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Intuitionistic fuzzy based DEMATEL method for developing green practices and performances in a green supply chain

Kannan Govindan [a,*], Roohollah Khodaverdi [b], Amin Vafadarnikjoo [b]

[a] Department of Business and Economics, University of Southern Denmark, Odense, Denmark
[b] Faculty of Management and Accounting, Allame Tabataba'i University Business School (ATUBS), Iran

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ABSTRACT

Environmental topics have gained much consideration in corporate green operations. Globalization, stakeholder pressures, and stricter environmental regulations have made organizations develop environmental practices. Thus, green supply chain management (GSCM) is now a proactive approach for organizations to enhance their environmental performance and achieve competitive advantages. This study pioneers using the decision-making trial and evaluation laboratory (DEMATEL) method with intuitionistic fuzzy sets to handle the important and causal relationships between GSCM practices and performances. DEMATEL evaluates GSCM practices to find the main practices to improve both environmental and economic performances. This study uses intuitionistic fuzzy set theory to handle the linguistic imprecision and the ambiguity of human being's judgment. A case study from the automotive industry is presented to evaluate the efficiency of the proposed method. The results reveal "internal management support", "green purchasing" and "ISO 14001 certification" are the most significant GSCM practices. The practical results of this study offer useful insights for managers to become more environmentally responsible, while improving their economic and environmental performance goals. Further, a sensitivity analysis of results, managerial implications, conclusions, limitations and future research opportunities are provided.

1. Introduction

Environmental management is an important topic in supply chain management (SCM). Due to governmental legislation and increased consciousness among stakeholders to preserve the environment, organizations are coerced into executing environmental practices to improve their green image and survive in the global market (Azevedo, Carvalho, & Machado, 2011; Buyukozkan & Cifci, 2012; Lin, 2013). The issue of an environmentally conscious supply chain or GSCM has grown in recent years and both academia and industry are interested in this (Gungor & Gupta, 1999; Ilgin & Gupta, 2010; Sarkis, Zhu, & Lai, 2011). GSCM has appeared as an organizational philosophy which assists firms to enhance their financial affairs and market share by reducing environmental negative impact and improving ecological efficiency (Azevedo et al., 2011; Rao & Holt, 2005; Zhu, Sarkis, & Lai, 2008a; Govindan, Azevedo, Carvalho, & Machado, 2015a). Beamon (1999) defined green supply chain as "the expansion of traditional supply chain to include activities to reduce waste of resources and negative environmental effects of a product throughout its entire life cycle, from extraction of raw materials to final utilization and disposal."(Eltayeb, Zailani, & Ramayah, 2011) GSCM is an integration of natural environmental worries into supply chain management by implementing various green practices like life cycle analysis (LCA), green design, green purchasing, 3Rs (recycling, reuse, and remanufacturing), environmental technologies, green logistics, and collaborative practices with suppliers, distributors, and customers (Ahi & Searcy, 2013; Cheng, Yeh, & Tu, 2008; Fu, Zhu, & Sarkis, 2012; Hervani, Helms, & Sarkis, 2005; Jabbour, 2015; Jayant & Azhar, 2014; Sarkis, 2006; Srivastava, 2007; Youn, Yang, Hong, & Park, 2013).

It is necessary to analyze the interrelationship between green practices and performances to reach GSCM efficiency and gain a sustainable competitive advantage. Anyway, many firms hesitate to take a more proactive approach to include GSCM practices due to a lack of verification as to whether GSCM performances and benefits surpass the costs of implementing such practices and initiatives (Montabon, Sroufe, & Narasimhan, 2007). Moreover, as studies which consider links and interrelationships between GSCM practices and performances are limited, it emphasizes the need for future research which examines the relationship of

* Corresponding author. Tel.: +45 65503188.
E-mail address: gov@sam.sdu.dk (K. Govindan).

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GSCM practices, and economic and environmental performances. Hervani et al. (2005) referred to a lack of studies linking GSCM practices, and economic and environmental performances. Rao and Holt (2005) also mentioned research that has hardly determined a potential connection between green GSCM initiatives and improved economic performance. Moreover, Zhu, Sarkis, and Lai (2007a) emphasized the need for studies that consider the links between GSCM practices and supply chain performance. Lin (2013) proposed a fuzzy DEMATEL method to analyze the influential criteria of 3 main GSCM practices and suggested that empirical studies should be conducted as future research. Azevedo et al. (2011) investigated the influence of GSCM practices on SC performance in the Portuguese auto components sector. They investigated earlier literature which considered GSCM and realized that the studies did not consider the links between each practice and performance. Diabat, Khodaverdi, and Olfat (2013) illustrated green supply chain practices and performances in an automobile manufacturing company. Lee, Ooi, Chong, and Seow (2014) identified the relationship between GSCM practices and technological innovation in Malaysian manufacturing firms. Wu, Liao, Tseng, and Chiu (2015) combined fuzzy set theory and the DEMATEL method to investigate the effects of every criterion within green supply chain practices. Wu and Chang (2015) provided a DEMATEL method to identify critical factors and their causal relationships in a case group in GSCM in the electronic industries of Taiwan. The current literature review indicates that most papers used traditional fuzzy set to handle the ambiguity of experts' judgments. Therefore, the main objective of this paper is to develop GSCM practices and performances and investigate the importance and causal relationships between them using an intuitionistic fuzzy DEMATEL approach. The intuitionistic fuzzy set is an extension of the traditional fuzzy set considering the degrees of hesitancy.

