Supplier Selection Using Fuzzy MCDM Techniques: A Literature Review

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Abstract—Supplier selection for an organization is a strategic decision which follows the practice of contemporary supply chain management of evaluating the potential supplier’s by taking into consideration multiple criteria’s for supplier evaluation. Finalizing a supplier for an organization is a complex issue and lots of uncertainties are involved with a compulsion to choose the best supplier among the provided alternatives. Fuzzy multi criteria decision making techniques will come in handy to deal with the qualms challenged, which eventually leads in picking up the best supplier for the elementary functioning of the organization. This article presents a comprehensive bibliographic study about the supplier selection using fuzzy logic through numerous approaches. Thus it gives a clear view on how the supplier selections are carried out by using various fuzzy and hybrid fuzzy algorithm in various sectors. This review indicates that the FTOPSIS approach is used by many researchers for their supplier section model.

Keywords—supplier selection; multi-criteria decision making; fuzzy logic; literature review.

I. INTRODUCTION

Procurement is the process of acquiring required parts, goods for any manufacturing organization to begin its production effectively through tendering or bidding practice. Lot of money is involved in the act of procurement. The demand from large scale manufacturing companies for its production is at a vast scale considering its enormous customer base. There are primarily two costs that every manufacturing firm would attempt to curb upon. These are production cost and raw materials cost. Companies have an uncompromising problem of alleviating both these costs to the foremost extent. Suppliers are the only source for the manufacturing firms for obtaining raw materials. This is when purchase department comes into handy for any firm.

Supply chain management’s most important strategic decision lies in the hands of the purchasing department, which procures the right quantity of materials at the right time, especially from the right suppliers. The suppliers are categorized by the organization on the basis of lucrativeness, throughput, and success in achieving their metrics within the postulated time. Purchase department do have an obligatory responsibility of maintaining a prolific rapport between the buyer and the vendor. The demand for the production to commence in most of the cases cannot be met by a single supplier considering the larger operational demands.

Selection of suppliers is indeed a multi criteria decision making process which comprises diverse opinions, and is confronted by various alternatives for the final outcome. Both qualitative and quantitative criteria’s defy the process of supplier selection. Lot of inputs are to be taken into contemplation to reach an effective result. Vagueness or uncertainty gets associated with the inputs that are being considered for the selection process. A Technique like fuzzy MCDM is considered one of the best ways and means to think through for alluding multiple criteria’s for decision making and handles imprecision’s. Fuzzy MCDM provides strong decision making in realms where selection of alternatives is highly multifaceted. This paper makes use of fuzzy MCDM for evaluation of suppliers based on diverse criteria.

II. INDIVIDUAL APPROACHES

A. Fuzzy TOPSIS and TOPSIS

Singh [1] analyses how to maximize the total purchase value of the product using TOPSIS algorithm. In cases where a single supplier is not able to meet out the demand for the buyer, a pool of suppliers can meet the demand. Four suppliers with four constraints namely, quality, price, time delivery, consistency are considered. A hybrid algorithm consisting of fuzzy set theory, TOPSIS and MILP is used to allocate demand to the suppliers. The ratings of the suppliers are given by TOPSIS method. In fuzzy multi criteria decision making, weights assigned to every criteria is a fuzzy number and fuzzy numbers characterizes the score of suppliers with respect to criteria. Fuzzy numbers are allocated not just to the suppliers, but to the criteria itself. They found that the Hybrid approach is more effective than the individual approach. Roshandel et al.[2] evaluated four suppliers for importing tripolyphosphate, based on twenty five criteria's using Hierarchical TOPSIS
method. Companies face a stern problem of reducing the production cost as cost of raw materials forms 70% of the final price of the product. Since the criteria's for supplier selection is from a multi-dimensional angle, they used fuzzy TOPSIS method as hierarchical for concise results. Their objective is to pick up the right supplier to decrease the purchase cost by looking into key performance indicators like quality, price, flexibility, due date. Jun-Rao et al.[3] proposed a model for coal procurement from multiple sources. They considered the attributes like price, quality, quantity, delivery, reputation of the supplier. The selection process is done by hybrid multi attribute decision making method. TOPSIS is used to rank all suppliers and select the best one among the lot. The values for the attributes considered in the process are given by the buyer. Since this is a complicated process, assigning values to the attributes vary according to the specifics of the attribute are considered as follows: (i). Real numbers is used for price, quantity, quality, (ii). Interval number is used for delivery time, and (iii). Fuzzy number is used for Supplier’s reputation. Tso-Lin and Chang [4], applied mixed integer programming (MIP) and used triangular fuzzy number to evaluate buyers. They used fixed quantity MIP model and flexible quantity MIP model to find the orders produced exceeding the production capacity and the price reduction as well. Nearness coefficient using TOPSIS model is considered for ranking the buyers and adjusting the price of the orders.

