Journal of Industrial Strategic Management

Evaluation Green Suppliers Using DEMATEL Technique in Fuzzy Environment

Reza Ehtesham Rasi[*a]

a Department of Industrial Management, Qazvin Branch, Islamic Azad University, Qazvin, Iran.

CHRONICLE

Article history:
Received: 05/02/2018
Received in revised: 13/01/2018
Accepted: 05/03/2019

Keywords:
** Green Supply Chain*
** Environmental*
** Production capability.*

Abstract

Green supply chain management (GSCM) is crucial for environmental compliance and business development of companies. Companies look for new ideas and methods to achieve environmental sustainability. GSCM is an innovative idea which involves all business value-adding operations, such as purchasing and in-bound logistics, production and manufacturing, distribution, out-bound logistics, and collaboration with patrons and suppliers with the minimum negative environmental impact. The main purpose of the present study was to find the interrelationship between green supplier criteria applying a novel model. Thus, experts' opinions were investigated through nominal group technique (NGT) to understand the interrelationship and causal preferences of the green supplier evaluation aspects through Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. The degree of importance factors shows that environmental performance is a proper index for displaying companies adopting their supply chain into the GSCM as the third most important criterion. The results of the priority weight analysis of the criteria demonstrated that the production Capability has minimal impact on GSCM adoption. The findings also revealed that the production capability falls under the effect group, and green design and production capability are correlated.

© All rights reserved

* Corresponding Author. Tel: 09122901128 Email address: ehteshamrasi@qiau.ac.ir

Introduction

A comprehensive conceptual model ranking different suppliers from GSM perspective has been ignored so far. Mingbo and Dan (2009) proposed a model stating the criteria of GSs' performance. Nevertheless, for the efficiency of model, a decision making tool lacks relationships between model constructs and significance of these relationships. According to new definition, a closed loop supply chain entails design, control, and implementing of a system to maximize value creation in the lifetime of a product, with a dynamic value generation from different returned products over time (Govindan et al., 2015).
The main aim of this study is to (1) find the relationships for the Mingbo and Dan (2009)'s model and (2) determine the significance of interrelationships between the criteria to assess supplier performance in uncertainty condition. Multi Criteria Decision Making (MCDM) helps organizations and SC managers make more efficient decisions (Chai et al., 2013). To promote this field of research and further integrate sustainability discussion into the suppliers' evaluation modeling area, the supplier evaluation problem in GSM context was modeled through a group decision making approach, called Decision Making Trial and Evaluation Laboratory (DEMATEL) method.This paper proceeds as follows. In section (2), the literature review is presented. Section (3) presents the proposed conceptual model. A case study in section (4) demonstrates the application of the proposed model. The last section discusses the implications of the work for academics and practitioners as well as pointing out the limitations and the avenues of future work.

Supply Chain (SC) is a network between a company and suppliers to generate and distribute a product; SCM is a prominent process since an optimized SC causes lower costs and a faster generation cycle. With increase of awareness of environmental protection, the green movement is inevitable towards conserving resources and protection of the environment, compelling on firms in the world. Growing environmental importance has penetrated into the overall institutional culture and contributed to re-concentration of corporations' strategies (Zhu and Sarkis,2006). Puigjaner et al. (2015) believed that use of biomass waste, entailing disposal problems can be an alternative to power production. Greening SC is an innovative idea that absorbs consideration in industry and many companies. Various positive impacts of internal measures have already been achieved by leading firms. This is one of the basic principles of the philosophy of greening SC necessary for successful implementation of industrial ecosystems and creation of value for corporations (Bose and Pal, 2012).In addition, Bacallan (2000) stated that "although they may have nothing to do at all with the problem, companies are often held accountable for labor practices and environmental liabilities of their suppliers". So, SC greening helps companies to avoid potential environmental problems emerging with their suppliers which in turn may put at risk their own environmental performance. The industry of developed countries has adopted GSC due to government regulation on environmental issues (Nurjanni et al., 2017). Liou et al. (2016) introduced new models for improvement of selection suppliers in GSCM. Bai et al. (2016) suggested methods for management of investments to develop GS.

