Expert Systems with Applications 42 (2015) 7951–7959

Contents lists available at ScienceDirect

Expert Systems with Applications

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

Group multi-criteria supplier selection using combined grey systems theory and uncertainty theory

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ARTICLE INFO

Article history:
Available online 18 June 2015

Keywords:
Supplier selection
Grey systems theory
Uncertainty theory
Uncertain programming

ABSTRACT

Supplier selection in supply chain is critical strategic decision for organization's success and has attracted much attention of both academic researchers and practitioners. Supplier selection problem consists of stochastic and recognitive uncertainties. However, the requirement of large sample size and strong subject knowledge to build suitable fuzzy membership function restrict the applicability of probability and fuzzy theories in supplier selection problem. In response, this study proposed a new tool for supplier selection. In this paper, we applied the combination of grey system theory and uncertainty theory which neither requires any probability distribution nor fuzzy membership function. The objective of this paper is to develop framework for reducing the purchasing risks associated with suppliers. The proposed supplier selection method not only selects the most appropriate supplier(s) but also allocate optimal purchase quantity under stochastic and recognitive uncertainties. An example is shown to highlight the procedure of the proposed model at the end of this paper.

1. Introduction

Many researchers have investigated supplier evaluation criteria and selection methods. Supplier selection is a multiple-attribute decision-making (MADM) problem (Karimi & Rezaeinia, 2014). Among various methods, the widely adopted methods are multi-criteria decision models (Wang & Lee, 2007) and linear weighting models (Sarkis & Talluri, 2002), the analytic hierarchy process (Sipahi & Timor, 2010), and mathematical programming (MP) techniques (Talluri & Narasimhan, 2003). These all above described methods give little insights for supplier selection issue, because supplier selection is highly associated with uncertainties and depends on large amount of domain knowledge where expert's assessment play an important role. Supplier selection problem is associated with *recognitive* and *stochastic* uncertainties. Therefore it is necessary to develop a more effective supplier selection method, which can handle recognitive and stochastic uncertainties simultaneously (Deng, Hu, Deng, & Mahadevan, 2014). The involvement of decision maker's (DM's) subjective judgment yields recognitive uncertainties and therefore traditional approaches may be fail to handle this type of uncertainty. Another uncertainty embed in supplier selection decision is stochastic nature of various decision parameters. Various researchers proposed supplier selection model deal with stochastic parameters (Hu, Munson, & Fotopoulos, 2012). These proposed stochastic models requires large amount of data to handle the assumption of certain probability distribution, this yield another problem for supplier selection decision as DM's have lack of knowledge or small availability of information for different set of suppliers. 'Probability and Statistics' theories can handle stochastic uncertainties but it requires large amount of historical data to produce reliable results, this is only possible when suppliers have long background and large sample data can be accessible to DMs, which is difficult in real situation. Recognitive uncertainty is largely due to lack of knowledge or incomplete information (Deng, 1985). Fuzzy mathematics is widely used to handle the recognitive uncertainty. The problem with the fuzzy mathematics is that, it requires strong knowledge about the subject to make membership functions. Recently, various researchers proposed fuzzy based techniques to deal with supplier selection problem (Boran, Genc, Kurt, & Akay, 2009). The requirement of large sample size and strong subject knowledge to build suitable membership function restrict the applicability of probability and fuzzy theories in supplier selection problem.

In this paper, we use combined grey systems theory and uncertainty theory for supplier selection and order allocation in order to achieve both quantitative and qualitative objectives associated

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http://dx.doi.org/10.1016/j.eswa.2015.06.018
0957-4174/

with suppliers. To our knowledge, no one has applied integrated grey system theory and uncertainty theory in supplier selection problem. The proposed model is more comprehensive and competitive than other published fuzzy and probabilistic theory based supplier selection model because it does not required any probability distribution and fuzzy membership function. Furthermore, we proposed uncertain goal programming model to determine the optimum order quantity to each supplier. The proposed supplier selection framework is based on three stages: (1) identification of supplier selection criteria, (2) defining weights to goals and ratings to supplier attributes as a grey linguistic variables, and (3) supplier selection and order allocation using uncertain goal programming considering uncertain demand and lead-time. Goal programming technique is widely used by many researchers to handle the multi-attribute supplier selection problem (Chai, Liu, & Ngai, 2013).

