Computers in Industry 62 (2011) 164–174

Contents lists available at ScienceDirect

Computers in Industry

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

A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information

Gülçin Büyüközkan *, Gizem Çifçi

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

ARTICLE INFO

Article history:
Available online 30 November 2010

Keywords:
Sustainable supply chain
Supplier selection
Analytic network process
Fuzzy logic
Incomplete preference relations

ABSTRACT

Both academic and corporate interest in sustainable supply chains has increased in recent years. Supplier selection process is one of the key operational tasks for sustainable supply chain management. This paper examines the problem of identifying an effective model based on sustainability principles for supplier selection operations in supply chains. Due to its multi-criteria nature, the sustainable supplier evaluation process requires an appropriate multi-criteria analysis and solution approach. The approach should also consider that decision makers might face situations such as time pressure, lack of expertise in related issue, etc., during the evaluation process. The paper develops a novel approach based on fuzzy analytic network process within multi-person decision-making schema under incomplete preference relations. The method not only makes sufficient evaluations using the provided preference information, but also maintains the consistency level of the evaluations. Finally, the paper analyzes the sustainability of a number of suppliers in a real-life problem to demonstrate the validity of the proposed evaluation model.

1. Introduction

Supply chain management (SCM) is a business term that has emerged in the last few decades and has been gaining in popularity ever since. The typical definition of the term supply chain management [1] is as follows: The supply chain comprises all those activities associated with the transformation and flow of goods and services, including their attendant information flows, from the sources of materials to end users. Management refers to integration of all these activities, both internal and external to the firm.

Nowadays, consideration is given to the convergence of green/environmental and sustainable SCM. Sustainable SCM is the management of material, information and capital flows, as well as cooperation among companies along the supply chain, while taking into account goals from all three dimensions of sustainable development – economic, environmental and social – derived from customer and stakeholder requirements [2]. In doing so, the focus on environmental management and operations is moved from local optimization of environmental factors to consideration of the entire supply chain during the production, consumption, customer service and post-disposal disposition of products [3]. While the first consideration of sustainability can be traced back to practices of many ancient cultures, more recent attention toward sustainability and the environment can be found in the literature [2–25]. In addition to the academic field, also communities, governments, businesses, international agencies, and non-government organizations are increasingly concerned with establishing a means to monitor performance and to assess progress toward sustainable development [26]. Meanwhile, suppliers are of great importance as triggers for sustainable supply chains (SSC). Further thought shows that partnership with environmentally, socially and economically powerful suppliers should enhance the performance of the supply chain.

Additionally, there is a need for supplier management for risks and performance, and eventually a need for an effective, sustainable supplier selection and evaluation process. For these reasons, the aim of the paper is to propose an efficient framework for the measurement of supplier sustainability to improve supply chain performance. There exist various techniques in the literature for evaluating and selecting suppliers, such as data envelopment analysis [27–30], mathematical programming [19,31,32], fuzzy set theory [33–35], analytic hierarchy process (AHP)/fuzzy AHP [11,36,37], and analytic network process (ANP)/fuzzy ANP [38–41]. Readers are referred to [42] for detailed information.

Sustainable supplier selection requires the evaluation of suppliers' performance with respect to several metrics. There are complex relationships among these metrics; therefore, the evaluation methodology should capture these relationships

* Corresponding author. Tel.: +90 212 227 4480.
E-mail addresses: gulcin.buyukozkan@gmail.com (G. Büyüközkan), gizem.cifci@gmail.com (G. Çifçi).

0166-3615/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.compind.2010.10.009

effectively. Moreover, it is difficult to obtain precise preferences of decision makers (DMs) because,

(1) The decision data of human judgments with preferences are often vague,
(2) As improvement of sustainability depends on environmental (planet), social (people) and economical (profit) aspects, DMs may not be able to evaluate suppliers from all these aspects. While one DM might have economic expertise, another might have experience with environment-related issues.

A model that can provide a solution even without enough information should be developed to address all the issues discussed above. Incomplete preference relations [43–49] can deal with this problem. Since each expert has his/her own experience, he/she could have some difficulties while trying to give his/her preferences in a complete manner. This may be due to an expert not having a precise or sufficient level of knowledge of the problem, or because that expert is unable to judge the degree to which some options are better than others [50]. Also due to time pressure, the DM may develop an incomplete linguistic preference relation in which some of the elements are missing. In such situations, experts are forced to provide incomplete preference relations. These show us that the group decision process needs to derive a single group preference from a number of incomplete individual preferences. Therefore, it is worth paying attention to this issue and this paper focuses on incomplete preference relations while making decisions.