Review of literature

Companies today definitely cannot neglect environmental issues with restricting government regulation and growing public consciousness in environmental protection provided that they assume surviving in the global market.Jabbour (2009) studied Brazilian companies to find out whether supplier selection criteria become green and indicated that a company with more developed environmental management has more formal methods for selection of environmentally proper suppliers compared with others. Niza et al. (2014) stated that environmental considerations have been developed in all industries, including extended producers' responsibilities for environmental influences.Enarsson (1998) proposed a fish bone diagram to evaluate environmental properties of suppliers. Humphreys et al. (2003a) used case-based reasoning to assess suppliers environmental performance. To merge sustainability into supplier selection, Bai and Sarkis (2010) used grey system and rough set methodologies. Humphreys et al.

not less than that under cap-and-trade regulation, so in this paper second strategy has been investigated and the effects of such regulations on decisions which are made by different firms and interactions between government and SCs are studied. The purchasing process becomes more complex when environmental and social aspects are considered (Lee et al. 2009). So, GS evaluation is more required for effective GSCM (Govindan et al. 2015).In this study first addresses effective factors on GSCM relation relying on field studies and expert views. Nominal group method was used for collecting vote and DEMATEL method for systematizing data structure under uncertainty condition. Hence, this method is usable for identification process, classification, and mutual impact which may occur indirectly or directly.

One of the crucial challenges faced by SC managers is constructing an operative supplier evaluation model. To assess potential suppliers, development of a set of relevant selection criteria is required. Thus, the traditional criteria are quality, cost efficiency, delivery, information, volume, lead time flexibility, and customer service level (Yeh and Chuang 2011). Some advocated criteria include innovation, the ability of the supplier to provide design and technological capabilities to the customer, supplier location, the suppliers' willingness to share information and legal terms (Aref et al. 2005). The Analytic Network Supplier Evaluation Model for GSC in this study proposes that the supplier evaluation criteria include five dimensions: competitive pricing and cost, reliability, production capability, environmental performance, and pollution control.

(2006) implemented dynamic fuzzy membership functions to assess environmental performance in the process of supplier selection. Amindoust et al. (2012) proposed ranking model on the basis of three criteria and eight sub-criteria; however, their study did not assume the entire relevant criteria for the selection of sustainable supplier. For supplier assessment, Handfield et al. (2002) used environmental criteria in AHP. Tuzkaya et al. (2009) showed a hybrid fuzzy MCDM approach to measure environmental performance assessment of suppliers.For high-tech industries, Lee et al. (2009) showed a green supplier selection model, using Delphi method and fuzzy extended analytic hierarchy process (ANP). Lu et al. (2007) proposed a multi-objective decision analysis to apply environmental tenets to evaluate green supplier at different supply chain levels. Humphreys et al. (2003b) prepared a multi-stage framework to combine environmental criteria with supplier selection process and examine environmental performance of suppliers against legal needs. Different multinational enterprises launch investments in researches and development of green products, applying standards to avoid the use of risky materials and training suppliers to deliver products free of hazardous substances at all supply chain levels. This phenomenon shows that companies demonstrate that environmental consciousness is an origin of competitive advantage (Bose and Pal, 2012; Walton et al., 1998). Also, GSCM can promote efficiency and synergy among business stakeholders and their leading corporations and also improve environmental performance, diminish waste, and acquire cost saving (Rao and Holt, 2005). Xu and He (2016) investigated and discovered that the social welfare under carbon tax regulation is

Proposed model

approaches. The GS evaluation methodology contains three main steps as following:

1. Establishment and analysis of sustainable criteria for supplier evaluation, applying experts ideas with NGT (Nominal Group Technique): the expert panel consists of five managers of environmental and SC departments in five companies. In this stage, the evaluation criteria for GSs are collected

A research design links data during initial questioning of the study. This research developed a conceptual model for GS evaluation, applying DEMATEL for adaption of uncertainties and complexities in the real world, assisting SC managers and organizations to find a proper tool for evaluation and controlling GSs via various

Step 1: Making the direct-influenced matrix
Finding direct-relation (average) matrix; there are five scales which determine values of relationships between various factors based on expert opinion. Five scales are used to measure the relationship between various criteria: 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence, 4 = very high influence.A fuzzy number generalizes a regular real number in sense that it does not refer to one single value, but rather to a related series of possible values, where each value has its own weight set between 0 and 1. This weight is named the membership function. A fuzzy number is a specific case of a convex, normalized fuzzy set of the real line. In the present study, a triangular fuzzy number is used. The fuzzy number shown with three points is as follows: (a1, a2, a3), this representation is interpreted as membership functions and entails the following conditions: (i) a1 to a2 is an increasing function (ii) a2 to a3 is a decreasing function (iii) a1 ≤ a2 ≤ a3.Also to compare each of the five criteria of verbal expression is used which the terms and amounts shown in Table (1) equivalents phase:

through literature review and discussion with managers in an industry and eco-experts with NGT according to the evaluation model of analytic network supplier for GSC (Figure 1).
2. Modeling DEMATEL for supplier performance evaluation in GSC context.
3. Validation of the model: a case study is illustrated to validate the new GS evaluation method.
DEMATEL is a professional group decision making procedure to formulate and evaluate a structural model involving the causal relationships among numerous and complex factors. This method can prove interrelations between criteria and constrain the relations which resonate the attributes of a system (Amiri et al. 2011). DEMATEL method has been developed according to the idea that suitable employment of scientific research procedures may enhance understanding of specific problems and determine solutions with executive capability applying a hierarchical structure (Lin and Lin, 2008). Applying the DEMATEL in a fuzzy context enables researchers to analysis the causal relationships of fuzzy variables and determine the level of interactive influence between variables i.e. cause and effect variables and a brief definition of fuzzy set theory is addressed here in order to deal with imprecise judgments, in addition to DEMATEL method. Fuzzy DEMATEL method involves four steps delineated as follows:

