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Ranking the Suppliers of Iranian Industries using a FAHP Approach

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Abstract— **Supply chain management is an important concept and discipline which enables business partners to integrate products and services effectively and to build long-term relationships. SCM can be extensively defined as effective coordination on material, product, delivery, payment, and information flows between enterprises and trading partners (Wu and Chuang , 2010). Supplier Evaluation is of increasing importance for companies and their further business development due to the fact that companies are concentrating on their core competencies. Next to that a distinctive supplier evaluation includes all internal departments and their feedback about supplier's performance to receive a whole picture of supplier's potential. Fuzzy Analytic Hierarchy Process (FAHP) is a new multi-criteria evaluation method evolved from Saaty's AHP. In this paper, designed Questionnaires are sent to 20 professional experts in different departments of Abzarsazi Company in Iran. So, this paper aimed to find out and rank the key factors of supplier selection criteria's and present a suitable ranking for supplier of Abzarsazi Company using a Fuzzy AHP approach.**

Index Terms— **Supply chain management (SCM), Fuzzy sets, Fuzzy AHP (Analytical Hierarchy Process)**

I. INTRODUCTION

Supply chain includes all the participants and processes: from a raw materials producer to the customer, but from the point of view of operative management, the three basic components are elaborated: supply, storage and distribution (Chopra et al., 2001). Supply Chain Management can be divided into the three main activities: purchase, production and transportation (Thomas et al., 1996). Logistics means managing operative tasks aimed at clients' needs (Tilanus 1997). The definition given by Johnson and Wood (cited in Tilanus 1997) pointed out "five key terms", and they are: logistics, input logistics, material management, physical distribution and delivery chain management. Social, economic, technological and some other changes in the world of business require changes in supply chain operation. Complexity of decision making in coordinated management has been persistently increasing. By application of coordinated management and control of the total costs in supply chain it can be significantly decreased (Dooley 1995).
In supply chain management there are many various problems. It is hard to make a unique classification in management and control, since most researchers refer to the same address of supply chains (Ballou 1992; Fazel Zarandi 2002; Thomas et al., 1996). According to the classification, there has been treated a problem belonging to the system, technical level and relation buyer-seller respectively.
In literature there are many papers dealing with the study of suppliers ranking aiming at the selection of a supplier meeting optimal requirements for cooperation. Ranking suppliers in the papers was based on mathematical, statistical or simulation techniques, while the matter of multi criteria analysis was based on application of cross evaluation matrixes, AHP method, multi-criteria statistical technique or simulation. Furthermore, there were presented some of the papers dealing with suppliers ranking (Harun 2011).
Traditional methodologies of the supplier selection process in the extant literature range from single objective techniques such as the cost-ratio method, linear or mixed integer programming to goal and multi-objective linear programming models (Yan et al., 2003; Oliveria et al., 2002). Wang et al., (2005) have developed a decision-based methodology for supply chain design that a plant manager can use to select suppliers. This methodology derived from the techniques of analytical hierarchy process (AHP) and pre-emptive goal programming. Li et al., (2007), use a grey-based decision-making method to deal with fuzziness in supplier selection. Pi et al., (2006), propose a supplier selection method that uses Taguchi loss functions and the Analytic Hierarchy Process (AHP) to obtain weights of major criteria.
In contemporary supply chain management, the performance of potential suppliers is evaluated against multiple criteria rather than considering a single factor (Ho et al., 2009).
In an increasingly complex world especially in difficult economic situations the right decision regarding supplier management has an important influence for companies and their future business. Since several years companies are outsourcing increasing business, concentrating on their core competencies and reducing their manufacturing share which leads to an increasing success-critical position of suppliers. Therefore companies have to select and identify the best suppliers for their business. That is where Fuzzy AHP supports the decision makers to find the decision that best suits their needs and their understanding of the problem.
In this research, according to the literature review first we identified the Supplier Selection Criteria in Iran and next FAHP approach is used for ranking the Suppliers of Abzarsazi Company.
The AHP was developed in the 1980s by Saaty. It is a systematic decision making method which includes both qualitative and quantitative techniques. It is being widely used in many fields for a long time. But one of the critical steps of

