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A hybrid group decision support system for supplier selection using analytic hierarchy process, fuzzy set theory and neural network

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ABSTRACT

Within procurement literature; many studies focus on providing decision support to the supplier selection problem. However, studies on group decision support are yet to be explored extensively within supplier selection literature, despite its benefits. This study presents the application of a hybrid approach for group decision support for the supplier selection problem. fuzzy set theory, analytic hierarchy process and neural networks have been integrated to provide group decision support under consensus achievement. Discriminant analysis has been used for the purpose of supplier base rationalization, through which suppliers have been mapped to highly suitable and less suitable supplier classes. The proposed integrated approach has been further studied through two case studies and the proposed approach has been compared with another approach for group decision making under consensus and other approaches for prioritization using AHP, without consensus achievement. A very high accuracy in capturing the collective consensual preferences of the group was established across eight cross-validation tests from the two case studies, for the hybrid approach, even with extremely limited count of data sets which were used for training the hybrid model.

1. Introduction

An extremely important activity in supply chain management is procurement management, since it is the primary point of contact with the supply chain partners [15,50,51]. As elaborated later in the detailed review of literature, within the domain of procurement, supplier selection is one of the highly researched problems due to the high degree of complexity and criticality of the domain. For a specific purchasing decision making context, there would be divergent vendor evaluation criteria. For example, buyers would want suppliers to quote lower prices, and yet deliver higher quality. The presence of multiple such divergent and multi-dimensional criteria makes the supplier selection problem very complex. Added to the complexity is the fact that complex decision making in organizational contexts are addressed by groups of experts. Each decision maker would typically be having a different prioritization on the evaluation criteria. Further the presence of both explicit and implicit evaluation criteria and information among a group of decision makers makes the supplier evaluation problem extremely complex. Although a wide variety of decision support theories has been used in the domain of supplier selection, there has been lesser exploration of decision support theories on group decision making has been explored in the supplier selection domain. For complex decision making problems, collective intelligence of a group of decision makers in consensus often is more effective than the same decision makers working in isolation [47,53,67]. In fact, group decision making under consensus has greater reliability, consistency and regularity than decision makers working in isolation for even the same prioritization problem [9,25,45]. Since systematic approaches to provide group decision support for the supplier selection problem is yet to be explored extensively, there is a need to enrich *group decision support literature in supplier selection*. In this study, the application of an hybrid method consisting of fuzzy analytic hierarchy process (AHP) for group decision making and neural networks (NN) to highlighted, to provide group decision support to the supplier selection problem, whereby the suppliers are mapped to highly suitable and less suitable suppliers using discriminant analysis theories for pattern classification. Two case studies have been conducted on a multi-national enterprise and on a medium sized firm and the outcome of the proposed method has also been compared to an existing approach of group decision making, which has been applied in the domain.

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2. Review of literature

2.1. Supplier selection

Supplier selection is a classic area of supply chain literature and studies date back to as early as the early 1960s. The supplier selection problem has been explored extensively in decision support literature. Different methods have been used in the domain like interpretive structural modeling [3]; weighted sum of products [17]; TOPSIS [35], mathematical programming [4,72]; neural networks [21,41,61]; agent based theories [50], rough set theory [66], clustering algorithms [60], genetic algorithms [41], quality function deployment [2] and inference systems [1] to name a few of the more prominent approaches. Further, there were two studies which have used hybrid approaches which combined methods like AHP and neural networks [11,65] but the focus was restricted to providing decision support from a *single decision maker's perspective* while prioritizing evaluation criteria and estimating trade-offs. In fact, after reviewing the existing supplier selection literature, it was found that very few studies have used group decision support theories for providing decision support to this problem despite the benefits of *group decision making under consensus* over *individual decision making*, for complex multi-criteria decision making problems like improved effectiveness, reliability, consistency and regularity like supplier selection [9,23,25,47].

Studies on group decision support have used approaches like AHP [16,31,62,68], mathematical programming [6,11], TOPSIS [27] and VIKOR [5]. The studies using AHP [16,62] focused on group decision making using the eigen vector method (EVM) for the prioritization of judgments of the group of experts. Similarly, although few studies [31,71] have used the geometric mean method (GMM) for prioritization but the *development of consensus* within the group was not explored. However, it is important to note that although consensus achievement is such an important criterion of success for group decision making [25,26,33], consensus achievement was not explored extensively earlier, which may be due to the recent development of some of these theories. The current study integrates fuzzy AHP with fuzzy NN and thus provides group decision support under consensus, which allows the exploitation of the diverse expertise of a group of experts for solving the complex problem.