Table 1: Verbal expression used in research and equivalents amounts

Verbal expression	Fuzzy amount
no influence	(0,0,0.25)
low influence	(0,0.25,0.5)
medium influence	(0.25,0.5,0.75)
high influence	(0.5,0.75,1)
very high influence	(0.75,1,1)

Then, in terms of effects and direction among criteria, sets of pair-wise comparisons are provided by decision makers, i.e. experts. Thereafter, the initial data can be obtained as a direct-relation matrix, which is a [n × n] matrix A. Each aij element is known as the degree in which the criterion i influences the criterion j.

Step 2: Normalize the initial direct-relation matrix. By normalizing the average matrix A, normalized initial direct relation matrix D is obtained in the following formulate.

$T = [t_{ij}]_{m\times m} \qquad i,j = 1,2,\dots,m$

$D = \left[\sum_{j=1}^{m} t_{ij}\right]_{m\times 1} = [t_{i.}]_{m\times 1}$

$R = [\sum_{i=1}^{m} t_{ij}]_{1\times m} = [t_{.j}]_{1\times m}$

Case Study

Saipa is an automaker headquartered in Tehran, Iran. Saipa was established in 1966, with 75% Iranian ownership, to assemble Citroëns under license for the Iranian market. Nominal Group Technique (NGT) is a method for decision making usable for different group sizes to speed decision making. However, individuals' opinions are taken into consideration. It is necessary to find professionals who verify relationships among affective success factors of GS performance. The experts organized the sets of pair-wise comparisons in terms of influences and direction among GS performance factors involving five dimensions: environmental performance, production capability, competitive pricing and cost, reliability, and pollution control. Hence, the initial data can be obtained as a direct-relation matrix which could be a 5 × 5 matrix A. Every element of Xij is marked as the degree, within which the element i affects the element j. At this phase, the relation among important factors can be noticed in each criterion. The causal diagram incorporating the horizontal axis (D+R) and vertical axis (D-R) is ready. The relative importance of each feature is depicted in horizontal axis, referred as "prominence" similarity features divided into cause and effect clusters in vertical axis and called "relation". Moreover, advanced causal relationships are visualized into observable structural model using causal diagram. Nevertheless, if (D-R) is negative, this facet lies in the effect group. Alternatively, if (D-R) is positive, the facet lies in the cause cluster. The relative significance of criteria is determined by the committee of expert decision makers.On the basis of step 2 and equation 4 for fuzzification data of matrix, normalized matrix of green supplier performance evaluation is depicted as follows

Normalization is calculated applying the following equation. Note that each ele (3)

of matrix X is maximum one and minimum zero.

$K= 1/(\max_{1<i<n}\sum^{m}_{j=1}a_{ij}) \quad i,j = \quad 1,2,\dots m.$

$X=K\times M$

Step 3: Calculate the total-relation matrix. A continuous reducing of the indirect effects of problems beside the powers of matrix D, like to an engrossing Markov chain matrix, guarantees convergent solutions to the matrix inversion.

By applying the following formula (1, 2), the total-relation matrix will be calculated. Note that I is the $m \times m$ identity matrix.

$$T = X(I - X)^{-1}$$

Step 4: Generating a causal diagram

The sum of rows and columns are separately marked as vector D and vector R through Equation 3. Then, the horizontal axis vector (D+R), called ''Prominence'', is generated through adding D to R, presenting the relative significance for each criterion. Similarly, the vertical axis (D-R), relation, is created through subtracting D from R, categorizing criteria into two groups comprising of cause and effect. Generally, the positive (D-R) implies that the criterion is set in the cause group. And the negative (D-R) demonstrates that the criterion displays the effect group. So, the causal diagram is attainable through mapping the dataset of (D+R, D-R), revealing some insights for facilitation of decision makings.

according equation (1) and (4): (Table 2). For taking all the experts, we mean

$$\tilde{z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^3 \oplus \ldots \oplus x^p}{p} \tag{4}$$