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AHP method is to set up the comparison matrixes. When the number of criteria's (or alternatives) in the hierarchy increases, more comparisons between criteria's (or alternatives) need to be made. This could easily cause confusion due to the excess of questions and hence the efficiency of the model. So a consistency check is required for the pair-wise comparison matrix. Therefore, whether the setting of the comparison matrix is scientific affects the correctness of AHP directly. When the comparison matrices are not consistent, we should adjust the elements in the matrixes and carry out a consistency test until they are consistent (Saaty 1965).Traditional AHP requires exact or crisp judgments (numbers). However, due to the complexity and uncertainty involved in real world decision problems, decision makers might be more reluctant to provide crisp judgments than fuzzy ones.

In this paper, we will use a fuzzy AHP approach in which substitute membership scales for Saaty's 1-9 scales to reduce adjusting times needed. 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.

The rest of this paper is organized as follows: In Section 2 the evaluation criteria's of suppliers are identified; Section 3 gives a literature review of Fuzzy AHP; In Section 4 data analysis is done, finally in section 5 is the conclusion of this paper.

II. 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, Dickson (1966) 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.

Table1: Factors Used In Vendor Rating Systems (Dickson, 1966)

Factor	Percentage Of Systems Using The Factor
Quality	96.6
Price	93.9
Delivery	93.9
Service	81.8
Technical Capability	63.6
Financial Strength	51.5
Geographical Location	42.4
Reputation	42.4
Reciprocal Arrangements	15.1
Other Factors	12.1

Also based on the previous literatures, Criteria's of supplier selection is as table 2: (Gharakhani 2012).

Table2: Criteria's of supplier selection (Gharakhani 2012)

Criteria	Reference
Quality	Weber, Current, & Benton (1991),Dickson (1966), Gunasekaran et al. (2001), Prahinski& Benton (2004), Kreng& Wang (2005), Kannan and Haq (2007), Forme et al. (2007), Chang et al. (2007), Sevkli et al.(2008)
Delivery	Rushton and Oxley (1991), Weber, Current, & Benton (1991), Christopher (1992), Dickson (1966), Gunasekaran et al. (2001), Prahinski& Benton (2004), Kreng& Wang (2005), Chang et al. (2007), Forme et al. (2007), Sevkli et al.(2008)
Service	Weber, Current, & Benton (1991),Prahinski& Benton (2004), Chang et al. (2007)
Technical/Engineering Capability	Weber &Current(1993), Meade and Sarkis (2002), Noorul&Kannan(2006), Kannan and Haq (2007), Sevkli et al.(2008)
Rejection rate	Gunasekaran et al. (2001)
Lead-time	Prahinski & Benton (2004), Chang et al. (2007), Sevkli et al.(2008)
Reaction to demand change	Prahinski & Benton (2004), Chang et al. (2007)
Production capability	Noorul & Kannan(2006), Sevkli et al.(2008)

Price	Dickson (1966), Prahinski& Benton (2004), Kreng& Wang (2005), Noorul & Kannan(2006), Chang et al. (2007), Sevkli et al.(2008)
Up to Date	Sevkli et al.(2008)
Willingness and Attitude	Ravi and Shankar (2005)
Reputation	Sevkli et al.(2008)

Based on the literature on supplier evaluation and interviews with company managers, the evaluation criteria's 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. BRIEF REVIEW OF AHP, FUZZY AHP