In the real world, criteria are directly or indirectly related and have a degree of interactive relationships. In such situations, it is very tough for experts and decision makers (DMs) to avoid interference between criteria and to obtain a specific objective. Moreover, few methods are capable of handling interdependence between criteria (Chang, Chang, & Wuc, 2011; Liou, Wang, Hsu, & Yin, 2011). The main contributions of this paper are:

- Considering the importance and interdependent relationships that exist among GSCM practices and performances with an integrated intuitionistic fuzzy DEMATEL a relatively new method in the multiple criteria decision making (MCDM) area and a novel method to achieve GSCM efficiency.
- Identifying a comprehensive list of GSCM practices and performances.
- A case study of an automotive industry in a developing country being presented for managers to realize the cause-effect relationships and to choose the best green practice to improve organization's economic and environmental performance. To best of our knowledge most earlier research on the GSCM practices and performances were conducted in developed countries and relatively little attention was assigned to developing countries like Iran.

In this study, the DEMATEL method (Gabus & Fontela, 1972) is used to develop mutual relationships of criteria and their interdependencies. This method generates causal diagrams to describe mutual relationships and their influence degree on the criteria. It evaluates the strength of effects for each criterion. Further, DMs will know how to enhance programs by considering the cause-effect diagram of criteria (Wu & Tsai, 2011). One of the advantages of this method is displaying the relationships between elements and criteria prioritization according to the types of relationships and their interdependencies. Moreover, this method does not need voluminous information and can easily propose the most important criteria which affect other criteria. These benefits result in the use of DEMATEL to find out the cause and effect criteria (Chang et al., 2011; Lin, 2013). In literature, the DEMATEL approach was successfully utilized in many areas like hotel service quality, supplier selection, e-learning evaluation, and cause analysis to solve complicated problems (Abdullah & Zulkifli, 2015; Altuntas & Dereli, 2015; Bai & Sarkis, 2013; Chang et al., 2011; Govindan, Kannan, & Shankar, 2014a; Li, Hu, Zhang, Deng, & Mahadevan, 2014; Lin & Wu, 2008; Tadić, Zečević, & Krstić, 2014; Tseng, 2009a; Tseng, 2009b; Tzeng, 2007; Wu & Lee, 2007).

Real life is quite uncertain by nature. It should be noted that the fuzzy nature of human life makes decision making process complicated. A way to deal with doubtful decisions and to embody the ambiguity which typifies human thinking is to declare favorites as fuzzy numbers rather than binary or classical logic, which are based on a specific theory (Buyukozkan & Cifci, 2012; Liou, 2012). So, fuzzy logic is used in evaluations which allow for uncertainty in measures (Bellman & Zadeh, 1970; Zadeh, 1965). Intuitionistic fuzzy numbers (IFNs) are used in this paper to express DMs' preferences. The concept of intuitionistic fuzzy set (IFS) was proposed by Atanassov (1986) to make the concept of fuzzy sets general. IFS is an extension of Zadeh's fuzzy set where the membership of an element in a special group is defined as a number between 0 and 1. IFS moves one step further by examining the membership and the non-membership of a member of a given set, defining them as real values between 0 and 1 (Wang, Li, & Xu, 2011). Compared to Zadeh's fuzzy set, IFS is very practical in handling vagueness. Hence, DMs use IFS to indicate information in an uncertain environment better (Xu & Yager, 2008; Ye, 2010). The IFS received attention in recent years and many researches were conducted to expand and improve the IFS theory, like Ye (2010), Chen, Lee, Liu, and Yang (2012), Wu and Liu (2013), Zhang, Jin, & Liu 2013, Li and Chen (2015) and Xu and Liao (2015).

Also, it is necessary to acquire experts' opinions to evaluate direct influences. The simplest way is to use crisp or deterministic numbers (i.e., in a direct relation matrix of the DEMATEL method) but crisp numbers have many weaknesses; for instance, they cannot handle the linguistic imprecision and ambiguity of experts' judgments because assessments are mainly based on human being's subjective ideas which cannot be measured easily. So, there is a need for a tool to overcome this drawback. A common solution is to use fuzzy numbers which remove this limitation to get more reliable evaluations. IFNs could represent vague and imprecise preference information from preferred, not preferred and indeterminate points of view (Xu & Liao, 2015). IFNs have the following benefits:

- IFNs introduce "degree of hesitation" which helps DMs to express their ideas more accurately.
- IFNs represent the extent of DMs' "disagreement".

The aforementioned benefits along with handling linguistic imprecision of human being's judgments make IFN a complete tool to assess direct influences compared to fuzzy numbers and crisp numbers. The other point is that IFNs crunching is justified in the framework of DEMATEL as in a prior research Nikjoo and Saeedpoor (2014) used this method to prioritize the components of a SWOT matrix for an Iranian insurance firm.

The industry is the best option to decrease the human being's harmful effects on the environment, as the damaging outcomes of industry are much greater than those of individuals. Hence, the attempts of the industrial sector to preserve the environment are more effective compared to those of individual human beings (Andiç, Yurt, & Baltacioglu, 2012). Over the last decades, there has been pressure on the automotive industry to take action to