Table 2. Opinions of experts

The average opinion of all experts	Competitive pricing	Reliability	Production Capability	Environmental performance	Pollution control
Competitive pricing	(0.750,1.000,1.000)	(0.500,0.750,0.875)	(0.750,1.000,1.000)	(0.250,0.438,0.688)	(0.000,0.000,0.000)
Reliability	(0.562,0.750,0.812)	(0.250,0.500,0.688)	(0.500,0.750,0.938)	(0.000,0.000,0.000)	(0.625,0.875,1.000)
Production Capability	(0.312,0.562,0.750)	(0.312,0.500,0.688)	(0.000,0.000,0.000)	(0.375,0.625,0.750)	(0.438,0.688,0.875)
Environmental performance	(0.375,0.625,0.750)	(0.000,0.000,0.000)	(0.438,0.688,0.875)	(0.500,0.750,0.875)	(0.375,0.625,0.750)
Pollution control	(0.000,0.000,0.000)	(0.562,0.812,0.875)	(0.375,0.562,0.750)	(0.375,0.625,0.812)	(0.500,0.750,0.875)

For normalizing the matrix obtained from equations (5) and (6) is used as following:

$$\widetilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}\right) = \left(l''_{ij}, m''_{ij}, u''_{ij}\right) \tag{5}$$

Where r is obtained from the following equation

$$r = max_{1 \le i \le n}\left(\sum_{j=1}^{n} u_{ij}\right) \tag{6}$$

Table (3) shows the normalized matrix:

Table 3. Normalized green supplier performance evaluation

Normalized	Competitive pricing	Reliability	Production Capability	Environmental performance	Pollution control
Competitive pricing	(0,0,0)	(0.070,0.123,0.193)	(0.211,0.281,0.281)	(0.140,0.211,0.246)	(0.211,0.281,0.281)
Reliability	(0.175,0.246,0.281)	(0,0,0)	(0.140,0.211,0.263)	(0.070,0.140,0.193)	(0.158,0.211,0.228)
Production Capability	(0.123,0.193,0.	(0.105,0.175,0.	(0,0,0)	(0.088,0.140,0.1	(0.088,0.158

	246)	211)		93)	,0.211)
Environmental performance	(0.105,0.175,0.211)	(0.140,0.211,0.246)	(0.123,0.193,0.246)	(0,0,0)	(0.105,0.175,0.211)
Pollution control	(0.140,0.211,0.246)	(0.105,0.175,0.228)	(0.105,0.158,0.211)	(0.158,0.228,0.246)	(0,0,0)

Then DEMATEL technique and total relationships matrix are applied to green supplier performance evaluation; important factors for green supplier performance evaluation are demonstrated in Tables(4).After calculating the above matrix, the matrix of fuzzy relations according to formulas 7 to 10 are obtained.

$$T = \lim_{k\to+\infty}(\tilde{H}^1 \oplus \tilde{H}^2 \oplus \ldots \oplus \tilde{H}^k) \tag{7}$$

$$[l^{\,t}_{ij}] = H_l \times (I - H_l)^{-1} \tag{8}$$

$$[m^{\,t}_{ij}] = H_m \times (I - H_m)^{-1} \tag{9}$$

$$[u^{\,t}_{ij}] = H_u \times (I - H_u)^{-1} \tag{10}$$

Table 4. Total relationships matrices for green supplier performance evaluation

Criteria	Competitive pricing	Reliability	Production Capability	Environmental performance	Pollution control
Competitive pricing	(0.146,0.664,2.892)	(0.186,0.682,2.795)	(0.333,0.901,3.156)	(0.255,0.775,2.839)	(0.327,0.889,2.992)
Reliability	(0.285,0.819,3.044)	(0.103,0.526,2.567)	(0.267,0.809,3.075)	(0.184,0.682,2.740)	(0.277,0.799,2.892)
Production Capability	(0.211,0.689,2.768)	(0.175,0.598,2.512)	(0.109,0.540,2.610)	(0.169,0.597,2.509)	(0.187,0.667,2.638)

Environmental performance	(0.212,0.732,2.865)	(0.216,0.672,2.646)	(0.233,0.757,2.928)	(0.099,0.522,2.455)	(0.215,0.733,2.752)
Pollution control	(0.247,0.770,2.937)	(0.195,0.659,2.679)	(0.228,0.747,2.956)	(0.247,0.724,2.699)	(0.129,0.600,2.626)

The next step is to obtain a total of rows and columns of the matrix. Whole rows and columns according to the formulas (11) and (12) would be as follows:

$$\widetilde{D} = (\widetilde{D}_i)_{n\times 1} = [\textstyle\sum_{j=1}^{n} \tilde{T}_{ij}]_{n\times 1} \tag{11}$$

$$\tilde{R} = (\tilde{R}_i)_{1\times n} = [\textstyle\sum_{i=1}^{n} \tilde{T}_{ij}]_{1\times n} \tag{12}$$