2. Literature review

A large number of articles dealing with supplier selection considered multi criteria when selecting suitable suppliers (Aissaoui, Haouari, & Hassini, 2007). Efficient evaluation of criteria and decision making techniques are two important elements in supplier selection problem. Aissaoui et al. (2007) presented a literature review on purchasing process. According to them most of the literature considered linear weighting models, fuzzy set, and dynamic programming to deal with uncertainty inherent in supplier selection process. Chai et al. (2013) presented a systematic review of 123 articles on supplier selection. Their analysis shows that most frequently decision making technique used in supplier selection problem is AHP (24.39%), followed by LP (15.44%), TOPSIS (14.63%), ANP (12.20%), DEA (10.57%), and multi-objective optimization (10.57%). They also concluded that around 60.98% of articles considered fuzzy hybrid approaches to deal with ambiguous information. In following sections, we reviewed only those articles that considered ambiguous information in supplier selection and order allocation problem.

2.1. Supplier selection considering uncertain information

Uncertainty is one of the most challenging problem in supply chain management (Amin, Razmi, & Zhang, 2011). As discussed earlier supplier selection problem inherent recognitive and stochastic uncertainties. In order to deal with these uncertainties, researchers have used different approaches such as probabilistic, fuzzy, and grey systems theory. Kumar, Vrat, and Shankar (2004) proposed fuzzy goal programming based approach for vendor selection. They consider triangular fuzzy membership function is their model. Amid, Ghodsypour, and O'Brien (2006) proposed interactive fuzzy multi-objective supplier section model. Li, Yamaguchi, and Nagai (2008) utilized grey-based rough set approach to supplier selection problem. Kilincci and Onal (2011) investigated FAHP based supplier selection methodology in Turkish washing machine company. Liao and Kao (2011) proposed integrated TOPSIS and MCGP based approach to solve the supplier selection problem. Arikan (2013) proposed interactive fuzzy multi-objective solution methodology for supplier selection problem. They considered three objectives including cost, quality, and on-time delivery. Deng et al. (2014) proposed D-AHP method for supplier selection problem. They extends classical AHP method using D numbers. The most of the above literature considered fuzzy based approaches to deal with uncertain information. However, as discussed earlier fuzzy based techniques required strong subject knowledge to build suitable membership function. Moreover, Liu (2012) showed that it is inappropriate to model uncertain quantities by using random variable or fuzzy variable. In the proposed method it will be illustrated that how combined grey system theory and uncertainty theory based approach can be applied to respond this shortage.

2.2. Supplier selection and order allocation

Recently, some researchers not only solve supplier selection problem but also determine order quantity to each supplier. Moghaddam (2015) proposed fuzzy multi-objective mathematical model to rank the best supplier and allocate optimal number of new, refurbished and final product to reverse logistics network. They integrate Monte Carlo simulation and fuzzy goal programming to find out Pareto-optimal solutions of the proposed model. Azadnia, Saman, and Wong (2015) used integrated approach of rule-based weighted fuzzy method, FAHP, and multi-objective programming to solve supplier selection problem and allocate order quantity for sustainable supplier selection. They considered four objective functions which are cost, social score, environmental score, and economic score. Similarly, other researchers combined fuzzy and various mathematical optimization method to solve the supplier selection and order allocation problem considering uncertain information. Table 1 shows summary of literature on supplier selection and order allocation considering uncertain information. Sadeghieh, Dehghanbaghi, Dabbaghi, and Barak (2012) utilizes grey systems theory to solve the supplier selection and order allocation problem. They integrate grey goal programming and genetic algorithm to solve the proposed model. However, application of their proposed model is difficult in practical scenario. This is due to reason that exact value of grey parameter is unknown and decision makers have to choose the optimal purchase quantity from the given range which is not possible in practical scenario. Kahneman and Tversky (1979) showed that decision makers usually overweight unlikely events. This problem limits the use of grey system theory in supplier selection problem for finding out optimal order quantity. In this scenario, Liu (2007) proposed uncertainty theory to deal with belief degree. In order to overcome above

Table 1
Summary of literature on supplier selection and order allocation considering uncertainty.

Author(s)	Supplier selection technique	Order allocation technique
Moghaddam (2015)	Fuzzy	Fuzzy goal programming
Azadnia et al. (2015)	FANP	Augmented ε-constraint method
Kannan, Khodaverdi, Olfat, Jafarian, and Diabat (2013)	FAHP	Multi-objective linear programming
Li, Wong, and Kwong (2013)	FEAHP	Dynamic programming approach
Sadeghieh et al. (2012)	Grey systems theory	Grey goal programming
Amin et al. (2011)	Fuzzy SWOT analysis	Fuzzy linear programming
Haleh and Hamidi (2011)	Fuzzy	Fuzzy linear programming
Razmi, Songhori, and Khakbaz (2009)	Fuzzy TOPSIS	Fuzzy linear programming
Lin (2009)	Fuzzy preference programming	Multi-objective linear programming
Ozgen, Onut, Gulsun, Tuzkaya, and Tuzkaya (2008)	FAHP	Multi-objective possibilistic linear programming
Lin and Chang (2008)	Fuzzy TOPSIS	Mixed integer programming