B. Fuzzy ART and Neural networks

Keskın et al.[5] applied fuzzy ART neural networks algorithm for supplier evaluation. This can be applied to all the sectors however huge the data is. Organizations give more importance to the process of supplier selection to minimise the purchasing cost and to develop a fruitful relationship between the buyer and the vendor. In accordance to that, organisations categorize suppliers based on profitability, productivity, and success in achieving targets within the stipulated time. In their model the vendors are categorized by similarities between them and are clustered all of them through a matching function unlike a conventional method which ranks every supplier and picks one among them.

C. Analytic Network Process (ANP) with Fuzzy TOPSIS

Onut et al.[6] applied ANP and TOPSIS approach for supplier evaluation in the telecommunication sector. TOPSIS method is used to select alternative and fuzzy ANP is used to calculate criteria weight. The criteria used in that model include cost, reference, quality of the product, delivery time, institutionally and the execution time.

D. Fuzzy decision support system

Garcia et al. [7] proposed a new supplier evaluation and selection model for commodity procurement using fuzzy decision support system (FDSS). The model can overcome the shortcomings of the simplistic method in terms of assigning weights. Two steps involved in the purchasing process, viz. Supplier evaluation and Bid Analysis. “FDSS” is used to improve the performance of the model by using the necessary knowledge involved in the process of assigning purchase of basic products. Knowledge inclusion makes it more intuitive and robust for evaluation and selection process. The results obtained by the process of FDSS show a better match than those obtained from the method of weights.

E. Fuzzy Analytic Hierarchy Process

Rezaei et al.[8] proposed two phase supplier section process for airline industry. The first phase reduces the initial set of potential suppliers prior to the final choice. The next phase FAHP method, evaluates the suppliers against criteria viz. cost, product quality, delivery, financial stability, corporate social responsibility and assortment. Kilinci and Onal [9] applied fuzzy extended AHP using triangular fuzzy numbers for supplier selection on Washing Machine Company. Raw materials and component purchase accounts for almost 70% of the main cost of a product in many manufacturing firms and it has made firms to focus more on the supplier selection process to be cost efficient. They select suppliers, who can increase its capacity as per the fluctuations in demand. Chamodrakas et al. [10] developed a two stage model for supplier selection for execution of electronic market In the First stage the large numbers of potential suppliers are screened initially with hard constraints being enforced on them. The next stage has appropriate supplies being selected through fuzzy preference programming and fuzzy AHP is used to Rank the suppliers. Chan and Kumar [11] used Fuzzy extended AHP for supplier selection globally. Supplier selection globally is more complex than selection of domestic suppliers as it involves more of qualitative and quantitative factors. Suppliers are manufacturer's external organizations. Their performance will decide the whole future of the supply chain. That makes the effective method of global supplier selection, the need of the hour in the current business scenario.

F. Fuzzy Multi-Objective linear model

Amid et al.[12] developed a multi objective model using fuzzy goals and fuzzy constraints. They formulated three objective functions namely net price, quality, services to minimise total monetary cost, maximise total quality.

G. Fuzzy Ranking approach

Hsu et al.[13] proposed a technique to select supplier based on the quality of the parts that they deliver to their customers. In this regard, the fuzzy method is used. Resolution identity method is used to construct the membership function for each supplier. The ranking method for all the fuzzy numbers are done on the basis of four criteria that are fuzzy preference, fuzzy ordering, distinguishing ability, and robustness. Their results indicate that the model has the capability to be flexible and deal with fuzzy data to choose with supplier.

H. Fuzzy multiple objective programming

Woo and Saghiri [14] proposed a model considering the main aspects of order assignment namely purchasing, holding
and ordering by considering three main parties in the supply chain namely the purchasing organisation, suppliers, and third party logistics providers using fuzzy multiple objective programming model. The main advantage of this method is that the purchasing department can select the right supplier, assign the right quantity to each supplier and manage the third party logistics cost as well. This allows the decision makers to assign their restricted resources to the best activities.

I. Fuzzy data envelopment analysis

Mirhedayatian et al. [15] applied FDEA and TOPSIS approach for selection of welding process.

