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A fuzzy multicriteria approach for evaluating environmental performance of suppliers

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ABSTRACT

In this paper, we present a fuzzy multicriteria approach for evaluating environmental performance of suppliers. The proposed approach consists of three steps. The first step involves identification of criteria for assessing environmental performance of suppliers. In step 2, the experts rate the selected criteria and the various alternatives (suppliers) against each of the criteria. Linguistic assessments are used to rate the criteria and the alternatives. These linguistic ratings are then combined through fuzzy TOPSIS to generate an overall performance score for each alternative. The alternative with the highest score is chosen as the one with highest environmental performance. The advantage of using fuzzy TOPSIS is that it distinguishes between Benefit (the more the better) and the Cost (the less the better) category criteria and selects solutions that are close to the positive ideal solutions and far from negative ideal solutions. In step 3, sensitivity analysis is conducted to evaluate the influence of criteria weights on the environmental performance evaluation of suppliers.

The strength of the proposed approach is its practical applicability and ability to provide solution under partial or lack of quantitative information. A numerical application is provided to demonstrate the proposed approach.

1. Introduction

Evaluation of environmental performance of suppliers is becoming more and more important in recent times. Reduction in environmental emissions, disposition of harmful wastes, adoption of green technology, products, and practices are on the priority list of several organizations. Companies are implementing several regulatory checks and procedures to ensure that the material received from suppliers is of high quality and conforms to allowable environmental standards and guidelines. Bala et al. (2008) examined five cases of supplier greening at Universitat Autònoma de Barcelona and found that collaboration and partnerships with suppliers may facilitate the introduction of green supply and guarantee the success of a green initiative in a public organization. Jabbour and Jabbour (2009) conducted case studies of Brazilian companies to find out whether supplier selection criteria are going green and concluded that a company with more advanced environmental management adopts more formal procedures for selecting environmentally appropriate suppliers than others.

In literature, several studies have been reported by researchers to evaluate environmental performance of suppliers and supply chains. Enarsson (1998) proposed a fishbone diagram to evaluate environmental characteristics of suppliers. Humphreys et al. (2003) use case-based reasoning to evaluate environmental performance of suppliers. Bai and Sarkis (2010) used grey system and rough set methodologies to integrate sustainability into supplier selection. Humphreys et al. (2006) employ dynamic fuzzy membership functions to assess environmental performance in the supplier selection process. Handfield et al. (2002) use environmental criteria in AHP for supplier assessment. Tuzkaya et al. (2009) present a hybrid fuzzy multicriteria decision approach for measuring environmental performance evaluation of suppliers. Zhang et al. (2003) proposed a fuzzy multi-agent decision-making strategy for environmentally conscious supplier management. Noci (1997) proposed 'green' vendor rating systems for the assessment of a supplier's environmental performance. Walton et al. (2006) propose an approach for greening the supply chain by integrating suppliers into environmental management processes. Lee et al. (2009) propose a green supplier selection model for high-tech industry using Delphi method and fuzzy extended analytic hierarchy process. Lu et al. (2007) proposed a multi-objective decision analysis to apply environmental

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principles to green supplier evaluation at different stages of supply chain. Humphreys et al. (2003), proposed multi-stage framework for incorporating environmental criteria with supplier selection process and checking suppliers' environmental performance checked against legal requirements. In Table 1, we present the most commonly used criteria in literature for evaluating environmental performance of suppliers.

It can be seen in Table 1 that availability of clean materials, environmental efficiency, green image, environmental costs, green product, environmental and legislative management, and green process management are the most commonly referred criteria in supplier evaluation.

In this paper, we present a multicriteria decision making approach based on fuzzy TOPSIS for evaluating environmental performance of suppliers. Fuzzy set theory is used to model vagueness and uncertainty in decision making processes arising due to lack of complete information (Zadeh, 1965). In fuzzy set theory, linguistic terms are used to represent decision maker preferences. This is the reason we have used fuzzy set theory in environmental performance evaluation of suppliers in this paper. For example, it is much easier to represent the environmental performance of suppliers as good, very good, poor, very poor, etc. than in numbers. The decision makers provide linguistic ratings to the environmental performance related criteria and to the alternatives (suppliers) which are then combined through fuzzy TOPSIS to generate an overall performance score for each alternative. The advantage of using fuzzy TOPSIS is that it distinguishes between Benefit (the more the better) and the Cost (the less the better) category criteria and selects solutions that are close to the positive ideal solutions and far from negative ideal solutions. The alternative with the highest score is finally chosen and recommended for procurement.

