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A comprehensive decision making model for the evaluation of green operations initiatives

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ABSTRACT

Green operations management has gained increasing interest among researchers and practitioners from the industry. It helps organisations to achieve competitive advantages. However, introducing green initiatives can bring various challenges to firms and supply chains. It is important to develop a systematic and effective decision support tool to help industrial practitioners to evaluate various green operations initiatives. This paper proposes a systematic decision making approach based on fuzzy Delphi, fuzzy extent analysis, and fuzzy TOPSIS for more rational selection decisions. A case study is presented and the analysis results demonstrate its effectiveness in supporting firms to make such a decision.

1. Introduction

Businesses are under extreme pressure of balancing the influences of resource availability, customer demand, consumer groups, and government regulations. To address the stakeholders' demand for more environmentally friendly practices, managers are more sensitive on decisions of what items are purchased for use in various processes, the effect on manufacturing processes, how products are packaged and delivered, and the recycle (or reuse) policies. Different green strategies that focus on both internal and external operations have been adopted by businesses. Internally, these strategies include the application of lean production principles (King and Lenox, 2001; Rothenberg et al., 2001), the implementation of an environmental management system (Melnyk et al., 2003), and the development of eco-friendly products and processes (Chan et al., 2013). In recent years, a more externally oriented approach involving the application of environmental management principles to the supply chain has emerged as a new way to address the sustainability challenge (Sarkis, 2003; Zhu and Sarkis, 2004; Rao and Holt, 2005; Srivastava, 2007; Zhu et al., 2008).

The main reason for implementing the abovementioned green practices is that organisations can generate more business opportunities than their competitors if they can address environmental issues successfully. As Zhu and Sarkis (2004) stated, the economic performance is the most important driver for enterprises that seek to implement green initiatives. Rao and Holt (2005) studied the relationship between the implementation of green supply chains and the economic performance and competitiveness of a sample of Asian firms. Their research shows that green supply chain practices can improve competitiveness. Zhu et al. (2007) evaluated the effectiveness of green supply chain management in Chinese manufacturing enterprises and the automobile industry respectively. Their studies delivered a similar message as above. More specifically, a greener product design may improve brand image and stimulate demand from 'green consumers' (Peattie, 2001). Using environmental friendly raw materials and green production process addresses issues such as environmental material substitution, waste reduction and decreasing the consumption of hazardous and toxic materials (Vachon, 2007; Zhu et al.,

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2007). Green logistics and packaging enhance cost savings by cutting energy consumption and packaging waste in times of rising commodities and energy costs being a particular concern (Zhu et al., 2008; Holt and Ghobadian, 2009). Azevedo et al. (2011) investigated the relationships between green practices and supply chain performance in the context of the automotive industry. Their research reveals that green practices have positive effects on quality, customer satisfaction and efficiency. It also identifies the practices which have negative effects on supply chain performance. Furthermore, the introduction of greener practices/initiatives requires different sets of sources and capabilities which might put different firms in the supply network a better position to adopt such practices than others. Therefore, it is crucial for decision makers to understand the potential ramifications of adopting green practices and initiatives (Sarkis, 2003).