3.1. Literature review of AHP

Multi-criteria decision making deals with the problem of choosing the best alternative, that is, the one with the highest degree of satisfaction for all the relevant criteria or goals. In order to obtain the best alternative a ranking process is required. Extensively adopted in MCDM, the analytic hierarchy process (AHP) has successfully been applied to the ranking process of decision making problems. The main advantage of the AHP is its inherent ability to handle intangibles, which are present in any decision making process. Also, the AHP less cumbersome mathematical calculations and, it is more easily comprehended in comparison with other methods. Analytic hierarchy process (AHP) is developed by Saaty (1982, 1988, and 1995) that is probably the best known and most widely used MCA approach. (Cathy et al. 2004). Also it has been extensively used as a multiple criteria decision-making (MCDM) tool or a weight estimation technique in many areas such as selection, evaluation, planning and development, decision making, forecasting, and so on (Vaidya et al., 2006).

AHP is a probably the most widely applied MCA for the evaluation of various transport projects related to organizational, technological, environmental and infrastructural decision subjects (see Ferreira, 2002; Tudela et al., 2006; Sharifi et al., 2006; Janic, 2003; Tzeng et al., 2005, and so on). AHP is especially advantageous with respect to its ability to decompose a complex problem into its constituent parts and its simplicity in use (Macharis et al., 2004; Dagdeviren, 2008; Konidari and Mavrakis, 2007). On the other hand, AHP is often criticized with respect to the complete aggregation of the criteria which might lead to important losses of information (e.g., in case where trade-offs between good and bad scores on criteria occur). Additionally, the amount of pair-wise comparisons for the evaluation of the alternatives in terms of their contribution to the criteria might become substantially high (Macharis et al., 2004).Duran et al. (2007), summarized the following advantages for AHP: (1) it is the only known MCDM model that can mea-sure the consistency in the decision maker's judgments; (2) the AHP can also help decision makers to organize the critical aspects of a problem in a hierarchical structure, making the decision process easy to handle; (3) pair-wise comparisons in the AHP are often preferred by the decision makers, allowing them to derive weights of criteria and scores of alternatives from comparison matrices rather than quantify weights/scores directly; (4) AHP can be combined with well-known operation research techniques to handle more difficult problems; (5) AHP is easier to understand and can effectively handle both qualitative and quantitative data.

The AHP method is based on three principles: (1) construction of a hierarchy, (2) priority setting and (3) logical consistency (Macharis et al., 2004). First, a hierarchy is used to decompose the complex system into its constituent elements. A hierarchy has at least three levels: the overall objective or focus at the top, the (sub-) objectives (criteria) at the intermediate levels and the considered alternatives at the bottom (Macharis et al., 2004; Dagdeviren, 2008). Second, the relative priorities of each element in the hierarchy are determined by comparing all the elements of the lower level against the criteria, with which a causal relationship exists. The multiple pair-wise comparisons are based on a standardized comparison scale of 9 levels; see Table 3(Saaty, 2008). The result of the pair-wise comparisons is summarized in the pair-wise comparison matrix Table 4, where its standard element $P_c(a_i, a_l)$ indicates the intensity of the preference of the row element (a_i) over the column element (al) in terms of their contribution to a specific criterion C. Lastly, the consistency of decision makers as well as the hierarchy can be evaluated by means of the consistency ratio (Wang and Yang, 2007). This procedure is explained in detail in Saaty (1988).

Table 3: The Saaty scale for pair-wise comparison (Saaty, 2008)

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Higher importance
7	Much higher importance
9	Complete dominance
2,4,6,8	Intermediate values
$\frac{1}{2}, \frac{1}{3}, \frac{3}{4}, \ldots, \frac{1}{9}$	Reciprocals

Table 4: Pair-wise comparison of elements in AHP

C	a_1	...	a_l	...	
a_1	1				
...		[1]			
a_i			$P_c(a_i, a_l)$		
...				[1]	
a_n					1

In summary, Implementation of this technique consists of five steps as follows: (Saaty, 1988).

1. Determining a Hierarchical Tree: AHP uses a multi-level hierarchical structure that comprises a goal, criteria (and sub criteria) and options.

