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Research Paper

AN EVALUATION OF ATTRIBUTE FOR IMPROVING THE GREEN SUPPLY CHAIN PERFORMANCE VIA DEMATEL METHOD

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Performance of green supply chain depends on several factors associated with their activities and thus need to analyse these attributes/factors. To improvement in overall performance, these factors should be formulated within a structural model to understand interacting relationships among them. In this way, DEMATEL (Decision Making Trial and Evaluation Laboratory) method is proposed for the purpose of this research for visualizing and constructing the interactions between identified factors related to GSC. Total 6 performance focused attributes has been identified and further classified into cause and effect group attributes utilizing DEMAEL method. Study results shows that supplier selection and related issue, governmental rules and regulations comes under cause group and green purchasing, design and operations, ecological benefits and resources management, green image, and green productivity forms effect group. Finally, a case example is presented to discuss the managerial usefulness of this research.

Keywords: Green supply chain, Green supply chain management, DEMATEL method, Attributes, Performance measurement, Decision making

INTRODUCTION

Supply chain management is among most prominent research subject in the area of operations management. It involves various activities and operations interacting with each other to fulfil the requirements of end users. It could be observed that each activity and operations of supply chains exhibit certain environmental impact (Beamon, 1999). Reducing the total environmental effect is becoming one of the primary objectives of today business, and hence the supply chain gradually including ecological factors to become environmental friendly or green supply chain (Zhu and Sarkis, 2006). To defining green supply chains involves monitoring the green impact all throughout the network while reducing environmental risk and increased its environmental efficiency. It also offers probable means to reduce overall waste and toxic generation and enhancement in productivity. The GSC is refers to Green Supply Chain

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Management (GSCM) which is defined as totality of green in procurement, manufacturing, distribution and reverse logistics (Hervani *et al.*, 2005). Further, green supply chains expressed as the means of achieving the economic advantage in long term, thereby their performance also increases (Srivastava, 2007). To this support, GSC and GSCM is described as the requirement for profitability (Kumar *et al.*, 2012).

However, performance of GSC depends on several factors associated with their activities and thus need to model these factors, and further formulate a structural model to understand interacting relationships among the factors. In this way, DEMATEL (Decision Making Trial and Evaluation Laboratory) method is utilized for visualizing and constructing the interactions between identified factors related to GSC for improving its performance. Conducting enquiry on related literature and discussion with decision makers, this study has identified the 6 significant GSC attributes, which involves crucial part in deciding the whole GSC performance namely as, Supplier selection and related issue, Governmental rules and regulations, Ecological benefits and resources management, Green purchasing, design and operations, Green image, Green productivity, etc. (Beamon, 1999; van Hoek, 1999; Rao and Holt, 2005; Zhu and Sarkis, 2006; Vachon and Klassen, 2006; and Linton *et al.*, 2007). Further, the remaining content of this article is as follows:

LITERATURE REVIEW

Due to growing concern of researchers and academicians in regarding to green or ecological issues, there is significant increase in literature over green supply chain management. Shifting from forward logistics to reverse logistics and hence green reverse logistics all are specifically substantiation of environmental (green) issues are becoming imperative, including notable of applying green in supply chains (Beamon, 1999; van Hoek, 1999; Rao and Holt, 2005; Zhu and Sarkis, 2006; Vachon and Klassen, 2006; and Linton *et al.*, 2007). Further, studies are also present over regarding variables and factors associated to GSC, suggesting their importance for adding more value to the GSC performance (Mangla *et al.*, 2012 and 2013). In this line of direction, DEMATEL method is very useful to work out complex issues. This method improves regarding understanding of relationships and further provides means for building structural model of the interactions among particular difficult group of interacted factors, and criteria. In regarding the usefulness of this method, it is widely adopted in solving multifaceted assignments (Wu and Lee, 2007; Tzeng *et al.*, 2007; Huang *et al.*, 2007; Wu, 2008; Lin and Lin, 2008; and Lin and Wu, 2008).

PROPOSED METHOD

For fulfilling the purpose of research, we have proposed a Decision Making Trial and Evaluation Laboratory (DEMATEL) method, for building and analysing a structural representation of the underlying relationships among the various complex factors (Lin and Lin, 2008). However, firstly the method used at Battelle Memorial Institute in Geneva between 1972 and 1976 and the focal objective of usage was to study and solve the difficult and intertwined problem (Tzeng and

Huang, 2011). There are several steps, which should be considered while applying DEMATEL method and are given as follows:

Construct the average matrix (or initial direct relation matrix): Using scales with meaning of involved terminology as follows, 0 = (no influence); 1 = (very low influence); 2 = (low influence); 3 = (high influence); 4 = (very high influence), the pair-wise comparisons is developed between attributes according to decision makers opinion. If there are '*M*' decision makers whom have to evaluate causality among the identified factors and given by x_{ij}^k. The entries written by decision making experts forms an×n matrix, i.e. $X^k = x_{ij}^k$, where, $k = 1, 2, 3, 4, ..., n$ (no. of experts). Further, the $n \times n$ average matrix Z, which is also called initial direct relation matrix for all decision makers, can be calculated as follows:

$$a_{ij} = 1/k \sum x_{ij}^k \quad ...(1)$$

- Obtain the normalized initial direct relation matrix (D) for the initial direct-relation matrix (Z) by using following Eqs:

$$m = \min\left[\frac{1}{\max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\sum_{i=1}^{n}|a_{ij}|}\right] \quad ...(2)$$

$$D = m \times Z \quad ...(3)$$

- Construct the total-relation matrix. Here, the normalized matrix is transformed to total relation matrix and expressed using Equation (12) as given below:

$$T = (1 - D)^{-1} \quad ...(4)$$

where, I: identity matrix, T: total relation matrix,

$$T = \left[t_{ij}\right]_{n\times n}$$

- The summation of rows and columns of the total relation matrix T are computed as an r and c $n \times 1$ vectors and are given as:

$$\left[r_i\right]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \quad ...(5)$$

$$\left[c_j\right]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \quad ...(6)$$

