Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2016, 3(5): 56-65

Review Article ISSN: 2394 - 658X

Multi Criteria Decision Making Tools for Supplier Evaluation and Selection: A Review

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ABSTRACT

In competitive markets, companies are always under intense pressure to find ways to reduce production and material costs to survive and sustain their competitive position in their respective markets. Since a qualified supplier is a vital element for a buyer in reducing such costs, evaluation and selection of the potential suppliers has become an important component of supply chain management. Most supplier selection models consider various tangible and intangible characteristics of suppliers. AHP, FAHP, FUZZY TOPSIS, DEA, ANP, ANN, FIS, GA etc. are the supplier selection and evaluation approaches that have different process to select and evaluate a supplier that has been focused in this paper and also classified individually and combined based on the previous researches. To analysis the cost the MOLP method and the Multi Criteria Decision making tools (MCDM) have been included in this paper to take the decision and to select the suppliers more accurately and makes a reflection on the effective suppliers selection criteria like supplier reliability, product quality and supplier experience etc. and also suggests on the most quantitative results on cost effective methods and supplier selection approaches.

Key words: Supplier selection, AHP, FAHP, FUZZY TOPSIS, DEA, ANP, ANN, FIS, GA, MCDM, MOLP.

INTRODUCTION

In today's competitive world, supplier selection has become a complicated problem that undoubtedly concerned a lot of academics and practitioners to scrutinize the subject matter. Now most companies are trying to attain the goals of low cost, high quality, included flexibility and more customer satisfaction. For attaining these goals they must work with their supply chain partners. Traditionally supply chain management is the integration of key business processes from end user to original suppliers, provides products, service and information that add value for customers. It is also very important to keep better relations with some reliable suppliers. But from various surveys it is found that in manufacturing industries, the cost of raw materials and components comprise the major portion of product's final cost, sometimes it can equal up to 70% product cost. In this situation purchasing department can play a key role in cost reduction. With the increasing significance of the purchasing function, purchasing decisions become more important. As organizations become more dependent on suppliers the direct and indirect consequences of poor decision- making become more severe. When comparing suppliers many firms make the fundamental mistake of focusing only on the quoted price, ignoring the fact that suppliers may differ on other important dimensions that affect the total cost of using a supplier. For instance suppliers have different replenishment lead times. Does it pay to select a more expensive supplier with a shorter lead time? Or consider suppliers that have different on time performance. Is the more reliable supplier worth the few extra pennies it charges per piece? In each of the aforementioned instances, the price charged by the supplier is only one of many factors that affect the supply chain surplus. When scoring and assessing suppliers the following factors other than quoted price must be considered are replenishment lead times, on time performance, supply flexibility, minimum lot size, delivery frequency, supply quantity, inbound transportation cost, pricing, information coordination capability, design collaboration capability, exchange rates, taxes and supplier viability etc. Supplier performance must be rated on each of these factors because all affect the total supply chain cost. Various supplier selection methods such as such as AHP, ANP, Fuzzy AHP, ANN, TOPSIS, DEA, Integer programming, Genetic Algorithm and combination of any two of this tools are observed in the literature which have been classified in to a number of broader categories. Fig. 1 presents various supplier selection methods.

