Int. J. Production Economics 135 (2012) 595–606

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

A two-stage fuzzy-AHP model for risk assessment of implementing green initiatives in the fashion supply chain

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ARTICLE INFO

Article history:
Received 9 December 2010
Accepted 23 March 2011
Available online 29 March 2011

Keywords:
Fuzzy
AHP
Fashion
Green initiative
Risk analysis

ABSTRACT

Green or environmental concerns are drawing more and more attention both in academia and industry. Careful deployment of green initiatives or policies could not only fulfil the requirements of environmental legislation but also lead to a competitive advantage for firms. Nevertheless, making optimal decisions in this regard is not easy. This is principally due to two reasons: (1) the qualitative nature of, and (2) the uncertainty associated with, the parameters involved in the decision-making process. Analytic hierarchy process could be a useful tool to tackle the first challenge because of its ability to handle both qualitative and quantitative variables (decision criteria). Unfortunately, this approach is inadequate at addressing the uncertainties common in real-life applications. This challenge is particularly noticeable in the fashion industry since demand is very volatile, and there are many uncertain variables associated with the whole supply chain. As a result, this paper blends fuzzy logic, which is a popular method of incorporating uncertain parameters into the decision-making process, with analytic hierarchy process to form a selection (decision-making) model for different green initiatives in the fashion industry. The rationale behind the model is to analyse the associated risk of different alternatives, subject to different factors, be they deterministic or not. A numerical example is included in this paper to demonstrate how the proposed model works.

1. Introduction

Environmental concerns from consumers, governments and academics have encouraged businesses in the fashion sector to introduce and promote business practices that help to ease the negative impacts of their actions on environment. These environmentally conscious practices have been widely reported in the literature ranging from eco-design, green procurement, environmentally friendly packaging and transportation, to the various product end-of-life practices such as recycling and remanufacturing (Sarkis, 1995, 1998; Carter and Carter 1998; Rao and Holt 2005; Yung et al., 2009). The implementation of these green initiatives could generate higher revenues in the fashion industry as retailers' green credentials are becoming an important differentiator that enables firms to secure greater customer loyalty. It also increases cost savings by cutting energy consumption and packaging waste in times of rising input costs, with rising commodities and energy costs being a particular concern. Deploying a proper green initiative or policy could generate a competitive edge for a company (Sarmiento and Thomas, 2010). Recent technological development like Radio Frequency Identification Technology (RFID) could provide companies with many opportunities to take green issues into consideration, although cost may always be a more important evaluation criterion (Gaukler et al., 2007).

Nevertheless, it is equally likely that deploying a poor green initiative might lead to considerable problems if implementation is not managed well (Cheng et al., 2008). Implementation of greener designs/practices is likely to face potential adjustments in their internal and external operations. With the trend of increased collaboration with international supply partners and expended supply networks, adopting greener practices could also increase the probability of experiencing adverse events in supply chains that significantly threaten normal business operations of the organisations in the supply chain. These problems could include an increase in total costs and reputation risk from failures along the supply chain. It is, therefore, clear that just like any strategic policy change, implementing green initiatives consists of a certain degree of risk, and hence a proper risk assessment tool is needed.

While more pressures are emerging from stakeholders to prompt companies and the entire fashion supply chain to adopt green supply chain practices, little effort has been paid on assessing the risk involved in implementing various green initiatives for managerial assessment purposes. A greener product design may improve brand image and stimulate demand from 'green consumers' (Peattie, 2001). However, this transition might require the

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doi:10.1016/j.ijpe.2011.03.021

use of new technologies in supply and production processes, as well as the development of new quality systems. Purchasing-wise, it might need the procurement of new raw materials and affect the supplier selection process. Logistics-wise, it might require new inbound and outbound logistics along with new packaging. Meanwhile, there is no guarantee of saleability and future growth in the wide market. Accordingly, it is important to use an integrated heuristic approach and analyse the risk involved in a supply chain context, thus enabling decision makers to understand the capabilities and resources that need to be deployed so as to successfully implement a 'green' supply chain in the fashion industry.

Making such judgement, however, is never an easy task as there are many qualitative factors concerned with the decision-making process. In the literature, analytic hierarchy process (AHP) is a widely employed methodology to facilitate this kind of process. Notwithstanding this, traditional AHP is unable to deal with another realistic concern: uncertainty. Without uncertainty, one may argue risk assessment is not necessary. Uncertainty is a particular issue in the fashion industry since demand is highly volatile (Wang and Chan, 2010). In view of this, a decision model that couples AHP with fuzzy logic, which is used to incorporate uncertain variables into the proposed model, is developed in this paper.

The rest of the paper is organised as follows: Section 2 presents a review of relevant literature. Section 3 formulates the blended fuzzy AHP approach, including its mathematical derivation. Then, a numerical example is presented in Section 4 to demonstrate how the model works. Section 5 concludes this paper.

