



Application of fuzzy VIKOR for evaluation of green supply chain management practices



Reza Rostamzadeh ^a, Kannan Govindan ^{b,*}, Ahmad Esmaeili ^c, Mahdi Sabaghi ^d

^a Department of Management, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

^b Department of Business and Economics, University of Southern Denmark, Campusvej 55, Odense, Denmark

^c Department of Industrial Management, Faculty of Management & Accounting, Allameh Tabataba'i University, 14348-63111 Tehran, Iran

^d Department of Mechanical Engineering, École Polytechnique de Montréal, C.P. 6079 Succ. Centre-Ville, Montréal, QC H3C3A7, Canada

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ABSTRACT

Environmentally sustainable activities have received an increasing interest among the firms to improve their practices in the supply chain. Although environmental regulations force firms consider these issues, but, green issues are new, evolving every day, and requires a continuous study in the field to gain a complete understanding of the problems. In this study, we illustrate the case of a laptop manufacturer in Malaysia that pursues to evaluate green supply chain management (GSCM) indicators among its practitioners. This paper develops a quantitative evaluation model to measure the uncertainty of GSCM activities and applies an approach based on Vlsekraterijumska Optimizacija I Kompromisno Resenje (VIKOR) method which is an extension of intuitionistic fuzzy environment aiming to solve the green multi-criteria decision making (GMCDM) problem. The triangular fuzzy numbers (TFNs) were used to handle imprecise numerical quantities. Then, a hierarchical multiple criteria decision making (MCDM) model was proposed based on fuzzy sets theory and VIKOR method to deal with the problem. The results show the alternative ranks of the four evaluated companies which was based on their performance in GSCM initiatives. The results also indicated that the main criteria of the research ranked as follows respectively: eco-design, green production, green purchasing, green recycling, green transportation and green warehousing. Finally, a comparative analysis of results by fuzzy VIKOR is presented. Additionally the scope for future studies is provided at the end of the paper.

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1. Introduction

Environmental concerns have gained a considerable attention under the name of sustainable development. With the increasing awareness of environmental protection, organizations are obliged to take into account environmental practices to strengthen the green image of their own companies, alongside with the true intent of protecting the environment (Yang et al., 2011; Tseng, 2011a; Tseng and Chiu, 2012; Lin, 2013). In this regard, companies try to put more standards and obligations on activities such as raw material extraction and overflowing waste sites to prevent environmental deterioration and pollution. As an increasingly important issue for a business, (Sarkis et al., 2011; Vachon and Klassen, 2008) GSCM can be regarded as an approach to the philosophy of management, integrating all supply chain components which is seen as an absolutely humane and progressive practice for organizations.

(Narasimhan and Carter, 1998; Vijayvargy and Agarwal, 2013). It also brings economic benefits to the manufacturers (Lin et al., 2011). Furthermore, despite the flourishing popularity of GSCM in the industrial countries, it seems that still there exists areas that have not put forward both in research and in practice (Large and Thomsen, 2011; Kenneth et al., 2012). GSCM in emerging markets also is getting priority to other philosophies of management due to the reason that they can benefit from the experience of more developed countries. China and Malaysia are among the largest emerging and developing economies. As seen in the review of the literature the after comings of GSC innovations and opening moves are explored by Eltayeb et al. (2011) among ISO 14001 certified firms in Malaysia, and the impact of internal and external criteria affecting environmental performance on GSCM in Malaysia is investigated by Zailani et al. (2012). However, in the process of GSCM, the selection of green practices has always been a problem which a multi-criteria decision making (MCDM) tool can be of a great help (Lee et al., 2009; Zhu et al., 2008; Srivastava, 2007; Tseng et al., 2008, 2009a; Tseng, 2011a). We can add to this the fact that firms in developing countries like Malaysia, compared to the developed countries, are taking the first steps of practical

* Corresponding author. Tel.: +45 6550 3188.

E-mail address: gov@sam.sdu.dk (K. Govindan).

incorporation of GSCM practices in their operations (Eltayeb et al., 2011; Rusli et al., 2012; Hsu et al., 2013).

Besides environmentally conscious consumers seek for rigorous environmental regulations. These regulations force manufacturers to integrate environmental concerns into their management practices (Rao and Holt, 2005; Yang et al., 2009; Paulraj, 2009; Azevedo et al., 2011). There has not been a general framework to represent an organization's practical roadmap to environmental activities and it is due to limited understanding of GSCM. Although those dimensions regarding environmental concerns that provide competitive advantage should not go unnoticed. An example of these competitive dimensions are companies in the electronic industry, for instances HP, Sony, IBM, Motorola, Panasonic, Dell, Fujitsu and Toshiba, acting proactively to adopt directives in the operational processes and claim that GSCM counts for a dominant role in environmental protection (Zhu and Sarkis, 2006; Tseng et al., 2008; Azevedo et al., 2011, 2013, Tseng, 2011a; Lin et al., 2013). Furthermore, external stakeholders put pressure to protect the environment, too.