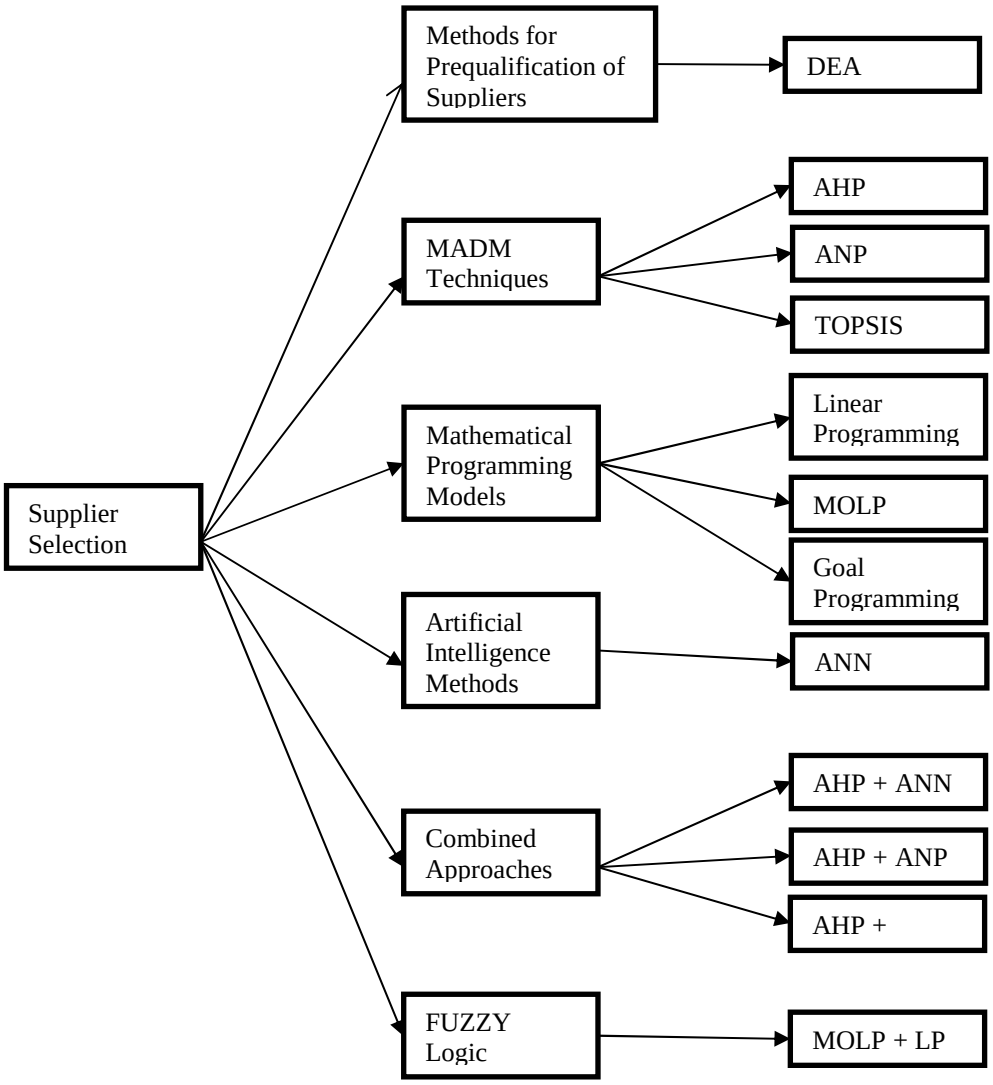

Fig. 1Various supplier selection techniques

Some of the most commonly used methods for supplier selection are discussed briefly here. This paper reviews articles on the multi-criteria supplier evaluation and selection approaches from 2012 to 2015. Based on the 53 articles following issues are analysed: (i) which approaches are prevalently applied? (ii) Which evaluating criteria are paid more attention to? (iii) Is there any inadequacy of the approaches?

This paper is organized as follows- Firstly the individual approaches and integrated approaches critically has been discussed, in next part analyses the most prevalently used approaches, discusses the most popular evaluating criteria, and find out the limitations of the approaches. The last section includes the conclusion of the paper.

INDIVIDUAL APPROACHES USED IN SUPPLIER SELECTION

Data Envelopment Analysis (DEA)

Data envelopment analysis is a unique technique for measuring productive efficiency of decision making units. Amindoust *et al* applied a multiple attribute utility theory based on Data Envelopments Analysis (DEA) to tackle supplier selection problem with consideration of some inputs and outputs. They implemented this approach in a telecommunication company for differentiating efficient and inefficient suppliers and ranking them [1]. Ma *et al* considered the competition between the suppliers and current game cross efficiency which was based on DEA to assess supplier performance in their paper. At last they got a unique efficiency and it was a pareto solution [2]. Sahai *et al* analyzed DEA for measuring supplier performance of two firms: multi-national telecommunication corporation and a manufacturing firm [3]. Hafezalkotob *et al* proposed DEA for the real application of DEA. In this approach, uncertainties about incomes and outcomes of decision making units (DMUs) were involved in the relative suppliers efficiencies. This approach was applied for the selection of suppliers in Supplying Automotive Parts Company (SAPCO) [4].