2. Finding priority of the criteria: AHP uses a set of pair-wise comparisons to calculate the relative weights of importance of the criteria.

3. Scoringof options based on each criterion: in this stage like stage 2, pair-wise comparison of options in terms of each criterion carry outs. Then, the ratings are normalized and averaged.

4. Obtaining Consistency Ratio (CR): The important stage is to obtain a CR to measure how consistent the judgments have been relative to large samples of purely random judgments. It is noteworthy that consistency ratio should calculate for each of pair-wise comparisons. The CR should be ≤ 0.1. It means that, if the CR is much in excess of 0.1, the judgments are untrustworthy and the pair-wise comparison is valueless and it must be repeated.

5. Calculating the final score: Finally, the option scores are combined with the criterion weights to make a final score for each option.

Sometimes, there are two or more decision makers (DMs). So, geometric mean method should be used to aggregate individual judgments.

3.2. Literature review of Fuzzy AHP

AHP is widely used for multi-criteria decision making and has successfully been applied to many practical problems (Saaty, 1980). In spite of its popularity, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the DM's perceptions to exact numbers. Traditional AHP requires exact or crisp judgments (numbers). However, due to the complexity and uncertainty involved in real world decision problems, decision makers might be more reluctant to provide crisp judgments than fuzzy ones. Furthermore, even when people use the same words, individual judgments of events are invariably subjective, and the interpretations that they attach to the same words may differ. Moreover, even if the meaning of a word is well-defined (e.g., the linguistic comparison labels in the standard AHP questionnaire responses), the boundary criterion that determines whether an object does or does not belong to the set defined by that word is often fuzzy or vague. This is why fuzzy numbers and fuzzy sets have been introduced to characterize linguistic variables. A linguistic variable is a variable whose values are not numbers but words or sentences from a natural or artificial language. Linguistic variables are used to represent the imprecise nature of human cognition when we try to translate people's opinions into spatial data. The preferences in AHP are essentially human judgments based on human perceptions (this is especially true for intangibles), so fuzzy approaches allow for a more accurate description of the decision-making process (M.-F.Chen et al. 2008). A number of methods have been developed to handle fuzzy AHP.

Decision making expert systems are often complex and multifaceted. In recent years, tools for modeling decision making have improved significantly, and multi-criteria decision making (MCDM) models are widely considered to be very useful in resolving conflicts related to the decision making process. Since Bellman and Zadeh (1970) developed the theory of decision behavior in a fuzzy environment, various methods have been developed for handling multi-criteria decision making systems (Beynon, et al. 2001; Chen et al. 2005; Chen et al. 2010; Chen et al. 2009; Fu, 2008; Hua et al. 2008; Kahraman et al. 2009; Kwon et al. 2004; Kwon et al. 2007; Lin et al. 2007; Mikhailov, 2003; Tacker et al. 1991; Yager, 1991, 1992).

