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Supplier selection using a novel intuitionist fuzzy clustering approach

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ABSTRACT

Supplier selection is a complicated decision-making problem involving multicriteria, alternative and decision makers (DMs). The main purpose of this paper is to demonstrate the use of a clustering-based method to solve a group decision making (GDM) problem and, also to achieve more realistic and homogeneous results. Intuitionistic fuzzy value (IFV) is used to show the decision makers' preferences and IFN clustering method is utilized to cluster around DM's preferences. Intuitionistic fuzzy weighted geometric (IFWG) is applied to aggregate the obtained clusters. Ranking process is used based on the two indices, score function and accuracy function, to rank the alternatives. Lastly, to demonstrate the efficiency of our proposed method, it is implemented to choose suppliers in a car factory.

The strength of the propose approach is considering the group agreement on proposed DMs' preferences for giving different effect on their judgment. Besides, encountering the qualitative judgment of DMs using IFV concept with score function and the accuracy function for modeling the DMs' knowledge is the other contribution of this paper.

1. Introduction

Supplier selection is the process of choosing suppliers based on a number of criteria that are compatible with a company's conditions. SC is one of the most important tasks of supply chain management (SCM) in the competitive world, but success in SCM is the most important point for achieving growth and progress between other competitors.

Today, SCM has become the most important area for both the factory owners and researchers. The main task of SCM is selecting the best supplier to diminish product process cost, diminish the risk while improving supply chain quality, and to maintain a long period of cooperation with suppliers. Therefore, companies have to find the most suitable suppliers to achieve competitive advantages. Selecting the best supplier that can be able to cover the corporation's needs in an optimal way is very important and strategic for each corporation. Supplier selection method should be applied in a real situation in order to be able to give the optimal results, and also to be able to improve the corporation's present situation. Researchers have proposed various methods for selecting suppliers including.

Data Envelopment Analysis (DEA), which is the most commonly used model for SC. The main concept of the DEA model is based on assessing the efficiencies of preferences (alternatives). Lui et al. [1] introduced a DEA model to choose a supplier who has a greater supply diversity by evaluating three input criteria and two output criteria. The model was carried out in an agricultural and construction equipment manufacturing company. Saen [2] employed the DEA model to evaluate technology suppliers in a nuclear power station concerning two outputs (electricity capacity, the amount of know-how transfer, and one input (cost)). An enhanced imprecise DEA model proposed by Wu et al. [3] to choose a supplier and to deal with the imprecise data for distinguishing efficient suppliers from other suppliers in an aviation electronics manufacturing company with respect to two inputs (cost and judgment) and two outputs (revenue and satisfaction) criteria. However, researchers may have some problems with the application of DEA, such as dealing with the number of output and input criteria, and they may be perplexed with them. In addition, the classification of the qualitative criteria is based on the intrinsic choice. Another group that used the DEA model to select a supplier is [2,4,5].

Basically, Mathematical Programming (MP) models take into account the quantitative criteria. Talluri and Narasimhan [6] who considered the performance changeability measure in alternative supplier's assessment. Moreover, some researchers highlighted linear programming introduced an integer linear programming to choose a group of bids in respect to a company's limitations [7]. Hong et al. [8] proposed a mixed-integer linear programming model to supplier selection, based on maximizing the revenue. A goal programming model to SC presented by Karpak et al. [9] regarded cost, delivery, and quality the three targets in this model. Another publication featuring MP in supplier selection problem is [10–12].

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To choose suppliers, a web-based Analytic Hierarchy Process (AHP) method presented by Akarte et al. [13] in an automobile casting concerning 18 criteria. Muralidharan et al. [14] presented a five-step AHP model to SC regarding nine criteria in a bicycle manufacturing company. Hou and Su [15] introduced a decision support system (DSS) based on the AHP model to SC to deal with the supplier selection problem in a printer manufacturing company in regard to seven criteria. Another AHP-based model used by researchers to a supplier selection problem includes [16–18].

Sarkis and Talluri [19] applied ANP to evaluate the supplier and to choose them based on seven evaluating criteria in a high technology metal-based manufacturing company. Chen et al. [20] suggested a hierarchy model that utilized fuzzy set theory (FST) technique to deal with linguistic value. Other researchers who used FST method in SC are [21,22].

Cluster analysis (CA) is a statistical method that uses a categorization algorithm to group numerous datasets into some clusters, so they can be evaluated easily. First of all, Hinkle et al. [23] used the CA technique. Bottani and Rizzi [24] presented integrated method, including cluster analysis and the AHP method, to evaluate and rank the alternative to select the suppliers. In this study, cluster analysis was applied to diminish the number of alternative to reach the best suppliers.