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty. The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a Shahroodi dealt with a brief review of the literature regarding AHP technique and its relevancy to its application in supplier selection process. He analyzed multiple criteria and various constraints related to supplier selection in manufacturing firms. After analysis he suggested that supplier reliability, product quality and supplier experience are the top three supplier selection problems that needs to be taken on priority for effective vendor selection [5]. Smart-Picker used AHP Sort instead of AHP for sorting problems that reduces the number of comparisons. In this technique at first the suppliers are classified into two groups- accepted and rejected suppliers. Then a single supplier is selected among the accepted suppliers [6]. Jaiswal applied AHP approach for selecting the best vendor out of available vendors for purchasing various computers, related equipment and maintenance of network of computers. He developed an AHP model and executed on computer using Expert Choice (EC), a software package. He concluded that the AHP approach is most suited to vendor selection problem because this does not require rigorous mathematics; it requires only simple matrix manipulation [7]. Benjamin *et al* evaluated strategically suitable suppliers for High-Tech start-up firms based on the selected performance metrics using the decision making framework AHP in their thesis work [8].

Khendek *et al* focused on developing methods to sustain supplier selection have been used assortments of factors as criteria for supplier selection. These criteria are linked to the nature of products, their targeted market, applicability, uncertainty in business Environment. Analytic hierarchy process (AHP) in a multi-period dynamic selection and evaluation of suppliers in a supply chain is used for achieving the goal using five major criteria: Quality, Delivery, Cost, Manufacturing Capabilities and Management. Including functional and behavioural aspects, the result of this study shows that such an AHP application can assist managers to effectively improve supplier selection and evaluation process even under complex economic conditions [9]. Koc *et al* extended the application of AHP using both tangible and intangible criteria's In this study, three main criteria as cost, availability and quality, additionally six sub-criteria as product price, transportation costs, quality assessment, technical capability, business improvement and management approach and four suppliers into account were taken. The results that obtained were considered acceptable and feasible by the decision maker in Car glass Turkey's Supply Chain Management Team where the model was used [10]. The most acceptable location throughout the state has been selected using AHP method [11] and to find out a best area to establish an automobile manufacturing hub by taking four potential locations in Andhra Pradesh state namely Kurnool, Vijayawada, Nellore and Visakhapatnam the AHP method also used [12].

Fuzzy Analytic Hierarchy Process (FAHP)

Fuzzy analytic hierarchy process (FAHP) method is used as the decision support system to help decision makers making better choices both in relation to tangible criteria and intangible criteria. Fuzzy set theory will be utilized to provide an effective way of dealing with the uncertainty of human subjective interpretation of tangible and intangible criteria. Mustafa Batuhan AYHAN examined the application of Fuzzy AHP in a gear motor company for determining the best supplier with respect to selected criteria. The contribution of this study was not only the application of the Fuzzy AHP methodology for supplier selection problem, but also releasing a comprehensive literature review of multi criteria decision making problems [13]. Rezaei *et al* considered two dimensions- the capabilities and the willingness of suppliers to cooperate with a particular firm for supplier selection. These dimensions cover almost all the existing supplier segmentation criteria mentioned in existing literature. For each particular situation, these dimensions can be specified using a multi-criteria decision-making method. The authors proposed fuzzy Analytic Hierarchy Process (FAHP) which used fuzzy preference relations to incorporate the ambiguities and uncertainties that usually exist in human judgment. The proposed methodology was used to segment the suppliers of a broiler company. The result is a segmentation of suppliers based on two aggregated dimensions [14]. Susanty *et al* applied FAHP in the supply chain of a basic industry and analysed its effect on the performance of SMEs [15]. Digalwar *et al* performed a case study in a manufacturing company for selecting the most suitable supplier for its product Anti-compounding relay valve (ACRV) based on FAHP and Tahriri *et al* also analyzed the efficiency of FAHP tool in a steel manufacturing company [16-17] and this also used for developing in choosing the Energetically Optimal Solution at the Early Design Phase of a Building by Szűts *et al* in [18].

