Application of Fuzzy AHP and COPRAS to Solve the Supplier Selection Problems

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***Abstract*— Supply chain management (SCM) can be considered as a key component of competitive strategy to enhance organizational productivity, performance and profitability. In this paper, investigated the supplier selection problem and for this purpose, designed questionnaires are sent to 5 professional experts in different departments of ABZARSAZI COMPANY in Iran. Proposed approach is based on Fuzzy Analytic Hierarchy Process (FAHP) and COPRAS (Complex Proportional Assessment) methods. The major purpose of this paper is ranking the suppliers of ABZARSAZI COMPANY by using a hybrid Fuzzy AHP and COPRAS approaches. Finally, results of this research, give an evaluation method for companies in order to help managers to identify and select the best suppliers.**

***Keywords*—** *Supply chain management, Suppliers selection, Fuzzy AHP, COPRAS*

1. Introduction

A supply chain is one of the most integral parts of new business management in the design of services from suppliers to customer[1-3]. In contemporary supply chain management, the performance of potential suppliers is evaluated against multiple criteria rather than considering a single factor[4].
Since managers typically rely on only a subset of information (e.g. heuristics), AHP helps managers make "more rational" decisions by structuring the decision as they see it and then fully considering all available information on the criteria and alternatives[5]. In other words, the process of developing the AHP model provides value on its own, independent of the final evaluation of the alternatives[6].
An important aspect reflects the matter of fact that AHP assures a structural hierarchy of process, criteria selection and objective handling as well as neutral results for the decision makers in a process where many stakeholders are involved to identify best-performing suppliers. Understanding and evaluating supplier performance is vital to ensure a well-functioning supply network and to keep business running[7]. Doing supplier evaluation in the right way means also to help reducing costs, lower risk as well as improving the companies and supplier's business[8]. One of the main motivation factors for developing new supplier evaluation approaches is directly deduced from practical problems in supplier selection due to the fact that mostly used approaches are based on simple weighted scoring methods primarily relying on subjective judgments and opinions of supply professionals and other involved parties in the evaluation process[9].
Ref [10], in their paper, treat supplier selection as a group multiple criteria decision making (GMCDM) problem and obtain decision makers' opinions in the form of linguistic terms. Then, these linguistic terms are converted to trapezoidal fuzzy numbers. They extended the VIKOR method with a mechanism to extract and deploy objective weights based on Shannon entropy concept. The final result is obtained through next steps based on factors R, S and Q. A numerical example is proposed to illustrate an application of the proposed method.
Ref [11], in her paper proposed, a conceptual framework in order to select the best supplier considering several criteria. The framework combines the weights obtained from analytical hierarchy process improved by fuzzy rough sets and those obtained from the classical AHP. Then, the VIKOR method is used for ranking the different suppliers.
Ref [12], in their research used fuzzy VIKOR, to select suppliers. Moreover, the fuzzy logic and trapezoidal fuzzy numbers utilized to overcome ambiguity of evaluation process. Afterwards, the evaluation criteria weighted, as a result decrease dependence of decision makers and provide more rational in decision making process. In the next phase, fuzzy VIKOR method used to rank suppliers and the supplier selection problem. Finally, the

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results of implementation in EMERSUN Industries presented.

Ref [13], utilizing a hybrid multi-criteria decision making (MCDM) model for selecting a supplier. First, eight evaluation criteria, including cost, quality, distance, delivery reliability, reputation, technology level, compatibility and development ability are identified. The Analytic Hierarchical Process (AHP) is initially used for calculating the weight of each criterion. The COPRAS of alternatives to Grey relations (COPRAS-G method) is adopted for ranking and selecting suppliers.

Ref [14], In their paper proposed method employs Fuzzy Analytic Hierarchy Process (FAHP) for weighting of criteria, and Fuzzy Inference System (FIS). The FIS determines the effectiveness ratio for FAHP method and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (FTOPSIS). The proposed method has been applied for supplier selection in a steel company to illustrate its applicability, flexibility and accuracy in different decision making situations.