Moreover, Choy and Lee [25] applied an overall model of case based reasoning (CBR) system in a consumables manufacturing company. Three groups of criteria were used to evaluating the candidate alternatives included organizational profile, technical capability, and quality system. Choy et al. [26] presented the same method that was presented by Choy and Lee [25]. This method was also implemented in the same case study with the different number of the evaluating criteria. Other scholars have used the CBR-system in the same way [27,28].

In addition to the above mentioned single methods, there are a great number of integrated methods employed to deal with a supplier selection problem. Mendoza and Ventura [29] introduced an integrated AHP and DEA method to supplier selection in a hypothetical case with respect to the four criteria, namely quality, technology, manufacturing cost, and after-sales service. This method is based on getting qualitative and quantitative information from AHP technique and uses DEA model to assess them. An integrated AHP and mixed integer non-linear programming model was presented by Mendoza and Ventura [29]. In this integrated model, AHP technique was used to pre-qualify the supplier and to reduce the number of suppliers, and the mixed integer non-linear programming model was applied to choose the optimum amount of order. Other integrated methods that were used to handle the supplier selection problem were integrated fuzzy and genetic algorithm method, integrated AHP, and goal programming model [29,30].

Besides the said methods, there are several new methods introduced by researchers to address the supplier selection problem such as the following.

Deshang Dash et al. [31] proposed a fuzzy multi objective programming (FMOP) model regarding risk factors to deal with a supplier selection process. They utilized a possibility approach to solve the FMOP model based on three levels by using the simulated historical quantitative and qualitative criteria. Boran et al. [32] proposed a three-step multicriteria model for evaluating environmental performance of suppliers, and rank the suppliers through fuzzy TOPSIS method. As well as, Awasthi et al. [33] proposed the combination of TOPSIS method with the intuitionistic fuzzy set for choosing the right supplier in a group decision making procedure. They consider the IFWA for aggregating the individual opinions of DMs. Even so, in this method, the group agreement for ranking the suppliers is not measured. It means they consider the preferences of each DM equal to the other DMs while the agreement of groups on the same preferences is not considered; thus, it is important to pay more attention for the preferences that is proposed with more than one DM for each alternative with respect to each criterion. In view of this fact, the proposed preferences of the DMs should be giving effect for ranking with different weight according to the group agreement or non-agreement on the proposed preferences.

The literature review demonstrates that the majority of researchers concentrated on vendor selection methods using probability distributions and in the best state, applying linguistic value by using fuzzy logic. They are also unable to handle real situations. So far, little investigation has been carried out on intuitionistic fuzzy supplier selection. IFS concept allows decision makers to assign the membership and non-membership degree to each alternative, based on the discrete criteria for their preferences. Moreover, it enables them to determine the existing uncertainty (hesitation) degree in each preference (attitude), whereas none of the mentioned methods can tackle the same approach.

The main factor in each group decision making is the preferences determined by DMs for alternatives concerning each criterion. The impressive method that uniforms the DMs' preferences is to decrease the impact of the outlier and irrelevant decisions in the decision-making process. Obviously, with increasing the number of criteria, eliminating the outlier decisions would be more difficult, and impossible in some situations. Therefore, we use the intuitionist fuzzy clustering method in this paper for encountering such a problem. In this paper, a new group decision-making method is presented, in which the impact of DMs' preference is based on all the DMs' preference density. On view of this fact, the frequency of the similar preferences for each alternative regarding to each criterion signified by each DM increase the weight of them in the aggregation process. Thus, the novelty of this paper is considering the group wisdom in the group decision-making process using intuitionist fuzzy clustering for weighting the preferences while the last researches did not pay attention to this in their proposed decision-making process. Moreover, the IFWG operator is used for integrating the DMs' preferences, and finally the score function and the accuracy function is used for ranking the alternatives.

The main purpose of this paper is to present a suitable method by using IFV, given preferences based on the vital criteria for each alternative by DMs, and IFS clustering technique to solve the supplier selection problem in an optimum way. It also aims at combining these techniques to achieve a new and applicable method to choose a supplier. Applying IFS in GDM process can express more compatibly the experts' preferences (attitudes) with the real situations. In addition, clustering technique can find the similar data set (similar preferences in GDM). This study attempts to present a high accuracy level method that will be more compatible with the real world, and also to be able to give optimal results in comparison with other proposed methods.

The rest of this paper is organized as follows: Section 2 deals with the explanation of the methodology, evaluating the criteria, and the concept of fuzzy, IFS and clustering for IFS. Proposed method is presented in Section 3, and the implementation of the method as a case study is presented in Section 4. Section 5 is the last section for concluding the results of paper.

2. Methodology

Most of the supplier selection methods use probability distributions and in the best state, apply linguistic value by using fuzzy logic. They also use historical data to deal with the supply chain problem, and they are unable to handle real situations. Proposed methods in this paper are constructed based on using the IFS concept and the IFS clustering technique to deal with SC problems. Due to the majority of DMs in the real world, they tend to usually