The $\widetilde{D}$ و $\tilde{R}$are respectively matrix n × 1 and 1 × n. Next, the importance of $(\widetilde{\mathrm{D}}_\mathrm{i} + \widetilde{\mathrm{R}}_\mathrm{i})$ and the relationship between the criteria $(\widetilde{\mathrm{D}}_\mathrm{i} - \widetilde{\mathrm{R}}_\mathrm{i})$ is determined. If $\widetilde{\mathrm{D}}_\mathrm{i} - \widetilde{\mathrm{R}}_\mathrm{i} > 0$the relevant criterion is then it is effective and if $\widetilde{\mathrm{D}}_\mathrm{i} - \widetilde{\mathrm{R}}_\mathrm{i} < 0$ is the relevant criterion then is bonding. Table (5) shows $\widetilde{\mathrm{D}}_\mathrm{i} + \widetilde{\mathrm{R}}_\mathrm{i}and\widetilde{\mathrm{D}}_\mathrm{i} - \widetilde{\mathrm{R}}_\mathrm{i}$.

Table 5. The importance and impact criteria (fuzzy numbers)

Criteria	$\widetilde{D}_i + \tilde{R}_i$	$\widetilde{D}_i - \tilde{R}_i$
Competitive pricing	(2.347,7.585,29.180)	(-13.260,0.236,13.574)
Reliability	(1.990,6.770,27.516)	(-12.084,0.499,13.443)
Production Capability	(2.021,6.844,27.761)	(-13.873,-0.662,11.867)
Environmental performance	(1.930,6.717,26.888)	(-12.267,0.115,12.692)
Pollution control	(2.179,7.188,27.795)	(-12.855,-0.188,12.761)

The next step is fuzzy numbers $\widetilde{\mathrm{D}}_\mathrm{i} + \widetilde{\mathrm{R}}_\mathrm{i}$and $\widetilde{\mathrm{D}}_\mathrm{i} - \widetilde{\mathrm{R}}_\mathrm{i}$ obtained from the previous step, we Difuzzy according to equation (13).

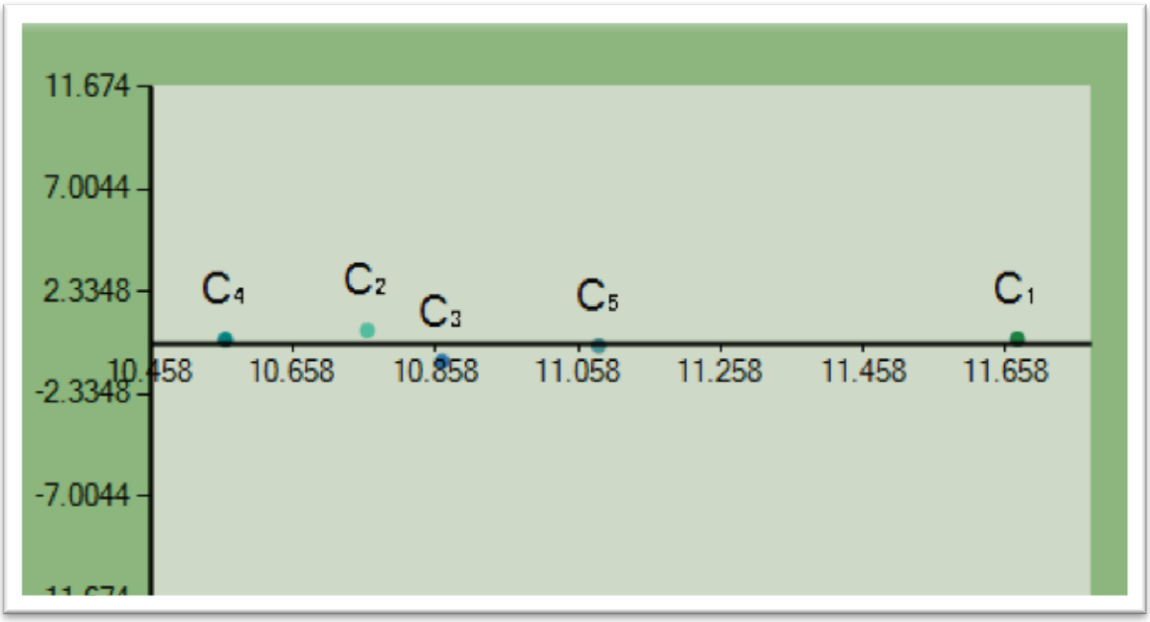
$$\mathrm{B} = \frac{(\mathrm{a}_1 + \mathrm{a}_3 + 2 \times \mathrm{a}_2)}{4} \tag{13}$$

B is Difuzzy the number$\widetilde{\mathrm{A}} = (\mathrm{a}_1, \mathrm{a}_2, \mathrm{a}_3)$. Table (5) shows diffuzification numbers of table (6).