The main objective of this paper is to propose comprehensive criteria to evaluate the GSCM practitioners using fuzzy VIKOR. Besides, as it will be explored, there is no investigation of GSCM indicator/practices using classic VIKOR in fuzzy environment. Therefore, this is the first work attempting to use this technique to evaluate green indicator/practices (hereafter the word practices will be used throughout the paper). The contribution of this paper in the GSCM literature is twofold: first the validity and reliability of developed criteria for GSCM, based on expert team and environmental and non-environmental literatures, can be comprehended. Second, it proposes an integration of various criteria based on literature review, which allows us to have a clear and deep perception about the critical success factors influencing GSCM practices. Also, in practice, organizations can understand and benefit from the related, dependable and proven criteria resulted from the practices of the case firms. These criteria can be used as benchmarking and improvement tools which in this case can reconcile the proven aspects of environmental practices.

The rest of this paper is structured as follows. In the next section, an overview of GSCM and a review of the research methodology is presented. In Section 3, research framework is put forward and the case study is elaborately explained. A numerical example of real case is illustrated in Section next. In Section 4, fuzzy sets theory and various MCDM methods alongside with VIKOR is presented. In Section 5, results and discussions are given and some managerial implications are drawn from the study. Finally, in Section 6, conclusions and outlines for future studies are clarified.

2. Theoretical background

This study establishes a review of GSCM perspectives, definitions, and criteria. Furthermore, the methodology adopted for the evaluation of GSCM practices includes a combined use of fuzzy set theory and VIKOR to evaluate GSCM practices, which is comprehensively presented in Section 3.

2.1. Green supply chain practices

The development of traditional supply chain activities which aims to constrain hazardous impacts of delivering a service or producing a product through the entire life cycle can be defined as "green" (Beamon, 1999; Eltayeb et al., 2011). Rao and Holt (2005) stated that it is consisted of green manufacturing, green packaging, and reverse logistics. All links in traditional supply chain, including raw material, industrial, distribution, consumer and waste can be a source of pollution for the environment. The recent standards for

the protection of the environment, requires manufacturers and all organizations to conform to the standards and employ environmentally friendly strategies in the entire supply chain. The confinement of all wastes within the industrial system itself and limitation of the hazardous material can be regarded as a basic goal in green supply chain management. Two main streams of research can be seen in the literature: those related to the development of a framework and those related to the performance measurement. The cooperative relation between the links of the supply chain are explored in some researches, and also some studies have explored the gaps between decision making and practical activities to incorporate green practices (An et al., 2006; Sarkis, 2003; Beamon, 1999).

Zhu et al. (2007a) investigated the initiatives and outcomes of GSCM implementation by various manufacturing sectors in China and examined the links between GSCM initiatives and performance outcomes. They claimed that some limitations of their own study should be avoided. These limitations include: the period to implement GSCM practices is only based on literature review, the relationship between issues should be further analyzed. Also the evaluation scales are based on perception of respondents which creates a research bias. Zhu et al. (2008b) proposed confirmation of a measurement model for GSCM practices implementation. They presented practitioners with a 21-items measurement scale for evaluating different facets of their GSCM practices implementation. The empirical findings suggested that both the first-order and second-order models for GSCM implementation were reliable and valid. However, the limitations of the research are that; firstly, sampling method based on convenience and random surveys are done to gather the data. The clarity of data can be of question. Secondly, in order to evaluate GSCM practices one should analyze performance outcomes, which in this case the implementation of GSCM practices was measured. Thirdly, the scales must have been more comprehensive, covering all criteria (Zhu et al., 2008b). And finally it has been claimed that to provide new opportunities to gain competitive advantage and gain new methods of acquiring value in business, environmental issues must be addressed from the point of the view of firms in the supply chain (Hansmann and Kroger, 2001).

Apart from the limitations shown in the literature, Hervani et al. (2005) confirms the gap of GSCM elements and performance measurement in studies and calls for researches addressing GSCM and environmental performance. To fill this gap, this study reviewed various literatures on green supply chain performance measurement, environmental management and traditional supply chain performance measurement. Some of the reviewed studies are as follows; four GSCM factors, namely hazardous materials, investment recovery (IR), product design, and supply chain relationships were identified by Zsidisin and Hendrick (1998) and continued to determine these factors with exploratory factor analysis (EFA). The environmental development of firms in china and specifically green production of them was investigated by Zhu and Geng (2001). In another study Sarkis (2003) developed a framework to measure various alternatives implemented by firms which affected the supplier and customer relationships. The decision frameworks modeled and solved as an ANP. Zhu and Sarkis (2004a) showed the relationships between GSCM practices implementation and performance with a focus on the moderating effects of quality and just-in-time (lean) practices. Kainumaa and Tawarab (2006) with the development of multiple attribute utility theory (MAUT) tried to measure re-use and recycling in the entire life cycle of products and services. Eltayeb and Zailani (2009) studied three green supply chain initiatives, i.e. GP, eco-design, and reverse logistics in order to highlight the steps that have to be taken by firms with the implementation of green supply chain in order to conquer sustainable development. Research findings

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