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An integrated fuzzy multiple criteria supplier selection approach and its application in a welding company

Sobhan Sarkar[a], Dilip Kumar Pratihar[b,*], Bijan Sarkar[c]

[a] Research Scholar, Department of Industrial and Systems Engineering, India
[b] Department of Mechanical Engineering, Indian Institute of Technology Kharagpur, Kharagpur 721 302, India
[c] Department of Production Engineering, Jadavpur University, Kolkata 700 032, India

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ABSTRACT

Supplier selection is a strategic decision-making task for any company, as it engages multiple criteria for the evaluation and selection of alternate suppliers. So, multi-criteria decision making (MCDM) is a necessary approach in this domain. When both the qualitative and quantitative criteria are available and required to be evaluated simultaneously in decision making process for the supplier selection, a proper integrated approach is necessary to be adopted in order to select the best supplier and to find out the interrelationship structure within criteria. To address these issues, this paper proposes a unique integrated multi-attribute decision making (MADM) and mathematical programming (MP)-based model in a mixed environment (i.e., considering qualitative and quantitative criteria together) by combining decision making trial and evaluation laboratory (DEMATEL)-based on analytic network process (ANP), i.e., DANP, fuzzy technique for order of preference by similarity to ideal solution, i.e., FTOPSIS and multiple segment goal programming (MSGP). Network relationship map (NRM) is used to outline the interrelationships among the dimensions and criteria. The novelty of the proposed supplier selection approach lies with the fact that both the qualitative and quantitative criteria have been considered in it. Sensitivity analysis has also been carried out to validate the result of our proposed methodology. In addition, the result of our proposed method is supported by DANP-based fuzzy VIseKriterijumska Optimizacija I Kompromisno Resenje (FVIKOR) technique and the best supplier has been identified. Delivery schedule and environmental collaboration are revealed to be the most and least important dimensions, respectively.

1. Introduction

Now-a-days, enterprises have been experiencing a huge competition in their supply chain. To remain competitive in the market, manufacturing organization should primarily focus on decreasing production costs and manufacturing cycle time. Under these circumstances, organizations need to outsource their many components of the product to various suppliers, whose performances decide the degree of success of supply chain of the organization, and enable the management to achieve the products of higher quality at a reduced cost with the satisfaction of downstream customer. To achieve these goals, selection of suppliers has become a critical aspect and a key strategic issue [1] of any organization. However, the main objectives of this selection include the reduction of purchase risk, value addition to the purchasers, and establishment of the proximity and long-term relationships between the purchasers and suppliers [2]. Supplier selection is operationally a pure decision-making process under certain conditions that helps the decision makers to select the potential suppliers among many [3]. Thus, decision is usually taken based on many qualitative and quantitative criteria related to the suppliers that ultimately make it a multi-criteria decision making (MCDM) process. The decision making, however, involves a high level of imprecision, vagueness or fuzziness in its process itself. However, to measure this fuzziness, traditional approaches are found to be ineffective. Therefore, there is a need for robust analytical methods and decision support tools, which could offer a fine trade-off among multiple criteria [4]. To tackle this situation effectively, fuzzy set theory has been widely used in supplier selection process [5], as it enables us to model the whole MCDM process using imprecise

* Corresponding author.
E-mail address: dkpra@mech.iitkgp.ernet.in (D.K. Pratihar).

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information of decision makers (DMs). Basically, this MCDM process consists of two categories: (i) multi-attribute decision making (MADM), and (ii) multi-objective decision making (MODM). MADM processes include various methods like technique for order of preference by similarity to ideal solution (TOPSIS), analytic network process (ANP), multi-attribute utility theory (MAUT), outranking methods, and others, which limit the number of alternatives, whereas MODM can determine the solutions for both single and multiple objectives subjected to specific constraints. It includes linear programming (LP), goal programming (GP), data envelopment analysis (DEA) etc. Therefore, when both the qualitative and quantitative data are available for the purpose of evaluation of suppliers, an integration of these MADM and MODM methods is required for better assessment of the performance of the suppliers in this mixed environment. Therefore, the aim of this study is set to propose a new integrated method combining decision making trial and evaluation laboratory (DEMATEL), ANP, fuzzy TOPSIS (FTOPSIS), and multi-segment goal programming (MSGP) in supplier selection problem under the fuzzy environment and identification of interrelationships among criteria and dimensions.

The remainder of the paper is organized as follows: Section 2 presents a brief review on existing literature of the supplier selection. Section 3 outlines the approaches, namely DEMATEL, ANP, FTOPSIS, Fuzzy VIKOR and MSGP. A case study addressed in this study has been demonstrated in Section 4. Results are stated and discussed in Section 5. Finally, in Section 6, conclusions are drawn and the scopes for future study have been suggested.