$[r_i]_{n \times 1}$, represents the total effects, provided by one criterion say (i) to the other criteria (j), where as represents the total effects, experienced by criteria j from the other criteria i. While, the summation of ($r_i + c_j$) that is called "Prominence" depicts the measure of significance of criterion in system and also provides a measure for showing the total effects, i.e., both influenced and influential power for the criteria. While, the ($r_i - c_j$) which is called "Relation" shows the entire effect of a criteria in a system. Further, when ($r_i - c_j$) is positive, the particular criteria falls into cause group, and when it is negative, it corresponds to the effect group.

- The inner dependence matrix can be produced by normalizing the total relation matrix

CASE EXAMPLE

A plastic manufacturing company located in northern part of India is looking for to improve their GSC performance. Company also desire to analyse related attributes for GSC to making it more productive. Hence, this research aims to help company in this dimension by applying proposed method, further; we form a team of two-decision makers (planning manager,

finance manager, etc.) to evaluate the problem, while systematic details of applying DEMATEL method are given as:

- Based on 0-4 scale, and using the Equation (1) the average matrix or initial direct relation matrix is given in Table 1:
- Using Equations (2-3) the initial direct matrix is transformed to normalized matrix and further total direct matrix can be obtained based on Equation (4).
- Prominence and relation interactions are obtained from Equations (5-6) and calculated by summing the rows and column entries (see Table 2) and which is further utilized to draw cause and effect diagram as shown in Figure 1.

Table 1: Initial Direct Relation Matrix

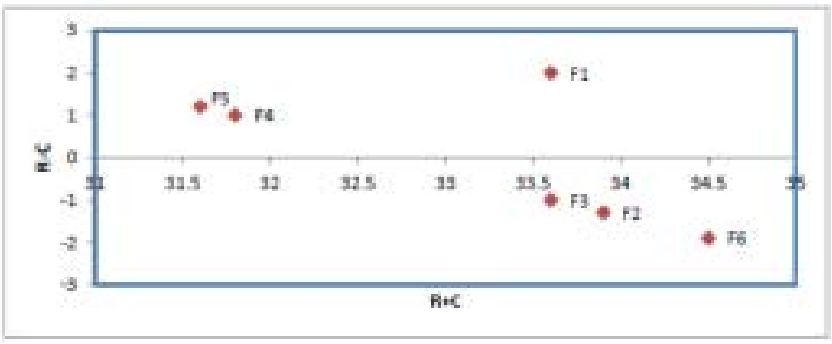
	F1	F2	F3	F4	F5	F6
F1	0	2.5	3	3	2.5	3
F2	2.5	0	3	3	3	3
F3	2.5	3	0	3	3	3.5
F4	2.5	4	3	0	2.5	3.5
F5	3	3	2	2	0	4
F6	2.5	2	3.5	2	2.5	0

Note: Supplier selection and related issue (F1), Ecological benefits and resources management (F2), Green image (F3), Governmental rules and regulations (F4), Green purchasing, design and operations (F5), Green productivity (F6).

Table 2: Total Direct Relation Matrix

	F1	F2	F3	F4	F5	F6	R	C	R+C	R-C
F1	2.7169	3.1368	3.1059	2.8115	2.7371	3.3292	17.8	15.8	33.6	2.0
F2	2.6109	2.8966	2.8282	2.5214	2.4949	2.9912	16.3	17.6	33.9	–1.3
F3	2.6109	2.8966	2.8282	2.5214	2.4949	2.9912	16.3	17.3	33.6	–1.0
F4	2.6109	2.8966	2.8282	2.5214	2.4949	2.9912	16.4	15.4	31.8	1.0
F5	2.6109	2.8966	2.8282	2.5214	2.4949	2.9912	16.4	15.2	31.6	1.2
F6	2.6109	2.8966	2.8282	2.5214	2.4949	2.9912	16.3	18.2	34.5	–1.9

Figure 1: Cause and Effect Diagram



Based on the values of relation, i.e., "R-C", the identified attributes are classified into cause and effect group elements. Cause group elements are vital due to their direct impact on the system (Fontela and Gabus, 1976). Generally, the performance of cause group attributes is important in identifying and evaluating the goal. Therefore, in beginning, it would be significant to focus primarily on the cause group attributes, as their influence on the effect group attributes is significant. In addition, supplier selection and related issue, governmental rules and regulations, and green purchasing, design and operations, forms cause groups, while ecological benefits and resources management, green image and process and green productivity comes under effect group.

CONCLUSION

An evaluation and analysis of attribute for improving the performance of GSC is presented. The study has presented an operational model for the understudy GSCM to evaluate causality among the identified attributes. However, total 6 performance focused attributes has been identified and further analysed utilizing DEMAEL method, which helps in building structural model including the considered attributes. Our Research also offers a comprehensive vision for identified attributes by providing visualization of interactions. Further, the cause and effect diagram illustrates the relative significance of attributes by categorizing attributes into cause and effect group elements. The cause and effect group element attribute would be important for improving the performance of GSC and focussing the relative important issues that should be greatly focused. The discussed case of plastic industry would be greatly help by this research in order to improve their GSC productivity. The study should be helpful for the case managers to work issues on GSCM.

The model proposed in this study can be extended for other problems in operations management and supply chain such as supplier evaluation and problems. There are some other multiple attribute decision-making methods namely ANP, AHP, TOPSIS, etc., that could be apply for analysing the factors and this would be quite attractive to comparing the results with the model proposed in the study.

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