J. Fuzzy DEMATEL

Chang et al.[16] applied fuzzy DEMATEL approach for revealing relationship between various factors that influence each other in the process of supplier selection. Businesses generally pay close attention to quality, product price, and delivery performance when selecting suppliers.

K. Fuzzy QFD and AHP

Soroor et al. [17] developed a smart module for supplier selection using Fuzzy logic, AHP, and QFD. The vendor management team interacts with the supply chain system to inquire about the best supplier selection. Once the bids are ready, the suppliers will be evaluated and selected. The evaluation is done mainly on the basis of customer order and coordination of supply. Yet again the greatest advantage of this model is that, both precise and complicated algorithms will perform their operations automatically. There are various types of fuzzy numbers involved in this. For instance the linguistic terms in QFD are represented by triangular fuzzy number. AHP is used to deal with unstructured complex decisions. This model also automatically performs all calculations for AHP including constructing pairwise comparisons with respect to each attribute, calculating priority weights for each alternative, and so on.

L. Fuzzy Multiple Goal Programming

Lee et al.[18] used fuzzy multi objective goal programming for film transistor LCD suppliers selection. Fuzzy AHP is used right at the start for analysing the factors influenced by expert’s opinion. Multi choice goal programming considers the constraints of various resources. This method can allocate purchase among the selected suppliers. Selecting the right suppliers which can maintain a continuous supply relationship requires a careful assessment as suppliers have varied strengths and weakness.

M. Fuzzy Grey Relational Analysis

Wu [19] developed an integrated method of FGRA and Dempster Shafer rule for international supplier selection. Experts’ opinion can be represented by fuzzy numbers and starts off with GRA. This is followed by Dempster Shafer rule to aggregate individual preferences into collective preferences for ranking the suppliers. Golmohammadi and Parast [20] applied FGRA for two phase supplier selection process. The first phase of the process enhances the weight assessment efficiency. In the first phase, some limitations in the grey methodology are resolved by fuzzy pairwise comparison. This also proposes a method to improve the results of the first phase. They analyzed a real case of consisting six suppliers and results outcome is compared with the manager’s rankings.

N. Neural network and Adaptive Neuro Fuzzy Interface System

Ozkan and Inal [21] developed a model for supplier evaluation and selection using adaptive neuro fuzzy interface system (ANFIS). ANFIS method analyses the thinking and judgment process of the decision maker with the neural network applications to predict the scores of various alternative suppliers. This method replaces neural networks for precise results. Each layer in ANFIS model is a fuzzy layer. The vendor’s attributes (quality, price, technology, location) are taken as input for analyses and the supplier score, which is calculated by the decision makers, is considered to be the output. ANFIS method proposes a better alternative to monitor the performance of suppliers with ease, reducing the burdensome effort.

O. Genetic Algorithm with Fuzzy Logic

Wang (2014) developed a model using fuzzy theory and genetic algorithm to appraise suppliers for parts replacement and also to change the configuration of the product. Fuzzy theory is used to quantify various parameters considered and genetic algorithm is used to find the optimal combination of nearest suppliers. Patra and Modal (2015) applied multi-objective genetic algorithm for supplier selection. The selection has been done by maximizing the profit and minimizing the risk, with respect to profit and risk function. The two objective functions that are considered are profit and risk and two different methods namely, credibility measure and alpha cut method have been introduced to defuzzify the fuzzy objectives.

P. Fuzzy Process Accuracy Index

Kaya and Kahraman [24] used process capability index as a tool for the process of supplier selection. Process capability index focuses on the distance between the process mean and target value. This index alerts the buyer when the process departures from the set target value. The supplier preferences are given by triangular fuzzy numbers using linguistic variables. Process accuracy index measures the magnitude of process variation. A ranking method is used to compare the suppliers using the process accuracy index.

Q. Hybrid Fuzzy Logic Approach

Aksoy et al. [25] developed a mathematical programming for supplier selection. The capacity of the supplier is deterministic and the demand is stochastic. Since the demand is stochastic, penalty cost is incurred. They proposed an
Adaptive neuro fuzzy interface system to calculate the penalty cost. This model helps buyers to select suppliers strategically more effectively when working with uncertain parameters. Shen and Yu [26] proposed an approach of efficacy evaluation for suppliers, which includes both operational metrics and strategic factors. Quality of a product is estimated by the process capability index, whereas, the business process improvement is used for assessing the supplier. Supplier's efficacy for the new product based on the organization's need is evaluated using the proposed strategies and are rated. A fuzzy approach is used to integrate the individual scores of the suppliers. In order to stabilize the selected supplier for the new product, an empirical case study was conducted to find out the best among the selected suppliers, the results of which would have managerial implications. The study helps firms in finding the strategic oriented supply chain partner for the initial stage of new product development.