Table 6. The importance and impact criteria

Criteria	$(\widetilde{D}_i + \tilde{R}_i)^{def}$	$(\widetilde{D}_i - \tilde{R}_i)^{def}$
Competitive pricing	11.674	0.197
Reliability	10.762	0.589
Production Capability	10.867	-0.832
Environmental performance	10.563	0.164
Pollution control	11.087	-0.117

Effect



Importance

Figure1. Results of Causal diagram of GSC using Fuzzy DEMATEL

of the overall system. First, because group criteria are required to be recognized and improved, leading to effect group criteria improvement to make an effective decision. Fuzzy DEMATEL methodology was used to assess the interactions among multiple criteria, filling gap left by traditional models. Traditional models indicate strategies through

Conclusion and Recommendations

Often complex criteria face either influence, called the cause group, or are affected by other criteria, making the effect group in group decision making problems. Since there is a dependence and feedback relationship among the criteria, improvement in one or two criteria does not necessarily result in the improvement their degree importance, were identified as pollution control > environmental performance > reliability > production capability. The results demonstrated that environmental performance is a suitable indictor for displaying companies adopting their SC into GSCM, as the third most important criterion. The results of the priority weight analysis of the criteria demonstrated that the 'production capability' has less impact on GSCM adoption. The facts reveal that producing capability falls under effect group, and there is a causal relationship between production capability and green design.

The results also illustrated that two criteria from the cause group, competitive pricing, cost, and reliability and environmental performance' are prioritized as the key criteria. The two main reasons are proposed for higher impact of environmental performance on GSCM selection by the industries. First, societal consideration for environmental protection stating that the regulations, stakeholder pressures, and public awareness is raised against the environmental influences (Sarkis, 2006). Second, greening various phases of SC causes an integrated GSC, eventually triggering competitiveness and economic performance (Bose and Pal 2012; Rao and Holt 2005).

GSCM's has not been commonly accepted although its significance and its benefits are well known due to a weak understanding of diverse affective factors of GSCM and the interdependence. These factors can be classified into barriers and drivers. Barriers consideration of direct effects or single directions of criteria.Final results that show impact levels of each criterion in the system, also on each other, are provided in Table(5). According to the 'D − R' values, the criteria are classified into two cause and effect groups. The criteria of environmental performance and competitive pricing and cost and reliability are set under cause group for having positive 'D − R' values. The criteria which have negative 'D − R' values are classified as effect group criteria, including pollution and production capability criteria. The cause and effect analysis results showed that competitive pricing which belongs to effect group is the prominent criterion in this group. This finding is in accordance with the findings of Rao and Holt (2005), demonstrating that integrated green SC leads, ultimately, to competitiveness and economic performance.

It is also found that the criterion competitive pricing is the prominent driver among all criteria through the analysis of 'R + D' values. The result is confirmed by the fact that competitive pricing, regarding GSCM benefits, is required to elicit their support for GSCM implementation. It would be difficult to order required resources for GSCM implementation without competitive pricing. Furthermore, competitive pricing provides an opportunity for preparation of the environmental policy of an organization and creation of the GSCM implementation plan. 'R + D' values of other criteria are investigated to evaluate their priorities following the confirmation of competitive pricing. The criteria, according to

Implications for practitioners

The managerial implications extracted from the study are as follows:

• Categorization of criteria into cause and effect group helps decision makers to indicate the group of factors (cause group), which need control and attention (Lin, 2013). Actually, the cause group criteria are hard to move while those included in effect group are easily moved (Govindan et al., 2016). Additional prioritization of the criteria assists the decision makers to identify the criteria which require improvement on a priority basis, subsequently improving other criteria and the entire system.

• Table (2) and Figure (1) (cause and effect diagram) show that competitive pricing is the prominent criterion in the ranking. Obviously, it has the highest ‘R’ value which is an indicator of the highest degree of impact allotted on other criteria and on the system (Akhilesh and Kamalakanta 2013).

