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A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers

Gülçin Büyüközkan *, Gizem Çifçi

Industrial Engineering Department, Faculty of Engineering and Technology, Galatasaray University, 34357 Ortaköy, İstanbul, Turkey

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ABSTRACT

It is well known that "green" principles and strategies have become vital for companies as the public awareness increased against their environmental impacts. A company's environmental performance is not only related to the company's inner environmental efforts, but also it is affected by the suppliers' environmental performance and image. For industries, environmentally responsible manufacturing, return flows, and related processes require green supply chain (GSC) and accompanying suppliers with environmental/green competencies. During recent years, how to determine suitable and green suppliers in the supply chain has become a key strategic consideration. Therefore this paper examines GSC management (GSCM) and GSCM capability dimensions to propose an evaluation framework for green suppliers. However, the nature of supplier selection is a complex multi-criteria problem including both quantitative and qualitative factors which may be in conflict and may also be uncertain. The identified components are integrated into a novel hybrid fuzzy multiple criteria decision making (MCDM) model combines the fuzzy Decision Making Trial and Evaluation Laboratory Model (DEMATEL), the Analytical Network Process (ANP), and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) in a fuzzy context. A case study is proposed for green supplier evaluation in a specific company, namely Ford Otosan.

1. Introduction

Money, components, processes and information flows might establish a supply chain management system but simultaneously, due to government legislation and increasing awareness among the people to protect the environment; firms today cannot ignore environmental issues if they want to survive in the global market. In this sense, green supply chain management (GSCM) has emerged as a way for firms to achieve profit and market share objectives by lowering environmental impacts and increasing ecological efficiency (van Hock & Erasmus, 2000). In response to demands, companies have to find ways to incorporate environmental and social aspects into their supply chain management.

In order to reap the greatest benefits from environmental management, firms must integrate all members in the green supply chain (GSC) (Lee, Kang, Hsu, & Hung, 2009). Among these expectations, increasing attention is devoted to suppliers' social responsibility with a particular focus on fair and legal use of natural resources. Hence, strategic partnership with environmentally, socially and economically powerful suppliers should be integrated within the GSC for improving the performance in many directions including reducing costs and lead time, eliminating wastages, improving quality and flexibility to meet the needs of the customers, etc. For this reason, the aim of this study is to propose an evaluation model to judge the appropriateness of suppliers for an organization which has environmental goals and measure the validity of the model with a real case study.

There are various mathematical techniques for evaluation of suppliers, such as data envelopment analysis (DEA) (Wu, 2009), heuristics (He, Chaudhry, Lei, & Baohua, 2009; Sen, Başligil, Şen, & Baraçli, 2007), analytic hierarchy process (AHP) (Sevkli, Koh, Zaim, Demirbag, & Tatoglu, 2007), fuzzy AHP (Chan & Kumar, 2007; Lee et al., 2009; Rao & Holt, 2005), fuzzy goal programming (Kumar, Vrat, & Shankar, 2006; Tsai & Hung, 2009), fuzzy analytic network process (ANP) (Lin, 2009; Tuzkaya & Önüt, 2008) in literature. For the purpose of evaluating and selecting green suppliers, both qualitative and quantitative factors must be considered. Thus, green supplier selection is a kind of multiple criteria decision making (MCDM) problem and we need to employ MCDM methods to handle it appropriately. Here emphasis is placed on the relationships of factors which can be handled by ANP (Saaty, 1996) effectively. The ANP can deal with the dependence in feedback systematically. In this study also Decision Making Trial and Evaluation Laboratory (DEMATEL) method (Gabus & Fontela, 1972) is used to extract the mutual relationships of interdependencies within criteria and the strength of interdependence. Lastly to choose the alternative for ideal solution of this problem, Technique for Order Performance

* Corresponding author. Tel.: +90 212 227 4480.
E-mail address: gulcin.buyukozkan@gmail.com (G. Büyüközkan).

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by Similarity to Ideal Solution (TOPSIS) is used. However it should not be ignored that the fuzzy nature of human life makes these kinds of MCDM analysis more difficult. Yet for human being's subjective judgment, a theory needed in measuring the ambiguity of these concepts. Therefore, fuzzy logic (Zadeh, 1965) is used in evaluations that allows for uncertainty among factors.

Briefly, fuzzy DEMATEL (Chen, Tseng, & Lin, 2008; Tseng, 2009a; Wu & Lee, 2007); fuzzy ANP (Liu & Lai, 2009; Tuzkaya, Ozgen, Ozgen, & Tuzkaya, 2009; Yüksel & Dağdeviren, 2010); and fuzzy TOPSIS (Salehi & Tavakkoli-Moghaddam, 2008; Yong, 2006; İç & Yurdakul, 2010) approaches used by several authors are workable. Because by applying these theories, it can be easy to discover things inside the complex problem. In the literature there are some works on these methods, but there is not any research that combines these three methods together. Thereby, this study proposes a new integrated approach that could cope with the interdependencies among various criteria in fuzzy environment. Ford Otosan is selected as a case company in this study for the evaluation of green supplier alternatives. The supplied case study provides additional insights for research and practical applications.