Application of fuzzy TOPSIS for traditional supplier selection has been investigated by researchers in recent years in Boran et al. (2009), Wang et al. (2009), Önüt et al. (2009), and Chen et al. (2006). Boran et al. (2009) propose a multicriteria intuitionistic fuzzy group decision making approach for supplier selection with the TOPSIS method. Wang et al. (2009) propose a hierarchical TOPSIS that employs rules based on Euclidean distances for supplier selection. Önüt et al. (2009) perform long term supplier selection using fuzzy AHP and fuzzy TOPSIS in a telecommunications company. Chen et al. (2006) employ fuzzy TOPSIS that employs trapezoidal fuzzy numbers for supplier selection. A detailed overview of other supplier selection methods can be found in Ho et al. (2010), De Boer et al. (2001), and Weber et al. (1991). Evaluation of supplier selection methods from a total cost of ownership perspective has been presented in Degraeve et al. (2000). The research on environmental performance assessment of suppliers is however limited and needs more studies.

The rest of the paper is organized as follows. In Sections 2 and 3, we present preliminaries of fuzzy set theory and fuzzy TOPSIS. In Section 4, we present a fuzzy multicriteria approach for evaluating environmental performance of suppliers. Section 5 presents a numerical application of the proposed approach. In Section 6, we present the conclusions and future work.

2. Preliminaries of fuzzy set theory

Some related definitions of fuzzy set theory adapted from (Zimmermann, 2001; Buckley, 1985; Zadeh, 1965; Kaufmann and Gupta, 1991; Dubois and Prade, 1982; Pedrycz, 1994; Klir and Yuan, 1995) are presented as follows.

Definition 1. A fuzzy set $\tilde{a}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{a}}(x)$ that maps each element x in X to a real number in the interval [0, 1]. The function value $\mu_{\tilde{a}}(x)$ is termed the grade of membership of x in $\tilde{a}$ (Kaufmann and Gupta). The nearer the value of $\mu_{\tilde{a}}(x)$ to unity, the higher the grade of membership of x in $\tilde{a}$.

Definition 2. A triangular fuzzy number is represented as a triplet $\tilde{a} = (a_1, a_2, a_3)$. Fig. 1 presents a triangular fuzzy number $\tilde{a}$.

Due to their conceptual and computation simplicity, triangular fuzzy numbers are very commonly used in practical applications (Pedrycz, 1994; Klir and Yuan, 1995; Yeh and Deng, 2004). The membership function $\mu_{\tilde{a}}(x)$ of triangular fuzzy number $\tilde{a}$ is

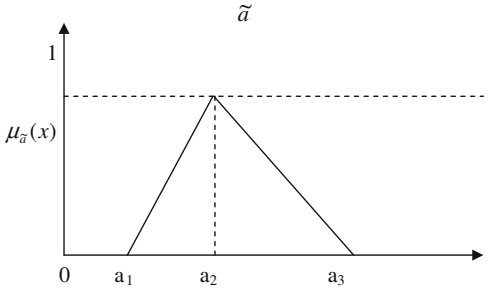

Fig. 1. Triangular fuzzy number $\tilde{a}$.

Table 1
Commonly used criteria for environmental performance assessment of suppliers.

Criteria	*Author*
Availability of clean technologies	Noci (1997), Lee et al. (2009)
Availability of clean materials (goods, packages)	Noci (1997), Min and Galle (1997), Lee et al. (2009), Walton et al. (2006)
Environmental efficiency/pollution control/waste management	Noci (1997), Tuzkaya et al. (2009), Min and Galle (1997), Lee et al. (2009), Handfield et al. (2002), Humphreys et al.(2003), Walton et al. (2006)
Green image	Noci (1997), Tuzkaya et al. (2009), Lee et al. (2009), Humphreys et al. (2003)
Net life cycle cost/environmental costs	Noci (1997), Tuzkaya et al. (2009), Min and Galle (1997), Lee et al. (2009), Humphreys et al. (2003)
Green product	Tuzkaya et al. (2009), Lee et al. (2009), Handfield et al. (2002)
Environmental and legislative management	Tuzkaya et al. (2009), Lee et al. (2009), Handfield et al. (2002), Humphreys et al. (2003), Walton et al. (2006)
Green process management	Tuzkaya et al. (2009), Lee et al. (2009), Humphreys et al. (2003)
Environmental partnership with suppliers	Min and Galle (1997)
Environmental mission	Min and Galle (1997)
Environmental regulations	Min and Galle (1997), Handfield et al. (2002)
Packaging, reverse logistics	Handfield et al. (2002), Walton et al. (2006)
Environmental programs	Handfield et al. (2002)
Management competencies	Humphreys et al.(2003)
Public disclosure of environmental record	Walton et al. (2006)
Second-tier supplier EFP evaluation	Walton et al. (2006)