R. Semi-fuzzy support vector domain description

Guo et al.[27] used a semi fuzzy support vector for the process of supplier selection. Support vector machines, one of the works proposed, is a machine learning method for supplier selection. The model can handle multiple classification problems in supplier selection and developed with support vector domain description being deployed in it. The extracted rules provide explanations to the classified results.

S. Literature Review papers

Ho et al. [28] attempted to review 78 journal articles from 2000 to 2008, to solve the supplier selection using multi criteria decision making approach. They found DEA to be the approach that most of the firms would prefer. Decision making on suppliers has always been on a strategic perspective, taking into considerations multiple criteria's of evaluation process. Firms study each supplier and its operations extensively to reach to a decision.

T. Fuzzy Analytical Hierarchical Process and Fuzzy Goal Programming

Kar [29] applied FAHP and fuzzy goal programming approach for supplier selection. Opinions of group of experts have been put to a consensual preference, which is integrated with fuzzy goal programming. This leads to two stages of classifying the suppliers, viz. highly capable suppliers, less capable suppliers. Consensus development was explored using FAHP for prioritizing suppliers.

U. Fuzzy Linear Programming

Amin et al.[30] used fuzzy logic and triangular fuzzy are integrated with SWOT analysis for the process of supplier selection. SWOT analysis enables managers to understand the position of suppliers for a competitive edge by considering both qualitative and quantitative criteria's. The number of parts to be obtained from each supplier is determined by fuzzy linear programming method.

V. Interval type-2 fuzzy sets

Heidarzade et al.[31] used clustering method, based on new distance for the process of supplier selection. The decision maker’s preferences are considered using fuzzy type-2 values. They used cluster analysis, which is a statistical method for grouping the databases into clusters for manipulation. Two types of clustering are used, viz. partitioned and hierarchical. The method primarily involves finding the proximity of the suppliers and it can determine the proximity of their suppliers on either of far or close.

W. AHP with D numbers

Deng et al.[32] developed integrated AHP and D-numbers for supplier selection. The concept of D-numbers is more effective in representing uncertain information. AHP method is extended using the D-numbers for decision making under uncertainty of data.

X. Fuzzy TOPSIS and multi choice goal programming

Rouyendegh and Saputro [33] used fuzzy TOPSIS and multi choice goal programming for supplier selection. FTOPSIS is expressed by fuzzy triangular number, considering the uncertainties in the decision making process. A multi choice goal programming closeness coefficient which gives a number closer towards the supplier relative distance, is considered for final selection process. They intend to adopt the hybrid method using FTOPSIS with triangular number and multi choice goal programming for selection and order allocation.

Y. Other approaches

Chai and Ngai [34] developed a mechanism for the complex strategic supplier selection process through fuzzy methodology. The suppliers chosen are in terms of established company strategies. The strategic factors arise from strategic criteria, which are supplier's long term and process oriented management system. The model elicits human preference, including preference representation and preference modelling. The rankings are based on structural pair-wise comparisons constructed from various experts’ opinion and preferences. Lopez [35] proposed added value strategy which combines both transaction and resource based theory for strategic supplier selection process. A self-organizing feature map (SOFM) is developed to get a view on the relative position of the sellers. Suppliers are selected based on self-organizing feature map method, which accounts for both direct and indirect variables. This paper analyses 84-value added attributes according to their relative importance. Attributes and preferences in the form of linguistic information is consolidated using 2-type fuzzy method for signifying the capabilities of the supplier in an improved way. SOFM identifies the strategies that vary suppliers have adapted. The tool can be effective in taking decisions based on competencies, both qualitative and quantitative attributes, etc.
In this paper, 38 journal articles from 2000 to 2016 have been collected through science direct website, which solved the supplier evaluation and selection problem using multi criteria decision making. The approaches, evaluating criteria, and their applications have been summarized. The primary objective of this paper is to find out the most popular approach used in supplier evaluation, i.e., evaluation of potential suppliers in view of multiple criteria.

