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## Int. J. Production Economics

journal homepage: [www.elsevier.com/locate/ijpe](http://www.elsevier.com/locate/ijpe)

# An integrated green supplier selection approach with analytic network process and improved Grey relational analysis



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## ARTICLE INFO

## Article history:

Received 12 September 2013

Accepted 17 September 2014

Available online 28 September 2014

## Keywords:

Green supply chain management (GSCM)

Environmental sustainability

Supplier selection

Analytic network process (ANP)

Improved Grey relational analysis (GRA)

Grey theory

## ABSTRACT

With increased worldwide awareness of environmental protection, green supply chain management (GSCM) has received much attention from both researchers and practitioners over the past decade. Traditionally, organizations have considered criteria such as cost, quality, and delivery to evaluate the performance of their suppliers. Although there is an abundance of studies considering the conventional criteria in supplier selection, there are a rather limited number taking into account the environmental issues. In this study, we use both economic and environmental criteria and propose a comprehensive green supplier selection model. The analytic network process (ANP) is used to deal with the interdependencies among the criteria, and the traditional Grey relational analysis (GRA) has been modified to better address the uncertainties inherent in supplier selection decisions. We utilize the ANP and an improved GRA to weight the criteria and rank the suppliers respectively. The proposed approach is novel, and allows decision-makers to participate in the assessment process and use linguistic evaluation in the green supplier selection process. A case study in the automotive industry is presented to demonstrate the effectiveness of the proposed approach.

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## 1. Introduction

The subject of green supply chain management (GSCM) has attracted increasing attention from both researchers and practitioners because of the growing concerns with regards to the detrimental impacts of businesses operations on the environment. This growing interest is fueled by the intensifying deterioration of the environment, increasing levels of pollution, overflowing waste sites, and diminishing raw material resources (Srivastava, 2007). Additionally, increasing government regulation, stronger public awareness, and consumer pressures are making businesses more cautious regarding the environmental impacts of their operations (Diabat et al., 2013; Lee et al., 2009; Srivastava, 2007). As organizational stakeholders including governments, customers,

employees, competitors and communities place more emphasis on protecting the environment, environmental management is becoming increasingly important (Sarkis, 1998). Today, businesses cannot simply neglect environmental issues if they intend to survive in the global market (Lee et al., 2009).

Within supply chain management, supplier selection decisions are generally considered to be one of the most significant responsibilities of managers (Golmohammadi and Mellat-Parast, 2012), and at the same time one of the most critical and complex issues they need to deal with (Bai and Sarkis, 2010b). In order to maintain a competitive advantage in the global market, organizations need to take into account environmental concerns and embrace evaluation models of supplier selection. Supplier selection decisions can be applied in many situations such as the case of multiple suppliers as well as in the different stages of a product's life cycle from initial raw material purchasing to end-of-life service providers (Bai and Sarkis, 2010b).

Current supply chain management tends to maintain long-term relationships with suppliers, and use fewer but more reliable suppliers (Ho et al., 2010). However, with increased awareness of environmental issues, managers today need to purchase from suppliers that can provide them goods and services with lower

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price, higher quality, shorter lead time, and at the same time with stronger focus on environmental responsibility (Lee et al., 2009). According to some researchers, supplier selection either in GSCM or sustainable supply chain management is considered to be very important in purchasing decisions (Hsu et al., 2013; Seuring and Müller, 2008).

While there are plenty of studies dedicated to supplier selection based on conventional criteria, the literature regarding green supplier evaluation or works that consider environmental criteria are rather limited (Handfield et al., 2002; Humphreys et al., 2003; Lee et al., 2009; Noci, 1997). Therefore, this study is aimed primarily at providing a comprehensive green supplier selection model by considering both economic and environmental criteria. We intend to develop a Grey-based green supplier selection model by integrating two techniques: the analytic network process (ANP) and an improved Grey relational analysis (GRA). Although we find several examples of GRA applications in the research literature, a number of drawbacks and limitations are associated with the current models such as the judgment bias of experts and not taking into account the interdependencies among criteria. As a result, the drawbacks of the existing models are discussed comprehensively and solutions are proposed. ANP is an extension of the analytic hierarchy process (AHP) and is capable of handling interdependencies among different criteria, thus being more realistic in certain situations where criteria are internally dependent. Moreover, since decision-making in supplier selection generally deals with uncertain information, such decisions become more difficult and complex. Grey theory is a decision-making approach under conditions of uncertainty, and has been found to be superior to comparable methods in the mathematical analysis of systems with incomplete information (Li et al., 2007). In this paper, we used ANP to calculate the criteria weights. In addition, the traditional GRA has been modified to address the interval problems and to better deal with the uncertainty in supplier selection decisions. A case study in the automotive industry is presented to demonstrate the effectiveness of the proposed approach in green supplier assessment and selection problems. Altogether, we contribute to both decision-making theory and practice by addressing limitations of the existing models, as well as implementing a comprehensive green supplier selection model in a case study of the automotive industry.