Ref [15], presents an integrated evaluation approach for decision support enabling effective supplier selection and ordering processes in textile industry. The integrated evaluation method in their study includes two phases that consist of fuzzy AHP and goal programming approaches Finally, a goal programming model is built using the goals about coefficients of suppliers, total ordering cost, number of wrong deliveries, total delivery cost under the constraints of required minimum and maximum number of orderings and acceptable quality cost levels of each supplier and demand constraint of the product.

Ref [16], by presenting a new hybrid method based on fuzzy Shannon's Entropy and fuzzy COPRAS, evaluate the CRM performance of Mellat Bank in Iran.

Abzarsazi Industries in Iran, produces metal components that tries to improve its quality, safety and occupational hygiene performance constantly by establishing quality management systems, safety and occupational hygiene based on ISO9001:2008 and OHSAS18001:2007 for achieving its strategic aims. At present, having efficient human resource and equipped and advanced shop floors and also various processes of production such as machining, thermal operations, forging, founding, die making, etc. this industry is one of pioneer component maker companies in the country.

In this research, according to the literature review, first we identified the Supplier Selection Criteria in Iran and then we will rank the suppliers of ABZARSAZI Co. using a combined approach of fuzzy AHP and COPRAS.

The rest of this paper is organized as follows: In Section 2 the evaluation criteria's of suppliers are Identified; Section3 gives a review of used technique (Fuzzy AHP, COPRAS); In Section 4, Data analysis is done, finally section5 is the conclusion of this paper.

2. Identification of evaluation criteria's

The first step of evaluation is the identification of decision/evaluation criteria which potential supplier will be evaluated upon. The identification and analysis of criteria for selection and evaluation of vendors has been the focus of attention for many academicians and practitioners. In his seminal work, Ref [17] conducted a questionnaire survey mailed to about 300 commercial organizations, primarily manufacturing firms. The purchasing managers of these firms were asked to identify factors that were important for selecting suppliers. His findings were divided into two categories: vendor selection practices by firms and vendor selection practices by individuals. Table 1 summarizes his results pertaining to factors commonly used to rate potential suppliers by firms. It identifies quality, price, and delivery as the most critical factors in the supplier selection process.

Also based on the previous literatures, Criteria's of supplier selection is as Table 1:

Table 1 Criteria's of supplier selection

Criteria	Reference
Quality	[18]–[20]
Delivery	[18]–[20]
Service	[19], [21]
Technical Capability	[10], [17], [22]
Rejection rate	[21], [23]
Lead-time	[19], [24], [25]
Reaction to demand change	[19], [20]
Production capability	[17], [21], [24]
Price	[17], [19]
Up to Date	[20], [25]
Willingness and Attitude	[12], [20], [26]
Reputation	[21], [25]

Based on the literature on supplier evaluation and interviews with company managers, the evaluation criteria of this research are defined as Quality (C1), Price (C2), Delivery (C3), Service (C4) and Technical Capability (C5), Also three suppliers have considered for evaluation.

3. A review of used technique

3.1. Fuzzy AHP

The Analytic Hierarchy Process is a tool utilized by many researchers worldwide. It is a decision making process which helps to set priorities when a quantitative and qualitative aspect is being considered in an equation. Many find it very practical and flexible to use[27]. This process works by minimizing complex evaluation criteria into a series of one to one comparisons. However, due to lack of certainty on information and difficulty evaluating strength of preferences, decision makers are unable to set the exact numerical values when conducting the test. Therefore, AHP plays a key role in solving this issue; it enables the users to deal with vagueness and uncertainty in the decision process[28].

FAHP consists of local priority from preference ratio, which is combined to generate what is known as the global priorities. According to article, the FAHP computes fuzzy priorities based on arithmetic operations for trapezoid or triangle numbers. Although this system is widely known; however, there are many critics of this theory, due to its consistency issue. This is because there is no specific articulation on what would make up an inconsistent comparison matrix and how the information would be handled. Also, the obtained fuzzy priorities are more likely to be flawed due to its lacking of a mechanism to eliminate inconsistent data.

Therefore, the solution to the problem is adopted. According to Chang's method, each object is taken and the extent analysis for each goal is performed respectively.