• Pollution control is the fourth most important criterion. It falls under the cause group and has the highest driving power in due to its highest ‘R’ value. So, managers must focus on pollution control and environmental performance to enhance GSCM performance. Also, they should formulate strategies that focus on fulfilling pollution requirements for improved environmental performance for balancing economic and environment indices (Wu and Pagell 2011).

resist GSCM implementation (Muduli et al., 2013). Drivers are different based on their strength of impact and on the entire system. Fuzzy DEMATEL method was proposed to assess the direct and indirect impacts of GSCM criteria. DEMATEL technique contributes to the decision-making process to evaluate the causal relationship and the influence/strength of the target system criteria and shows the direct and indirect impacts of criteria via a visual diagram (Govindan et al. 2016).The results of analysis were divided into two parts; First, the degree of impact of each criterion (priority weight) on the system was evaluated and applied as a basis for their ranking. Secondly, the criteria were classified as the net dispatcher (cause group) criterion or net receiver (effect group). This study has several particular contributions since DMATEL simplifies the complex criteria and recognize interrelationship influences between factors of GSs, including: 1. indicating the explicit criteria , sub-criteria and interrelationship between them with respect to all factors of competitive pricing and cost, reliability, environmental performance, pollution control, and production capability for balancing greening SC issues; 2. modeling the DEMATEL for determining interrelationship between criteria to assess supplier performance, and 3. developing a practical model in GSC context to assist organizations and SC managers make more effective decisions by fuzzy numbers under uncertainty.

Future studies might aim modeling the supplier evaluation problem in GSC context with a novel approach first introduced by Charnes to promote this area of research and further integrate sustainability discussion into the suppliers' evaluation modeling area (1978). This approach uses Network Data Envelopment analysis (DEA), a relatively new "data oriented" approach, to assess the performance of a set of peer entities, called Decision Making Units (DMUs), which turn multiple inputs into multiple outputs (Kao, 2009).

Limitations and future work

Analysis of GSCM criteria with fuzzy DEMATEL method was carried out applying the judgment of few experts. However, future studies should include a network base data envelopment analysis model for constructing a solid model. Although some methods have been introduced with a variety of formal modeling techniques, they may be constrained because of different reasons. MCDM methods and decision support tools and methodologies can help organizations and supply chain managers develop more influential decisions.

References

1. Akhilesh, B., and Kamalakanta, M. (2013). Modelling the challenges of green supply chain management practices in indian mining industriesnull, Journal of Manufacturing Technology Management , 24(8); 1102-1122.
2. Amindoust, A., Ahmed, S., Saghafinia, A., and Bahreininejad, A. (2012). Sustainable supplier selection: a ranking model based on fuzzy inference system. Applied Sofware Computing. 12(6);1668-1677.
3. Amiri, M., Sadaghiyani, J. S., Payani, N., and Shafieezadeh, M. (2011). Developing a dematel method to prioritize distribution centers in supply chain, Management Science Letters, 1(3);279-288.
4. Aref, A. H., Marilyn, M. H., and Joseph, S. (2005).Performance measurement for green supply chain management, Benchmarking: An International Journal, 12(4);330-353.
5. Bacallan, J. (2000).Greening the supply chain, Business and Environment, 6(6); 11-12.
6. Bai, C., and Sarkis, J. (2010).Integrating sustainability into supplier selection with grey system and rough set methodologies,International Journal of Production Economics, 124(1); 252-264.
7. Bai, C., Dhavale, D., and Sarkis, J. (2016). Complex investment decisions using rough set and fuzzy c-means: an example of investment in green supply chains. European Journal of Operational Research, 248(2);507–521.
8. Bose, I., and Pal, R. (2012). Do Green supply chain management initiatives impact stock prices of firms?, Decision Support Systems, 52(3); 624-634.
9. Chai, J., Liu, J. N., and Ngai, E. W. (2013). Application of Decision-Making Techniques in Supplier Selection: A Systematic Review of Literature,Expert Systems with Applications, 40(10); 3872-3885.
10. Charnes, W. (1978).Measuring the efficiency of decision making units* 1, European journal of operational research, 2(6); 429-444.
11. Enarsson, L. (1998).Evaluation of suppliers: how to consider the environment, International Journal of Physical Distribution & Logistics Management, 28(1); 5-17.
12. Govindan, K., Muduli, K., Devika, K., and Barve, A. (2016). Investigation of the influential strength of factors on adoption of green supply chain management practices: an indian mining scenario,Resources, Conservation and Recycling,107(2);185-194.
13. Govindan, K., Rajendran, S., Sarkis, J., and Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: A Literature Review, Journal of Cleaner Production, 98(14); 66-83.
14. Green, K., Morton, B., and New, S. (1996).Purchasing and environmental management: interactions, policies and

opportunities, Business Strategy and the Environment, 5(3);188-197.