Most of the early literature on green operation/supply chain management may be limited to exploring the broad environmental criteria of either quantitative or qualitative property concerning environmental cost, production process, product, and management system. For instance, one stream of research studied eco-design from environmental perspectives (Donnelly et al., 2006; Kobayashi, 2006; Cerdan et al., 2009; Chan et al., 2013; Wang et al., 2014). Although environmental performance throughout a product life cycle is evaluated, the operational performance and resources are often neglected in these studies. However, from firms' point of view, the purpose of any green innovations is not only to mitigate environmental risks. It is also crucial for firms to gain or, at least, to maintain their operational competitiveness. Therefore, in addition to the environmental criteria, it is also important to incorporate the organisational performance and operations associated criteria in the evaluation of green initiatives. Another stream of research integrated the environmental concern in the supplier selection problem (Enarsson, 1998; Humphreys et al., 2003, 2006; Lu et al., 2007; Lee et al., 2009, 2012; Bai and Sarkis, 2010; Hsu et al., 2013). However, these studies often focus on external operations and address supplier selection issues in green supply chain viewed from environmental perspectives. Among the few studies that consider the environmental concerns and both internal and external operational needs, Vachon (2007) examined the linkage between green supply chain practices and the selection of environmental technologies using the data from a survey of the Canadian and United States package printing industry. Sarminento and Thomas (2010) proposed a hierarchical framework to assess supply chain resources and capabilities for implementing green initiatives. However, their investigation is conceptual in nature although various potential challenges that firms might face when adopting green initiatives are examined. Wang and Chan (2013) extended their work by assessing improvement areas when implementing green supply chain initiatives in the context of the fashion industry. However, similar to the work of Sarminento and Thomas (2010), the evaluation criteria adopted in their work are not comprehensive enough to reflect the complexity of green initiative evaluation. This paper extends the existing literature by proposing a systemic decision making approach for the evaluation of green initiatives. This research attempts to identify and analyse key decision criteria that reflect the complexity of green initiative evaluation. Whilst examining the trade-off between organisational performance and environmental performance, it also considers the company's existing operations resources and capabilities.

In order to achieve sustainable economic and environmental performance, it is important to develop a systematic and effective decision support tool to help industrial practitioners to evaluate various green operations initiatives. Nevertheless, such an evaluation imposes the difficulty of decision making from the increased level of complexity involved in taking various organisational and environmental performance indicators and operational factors into account. To address this challenge, Multiple Criteria Decision Analysis (MCDA) approaches are often applied to identify common themes as to how managers handle information uncertainty, make trade-offs, and balance the potentially competing needs to be profitable and environmentally sustainable.

Among various MCDA approaches, Analytic Hierarchy Process (AHP) has been extensively applied by academics and professionals in the green operations and supply chain management literature (Handfield et al., 2002; Ho, 2008; Sarminento and Thomas, 2010; Wang and Chan, 2013). Developed by Saaty (1980), AHP considers a hierarchical model which gives the ability of taking into consideration more information and provides superiority to solve such complex decision problems. Nevertheless, AHP has difficulty in handling the uncertainty and ambiguity present in deciding the ratings of different attributes (Chan and Kumar, 2007). Uncertainty, which comes from lack of data, is common in the evaluation of green initiatives. In fact, the decisions on implementing green initiatives contain considerable amount of uncertainty causing elements, which confuse the decision maker to reach the targeted performance. Uncertainty arises from both internal and external multiple sources including technical, operational, and commercial issues. To address this limitation, some scholars have made use of fuzzy logic. The major benefit introduced by fuzzy AHP is that it enables a more accurate description of the decision-making process that takes place in real applications where uncertainties are not uncommon (Huang et al., 2008). Since Van laarhoven and Pedrycz (1983) and Buckley (1985) presented their preliminary work in fuzzy AHP, many studies on fuzzy AHP are proposed in different green operations problem environments (Lu et al., 2007; Wang et al., 2012). Another important fuzzy extension of AHP is fuzzy synthetic extent analysis, which was developed by Chang (1996) to help formulate the multi-tier fuzzy decision-making process. Like the basic fuzzy AHP, the fuzzy judgement matrix is first constructed with the help of linguistic parameters. Then, the synthetic degree value is calculated (instead of defuzzifying the matrix). The main advantage of this method is that the computational effort is reduced. Since its inception, the method has also been applied in many green innovation applications e.g. green supplier selection (Lee et al., 2009) and eco-design evaluation (Chan et al., 2013).

Although AHP and its fuzzy extensions have the advantage of simplicity in concept and ease of use for pair-wise comparison of decision criteria and alternative solutions, it has often been criticised from several perspectives. Especially when an assessment is influenced by a big number of decision criteria, it requires cumbersome data collection and increases complexity of calculations. To address this issue, some researchers applied TOPSIS to solve similar MCDA problems because of its effectiveness in evaluating alternatives and computational