Step 1: The value of fuzzy synthetic extent with respect to the i^{th} object is determined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \oplus [\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} \quad (1)$$

To derive $\sum_{j=1}^{m} M_{gi}^{j}$, the fuzzy addition operation of m extent analysis values for the certain matrix is performed such as

$$\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \quad (2)$$

And to acquire $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]$, by performing the fuzzy addition operation of M_{gi}^{j} (=1,2,…,m) such that

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \quad (3)$$

And $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}$ can be calculated by the inverse of Eq.(4), as follows :

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} = (\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}) \quad (4)$$

Step 2: as $M_1 = (l_1, m_1, u_1)$, and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 \geq M_1$ is defined as

$$V = (M_2 \geq M_1) = \sup_{y \geq x}[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (5)$$

And can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_2 \geq u_2 \\ \frac{(l_1 - u_2)}{(m_2 - u_2) - m_1 - l_1} & Otherwise \end{cases} \quad (6)$$

Where d, as shown in Figure 1, *is* the ordinate of the highest intersection point D between μ_{M1} and μ_{M2}. To compare $M_1 = (l_1, m_1, u_1)$, and $M_2 = (l_2, m_2, u_2)$, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

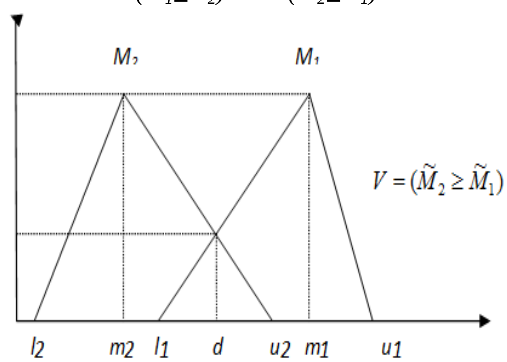

Figure 1 Intersection between M1 and M2

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy M_i (i= 1, 2..., k) numbers can be defined by

$$V\ (M \geq M_1, M_2, M_k) = v\ [\ \geq M_1\ and\ M \geq M_2\ and\ M \geq M_k]$$

$$= \min v\ M \geq M_1,\ i=1, 2\ldots, k \quad (7)$$

Assume that
$d'(A_i) = \min V\ (S_i \geq S_k)\ for\ k=1, 2\ldots, n;\ k \neq i$ Then the weight vector is given by

$$W' = (d'(A_1), d'(A'_2\ldots, d'(A_n))^T \quad (8)$$

Where A_i (i=1, 2…, n) are n elements.

Step 4: Via normalization, the normalized weight vectors are
$w = (d(A_1), d(A_2) \ldots, d(A_n))^T$ (9)

Where w is a non- fuzzy number.

3.2. COPRAS

The COPRAS (***CO****mplex* ***PR****oportional* ***AS****sessment*) method is presented by Zavadskas and Kaklauskas[29]. Description of COPRAS methods and possibilities of its application are published in a large number of papers[30]. Ranking alternatives by the COPRAS method assumes direct and proportional dependence of significance and priority of investigated alternatives on a system of criteria. The determination of significance and priority of alternatives, by using COPRAS method, can be expressed concisely using four stages[31]:

***Stage*1. The normalized decision-making matrix D is constructed**. In MCDM process, criteria usually have different units of measure. In order to transform performances of considered alternatives into comparable dimensionless values, normalization procedure is used. An overview of some of the most important multi-criteria methods and their normalization procedures, is shown in [32]. A detailed overview of the most important normalization procedures is also discussed in[33].

For normalization in COPRAS method the following formula is used:

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (10)$$

Where x_{ij} is the performance of the i-th alternative with respect to the j-th criterion $\tilde{x}_{ij}$ is its normalized value, and m is number of alternatives.

***Stage* 2. The sums of weighed normalized criteria describing the *i*-th alternative are calculated**.

In COPRAS method, each alternative is described with its sums of maximizing attributes S_{+i}, i.e. optimization direction is maximization, and minimizing criteria S_{-i}, i.e. optimization direction is minimization n.

