



Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry



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ARTICLE INFO

Article history:

Received 9 November 2014

Revised 14 November 2015

Accepted 26 February 2016

Available online 4 March 2016

Keywords:

Green supplier selection

Environmental sustainability

Fuzzy set theory

TOPSIS

VIKOR

GRA

Agri-food industry

ABSTRACT

The incorporation of environmental criteria into the conventional supplier selection practices is essential for organizations seeking to promote green supply chain management. Challenges associated with green supplier selection have been broadly recognized by procurement and supplier management professionals. The development and implementation of practical decision making tools that seek to address these challenges are rapidly evolving. This article contributes to this knowledge area by comparing the application of three popular multi-criteria supplier selection methods in a fuzzy environment. The incorporation of fuzzy set theory into TOPSIS, VIKOR and GRA methods is thoroughly discussed. The methods are then utilized to complete a green supplier evaluation and selection study for an actual company from the agri-food industry. Our comparative analysis for this case study indicates that the three fuzzy methods arrive at identical supplier rankings, yet fuzzy GRA requires less computational complexity to generate the same results. Additional analyses of the numerical results are completed on the normalization functions, distance metrics, and aggregation functions that can be used for each method.

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1. Introduction

“Supplier selection” has been recognized as a critical issue for organizations in maintaining a strategically competitive position due to its direct impact on the cash flow and profitability. The process of supplier evaluation and selection is rather intricate for a variety of reasons including the range of influencing factors [35], the mix of quantitative and qualitative selection criteria [54], and the breadth and diversity of suppliers across the supply chain [5]. Increasing outsourcing and offshoring trends, complex and tightening governmental and regional policies, and conflicting organizational and supply chain objectives have added to the significance and complexity of supplier selection decisions. The challenge is not only to recognize the role of supplier management and practices, but rather to develop strategies and approaches to tackle supplier selection concerns facing procurement and supplier management professionals.

One of the challenges facing organizations and their supply chains is to decouple economic growth from the commensurate

environmental degradation due to a variety of pressures, including the ever tightened environmental regulatory mandates as well as the rise of consumer awareness and attendant shift of attitudes to purchase greener products [71,22]. For organizations to manage environmental burdens of their supply chains, not only can they focus on greening the intra-organizational supply chain operations (e.g. greening internal production, transportation and warehousing operations), but they also need to focus on inter-organizational aspects which needs going beyond their organizational boundaries and look into their suppliers’ performance [21,4]. Green supplier selection aims to address the latter focus, a major milestone towards the development and management of eco-efficient supply chains. Green supplier selection requires the incorporation of environmental criteria into the conventional supplier selection practices and approaches [23]. Price, quality and service level have been the predominant conventional supplier selection criteria, while carbon footprint and emissions, energy efficiency, water usage, and recycling initiatives have been the more common environmental measures [14,59,66,7].

In this environment, organizations can find utility in multi-criteria decision making (MCDM) tools that can assist with evaluating and selecting suppliers taking into account a mix of conventional and environmental criteria. A small number of case

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studies and formal modeling efforts exist that focus on the development of MCDM tools and approaches aiming to incorporate some of the environmental factors into conventional supplier selection models. The recent review of Govindan et al. [23] show that most of the modeling efforts in this area are based on the integration of fuzzy theory into the conventional MCDM. This is predominantly due to the ability of fuzzy-based approaches in managing uncertainty in input data and in particular the impreciseness of human judgments.

In this paper, we aim to compare the performance of three popular MCDM methods, including Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), VišekriterijumskoKompromisnoRangiranje (VIKOR), and Grey Relational Analysis (GRA), when integrated with fuzzy sets to address concerns related to decision uncertainties. The development stages are described for the three methods and model implementations are completed for an actual case situation where real data is utilized to select green suppliers of raw material for a case company from agri-food sector. Given the growing environmental concerns in agriculture and food processing industries during the past decade, stakeholders are more than ever encouraging food producers to improve the environmental performance of their supply chains and keep closer eyes on the sustainability performance of their suppliers. However, despite this recognized significance of green supplier selection practices in agri-food sector, due to the considerable environmental burdens of the related operations [6], a small number of related case studies have been investigated compared to those of electronic and automotive industries. Thus, second to a comparative analysis contribution of this paper is investigating the application of the proposed integrated models in an industry that is a major contributor to the climate change and global warming.