In every fuzzy multi criteria decision making, fuzzy numbers are assigned to every criterion, from which score for the suppliers are obtained. This paper starts with TOPSIS method which maximises the total purchase value of the product. In most of the journal articles in this paper, four major criteria that are considered are quality, price, on time delivery and consistency. Hybrid algorithm of TOPSIS and MILP identifies the best supplier based on the demanded quantity by allocating proper demand to the vendors. Hierarchical TOPSIS is effective in ranking suppliers based on the overall performance. Values for the various attributes are given in terms of real numbers, interval number and fuzzy number considering the specifics of that attributes. TOPSIS function is primarily dependent on the positive and negative ideal solution. Acceptance of a supplier is based on the value of closeness from the positive ideal solution. Nearness coefficient using TOPSIS model is considered for ranking the buyers and adjusting the price of the orders. In cases where benefit and cost criteria’s are considered for effective supplier identification, fuzzy triangular numbers are used to evaluate the buyers for the criteria.

Fuzzy art algorithm, which categorizes the potential suppliers based on similarities, has two layers, the input and output layer. This method controls the degree of similarity of patterns in supplier evaluation and selection by clustering and placing same criteria in a conjoint group. A conventional method ranks every supplier and picks one of them, but Fuzzy ART algorithm clusters criteria’s based on similarities.

Pairwise comparisons using Fuzzy analytic hierarchical process, that analysis qualitative and quantitative value is a multi-attribute approach for decision making. In these cases, a hybrid combination of fuzzy ANP and Fuzzy TOPSIS method are being used for the selection process. Another method of deploying the interpretive structural model to rank the criteria’s for assessing the agile suppliers can be accomplished by employing proper outsourcing of agile suppliers. Agility guarantees the progress of the organization.

Fuzzy decision support system identifies the important criteria’s for the selection process by comparing historical and new suppliers. The final outcome of this process is the result of sum of supplier evaluation and Bid analysis. This method overcomes the difficulty of the traditional method by assigning weights at ease. In some journal articles considered in this paper, the evaluation of suppliers happens in two phases namely qualification phase and final choice phase, for which the priorities are derived from the decision maker’s opinion.

Extended fuzzy analytic hierarchy process uses pair-wise comparisons for triangular fuzzy numbers for assigning weights and for further comparisons. Triangular Fuzzy represents decision makers’ judgments. Global suppliers are selected based on the priorities derived as per the organization.

Some journal articles in this paper discusses about the order assignments using fuzzy multi objective programming model with three main aspects in a supply chain namely, purchasing organization, suppliers, and third party logistics. The resources thereby are restricted to the best supplier by this method which allocates the right quantity to the right suppliers based on demand. Fuzzy multi objective model is also used in the process of reverse logistics, where the returned parts are Re-manufactured, Re-used, refurbished, by considering the uncertainty in the customer’s demand. The integrated approach of FTOPSIS and Data envelopment analysis in the welding selection process to repair cast iron has an advantage of not assigning weights to criteria. FDEMATEL system for developing supplier selection criteria, which uses triangular fuzzy numbers for solutions from decision makers, generates a structural model of a system from the root cause of the problem. Fuzzy logic, AHP, and QFD are used in some models of supplier evaluation whose precise and complicated set of rules are accomplished by design.

Supplier selection in a fuzzy group setting using Dempster–Shafer theory, aggregates individual preferences of expert’s opinion into collective preferences. This model provides more information to the decision making process, thereby helping to rank the alternatives and to choose the best supplier. Grey relational analysis, a supplier selection method, defines situations of no information with black, and those with information as white. This method captures, processes, and analysis uncertainty in the decision making process. Besides, some recommendations were made based on the inadequacies of some approaches. This can definitely aid the researchers and decision makers in solving the supplier selection problem effectively.

IV. CONCLUSION

This paper is based on the multi criteria decision making approaches for supplier evaluation and supplier selection using fuzzy algorithm. Numerous methodologies under fuzzy logic in the form of FTOPSIS, FAHP, etc., have been implemented to decide the best supplier for the basic operations of an organization considering its demand. This paper progressed by individual approaches, discusses the supplier selection problem by handling both qualitative and quantitative considerations. The FTOPSIS approach is used by many researchers for their supplier section model. Contemporary supplier selection is as such that the traditional single criteria approach for low cost is not supportive and strong enough. As
a result of this, four main criteria’s namely cost, delivery, quality and consistency are considered for comprehensive evaluation of suppliers. These criteria will certainly aid the researchers, practitioners and decision makers for supplier selection effectively.

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