In order to simplify calculation of S_{+i} and S_{-i} in the decision-making matrix columns first of all are placed maximizing criteria and then minimizing criteria. In such cases, S_{+i} and S_{-i} is calculated as follows:

$$S_{+i} = \sum_{j=1}^{k} \tilde{x}_{ij} \cdot q_j \quad (11)$$

$$S_{-i} = \sum_{j=k+1}^{n} \tilde{x}_{ij} \cdot q_j \quad (12)$$

In formulas (8) and (9), k is number of maximizing criteria; n is total number of criteria; and q_j is significance of the j-th criterion.

***Stage* 3. Calculation of the relative weight of each alternative**. The relative weight Q_i of i-th alternative is calculated as follows:

$$Q_i = S_{+i} + \frac{\min_i S_{-i} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{\min_i S_{-i}}{S_{-i}}} \quad (13)$$

Formula (10) can also be written in simplified form as follows:

$$Q_i = S_{+i} + \frac{\sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{1}{S_{-i}}} \quad (14)$$

***Stage* 4. Determine the priority order of alternatives**. The priority order of compared alternatives is determined on the basis of their relative weight. The alternative with higher relative weight has higher priority (rank), and the alternative with the highest relative weight is the most acceptable alternative.

$$A^* = \left\{ A_i \middle| \max_i Q_i \right\} \quad (15)$$

The presented procedure of COPRAS method indicates that it can be easily applied for evaluating the alternatives and selecting the most efficient one, with decision maker being completely aware of the physical meaning of the process.

However, many decisions are made in real-world situations where criterion values are not precisely known. Then criterion values can be expressed in the form of intervals. For this reason, a new method of multiple-criteria complex proportional assessment with values determined in intervals – COPRAS-G is developed [34].

4. Data analysis

In this section, first we calculate the weight of criteria's using 5 steps as following:

4.1. Calculating the weight of criteria with Fuzzy AHP

Now we use fuzzy AHP to evaluate the suppliers (Alternatives: three suppliers) of Abzarsazi Company in Iran according to the five criteria's. First, set up the analytic hierarchy model of the supplier's evaluation as figure2:

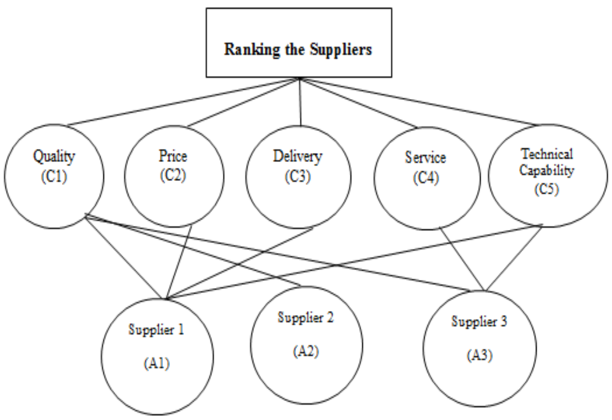

Figure 2 The hierarchy model of the supplier's evaluation

Next, we give the Fuzzy Pair-wise Matrix for supplier's evaluation:

In this step, a questionnaire prepared and five experts in SCM completed it with linguistic variables. Finally, the final geometric fuzzy pair-wise matrix is implemented as Table2.

Table 2 The final geometric fuzzy pair-wise matrix

COMPOSED	***C1***			***C2***			***C3***			***C4***			***C5***		
C1	1.00	1.00	1.00	1.69	2.29	2.93	0.34	0.34	0.34	0.84	2.15	3.86	2.00	5.00	7.00
C2	0.34	0.44	0.59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	8.00	0.99	1.47	1.69
C3	0.74	1.12	2.92	0.14	0.20	1.00	1.00	1.00	1.00	0.56	1.08	1.36	0.34	2.34	4.58
C4	0.26	0.46	1.19	0.13	0.20	1.00	0.73	0.73	0.73	1.00	1.00	1.00	1.50	2.50	7.00
C5	0.14	0.20	0.50	0.59	0.68	1.01	0.22	0.22	0.22	0.14	0.40	0.67	1.00	1.00	1.00

Next, we calculate the composed Fuzzy Column Matrix in EXCEL software. In the next step we determinate the Composed Crisp Column Matrix based on value degree. Consistency check and deriving priorities and Weighting and Ranking of Criteria's as Table3. In this paper, Fuzzy AHP is implemented in the EXCEL software. Calculated consistency ratio by software is 0.05and 0.04 for two indexes, then that represents the relative consistency of decision makers' judgments.