2. Literature review

Green supply chain management has been the subject of increased academic interest in recent years. For example, 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. Not surprisingly, this research shows that implementing Green Supply Chain Management (GSCM) can improve competitiveness, which is in line with Bacallen (2000). Zhu and Sarkis (2004) and 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. Hansmann and Claudia (2001) also claimed that organisations can generate more business opportunities than their competitors if they can address environmental issues successfully. It is clear that green supply chain management should be taken into account at the strategic policy formulation level (Sarkis, 2003). For a more extensive review of the literature, readers are referred to Mollenkopf et al. (2010).

Despite the clear motivation regarding green supply chain management, studies in this strand of research are highly unstructured, and there is no universally accepted "green" analytical framework (e.g. Vachon and Klassen, 2006). In the context of the fashion industry, De Brito et al. (2008) conduct a survey of stakeholder to explore how green initiatives impact the fashion retail supply chain organisation and its performance. They found that green issues in the fashion industry were particularly sensitive due to intense competition, high resource use and concerns about labour practices. Further, they observe that conflict between the multiple goals of green supply chain management can be particularly intense in this context, given the need for rapid response due to the vagaries of demand. Svensson (2007), based on a study on the use of renewable materials for the clothing industry, discovered that there is a need to analyse the connection between different tiers of a supply chain, which has been overlooked in the past studies. In this connection, deploying a green initiative is not risk-free and hence a good risk management analytical framework is needed. Accordingly, a fuzzy AHP approach is proposed to evaluate the risk associated with different green initiatives in the fashion industry. The rest of this section presents an overview of the related literatures associated with this approach.

AHP is employed to solve multi-criterion (or attribute) decision-making (MCDM) problems, particularly when qualitative assessment parameters are involved. It was proposed by Saaty (1980). A MCDM problem could be solved analytically if all the parameters are well-defined and quantitative (or quantifiable) in nature. Unfortunately, many evaluation criteria are subjective and qualitative in nature. This makes the task of expressing preferences using exact numerical values very difficult, hence decision making becomes challenging (Chan and Kumar, 2007). In contrast, AHP analyses a MCDM problem by setting up a hierarchy of criteria and sub-criteria, which could be either quantitative or qualitative in nature. This can be done by introducing pair-wise comparison between those criteria, which are assessed by professional or experts in the corresponding area.

The literature on AHP in various applications is very rich (e.g. Lee and Kozar, 2006; Chan et al., 2006; Chang et al., 2007; Korpela et al., 2007; Ramanathan, 2007; Dağdeviren, 2008; Sharma and Agrawal, 2009; Chan and Chan, 2010; Sarminento and Thomas, 2010). AHP has also been employed for the risk management of different alternatives (Gaudenzi and Borghesi, 2006; Zayed et al., 2008). In relation to green supply chain, Sarkis (2003) developed an AHP for evaluating the environmental impacts of different stages of a supply chain life cycle, including procurement, production, distribution, reverse logistics, and packaging. Although AHP is a celebrated method for MCDM problems, particularly when qualitative assessment is needed, it is unable to process uncertain variables (Wang et al., 2008). To address the deficiency of AHP, some scholars merged fuzzy logic with AHP to form a new domain of research. Fuzzy logic was developed by Zadeh (1965) in the 1960s and has become a major tool to analyse problems when uncertain parameters are present.

Fuzzy AHP has been utilised in solving many industrial problems. To mention a few, Chan and Kumar (2007) applied fuzzy AHP to investigate the risk associated with various options for global supplier selection. Risk factor was one of the criteria included in their model. They modelled some non-deterministic variables by fuzzy membership functions. Huang et al. (2008) employed fuzzy AHP to make selection on different R&D projects. Celik et al. (2009) made use of fuzzy AHP to select between alternative legal domiciles for registering ships. Güngör et al. (2009) even applied fuzzy AHP to rank the performance of different applicants for human resources selection. The reasons behind using fuzzy AHP in these examples is obviously due to the uncertain nature of the problem. Further examples include, Faez et al. (2009) who combined fuzzy AHP with a case-based reasoning approach for solving vendor selection problems. Abdi (2009) applied fuzzy AHP to select between different configurations in a (reconfigurable) machine system. Ng and Chuah (2010) applied fuzzy AHP for evaluating different eco-design alternatives. Based on the above, it is clear that fuzzy AHP is highly coupled to decision-making problems when selection between alternatives is required.

Among those published studies for AHP application in the fashion industry, Cebeci (2009) attempted to apply the fuzzy AHP for selecting different ERP systems, together with balanced scorecard. Chan and Chan (2010) employed AHP for selecting different suppliers in the fashion industry. Noticeably, these studies do not consider green initiatives in any way. In addition, not many studies incorporate risk assessment of green initiatives.