Analytic Network Process (ANP)

Many decision-making problems couldn't be structured hierarchically because they involve the interaction and dependency of higher-level element. In these problems not only does the importance of the criteria determine the importance of the alternatives, but also the importance of the alternatives themselves determines the importance of

the criteria. To solve these problems, ANP can be used. ANP, developed by Saaty, is the first mathematical theory that makes it possible for decision-maker to deal systematically with this kind of dependence and feedback.Two papers proposed ANP to tackle the supplier selection problem. Agarwal *et al* presented a methodology to evaluate suppliers using portfolio analysis based on the analytical network process (ANP) and environmental factors. Since environment protection has been concern to public but the traditional supplier selection did not consider about this factor; therefore, they introduced green criteria into the framework of supplier selection criteria. They also considered intangible factors related to supply chain [19]. Sadeghi *et al* used ANP in a group decision making concerned with supplier selection [20]. Analytical Network Process (ANP) was applied as a model for prioritizing generated strategies based on the factors and sub-factors within the SWOT analysis, in the case of the Technical Faculty in Bor (TFB), University of Belgrade (UB), Serbia by Živković *et al* in [21].

Fuzzy-Technique of Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS)

Yayla *et al* utilized the fuzzy TOPSIS method to select the most appropriate supplier of garment 'X' operating in Turkey. The ranking were determined by firm in terms of closeness index values: supplier 1, supplier 2 and supplier 3 [22]. Shahroudi *et al* applied TOPSIS to evaluate suppliers in supply chain cycle based on various variables and effective criteria [23]. Hüseyin *et al* performed a case study in a filter company to identify the best supplier considering four criteria- quality, cost, delivery time and institutionalization by applying the steps of fuzzy TOPSIS [24]. Singh *et al* appied Fuzzy TOPSIS for selection of suppliers in supply chain cycle in an automobile industry. They provided weights to each criterion. By using these weights every supplier were provided rank [25]. Das *et al* proposed an application of weighted type-2 fuzzy multi-attribute decision making method based TOPSIS on supplier selection in a risk oriented supply chain. Eight risks-evaluative attributes namely, Performance risk, Demand risk, Environmental risk, Process risk and Logistics risks were taken for selection among three supplier alternatives. The proposed method remarkably reduced the degree of computation required for constructing the average decision matrix and weighted decision matrix of attributes enhancing Lee and Chen' ranking value approach of trapezoidal interval type-2 fuzzy sets in selection of alternatives [26]. Zahar *et al* proposed fuzzy TOPSIS method and supporting software for the selection of appropriate artificial hip prosthesis suppliers in the Orthopaedic Clinic of Kragujevac Medical Center, Serbia. The proposed method dealt with the rating of both quantitative and qualitative criteria and selected a suitable supplier effectively. The relative importance of criteria was described by linguistic expressions which are modelled by fuzzy sets. These values were calculated by using method of average value. All uncertainties and imprecision were modelled by triangular fuzzy numbers [27]. Öztürk *et al* applied Fuzzy TOPSIS method for the performance evaluation and selection of an appropriate sustainable supplier of an energy company [28]. Haoran *et al* mainly focused on the conceptual, descriptive and simulation. They attempted to identify the factors which have impact on the distribution cost and the selection for better distributors in an agricultural enterprise in China based on quantitative method fuzzy TOPSIS [29].

Fuzzy Inference System (FIS)

A fuzzy inference system (FIS) is a system that uses fuzzy set theory to map inputs (features in the case of fuzzy classification) to outputs (classes in the case of fuzzy classification). Amindousta *et al* applied Fuzzy Inference System (FIS) for sustainable supplier selection. At first the sustainable supplier selection criteria and sub-criteria were determined and based on those criteria and sub-criteria evaluation and ranking of suppliers was performed using FIS [30]. Asghari *et al* attempted to demonstrate the application of FIS in evaluating suppliers based on a comprehensive framework of qualitative and quantitative factors besides the effect of gradual coverage distance [31]. Fuzzy inference system (FIS) also used to develop a biomass for energy purposes which remains controversial concerns their full environmental sustainability in [32].