The remainder of the paper is organized as follows: Section 2 reviews the literature on GSCM, green supplier selection criteria and evaluation methods. Section 3 deals mainly with the research methods including ANP and improved GRA. Section 4 presents the green supplier selection approach proposed in this study. In Section 5, a case study of the automotive industry is presented. Section 6 deals with the results followed by a sensitivity analysis. Finally, in Section 7 we present our managerial implications and in Section 8 we present our conclusions and future research directions.

## 2. Literature review

### 2.1. Green supply chain management

GSCM has its roots in both the supply chain management and environmental management literature. The scope of GSCM in the literature has ranged from green purchasing to integrated green supply chains flowing from supplier to customer, and even reverse logistics (Srivastava, 2007; Zhu and Sarkis, 2004). GSCM is defined by Srivastava (2007) as “integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, as well as end-of-life management

of the product after its useful life”. Sarkis (2006) defines GSCM in a relatively similar way and describes it as the integration of natural environmental factors into supply chain management. According to Green et al. (1996), “green supply refers to the way in which innovations in supply chain management and industrial purchasing may be considered in the context of the environment”. In addition, Narasimhan and Carter (1998) argue that “environmental supply chain management consists of the purchasing function's involvement in activities that include reduction, recycling, reuse and the substitution of materials”. From the viewpoint of Messelbeck and Whaley (1999), “the environmental effects of developing, manufacturing, storing, transporting, and using a product, as well as disposing of the product waste, must be considered” in GSCM.

Practices implemented to protect the environment might range from reactive monitoring of the environmental management programs to more proactive practices such as recycling, reclamation, remanufacturing, and reverse logistics (Zhu and Sarkis, 2004). Other examples of GSCM practices include developing the environmental life cycle analysis of products into supplier processes, encouraging implementation of environmental management systems into suppliers' organizational structure, incorporating supplier input into greening organizational practices, reducing packaging and waste, and many other similar initiatives (Sarkis, 2006). On the other hand, some organizations green their supply chains through evaluation and selection of appropriate green suppliers (Fu et al., 2012; Sarkis, 2006). The GSCM literature suggests encouraging existing suppliers to enhance their environmental performance by acquiring certifications or introducing green practices (Fu et al., 2012). While earlier studies in the literature have mainly focused on conventional criteria such as price, quality and delivery time, more recent research is moving towards the integration of environmental factors into supplier selection decisions (Baskaran et al., 2012).

### 2.2. Green supplier selection criteria

#### 2.2.1. Economic criteria

In reviewing the literature, we see that several conventional criteria have been identified by scholars of supply chain management. In fact, the theoretical basis for the evaluation of suppliers started with transaction cost economics and a resource-based view of the organization. The main concept underlying the term ‘transaction cost economics’ is that an organization's primary concentration should be ‘profit maximization’. As a result, the ‘price’ criterion has received more attention than other criteria such as quality or delivery (Baskaran et al., 2012). Several studies taking into account the conventional criteria have emphasized the price criterion as the main concern of industries (Gupta and Krishnan, 1999; Simpson et al., 2002). Ho et al. (2010) concluded in a literature review of supplier selection models that the most popular economic criteria among researchers are quality, delivery, cost, management, technology, and flexibility. They argue that the single criterion approach based on the lowest cost bidding is no longer relevant and significant in contemporary supply chain management. Table 1 presents a summary of the most important economic criteria in the research literature.

#### 2.2.2. Environmental criteria

Among conventional studies of supplier selection, neither environmental nor social sustainability criteria have been emphasized (Bai and Sarkis, 2010b). With environmental awareness, increasingly more and more authors are addressing supplier selection in the light of environmental aspects (Handfield et al., 2002; Lee et al., 2009; Sarkis, 2006). However, although a firm

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