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An intelligent supplier evaluation, selection and development system

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ABSTRACT

Supplier evaluation and selection process has a critical role and significant impact on purchasing management in supply chain. It is also a complex multiple criteria decision making problem which is affected by several conflicting factors. Due to multiple criteria effects the evaluation and selection process, deciding which criteria have the most critical roles in decision making is a very important step for supplier selection, evaluation and particularly development. With this study, a hybridization of fuzzy *c*-means (FCM) and rough set theory (RST) techniques is proposed as a new solution for supplier selection, evaluation and development problem. First the vendors are clustered with FCM algorithm then the formed clusters are represented by their prototypes that are used for labeling the clusters. RST is used at the next step of modeling where we discover the primary features in other words the core evaluation criteria of the suppliers and extract the decision rules for characterizing the clusters. The obtained results show that the proposed method not only selects the best supplier(s), also clusters all of the vendors with respect to fuzzy similarity degrees, decides the most critical criteria for supplier evaluation and extracts the decision rules about data.

1. Introduction

A supply chain management (SCM) is a system consists of three key parts, which are: the supply focuses on obtaining raw materials to manufacturing, the manufacturing focuses on converting obtained raw materials into finished products and the distribution focuses on reaching these finished products to customers through distributors, warehouses and retailers. Supply chain activities begin with customer orders and end with customer satisfactions. Selection of suppliers plays a critical role in an organization because it heavily contributes to the overall performance of a supply chain system. Assessing suppliers and selecting suitable ones among them a complex and critical decision making problem due to considering several criteria such as quality, cost, service, production lead time and environmental impact [19]. Eventually firms should select the most appropriate suppliers, because significant supplier selection reduces the purchasing cost and improves corporate competitiveness however inaccurate selection of supplier may lead to problems of finance and operation.

In the literature, there are several approaches as linear weighting methods, total cost approaches, mathematical programming techniques, statistical methods and artificial intelligence approaches have been proposed for supplier selection and evaluation process, they mostly locks onto ranking the suppliers and selecting the most appropriate suppliers. However in this paper, all the vendors are clustered by similarity degrees among them so not only the most appropriate supplier is determined but also the supplier categories and the membership degrees to them are determined. With this aspect, the proposed approach makes the decision making process much more flexible. Furthermore, in the literature the majority of researches have focused on supplier selection or evaluation or development separately, but despite that, we focus on an integrated flexible and efficient decision making model for supplier selection, evaluation and development.

The proposed model can cope better with uncertainty than conventional methods because it is designed to be more like human decision making functioning by its clustering, rule induction and feature extraction modules. In the clustering module, suppliers are clustered with a fuzzy clustering algorithm – fuzzy *c* means (FCM) – to evaluate their performance and similarities degrees. For every vendor, the membership degrees to different clusters are calculated. Unlike traditional hard clustering schemes, such as *k*-means, that assign each data point to a specific cluster, the FCM algorithm employs fuzzy partitioning such that each data point belongs to a cluster to some degree specified by a membership grade [11]. If data groups are well-separated, the hard clustering approach can be a natural solution. However, if the clusters are overlapped and some of data belong partially to several clusters, then fuzzy

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clustering is a natural way to describe this situation. In this case, the membership degree of a data object to a cluster is a value from the interval [0, 1].

In terms of supplier selection, supplier can be described by large scaled attributes, which can be represented with features in the view of machine learning. Indeed the weights of these attributes considered differently while we are evaluating suppliers. So some intelligent methods should be used to determine the most critical and important supplier attributes. The feature extraction methods in machine learning are used to find which attributes are more efficient and important in a clustering or classification model. In the rule induction and feature extraction module of the proposed model, decision rules for these clusters are defined then the most efficient criteria in decision making process are discovered by a feature selection method based on RST and these criteria considered as the most important features for further supplier development process. This extraction would be also very valuable for the supplier firms. They can try to improve these attributes primarily to be preferred at the next time. A case study is conducted to illustrate the proposed system. The system can also be easily implemented with different real supplier selection problems.