Genetic Algorithm (GA)

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the principles first laid down by Charles Darwin of 'survival of the fittest', since in nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones. Bozorgmehr *et al* explained that 70% of total cost occurred in industries due to the cost of raw materials and products. So it is very important to select appropriate supplier for reducing the purchasing cost and also increasing the total quality of product. They analyzed a Mall's supply chain through applying Genetic Algorithm (GA).Therefore, malls studied using initiative Genetic Algorithm method since the goal of supplier selection is to decrease purchasing risk, increase the value for customer. During the total cost of supply was determined first and then, an optimal value was determined with respect to the production and its demand [33]. Rungreunganaun *et al* calculated the optimal inventory lot-sizing for each supplier and minimized the total inventory cost which includes joint purchase cost of the products, transaction cost for the suppliers, and holding cost for remaining inventory. Genetic algorithms (GAs)

were applied to the multi-product and multi-period inventory lot-sizing problems with supplier selection under storage space. Also a maximum storage space for the decision maker in each period was considered. The decision maker needs to determine what products to order in what quantities with which suppliers in which periods. The authors assumed that demand of multiple products was known over a planning horizon. The problem was formulated as a mixed integer programming and is solved with the Gas [34]. To find the optimal configuration for a stochastic discrete events for computer simulation models Genetic Algorithmic Approach has been used in [35].

INTEGRATED APPROACHES USED IN SUPPLIER SELECTION

AHP & ANP

In AHP, the criteria are considered independently but in ANP interdependencies between criteria are also considered. For achieving better results two methods are combined applied. Ali GÖRENER provided the appropriate operational actions for the right markets at the correct time. They proposed to enhance SWOT analysis with multi criteria decision making techniques called Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP). AHP approach achieves pair wise comparisons among factors or criteria in order to prioritize them at each level of the hierarchy using the Eigen value calculation. In addition to AHP, ANP technique is a general form that allows interdependencies, outer dependencies and feedbacks among decision elements in the hierarchical or nonhierarchical structures [36]. Azizi *et al* applied two approaches, namely, Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) to propose a framework for recognizing the most agile automotive factory in supply chain. Five criteria, which are involved in that study, were: response to changes, flexibility, competency, economical optimization, and speed. The related sub-criteria were identified by industrial experts and Delphi method. Two models are elaborated using two AHP and ANP approaches considering four suppliers: A, B, C, D factories. Pairwise comparison matrixes were designed in questionnaires for determining the importance degree between criteria and sub-criteria based on Saaty scale (1-9). The validity of questionnaires was also confirmed by industrial experts using Cronbach's alpha. The geometrical mean was used to summarize the evaluations. The results of models were valid because the overall inconsistency of models were lower than 0.1 in all matrices. Finally, regarding to the obtained ultimate weights, the suppliers were ranked. It was identified that factory A with ultimate weight of 50.4% in AHP and weight of 54.2% in ANP models has been selected as the most agile supplier. On the other hand, factory D with 7.2% in AHP and 7.1% in ANP was recognized as the least agile supplier [37].