2. Review of literature

The research on supplier selection in supply chain management (SCM) has been getting matured since 1960s. A large number of approaches had been used by many researchers, academicians, practitioners and others. These approaches can be grouped into four categories [6] as follows: (i) MADM; (ii) mathematical programming (MP); (iii) artificial intelligence (AI); and (iv) hybrid approaches.

2.1. MADM approaches

Among many other MADM techniques, analytic hierarchy process (AHP) and ANP are the most popular ones to deal with the multiple criteria, which involve qualitative aspects [7,8]. These two methods are used to evaluate the criteria weights using pairwise comparison matrix and experts' judgments. They are much popular for effectively treating qualitative factors than other models. AHP can only be employed in hierarchical decision cases. However, in most of the real-world problems of decision making, there hardly exists hierarchical structure. Instead, a network structure of interdependency is mostly adopted in those cases. To deal with this situation, ANP, which is a generalization of AHP, is used considering dependencies between the elements in hierarchy. Usually, it is observed that ANP is used very often in combination with other methods like DEMATEL [9,10], TOPSIS [11] etc. However, some of the previous studies took an assumption that each cluster in ANP structure has equal weight to obtain weighted super matrix [10,12]. Moreover, a combination of DEMATEL and ANP (i.e., DANP) was used to evaluate the weights of criteria utilizing network relationship map (NRM) [7]. Other MADM techniques used in supplier selection literature include Elimination Et Choix Tradusant La Réalite (ELECTRE) [13,14], preference ranking organization method for enrichment evaluations (PROMETHEE) [15,16], TOPSIS [17], VIKOR [18], simple multi-attribute rating technique (SMART) [19], grey relational analysis (GRA) [20] etc. The fuzzy MCDM application in supplier selection domain had attained the interest of many researchers. Some of them include fuzzy TOPSIS [1,21], fuzzy VIKOR [22,23], fuzzy PROMETHEE [24], fuzzy DEMATEL [25,26], fuzzy AHP [27], fuzzy ANP [28,29], and so forth. However, those approaches could not handle the combined qualitative and quantitative criteria for the supplier selection tasks.

2.2. MP approaches

In mathematical programming models used in supplier selection problem, data envelopment analysis (DEA) is the popular one [30,31]. Other than DEA models, single objective mathematical programming, like linear programming, non-linear programming, mixed integer programming were used, where, in most of the cases, cost was set as only one objective function and other criteria were considered as the constraints [32]. On the other hand, some researchers used multi-objective mathematical programming to solve the supplier selection problem. For instance, Yeh & Chuang used multi-objectives Genetic Algorithms (GA) to obtain the Pareto front of solutions, while dealing with four objectives simultaneously, namely quality, green score, time and cost [33]. Fuzzy multi-objective linear programming model was used by Shaw et al. for supplier selection [34]. Kannan et al. utilized fuzzy MCDM and multi-objective programming for order allocation and green supplier selection [35]. Genetic programming (GP), a powerful multi-objective MP model, had been used by many researchers in this problem. Among those studies, Karpak et al. used GP to allocate purchase orders by minimizing the product costs and maximizing the quality of product and reliability of delivery [36]. Kumar et al. used fuzzy GP in their study for selecting the suppliers [37]. Tsai & Hung implemented fuzzy GP for the selection of green suppliers by considering the cost and performance evaluation in the associated supply chain structure [38]. Later on, in order to handle the vagueness of goals and constraints, fuzzy multi-objective linear model was used by allowing the DMs to select different weight values on various objectives [37,39]. In line with this, fuzzy multiple GP model was also found to be useful for downstream supplier selection problems [40].

Moreover, this GP model could enable the DMs to fix their levels of aspiration for each of the goals with an objective to reduce the deviation between the achievement of the goals and their corresponding aspiration levels. In 2007, Chang declared that DMs sometimes take decisions on the problems with the goal that can be achieved from some particular aspiration levels [41]. Here, the application of multi-choice GP (MCGP) became useful. Recently, Karimi & Attarpour proposed a multi-aspiration GP (MAGP) model, which could combine both MCGP and multi-segment GP (MSGP) [42]. The concept of using MSGP in supplier selection paradigm was the multi-objective planning. In that case, the objectives of the DMs were so diverse that they could not be merged into a single goal. But, DMs attempted to achieve the acceptable solution to the problem of a multi-segment aspiration level, where they were interested to minimize the deviation between the achievement of the goal and the aspiration levels of the variable co-efficients of decision.

2.3. Artificial intelligence (AI) approaches

In the supplier selection literature, AI techniques had also been used rapidly. Basically, AI is the study of intelligent agents, which perceives its surroundings and accordingly take actions that can maximize its chances of success [43]. For examples, artificial neural network (ANN), GA, data mining approaches, grey system theory were used for supplier selection [44–46]. Choy et al. used ANN model to select potential partners in a consumer