Table 3 The Weighting & Ranking of Criteria's

	C1	***C2***	***C3***	***C4***	***C5***
WEIGHT	0.243	0.256	0.186	0.188	0.125
RANK	2	1	4	3	5

4.2. Ranking the alternatives (Suppliers) with COPRAS

In order to select the best supplier of ABZARSAZY Company, COPRAS method was used. Each of the decision makers evaluated every supplier according to the five criteria as tabulated in Table4.

Table 4 Evaluation of different supplier

	W_J	***A1***	***A2***	***A3***
C1	0.243	3	4	2
C2	0.256	800	750	840
C3	0.186	3	3	5
C4	0.188	2	3	4
C5	0.125	4	3	4

Now using Eqs. (10), (11), (12), (13), (14) and (15) we get the final result as tabulated in Table5.

Table 5 Final result of supplier ranking

S_J+	0.169	0.172	0.13
S_J-	0.013	0.018	0.008
$1/S_J-$	76	54.286	126.66
Q_J	0.183	0.181	0.153

5. Discussion

Using COPRAS, an initial assessment of the selecting of best supplier has been conducted. The analysis compared three alternative supplier based on five weighted decision criteria. Based on the judgment of decision makers as ranking the suppliers is compiled (table5): priority1= A_1, priority2= A_2, priority3=A_3. Therefore, the best supplier is A_1. The concept of the method COPRAS is unambiguously distinct, that the value of the i-th alternative Q_i, is directly proportional to the effect of maximizing criteria (R_i). It has been observed that the maximizing criteria(P_i) of A_3 is high but still its ranks 3 among the suppliers, this is because its R_i value is highest which eventually lowers the overall Q_i value.

6. Conclusion

Evaluation and selection of the right business partner/supplier is very important for companies to create and increase competitive advantages. The supplier selection problem is of vital importance for operation of every firm because the solution of this problem can directly and substantially affect costs and quality. Indeed, for many organizations effective supplier evaluation and purchasing processes are critical success factors. This paper demonstrates the structured approach of Fuzzy AHP which can be used as a tool in supplier evaluation to identify best-in-class suppliers and build a ranking out of the defined criterion's weight and the degree of performance. The Fuzzy AHP represents a compatible process in supplier evaluation to assure a clear, objective and comprehensible evaluation. Meanwhile, proposed method has some drawbacks as well. When a new potential supplier is included in the system, the evaluation has to be restarted. Furthermore, development and evaluation of pair-wise comparisons and illustration of the results are very time consuming if no AHP software is used. Most supplier selection decisions are made today in increasingly complex environments where the theory of fuzzy decision making can be of significant use. In many of such decision-making settings the theory of fuzzy decision-making can be of use. In this paper we used a new model for weighting and ranking the criteria's and alternatives. This model is the combination of Fuzzy AHP and COPRAS methods which selects the best suppliers and their main criteria's based on evaluation of factors that have major impacts on quality of suppliers. Different from other studies in the literature, in this paper FAHP and COPRAS methods used together. FAHP used for determining the weights of the criteria's and COPRAS method used for determining the ranking of the suppliers because this method simultaneously considering the negative and positive criteria that in this research existence both of negative and positive criteria's. also other innovation of this study is combination of Fuzzy AHP and COPRAS method that wasn't noted in any research.

The results of research show that Price (C2) is the most important of criteria's for supplier's selection and such the supplier1 is the best suppliers of Abzarsazi Co.

- This proposed decision making model can be used in other areas of managerial decision making such as project selection, location selection and technology selection in supply chain.
- Other categorizing approaches would be used for classifying items and suppliers and develop the model depend upon it.
- Other categorizing approaches would be used for classifying items and suppliers and identify important, strategic, value added and relevant to organizations criteria and develop model based on them.
- Classification the criteria were introduced for supplier selection and present a comprehensive index for evaluating with classification technique.

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