Although all of these proposed supplier selection models have useful and interesting principles, none of them is an integrated long-term relationship system as our system which presents the supplier evaluation rules due to fuzzy clusters and the attributes of suppliers due to their importance degrees. Therefore, there is a space for the development of new intelligent approaches toward effective support in the evaluation of suppliers, mainly for long-term relationships, characterized by the important supplier attributes. Beyond these, the classification methods must use the previous experiences to evaluate the performance levels of the available suppliers. However, if the supplier evaluation is realized due to a hard or fuzzy clustering algorithm, the past experiences are not required any more. This point is the one of the important reasons of selecting the FCM algorithm as a machine learning technique for this study. After the clusters are formed the second important point is to represent these clusters accurately. The rough set technique is generally used as a classifier and rule extractor in the literature. But it cannot be very sufficient to extract confident rules when it is used as a classifier method. On the other hand, rough set is a very robust rule and core attribute extractor. Therefore the rough set is applied on the clusters formed by FCM which is the most efficient fuzzy clustering algorithm. Briefly, this paper contributes to the state-of-art of the supplier selection problem, presenting a new and novel approach that integrates FCM and RST to construct a long-term relationship with suppliers.

The rest of the paper is organized as follows: Section 2 surveys relevant literature. Section 3 provides brief background knowledge about FCM and RST. The proposed system and obtained results from a sample supplier selection problem are presented in Section 4. The final section discusses the findings and concludes with a summary of this study and future directions.

2. Literature review

Extensive multi-criteria decision making approaches have been proposed in the literature for supplier selection and evaluation, such as the analytic hierarchy process (AHP), analytic network process (ANP), case-based reasoning (CBR), data envelopment analysis (DEA), multi-objective programming (MOP), fuzzy set theory, genetic algorithms (GA), mathematical programming models, simple multi-attribute rating technique (SMART), artificial neural networks (ANN) and the hybrid approaches. There are also journal articles reviewing the supplier evaluation and selection models in the literature [13,18].

It is difficult to find the best way to evaluate and select suppliers, so the companies use a variety of different methods to deal with it. Therefore, the most important issue in the process of supplier selection is to develop a suitable method to select the right supplier [9]. The proposed supplier evaluation and selection methods in the literature have been classified as linear weighted models, total cost models, mathematical programming models and artificial intelligent (AI) based techniques.

In linear weighted models, every criterion is being weighted and supplier's performance is multiplied by weights of criteria. The total performance of a supplier is calculated by the sum of these multiplications. Although it is a very simple method, it depends heavily on human judgment and also the criteria weighted equally, which rarely happens in practice. So the decisions by made these models are subjective. Categorical method, weighted point model (linear weighted model) and analytical hierarchy process (AHP) model are some of these models. Total cost models are complex methods which depend to cost. They consider not only the rate of product but also indirect item cost. The subjectivity cannot be removed by these models such as cost ratio method and ownership total cost model. Mathematical models are used to represent the complex structure of supplier selection and have been widely used for modeling selection and allocation problems. In multi-attribute-decision-making methods the ratings and weight of attributes must be known precisely, but in real applications judgments of the decision makers cannot be estimated by a certain numerical value. Linear programming, integer programming, mixed integer programming, multi criteria programming and goal programming are some of these models. Also the methods such as data envelopment analysis, neural networks, fuzzy set theory, and analytic network process and quality function deployment are used for supplier selection. Except these models, hybrid models such as using linear programming and analytic hierarchy process together are existed [22].

The AI techniques can accomplish better with multi-criteria, complex and uncertain problems than conventional techniques. There are several AI approaches have been proposed for supplier evaluation and selection problem in the literature in recent years, our study is also extends them. Therefore only artificial intelligence and machine learning techniques are analyzed in this section to guide readers which techniques are used successfully and which are not yet in SCM.

Ko et al. [23] summarized the findings by a review of research papers concerning the application of soft computing techniques to SCM and concluded that genetic algorithms and fuzzy logic approach are the most popular techniques adopted to solve supply chain management problems; neural networks are broadly used to improve sales forecasting performance.

Lee and Ou-Yang [27] developed an accurate artificial neural network-based predictive model can be applied for providing negotiation supports and recommendations to demander in supplier selection negotiation process. Wu [43] have presented a hybrid model that fist applies DEA and classifies suppliers into clusters based on the resulting efficiency scores, then utilizes firm performance-related data to train decision tree and neural networks model, finally apply the trained decision tree model to new suppliers. Last they achieved admissible classification and prediction accuracy rate. Vandani et al. [40], presented a more efficient AI approach than the existing AI approaches to predict the performance rating of the suppliers in cosmetics industry. The proposed model is trained by a locally linear model tree learning algorithm and demonstrated by multi-layer perceptron (MLP) neural network, radial basis function (RBF) neural network and least square-support vector machine (LS-SVM) techniques. Moghadam et al. [32] proposed a hybrid method which uses fuzzy neural network and GA for demand rate forecasting and selects the most appropriate supplier. Kuo et al. [25], tried to develop an intelligent