15. Handfield, R., Walton, S., Sroufe, R., and Melnyk, S. (2002). Applying environmental criteria to supplier assessment: a study in the application of the analytical hierarchy process, European Journal of Operational Research, 141(1);70-87.
16. Humphreys, P., McCloskey, A., McIvor, R., Maguire, L., and Glackin, C. (2006).Employing Dynamic fuzzy membership functions to assess environmental performance in the supplier selection process,International Journal of Production Research, 44(12); 2379-2419.
17. Humphreys, P., McIvor, R., and Chan, F. (2003a).Using case-based reasoning to evaluate supplier environmental management performance,Expert Systems with Applications, 25(2); 141-153.
18. Humphreys, P. K., Wong, Y. K., and Chan, F. T. S. (2003b).Integrating environmental criteria into the supplier selection process,Journal of Materials Processing Technology, 138(13);349-356.
19. Jabbour, A., and Jabbour, C. (2009). Are Supplier Selection Criteria Going Green? Case Studies of Companies in Brazil,Industrial Management & Data Systems, 109(4); 477-495.
20. Kao, C. (2009). Efficiency decomposition in network data envelopment analysis: a relational model," European Journal of Operational Research, 192(3); 949-962.
21. Lee, A., Kang, H., Hsu, C., and Hung, H. (2009). A Green supplier selection model for high-tech industry, Expert Systems with Applications, 36(4); 7917-7927.
22. Lin, K. M., and Lin, C. W. (2008).Cognition map of experiential marketing strategy for hot spring hotels in Taiwan using the dematel method, Natural Computation, ICNC'08. Fourth International Conference on: IEEE, pp. 438-442.
23. Lin, R. J. (2013)."Using fuzzy dematel to evaluate the green supply chain management practices,Journal of Cleaner Production, 40(8); 32-39.
24. Liou, J. J. H., Tamošaitienė, J., Zavadskas, E.K., Tzeng, G., (2016).New hybrid COPRAS-G MADM model for improving and selecting suppliers in green supply chain management. International Journal of Production Research, 54(1); 114–134.
25. Lu, L., Wu, C., and Kuo, T. (2007). Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis, International Journal of Production Research, 45(18); 4317-4331.
26. Mingbo, S.,Dan, Y.(2009).Integrating environmental performance into the supplier evaluation: a gra-based method, Industrial Engineering and Engineering Management, 2009. IE&EM '09. 16th International Conference on, ;162-166.
27. Muduli, K., Govindan, K., Barve, A., and Geng, Y. (2013).Barriers to green supply chain management in indian mining industries: a graph theoretic approach, Journal of Cleaner Production, 47(2);335-344.
28. Niza, S., Santos, E., Costa, I., Ribeiro, P., Ferrão, P.(2014). Extended producer responsibility policy in Portugal: a strategy towards improving waste management performance. Journal of Cleaner Production, 64(64); 277–287.
29. Nurjanni, K. P., Carlvaho, M. S., Costa., L. (2017). Green supply chain design: A mathematical modeling approach based on a multi-objective optimization model, International Journal of Production Economics, 183(2);421–432.
30. Puigjaner, L., Pérez-fortes, M., and Laínez-aguirre, J. M. (2015). Towards a carbon-neutral energy sector: opportunities and challenges of coordinated bioenergy supply chains—A PSE Approach., 56(2);13–5660.
31. Rao, P., and Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance?, International Journal of Operations & Production Management, 25(9); 898-916.
32. Tuzkaya, G., Ozgen, A., Ozgen, D., and Tuzkaya, U. (2009).Environmental performance evaluation of suppliers: a hybrid fuzzy multi-criteria decision approach, International Journal,6(3); 477-490.
33. Verghese, K., and Lewis, H. (2007). Environmental innovation in industrial packaging: a supply chain approach, International Journal of Production Research,45(18);4381-4401.
34. Walker, H., Di Sisto, L., and McBain, D. (2008). Drivers and barriers to environmental supply chain management practices: lessons from the public and private sectors, Journal of Purchasing and Supply Management,14(1);69-85.
35. Walton, S. V., Handfield, R. B., and Melnyk, S. A. (1998). The green supply chain: integrating suppliers into environmental management processes,"

38. Yeh, W.-C., and Chuang, M.-C. (2011). Using Multi-objective genetic algorithm for partner selection in green supply chain problems, Expert Systems with Applications, 38(4); 4244-4253.
39. Zhu, Q., and Sarkis, J. (2006). "An inter-sectoral comparison of green supply chain management in china: drivers and practices," Journal of Cleaner Production, Vol. 14, No. 5, pp. 472-486.

Journal of Supply Chain Management, 34(2); 2-11.

36. Wu, Z., and Pagell, M. (2011). Balancing Priorities: decision-making in sustainable supply chain management, Journal of Operations Management, 29(6);577-590.
37. Xu, X., Xu, X., & He, P. (2016). Joint production and pricing decisions for multiple products with cap-and-trade and carbon tax regulations. Journal of Cleaner Production, 112(2); 4093–4106