J., LAI K. Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers. J. Environ. Manage. **85**, (1), 179, **2007**.
59. JOHANNSON LE. Greening supply chain: Enhancing competitiveness through green productivity "Linking Green Productivity, Green Purchasing, and Quality Management Systems ".Report of the Top Forum on Enhancing Competitiveness through Green Productivity held in the Republic of China.1, **2001**.
60. ZHU Q., SARKIS J., CORDEIRO J., LAI K.H. Firm-level correlates of emergent green supply chain management practices in the Chinese context. Omega. **36**, (4), 577, **2008**.
61. WU G.C., DING J.H., CHEN P.S. The effects of GSCM drivers and institutional pressures on GSCM practices in Taiwan's textile and apparel industry. Int. J. Prod. Econ. **135**, (2), 618, **2012**.
62. SHEU J.B., CHOU Y.H., HU C.C. An integrated logistics operational model for green-supply chain management. Transportation Research Part E: Logist. Transport. Rev. **41**, (4), 287, **2005**.
63. YEH W.C., CHUANG M.C. Using multi-objective genetic algorithm for partner selection in green supply chain problems. Expert. Syst. Appl. **38**, 4244, **2011**.
64. LIN S.S., JUANG Y.S. Selecting Green Suppliers with Analytic Hierarchy Process for Biotechnology Industry. Operation and supply chain management. **1**, (2), 115, **2008**.
65. DIABAT A., GOVINDAN K. An analysis of the drivers affecting the implementation of green supply chain management. Resour. Conserv. Recy. **55**, (6), 659, **2011**.
66. WAN M., WAN H., AB R., MOHDD N., DEROS BABA Md. The Relationship between Manufacturing System Performance and Green Practices in Supply Chain Management. World Academy of Science, Engineering and Technology. **59**, 2454, **2011**.
67. KANNAN G., HAG AN., KUMAR PS., ARUNACHALAM S. Analysis and selection of green suppliers using interpretative structural modeling and analytic hierarchy process. International Journal of Management and Decision Making. **9**, (2), 163, **2008**.
68. FABBE-COSTES N., JAHRE M., ROUQUET A. Interacting standards: a basic element in logistics networks. International Journal of Physical Distribution & Logistics Management. **36**, (2), 93, **2006**.
69. WEBER C.A., CURREN J.R., BENTON W.C. Vendor selection criteria and methods. Eur. J. Oper. Res. **50**, (1), 2, **1991**.
70. PRAHINSKI C., BENTON W.C. Supplier evaluations: Communication strategies to improve supplier performance. J. Oper. Manag. **22**, (1), 39, **2004**.
71. CHANG S.L., WANG R.C., WANG S.Y. Applying a direct multi-granularity linguistic and strategyoriented aggregation approach on the assessment of supply performance. Eur. J. Oper. Res. **177**, (2), 1013, **2007**.
72. ADAMCZYK J., NITKIEWICZ T. Programming of Sustainable Development in Companies. PWE, Warsaw. **2007**.
73. VENABLES A.J. Resource rents; when to spend and how to save. Int Tax Public Finan. **17**, (4), 340, **2010**.
74. TSENG M.L. Using linguistic preferences and grey relational analysis to evaluate the environmental knowledge management capacities. Expert. Syst. Appl. **37**, (1), 70, **2010**.
75. CHANG B., CHANG C.W., WU C.H. Fuzzy DEMATEL method for developing supplier selection criteria. Expert. Syst. Appl. **38**, 1850, **2011**.
76. AKARTE M.M., SURENDA N.V., RAVI B., RANGARAJ N. Web based casting supplier evaluation using analytical hierarchy process. J. Oper. Res. Soc. **52**, 511, **2001**.
77. LIAOA Z., RITTSCHERB J. A multi-objective supplier selection model under stochastic demand conditions, Int. J. Prod. Econ., **105**, (1), 150, **2007**.
78. HUANG S., KESKAR H. Comprehensive and configurable metrics for supplier selection. Int. J. Prod. Econ. **105**, (2), 510, **2007**.
79. CHEN Y.H., TSENG M.L., LIN R.J. Evaluating the customer perceptions on in flight service quality. African Journal of Business Management, **5**, (7), 2865, **2011**.
80. TSENG M.L., LIN Y.H., CHIU A.S.F. FAHP based study of cleaner production implementation in PCB manufacturing firms. Taiwan. Journal of Cleaner Production. **17**, (14), 1249, **2009**.

81. ZHU Q., HUANG W.L., ZHANG Y. Identifying critical success factors in emergency management using a fuzzy DEMATEL method. Safety Sci. **49**, 243, **2011**.
82. CHENG C.H., LIM Y. Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. Eur. J. Oper. Res. **142**, (1), 174, **2002**.
83. WU K.J., TSENG M.L., VY T. Evaluation the drivers of green supply chain management practices in uncertainty. Procedia - Social and Behavioral Sciences. **25**, 384, **2011**.
84. OPRICOVIC S., TZENG G.H. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. Eur. J. Oper. Res. **156**, (2), 445, **2004**.
85. FONTELA E., GABUS A. The DEMATEL observer, DEMATEL 1976. Report. Geneva: attele Geneva Research Center. **1976**.
86. GABUS A., FONTELA E. Perceptions of the world problematique: Communication procedure, communicating with those bearing collective responsibility (DEMATEL report No. 1). Battelle Geneva Research Centre. Switzerland Geneva. **1973**.
87. GABUS A., FONTELA E. World Problems, An Invitation to Further thought within the Framework of DEMATEL. Battelle Geneva Research Centre, Switzerland. Geneva. **1972**.
88. SANKAR N.R., PRABHU B.S. Modified approach for prioritization of failures in a system failure mode and effects analysis. International Journal of Quality and Reliability Management. **18**, (3), 324, **2001**.
89. SEYED-HOSSEINI S.M., SAFAEI N., ASGHARPOUR M.J. Reprioritization of failures in a system failure mode and effects analysis by decision making trial and evaluation laboratory technique. Reliab. Eng. Syst. Safe. **91**, (8), 872, **2006**.
90. HERRERA F., HERRERA-VIEDMA E., MARTINEZ L. A fusion approach for managing multi-granularity linguistic term sets in decision making. Fuzzy. Set. Syst. **114**, (1), 43, **2000**.
91. CHIU A.S.F. Metro Manila solid waste management and circular economy promotion study. Technical studies under Institute for Global Environmental strategies project on integrating global Concerns in the waste sector in Asian Cities. **2006**.
92. HORI S., SHIMIZU Y. Designing methods of human interface for supervisory control systems. Control Eng. Pract. **7**, (11), 1413, **1999**.
93. WANG R., CHUU S. Group decision-making using a fuzzy linguistic approach for evaluating the flexibility in a manufacturing system. Eur. J. Oper. Res. **154**, (3), 563, **2004**.
94. TZENG G.H., CHIANG C.H., LI C.W. Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL. Expert. Syst. Appl., **32**, (4), 1028, **2007**.
95. YANG J.Y., TZENG G.H. An integrated MCDM technique combined with DEMATEL for a novel cluster-weight with ANP method. Expert. Syst. Appl. **38**, 1417, **2011**.