AHP is one of the more widely used methods for decision support in supplier selection literature. The earlier studies on supplier selection [e.g. 56, 15, 39] used the crisp AHP approach. However the more recent studies [e.g. 63, 14, 48, 71, 18, 9, 12, 69] have integrated AHP with fuzzy set theory to accommodate subjectivity in the human decision making process, especially while prioritizing amongst options in complex multi-criteria decision making problems. Inclusion of fuzzy set theory [36–38] in the decision support model accommodates the subjectivity in the decision making process arising out of high complexity of problem definition and divergence of the different objectives and goals. Similarly, NN has also been used by quite a few studies in supplier selection literature. These studies [20,22,54,55,60] have used the NN theories for estimating the relative importance of the supplier evaluation criteria in a systematic iterative approach in isolation and also by integrating with other decision support theories. However, there was no attempt to leverage upon the collective intelligence of a group of experts and thus provide group decision support using NN.

In this study, we highlight the application of the fuzzy AHP integrated with the fuzzy NN for providing *group decision support* to the supplier selection problem. While AHP and NN have been integrated earlier to provide decision support for the supplier selection problem [11,65], there was no attempt on providing group decision support in these studies. Also, the prioritization was achieved using the eigen vector method (EVM) while using AHP. In the current study, the geometric mean method (GMM) within AHP has been used for achieving prioritization and aggregation of the supplier evaluation criteria in the first step. Subsequently, NN has been used for the mapping of supplier performances (vector) to two distinct sets, i.e. namely that of the high quality suppliers and the low quality suppliers.

2.2. Fuzzy set theory

Fuzzy set theory [36–38] has been extensively used in decision support literature to accommodate the subjectivity in complex decision making process. It has especially found wide application in the supplier selection problem [7,19,46,51]. In fact, fuzzy set theory has found even more extensive application in integrated approaches with many other decision support approaches like VIKOR [5], AHP [12,14,18,48,63,71], TOPSIS [27,35], NN [11] in the supplier selection problem. In this study, fuzzy set theory has been integrated with both AHP and NN for providing group decision support for the supplier selection problem. The inclusion of multiple evaluation criteria in the selection process induces a lot of subjectivity in the problem due to the high levels of complexity. Inclusion of fuzzy set theory accommodates the subjectivity in the decision making process arising out of high complexity of problem definition, subjectivity in the prioritization of the evaluation criteria and the condition for the selection of a supplier.

2.3. Analytic hierarchy process

The AHP [64] is a theory of measurement used to derive ratio scales from discrete and continuous paired comparisons in hierarchic problems taken from a scale reflecting the relative strength of preferences. The AHP decomposes the problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently through pairwise prioritization. AHP has been used in this study for estimating the collective preferences of a group of decision makers in consensus since it has been enriched with a plethora of literature for group decision making, although the applicability of the same is yet to be explored extensively for supplier selection. AHP has appropriate measures for estimating consistency of priorities of expert decision makers [30,33,42,68] and then subsequently improve the consistency of these priorities [20,34,73]. Also AHP provides extensive theories for the aggregation of group preferences [23,24,43,44,53] and subsequently to build consensus systematically using these aggregated preferences [33,42,45,52,70]. Thus AHP is extremely suitable for group decision support and has thus been adopted for this study.

There are many methods of prioritization within AHP like GMM, EVM, least square method, sum method, new least square method, minimax method and absolute deviation method [30,59,68]. GMM is preferred to some of the other methods in *group decision making* due to few reasons [9,30,44,69]. Combining judgments from expert decision makers using GMM accommodates extreme estimates or preferences suitably. The aggregation of individual hierarchies using GMM provides a better preservation of both expert preferences as well as reciprocal properties. Further the computational time complexity of GMM is $o(n)$ which is lower than that of the others (i.e. $o(n^2)$). This means that GMM has lower computational complexity while estimating the priority from judgments. Thus the number of computations and the time taken decrease significantly while attempting to achieve consensus through multiple iterations. Thus GMM has been used in this study to estimate collective preferences of a group of experts in consensus. These methods of AHP for group decision making have been further extended, by incorporating fuzzy set theory to accommodate the subjectivity in human decision making process for complex prioritization problems.