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An integrated FCM and fuzzy soft set for supplier selection problem based on risk evaluation

Zhi Xiao, Weijie Chen *, Lingling Li

School of Economics and Business Administration, Chongqing University, Chongqing 400044, PR China

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ABSTRACT

Supplier selection problem, considered as a multi-criteria decision-making (MCDM) problem, is one of the most important issues for firms. Lots of literatures about it have been emitted since 1960s. However, research on supplier selection under operational risks is limited. What's more, the criteria used by most of them are independent, which usually does not correspond with the real world. Although the analytic network process (ANP) has been proposed to deal with the problems above, several problems make the method impractical. This study first integrates the fuzzy cognitive map (FCM) and fuzzy soft set model for solving the supplier selection problem. This method not only considers the dependent and feedback effect among criteria, but also considers the uncertainties on decision making process. Finally, a case study of supplier selection considering risk factors is given to demonstrate the proposed method's effectiveness.

1. Introduction

Supply chains have become major elements in the global economy. Nowadays, the competition among enterprises has evolved into the competition among the supply chains. But supply chains expose to different kinds of risks that increase along with increasing globalization. Therefore, supply chains risk management (SCRM) is a field of escalating importance and is aimed at developing approaches to the identification, assessment, analysis and treatment of areas of vulnerability and risk in SC [1]. The research on supplier risk is one of important areas of supply chains risk. An effective supplier assessment and selection process is essential for improving the performance of a focal company and its supply chains [2]. So the supplier selection problem taking risk evaluation into consideration is greatly meaningful.

Although the evaluation of supplier risk has begun to draw considerable attention, research on supplier selection under operational risks is limited. Huang and Chen [3] discussed a possible Risk Breakdown Structure (RBS) for virtual enterprises and suggested a risk evaluation method. Then they applied the proposed risk evaluation method to the partner selection problem. Wu and Olson [4] considered three types of vendor selection methodologies in supply chains with risk: chance constrained programming (CCP), data envelopment analysis (DEA) and multi-objective programming (MOP) models. Wu et al. [5] proposed a fuzzy multi-objective programming model to decide on supplier selection taking risk factors into consideration.

Various models are available to select supply chain partners. In the existing research on supplier selection models, the criteria used by most of them are independent, but the dependent and feedback effects are often overlook. The expert system developed by Vokurka et al. [6] captured the previous supplier selection process in a knowledge base, which

* Corresponding author. Tel.: +86 15826179572.
E-mail address: chwj721@163.com (W. Chen).

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can be used to suggest selection criterion for future supplier selection process. Kokangul and Susuz [7] applied an integration of analytical hierarchy process and non-linear integer and multi-objective programming under some constraints to determine the best suppliers. Cakravastia et al. [8] developed an analytical model of mixed-integer programming for the supplier selection process in designing a supply chain network. Choy et al. [9] described a knowledge-based supplier selection and evaluation system, which was a case-based reasoning decision support system for outsourcing operations at Honeywell Consumer Products (Hong Kong) limited in China. Bevilacqua et al. [10] proposed a fuzzy quality function deployment (QFD) approach to support supplier selection. Chen et al. [11] presented a fuzzy model to determine the ranking order of all suppliers according to the concept of the TOPSIS. Seydel [12] used DEA to tackle the supplier selection problem. Ha and Krishnan [13] applied an integrated approach in an auto parts manufacturing company for supplier selection.

Based on the assumption of preferential independence, above the methods can be seen that the dependence and the feedback effects cannot be considered. However, the real-life situation usually emerges the dependence and the feedback effects simultaneously while making decision. Agarwal and Shankar [14] proposed an analytic network process (ANP) to evaluate alternatives that provided the route of performance improvement in supply chain. Gencer and Gurpinar [15] proposed an ANP model to tackle the supplier selection problem. Although the interrelationships among criteria were considered in the selection process, two main problems should be highlighted as follows [16]. The first is the problem of comparison. Sometimes it is hard for experts to compare the important degree of an index to another. Furthermore, the key for the ANP is to determine the relationship structure among features in advance [17]. The different structure results in the different priorities. However, it is usually hard for the decision maker to give the true relationship structure by considering many criteria.

As we know, due to the problem with compound and interaction effects, it is hard for decision makers to make a good decision using the simple weighted method. In order to deal with the problem, we use FCM to find the weights of criteria, which not only can overcome the preferential independent and but also can overcome the shortcomings of ANP.

Moreover, in practice decision-making on supplier selection problem includes a high degree of fuzziness and uncertainties. Molodtsove [18] initiated the concept of soft set theory, which is a new mathematical tool for dealing with uncertainties. Fuzzy soft set has rich potential for applications in several directions. In the present paper, we firstly apply fuzzy soft sets in supply chains.

This paper attempts to develop a novel evaluation framework to select supplier considering risk. We first integrate FCM and fuzzy soft set for solving supplier selection problem. The structure of integrated method is shown in Fig. 2. First, the weights of criteria/attributes can be effectively captured by FCM, which not only considers the dependence and the feedback effects among criteria but also can overcome the shortcomings of ANP. Second, in order to compensate for FCM method's dependence for expert advice in the reasoning process, we use PSO algorithm to train fuzzy cognitive maps and obtain the weight of each criterion. Finally, fuzzy soft set is formulated and solved to identify the best partner. The major advantages of combining FCM with fuzzy soft set are that the evaluation can account for the interdependency of criteria/attributes and the uncertainties in decision making process. Such a combination was rarely seen in literature before.

The remainder of the paper is organized as follows. Section 2 introduces the basic principles of FCM, PSO and fuzzy soft set. The proposed model is presented in Section 3. Section 4 illustrates the procedures in the proposed system using a numerical example. Finally, conclusions are drawn in Section 5.

2. Theoretical background

In this section, we briefly review basic theoretical background on fuzzy cognitive maps, particle swarm optimization algorithm and fuzzy soft set, respectively.

2.1. The basic theory of fuzzy cognitive maps

Fuzzy cognitive maps (FCMs), introduced by Kosko [19], extend the idea of cognitive maps [20] by suggesting the use of fuzzy causal functions taking numbers in $[-1,1]$ in concept maps. Recently, FCM have been widely employed in the application of political decision making [21], fault detection [22], process control [23], data mining in internet [24], medical decision system [25], modeling LMS critical success factors [26]. But to date, few studies have adopted FCMs in supply chains. In this paper, we first apply the FCM in evaluation supplier considering the risk factors.

FCMs are soft computing tools, which combine elements of fuzzy logic and neural networks. Strictly speaking, fuzzy cognitive map is a directed cyclic graph composed by the nodes and edges. Nodes of the map are commonly known as the concepts, indicating the main features, nature or attributes of the system. The edges between nodes can show the various causal relationships. Fig. 1 illustrates a simple FCM, where each concept node C_i in fuzzy cognitive map corresponds to a concept value $A_i \in [0,1]$, and the edges between the nodes correspond to a value, showed by the connection weight w_{ij}, in the interval $[-1,1]$. The weights correspond to the three main situations: positive, negative and zero, indicating that the concepts of positive correlation, negative correlation and not related respectively, and the absolute values reflect the extent of the impact between the concepts.