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How to assess sustainability of suppliers in volume discount context? A new data envelopment analysis approach

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ABSTRACT

In this paper, we reformulate conventional data envelopment analysis (DEA) models and propose a novel method for evaluating sustainability of suppliers in the presence of interval volume discount offers, fuzzy data, and ordinal data. To this end, we convert all data into interval data. To convert fuzzy data into interval data, we use nearest weighted interval approximation by applying weighting function and we convert each ordinal data into interval one. Then, using enhanced Russell model, interval efficiencies are obtained. After that, using preference degree approach, we rank suppliers. Finally, a case study is presented to illustrate our proposed approach.

1. Introduction

Supply Chain Management (SCM) is a wide topic and has been studied by researchers in recent years. One outstanding research area is application of sustainability concept in SCM (Beske et al., 2014). Sustainable SCM (SSCM) is management of material, information, and capital flows, as well as cooperation among companies along supply chain while taking into account economic, environmental, and social factors (Seuring and Müller, 2008). SSCM has become an outstanding issue in recent years. To respond increasing market demands and pressures from stakeholders and to comply with environmental regulations, companies have commenced to review their supply chain to improve its sustainability aspect (Büyüközkan and Çifçi, 2011).

Sustainability has an undeniable role in SCM. Suppliers have to be selected cautiously as they can have constructive or negative impact on organization's performance (Ramanathan, 2007). Suppliers that are unfriendly to environment can damage reputation of organization (Dou and Sarkis, 2010). Sustainable supplier selection can be defined as a supplier selection problem in which environmental and social criteria are considered along with economic criteria (Bai and Sarkis, 2010; Baskaran et al., 2012). SSCM evaluation can be used in several perspectives such as supplier selection and performance monitoring (Gimenez and Tachizawa, 2012).

A supply chain is not sustainable if environmental measures are not conducted by suppliers. Producing sustainable products is a rejoinder to forces coming from governments, consumers, and non-governmental organizations (Seuring, 2013). Over past decades, due to rapid reduction of natural resources and concerns over wealth inequality and corporate social responsibility, sustainability has become important for scholars (Govindan et al., 2013). Dao et al. (2011) discussed that this

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concern has increased responsibility of firms. In addition, communities, governments, businesses, international agencies, and non-governmental organization are increasingly concerned about establishing a means to monitor performance and assess progress toward sustainable development (Tsoulfas and Pappis, 2006). As addressed by Dyllick and Hockerts (2002), SSCM is combination of sustainable development and SCM whereby sustainable development is defined as combining environmental, social, and economic factors. Cetinkaya et al. (2011) explained that sustainable supply chains are not limited to green supply chains, but they should consider financial issues and help society. To achieve a sustainable supply chain, all members in supply chain from suppliers to top managers should have affinity with sustainability.

Data envelopment analysis (DEA) is a linear programming approach for measuring relative efficiency of decision making units (DMUs). Since (Charnes et al., 1978) introduced DEA, it has been widely applied to evaluate the relative efficiency of various DMUs (see Emrouznejad et al., 2008; Izadikhah and Farzipoor Saen, 2015; Farzipoor Saen and Zohrehbandian, 2008; Masoumzadeh et al., 2014; Toloo, 2009, 2012a, 2012b, 2013, 2014a, 2014b, 2014c, 2015; Toloo et al., 2015; Toloo and Ertay, 2014; Toloo and Kresta, 2014; Toloo and Nalchigar, 2009; Toloo and Tichý, 2015; Dibachi et al., 2014, 2015).

The relative efficiency of each DMU is defined as ratio of weighted sum of outputs to weighted sum of inputs. Classical DEA models assume that inputs and outputs are precise (Charnes et al., 1994). However, this assumption may not be valid, i.e. some or all inputs and outputs may be imprecise. Due to existence of uncertainty, DEA sometimes faces with imprecise data, especially when a set of DMUs contain ordinal and fuzzy data. Imprecise data in DEA was initially proposed by Cooper et al. (1999) and Cooper et al. (2001).

Saeidifar (2011) introduced a weighted mean to rank fuzzy numbers. He proposed a new ranking method for fuzzy numbers and defuzzified fuzzy numbers. He defined a weighted distance measure for fuzzy numbers. Then, by minimizing this distance, he obtained nearest weighted interval and point approximations of fuzzy numbers. Izadikhah (2014) proposed new fuzzy TOPSIS method using the nearest weighted interval approximation of fuzzy numbers.

In this paper, we convert ordinal data into interval data. Then, using the nearest weighted interval approximation of a generalized fuzzy number, we convert fuzzy numbers into interval numbers. As a result, all dataset will be in interval form. Furthermore, we develop a methodology for calculating interval efficiencies in the presence of fuzzy and ordinal volume discounts. Finally, using preference degree method, we compare obtained intervals and present a ranking method. In summary, contributions of this paper are as follows:

- For the first time, we use the nearest weighted interval approximation for converting fuzzy data into interval data.
- For the first time, we incorporate fuzzy and ordinal data in DEA to deal with volume discounts in assessing sustainability of suppliers.

This paper is organized as follows: In Section 2, we present literature review. In Section 3 some preliminaries are discussed. Section 4 proposes a new method for ranking suppliers (DMUs). Section 5 compares our method with other methods. In Section 6, an illustrative example is given to demonstrate our proposed approach. Also, a case study shows applicability of our proposed method. Conclusions and directions for future researches are given in Section 7.

2. Literature review

2.1. Sustainable supplier selection

To integrate sustainability factors into the supplier selection problem, Bai and Sarkis (2010) utilized grey system and rough set theory. Amindoust et al. (2012) and Bai and Sarkis (2014) listed sustainable supplier selection criteria and sub-criteria and based on those criteria and sub-criteria a methodology was proposed to rank suppliers.

Orji and Wei (2015) presented an approach for integrating information on supplier behavior in fuzzy environment with system dynamics simulation modeling technique. Mani et al. (2014) presented a methodology that focused on socially sustainable supplier selection through social parameters using analytic hierarchy process (AHP) technique. Lin et al. (2015) applied analytic network process (ANP) in supplier selection problem at Taiwanese Electronics Company under sustainability. Gold and Awasthi (2015) proposed a two-step fuzzy AHP approach for sustainable global supplier selection problem. Su et al. (2015) proposed a hierarchical grey decision-making trial and evaluation laboratory method to identify and analyze criteria and alternatives in incomplete information in sustainable supply chain management context.

Sarkis and Dhavale (2015) developed a methodological approach based on a Bayesian framework and Monte Carlo Markov chain simulation to rank and select sustainable suppliers. Jakhar (2015) presented sustainable supply chain performance measures and proposed a partner selection and flow allocation decision-making model. Trapp and Sarkis (2016) developed an optimization model that simultaneously addresses supplier selection, supplier development, and sustainability considerations.

2.2. Supplier selection via DEA

Managing the supplier selection process is a necessary step for companies seeking to manage their corporate legitimacy and reputations. DEA has been widely used for supplier selection problems. Kleinsorge et al. (1992) used DEA to track