The remainder of this paper is organized as follows: Section 2 presents a brief review of the selection criteria and MCDM methods used for green supplier evaluation and selection. Section 3 presents an introduction to fuzzy set theory and its incorporation in three popular group decision making methods including TOPSIS, VIKOR and GRA. Section 4 describes the application of these methods in a real case study. Section 5 presents summary of the numerical results and provides a detailed technical comparison of the selected approaches. Conclusions, research limitations, and directions for future work in the area are presented in Section 6.

2. Literature review

2.1. Review of supplier selection criteria

A number of literature reviews have been completed on the supplier selection criteria adopted and decision models developed [1,23,9]. Some others have addressed the possible tradeoffs amongst these criteria in order to select the most desirable alternatives given specific problem variables and constraints [35]. Supplier evaluation and selection decision making, in general, is reliant on a broad range of quantitative and qualitative criteria. Given the increasing global trends on environmental sustainability policy and practices, many of the recent supplier evaluation studies consider a

set of conventional and environmental criteria to tackle green supplier selection problems [23].

Dikson [17] identifies 23 supplier selection criteria which have since been widely adopted and reviewed in several studies. Weber et al. [66] introduce price, delivery, quality, production facilities and capacity as the most popular criteria during a 25-year period, 1966–1990. Cheraghi et al. [13], Ho et al. [27] and Thiruchelvam and Tookey [59] add manufacturing capability to these. Service level, quality and price appear to be the most widely adopted criteria in the conventional supplier selection literature.

Within the context of green supplier selection, the recent review of Govindan et al. [23] identified Environmental Management Systems (EMS) as the most popular environmental criteria due to its flexibility. Nielsen et al. [45] reviewed 57 related papers and, similar to Govindan et al. [23], found EMS the most important and comprehensive environmental criteria amongst over 90 identified measures. EMS is a set of processes and practices that helps organizations improve their environmental performance and operations efficiency. It involves a wide range of prerequisite actions including environmental planning and policies such as the management of wastes and energy usage in manufacturing [45] and codes of conducts and standards such as ISO14000 series, REACH, RoHS and WEEE [67]. Many companies follow one or more common EMS criteria in their green supplier selection practices [67].

Using these reviews and the identified criteria, a combination of conventional and green supplier selection criteria is used in our study for the purpose of supplier assessment. The importance of each criterion is assessed and weighted based on expert judgments. Table 1 outlines these criteria and the related references to each category.

2.2. Review of supplier selection methods

Several supplier selection methods have been developed, ranging from basic single-objective to complex multi-objective methods. The use of hybrid methods combining more than two techniques has received more recent attention due to their flexibility [44]. Yet, over 80% of published models are based on single methods [9] due to (1) the relatively recent emergence of the integrated methods, and (2) the complexities associated with modeling of integrated approaches. Chai et al. [9] and Govindan et al. [23] present reviews of the published models for conventional and green supplier selection, respectively. Here we seek to review the most popular MCDM methods adopted in the past green supplier selection studies which would then allow us to position our study in this literature set.

Both quantitative and qualitative criteria can be used for effective supplier selection. Qualitative criteria are those decision factors that cannot be easily expressed in numerical terms [25]. These may include intangible factors such as risk, reputational damage, and some of the sustainability-related issues. We focus our review and analysis on descriptive qualitative methods. As the area of sustainable supply chain management continues to mature, the application of qualitative methods is expected to grow as more social and environmental factors can be expressed mathematically and numerically [62,21].

Table 1
Summary of the identified supplier selection criteria.

	Criteria	Description
Conventional supplier selection criteria: Weber et al. [66]; Dikson [17]; Cheraghi et al. [13]; Ho et al. [27]; Thiruchelvam and Tookey [59]	Service level	On time delivery, after sales service and supply capacity
	Quality	Quality of material, labor expertise and operation excellence
	Price	Product/service price, capital and financial power
Green supplier selection criteria: Govindan et al. [23]; Nielsen et al. [45]	EMS	Environmental prerequisite, planning and certificates

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