While dealing with missing preferences of DMs, the solution procedure should also consider the dependence and interactions among criteria. The increasing complexity and uncertainty of the socio-economic environment makes it less possible to assume all criteria as independent. Hence, this work proposes a new integrated group decision approach based on the ANP [51] method with incomplete linguistic preferences in fuzzy environments [52]. The ANP [53–56] approach is applicable to this study since it allows easy discovery of relations inside the complex problem. ANP can overcome the problem of dependence and feedback among criteria or alternatives. Simultaneously, with the help of fuzzy incomplete preferences, this integrated method can deal with uncertainty of DMs and missing data. As incomplete fuzzy preferences are not widespread currently, the main contribution of this paper is the integration of incomplete preferences into ANP and usage of this integration in sustainable supplier selection problem. No study exists in the literature that combines incomplete preference relations with other methods or any applications in the supply chain field.

The paper is organized as follows. Section 2 introduces the SSC concept and the evaluation framework for sustainable supplier selection. Section 3 describes the methodology adopted in the paper and characterizes the novel computational procedure. Section 4 includes an implementation of the proposed evaluation framework through the case study and presents the results. Section 5 concludes the paper.

2. A new integrated evaluation framework for sustainable supplier selection

2.1. Sustainable supply chain and sustainable supplier selection

Supply chain operations with sustainability considerations have become an increasingly important issue in recent years. While diverse interpretations of sustainability exist, one central concept that helps to operationalize sustainability is the triple bottom line approach, where a minimum performance is to be achieved in the environmental, economic and social dimensions [57]. With this perspective, in SSCs, environmental/ecological, social and ethical criteria need to be fulfilled by the supply chain members to remain within the chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria.

To meet the increasing market pressures and demands from various stakeholder groups and to comply with more demanding environmental legislation, companies start to look at their supply chain to enhance their overall sustainability profile. Many companies invest in voluntary environmental management and communication tools, such as standardized environmental management systems (ISO 14001 in particular), life cycle assessments, environmental labeling of products, carbon disclosure projects, and sustainability reporting schemes [58].

Responsibility for sustainability cannot be given to a separate entity; it must be a part of everyone's job in a SSC from the suppliers to the top management. Supply chain strength generally depends on the linkage between:

- The number and quality of the suppliers and customers in a country, and
- The three dimensions of sustainable development; namely, environmental, economical and social.

These also show the importance of suppliers' sustainable performance and its evaluation for a SSC.

There are several papers concerning sustainable (or green) suppliers. Yuzhong and Liyun [59] proposed a method for a green supplier selection that used the grey entropy method. Lu et al. [15] presented a paper for environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. Recently, Tsai and Hung [19] studied a fuzzy goal programming approach for green supply chain optimization under activity-based costing and performance evaluation with a value-chain structure. Another study proposed by Tuzkaya et al. [60] for environmental performance evaluation of suppliers used a hybrid fuzzy multi-criteria decision approach. Lee et al. [61] also introduced a green supplier selection model for high-tech industry.

Although these papers brought great insights to sustainable/green supplier evaluation literature, no attention is received for supplier evaluation with incomplete preferences. Incomplete preference-related works with case studies are rare in the literature. In 2006, Alonso et al. [62] proposed a decision aid system to provide consistent linguistic preference relations dealing with incomplete or inconsistent information. Xu [46] studied incomplete linguistic preference relations and their fusion with an illustrative example. Xu [47] also examined integrating multiple types of incomplete linguistic preference relations in multi-person decision making. Herrera-Viedma et al. [45,48] proposed two studies about a consensus model for group decision making with incomplete fuzzy preference relations in 2007. Same year, Fedrizzi and Giove [63] examined incomplete pairwise comparison and consistency optimization with a numerical example.

Recently, Wang and Chen [49] studied incomplete fuzzy linguistic preference relations in uncertain environments and considered the practice of Chan and Kumar [36] for selection of a global supplier. Another study is proposed by Chiclana et al. [64] as the comparison of similar methods for estimating missing pairwise preference values based on additive consistency [48,63]. Wang et al. [65] applied the incomplete linguistic preference relations on the performance of web shops.

2.2. The proposed evaluation framework for sustainable supplier selection

The objective of sustainable supplier selection is to identify suppliers with the highest potential for meeting a firm's needs