The organization of the paper is then as follows. The paper begins with the literature survey of GSCM. Then, after a brief review of methodologies, various main components of the GSCM are examined to structure a framework for green supplier evaluation. The next section includes the illustration of the proposed green supplier methodology through the case of Ford Otosan. The paper concludes with future directions.

2. Literature survey

Industrial production can have a great impact and damage on the sustainability of the natural environment and human life such as the impacts include depletive resource use, global environmental impacts, local environmental impacts, health impacts, and safety risks. These environmental issues have received more and more attention in recent years and supply chain operation with sustainable consideration has become an increasingly important issue. Thereby, these growing interest and importance to the supply function raise the importance of the environmental performance of suppliers (Faruk, Lamming, Cousins, & Bowen, 2002; Hall, 2000; Sarkis, 2003; Simpson & Power, 2005). The benefits to the firm arising from advanced environmental management practice can include: cost reduction (efficient use of raw materials, reduction in fines, risks or insurance costs); quality improvement; early adoption of new regulations; and better human resource management practice (Simpson & Power, 2005; Theyel, 2001).

GSCs are gaining increasing interest among researchers and practitioners. GSC is a broad concept that refers to a variety of methods by which companies work with their suppliers to improve and maintain the performance of their products or manufacturing processes of the suppliers, customers or both. The emergence of GSC is one of the most significant developments in the past decade, offering the opportunity for companies to align their supply chains in accordance with environmental and sustainability goals.

The most common GSCM practices involve organizations assessing the environmental performance of their suppliers, requiring suppliers to undertake measures that ensure environmental quality of their products, and evaluating the cost of waste in their operating systems (Handfield, Walton, Sroufe, & Melnyk, 2002). A high level of environmental performance achieved by a firm may be broken down by a poor level of environmental management by its suppliers. Therefore, green suppliers and their selection, evaluation, etc. processes are vital in a green supply chain.

The past few years have led researchers to investigate the environmental concepts in management and supply chains. Lu, Wu, and Kuo (2007) proposed environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. According to current environmental regulations, companies' environmental policies, and nongovernmental organizations' environmental guidelines; the main environmental criteria were determined as materials, energy use, solid residue, liquid residue, gaseous residue. And this framework was evaluated using a fuzzy AHP methodology. Ozgen, Önüt, Gülsün, Tuzkaya, and Tuzkaya (2008) presented a two-phase possibilistic linear programming methodology for multi-objective supplier evaluation and order allocation problems. The required dimensions for evaluating suppliers were indicated as delivery reliability, flexibility and responsiveness, cost, assets and environmental responsiveness. Tuzkaya, Ozgen, Ozgen, and Tuzkaya (2009) evaluated the environmental performance of suppliers with a hybrid fuzzy multi-criteria decision approach: fuzzy ANP and Fuzzy Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) methodology. In their study, evaluation criteria are determined as pollution control, green process management, environmental and legislative management, environmental costs, green product, and green image. Gumus (2009) introduced evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. The determined criteria were hygiene and safety, quality of service, complementary service, economic factors, service time, taking care of the human health and environmental protection standards, problem solving ability, and the owned vehicle fleet. Lee et al. (2009) presented a green supplier selection model for high-tech industry. The required dimensions for evaluating green suppliers were indicated as quality, technology capability, pollution control, environment management, green product, and green competencies/green image.

Recently, Bai and Sarkis (2010) proposed a study for green supplier development and performed an analytical evaluation using rough set theory. The methodology generates decision rules relating the various attributes to the performance outcomes (environmental, business, and joint performance). Kuo, Wang, and Tien (2010) integrated artificial neural network (ANN) and two multi-attribute decision analysis (MADA) methods: DEA and ANP for green supplier selection. Their green supplier selection structure contains quality, cost, delivery, service, environment, and corporate social responsibility. Punniyamoorthy, Mathiyalagan, and Parthiban (2011) introduced a strategic model using structural equation modeling and fuzzy logic in supplier selection. Their criteria of supplier selection are management and organization, quality, technical capability, production facilities and capacities, financial position, delivery, services, relationships, safety and environmental concern, and cost. Awasthi, Chauhan, and Goyal (2010) proposed a fuzzy multi-criteria approach for evaluating environmental performance of suppliers. They used fuzzy TOPSIS for evaluation and their criteria were usage of environment friendly technology, environment friendly materials, green market share, partnership with green organizations, management commitment to green practices, adherence to environmental policies, involvement in green projects, staff training, lean process planning, design for environment, environmental certification, and pollution control initiatives.

3. Proposed green supplier evaluation framework

This study proposes a novel hybrid analytic approach based on the fuzzy DEMATEL, fuzzy ANP, and fuzzy TOPSIS methodologies to assist in GSCM strategic decisions. The general view of the proposed green supplier evaluation methodology is shown in Fig. 1.