AHP/FAHP & Fuzzy TOPSIS

The weights of criteria are calculated by analytical hierarchical process (AHP) and the final ranking is achieved by fuzzy technique for order preference by similarity to an ideal solution (TOPSIS). TOPSIS helps obtaining the best solution close to ideal solution. Golam Kabir *et al* proposed fuzzy analytic hierarchy process (FAHP) approach based on technique for order preference by similarity to ideal solution (TOPSIS) method for evaluating and selecting an appropriate logistics service provider, where the ratings of each alternative and importance weight of each criterion were expressed in triangular fuzzy numbers [38]. Sarfaraz et *al* solved problem of selecting a person in human resource management. Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution with Grey Relations (TOPSIS grey) were applied for this aim. AHP was used for identifying the importance of each criterion when selecting a group member. TOPSIS grey was applied for ranking of alternatives, i.e. particular personnel, characterized by a set of criteria that are determined by grey relations and expressed in intervals. They performed a case study about process of selecting a new drummer for a rock band to demonstrate the applicability and the effectiveness of the proposed model. Criteria as technical ability, ability of accommodation to band and genre, discipline, ability to work with band (teamwork), general issues like age, behaviour, ideology and etc., ability of composing and motivation were prioritized from the most important to the least important, respectively, based on AHP results. Four potential candidates were considered. One of them was selected as the best drummer for the band among four applicants based on TOPSIS grey results. Finally they proposed that AHP is useful for determining the importance of each criterion and calculating weight of each criterion, while the second part with TOPSIS grey is useful for evaluating alternatives more precisely than usual crisp TOPSIS [39]. Wangchen *et al* developed a methodology to evaluate suppliers in supply chain cycle based on Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS). They considered some important criteria which affect the process of supplier selection such as product quality, service quality, delivery time and price and calculated the weights for each criterion based on Analytic Hierarchy Process (AHP) and then inputted these weights to the TOPSIS method to rank suppliers. They also made a trade-off between these tangible and intangible factors, some of which were conflict able [40]. Abdolshah *et al* solved supplier selection problem of a well-known ship & sea structures manufacturer company in Iran. Fuzzy AHP model was used to determine weights for criteria & sub criteria. Then the technique of TOPSIS was used for prioritizing suppliers. Finally they determined the best supplier for the most important device of the ship called main engine in the production of MPSV Ship [41]. Yazdani *et al* intended to present a reliable and applied pattern for assessment of their own organization's indices and selecting suitable suppliers for raw materials by combining group AHP approach and the TOPSIS technique. They performed a case study in Mazandaran wood & paper industries (MWPI), which is the largest producer of paper in

the Middle East and uses a continuous production line for producing its products [42]. Yazdani focused on finding the right supplier based on fuzzy multi criteria decision making (MCDM) process. They applied this combined techniques in an automobile manufacturing supply chain [43].

ANP & Fuzzy TOPSIS

ANP is used to calculate the weights of each criterion of the model and for the sake of complexity in evaluation to prepare exact numerical values for the criteria fuzzy TOPSIS may be used for selecting the best option. Yahya *et al* proposed an integrated method using Analytic Network Process (ANP) and Fuzzy-Technique for Order Preference by Similarity to the Ideal Solution (FTOPSIS) [44]. Shahroudi *et al* presented an integrated model and a supporting approach for effective supplier selection decisions in their research paper. Therefore, an integrated approach of ANP- TOPSIS (Analytic Network Process and Technique for Order Preference by Similarity to Ideal Solution) was proposed in choosing the best suppliers. They considered seven main criteria for supplier selection. They discovered that applying a two phase ANP-TOPSIS methodology causes to some important advantages such as: Long-term relationship, consist quality, lower cost, special attention and etc. [45]. Kassaee *et al* employed fuzzy approach for achieving more accurate results in uncertain environment. In their research paper they proposed the structural relationships and the interrelationships among all the evaluation's dimensions based on the Analytic Network Process (ANP) method determining appropriate weightings to each sub-criterion and then alternatives priority were determined which can aid the decision making. For this purpose, the TOPSIS (technique for order performance by similarity to ideal solution) was used to rank all competing alternatives in terms of their overall performances. They applied these techniques in an Iranian automotive industry for solving of vendor selection problem [46]. Alam-Tabriz *et al* also proposed integrated Fuzzy ANP and TOPSIS method for solving supplier selection problem and provided a numerical analysis regarding this field [47].

Fuzzy AHP and ANN

Tang *et al* developed a hybrid approach between the Analytic Hierarchical Process (AHP) and Artificial Neural Network (ANN) to evaluate and select the best supplier for shoes manufacturing. Firstly, questionnaire was setup based on previous study to obtain supplier selection criteria for shoes manufacturing. The proposed hybrid methodology used the AHP to determine the local and global weights of criteria, and the ANN method to select the best supplier [48]. Lakshmanpriya *et al* presented a hybrid model using Analytic Hierarchy Process (AHP) and Neural Networks (NNs) theory to review vendor performance in their research paper. The model consists of two sections: Section 1 applies AHP using pair wise comparison of criteria for all vendors, Section 2 applies the results of AHP into NNs model for vendor selection. The results give up the best vendor [49].

Fuzzy ANP and ANN

Goztepe *et al* selected the best supplier through considering different qualitative and quantitative criteria. They used analytic network process (ANP) method for defining the relationship between the criteria themselves; criteria and alternatives. To overcome the delay of decision making in each consideration ANN was used. They also found another superiority of ANN model was that the weights search by pair wise comparison matrix can be found by ANN without a need for fuzzy extent analysis method [50].

ANP & MOLP

Malmir *et al* incorporated an integrated decision making model based on Multi-objective linear programming and Analytic Network Process under benefits, opportunities, costs and risks (BOCR) concept. In the first step, the decision model was constructed by 20 decision criteria and 4 strategic criteria, obtained from SCM functional strategies, and the priorities of suppliers was used as the parameters of the first objective function in the second step. The allocation process was completed by considering three objective functions: supply value, financial value, and delivery time value. The study which was conducted in a major Asia car manufacturers, contributes not only to select the best suppliers but also to determine the amount of purchase to each high-priority supplier [51].

AHP/FAHP -TOPSIS and MOLP

Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (FAHP), Technique for Order Preference by Similarity (TOPSIS) process is not suitable for determining the allocation of order for supplies from various suppliers that can be easily solved using MOLP. Shahroudi *et al* introduced an integrated model for supplier's selection and order allocation in an automotive company by dividing their research into two phases (conceptual modeling and mathematical modeling) with four steps and solved by Analytic Hierarchy Process and Technique for Order Preference by Similarity to Ideal Solution (AHP-TOPSIS) and Multi-Objective Linear Programming (MOLP) [52]. Kannan *et al* presented an integrated approach, of fuzzy multi attribute utility theory and multi-objective programming, for rating and selecting the best green suppliers according to economic and environmental criteria and then allocating the optimum order quantities among them. At first, the fuzzy analytic hierarchy process and fuzzy technique for order preference by similarity to ideal solution (TOPSIS) was applied in order to analyze the importance of multiple criteria by incorporating experts' opinion and to determine the best green suppliers. Next,

multi-objective linear programming is used to consider and to formulate various constraints such as quality control, capacity, and other objectives [53].

The articles that have been analysed for separately or combined are shown briefly by the following Table 1 where the authors used different approaches as the best approach to select the suppliers.

Table -1 Focus on the Researches of Supplier Selection Approaches Individually and Combined

Supplier Selection Approaches	Approaches Analysed By	Analysed In
Data Envelopment Analysis (DEA)	Atefeh Amindoust *et al*[1], Ruimin Ma *et al* [2], Manjari Sahai *et al* [3] and Ashkan Hafezalkotob *et al* [4].	2012, 2014, 2014 & 2014
Analytic Hierarchy Process (AHP)	Shahroodi *et al* [5], Alessio Ishizaka *et al* [6], Umesh Chandra Jaiswal [7], Benjamin and Birger [8], Mohamed Khendek *et al* [9], Eylem Koc *et al* [10], Željko Stević *et al* [11] and Sreenivasulu Reddy .A *et al* [12].	2012, 2012, 2012, 2013, 2013, 2014,2015 & 2015
Fuzzy Analytic Hierarchy Process (FAHP)	Mustafa Batuhan AYHAN [13], Jafar Rezaei *et al* [14], Aries Susanty *et al* [15], Abhijeet K. Digalwar *et al* [16], Farzad Tahriri *et al* [17] and András Szűts *et al* [18].	2013, 2013, 2014, 2014, 2014 & 2015
Analytic Network Process (ANP)	Gopal Agarwal *et al* [19], Mohammadreza SADEGHI *et al* [20] and Živan Živković [21].	2012, 2012 & 2015
Fuzzy-Technique of Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS)	A. Yeşim Yayla *et al* [22], Kambiz SHAHROUDI *et al* [23], Dr. Hüseyin [24], Ravendra Singh *et al* [25], Pritha Das *et al* [26], Marija Zahar Djordjevic *et al* [27], Burcu Avcı Öztürk *et al* [28] and Shi Haoran *et al* [29].	2012, 2012, 2012, 2012, 2013, 2014, 2014 & 2014
Fuzzy Inference System (FIS)	Atefeh Amindousta *et al* [30], Mohammad Asghari *et al* [31] and Fausto Cavallaro *et al* [32].	2012, 2014 & 2015
Genetic Algorithm (GA)	Ardeshir Bozorgmehr *et al* [33], Vichai Rungreunganaun *et al* [34] and Chandrashekhar Meshram [35].	2013, 2013 & 2015
AHP & ANP	Ali GÖRENER [36] and Amir Azizi *et al* [37]	2012 & 2014
AHP/FAHP & Fuzzy TOPSIS	Golam Kabir [38], Sarfaraz Hashemkhani *et al* [39], Pema Wangchen Bhutia *et al* [40], Mohammad ABDOLSHAH *et al* [41], Amir Abbas Yazdani *et al* [42] and Morteza Yazdani [43].	2012, 2012, 2012, 2013, 2014 & 2014
ANP & Fuzzy TOPSIS	Ali A. Yahya Tabar *et al* [44], K. Shahroudi *et al* [45], Massoud Kassaee [46] and Akbar Alam-Tabriz *et al* [47].	2012, 2012, 2013 & 2014
Fuzzy AHP and ANN	S. H. Tang *et al* [48] and C. Lakshmanpriya *et al* [49],	2013 & 2013
Fuzzy ANP and ANN	Kerim Goztepe *et al* [50].	2012
ANP & MOLP	Reza Malmir [51]	2013
AHP/FAHP -TOPSIS and MOLP	Kambiz Shahroudi [52] and Devika Kannan [53].	2012 & 2013

RECOMMENDATIONS

MOST PREVALENTLY USED APPROACHES

In this paper 53 articles are collected which appeared in the period from 2012 to 2015 for solving the supplier evaluation and selection problem using the multi criteria decision making approaches. The first objective of this paper is to find out the most popular approach adopted in supplier evaluation and selection literature. The most popular approach is Fuzzy TOPSIS, followed by DEA, AHP, FAHP, ANP, FIS and GA. Fuzzy TOPSIS has attracted more attention mainly because of its capability to evaluate suppliers in supply chain cycle based on various variables and effective criteria. This method provides weights to each criterion and by using these weights every supplier are ranked. In past it is used to measure the relative efficiencies of homogeneous DMUs based on numerical data only. As the supplier selection problem involves both qualitative and quantitative criteria. Fuzzy TOPSIS has been modified to handle both of these criteria effectively. By this method relative importance of this criteria are described as linguistic expressions and all uncertainties and imprecision are modelled by triangular fuzzy numbers. Besides this tool AHP and Fuzzy AHP are also used widely. There are various integrated approaches for supplier selection. It is noticed that the integrated AHP/FAHP and Fuzzy TOPSIS are more prevalent. The wide applicability is due to its flexibility, ease of use and ability to provide a measure of the consistency of the decision maker's judgement. It is one of the best ways for evaluating and selecting appropriate logistics service provider where the ratings and importance weight of each alternative are expressed in triangular fuzzy numbers. By using FAHP and Fuzzy TOPSIS uncertainty and vagueness from subjective perception and experiences of the decision makers can be effectively represented and more effective decision can be easily obtained. Besides this it is found that ANP and Fuzzy TOPSIS method is widely used for supplier selection problem. But for quantitative results such as cost analysis purposes MOLP is most suitable.

CONCLUSIONS

This paper is based on a literature review on the multi-criteria decision making approaches for supplier evaluation and selection from 2012 to 2014. First, it was found that numerous individual and integrated approaches were proposed to solve the supplier selection problem. They are all capable of handling multiple quantitative and qualitative factors. The most prevalent individual approach is FUZZY TOPSIS, whereas the most popular integrated approach is AHP–FUZZY TOPSIS. Second, it was observed that price or cost is not the most widely adopted criterion. Instead, the most popular criterion used for evaluating the performance of suppliers is quality, followed by delivery, price or cost, and so on. This proves that the traditional single criterion approach based on lowest cost is not supportive and robust enough in contemporary supply management. The traditional cost-based approach cannot guarantee that the selected supplier is global optimal because the customer-oriented criteria (quality, delivery, flexibility, and so on) were not considered. 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.

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