In the literature, several approaches to fuzzy AHP have been proposed by various authors. The first method was proposed by Van Laarhoven and et al. (1983). In this method, elements in the reciprocal matrix were expressed by triangular fuzzy numbers. In contrast, Buckley (1985), used trapezoidal numbers to determine fuzzy comparison ratios. He criticized Laarhoven and Pedrycz's method since linear equations do not always yield a unique solution, and this method is only valid for triangular fuzzy numbers. Bounder et al. (1989), pointed out an error in the method of Laarhoven and Pedrycz, and showed how it can be corrected. Mohanty and Singh (1994), introduced a procedure for solving an AHP problem in a fuzzy environment. (Ruoning et al. 1992), discussed the extensions of AHP to fuzzy environments and presented a procedure for constructing the fuzzy judgment matrix. Their subsequent paper, continues the discussion and goes further into the problem of extracting the fuzzy weights from the fuzzy judgment matrix by the logarithmic least squares method, which is one of the main ranking methods in AHP(Ruoning et al. 1996). Chang (1996), proposed a method that uses triangular fuzzy numbers for the pair-wise comparison scale of fuzzy AHP and extent analysis for the synthetic extent values of pair-wise comparisons. Gogus and Boucher (Gogus et al. 1997) presented some results and extensions of the use of fuzzy pair-wise comparisons in multi-criteria decision analysis. In another paper, Gogus et al. 1998 defined strong transitivity and weak monotonicity for fuzzy pair-wise comparison matrices. Deng (1999) presented a simple and straightforward fuzzy approach to qualitative multi-criteria analysis problems. Zhu et al. (1999), proved the basic theory of triangular fuzzy numbers and improved the criteria for comparing the sizes of triangular fuzzy numbers. Ruoning (2000), dealt with the question of estimating the weights of factors by least squares from a fuzzy judgment matrix. Mikhailov (2000) proposed a new Fuzzy Programming Method, based on a geometrical representation of the prioritization process. Csutora et al. (2001), presented a new method of finding the fuzzy weights in fuzzy hierarchical analysis, which is the direct fuzzification of the kmax method. Buckley et al. (2001), presented a new method of finding the fuzzy weights. By applying the properties of goal programming (GP) to treat a fuzzy AHP problem, Yu (2001), incorporated an absolute term linearization technique and a fuzzy rating expression into a GP–AHP model for solving fuzzy AHP problems in group decision-making. Mikhailov (2003) proposed a new approach to deriving priorities from fuzzy pair-wise comparison judgments, based on an a-cuts decomposition of the fuzzy judgments into a series of interval comparisons. Eneaet al. (2004) presented an approach based upon a fuzzy extension of the AHP. This paper focuses on the constraints that have to be considered within fuzzy AHP in order to take into account all the available information. This study demonstrates that more certain and reliable results can be achieved by considering all the information derived from the constraints. Kulak et al. (2005) dealt with a multi-attribute transportation company selection for effective supply chain using both fuzzy multi-attribute axiomatic design and fuzzy AHP. Erensal et al. (2006), used the fuzzy AHP to analyze the links between competitive advantages, competitive priorities and competencies of a firm in the context of technology management. Göleçet al. (2007), presented a comparative study to establish complex fuzzy methodologies in evaluating the performance of a manufacturing system and showed that fuzzy AHP leads to the best result.

3.3. Fuzzy AHP stepwise procedure

Fuzzy AHP uses fuzzy set theory to express the uncertain comparison judgments as a fuzzy numbers. The main steps of fuzzy AHP are as follows:

Step1: Structuring decision hierarchy, Similar to conventional AHP, the first step is to break down the complex decision making problem into a hierarchical structure.

Step2: Determination of Fuzzy Pair-wise Matrix as below:

	C_1	C_2	...	C_n
C_1	(1,1,1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$
⋮			⋮	⋮
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)

That: $(a_{ij}^l, a_{ij}^m, a_{ij}^u) = (\frac{1}{a_{ji}^u}, \frac{1}{a_{ji}^m}, \frac{1}{a_{ji}^l})$

Consider a prioritization problem at a level with n elements, where pair-wise comparison judgments are represented by fuzzy triangular numbers $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$. As in the conventional AHP, each set of comparisons for a level requires $\frac{n(n-1)}{2}$ judgments, which are further used to construct a positive fuzzy reciprocal comparison matrix $\tilde{A} = \tilde{a}_{ij}$ such that:

$$\begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix}$$

Step3: Determination of composed Fuzzy column Matrix as:

	C_1	C_2	...	C_n	$\tilde{s}_i$
C_1	(1.1.1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$
⋮			⋮	⋮	⋮
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)	$\tilde{s}_m = (s_m^l, s_m^m, s_m^u)$

That:

$$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u) = \left(\frac{a_{11}^l + a_{12}^l + \cdots + a_{1n}^l}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}^u}, \frac{a_{11}^m + a_{12}^m + \cdots + a_{1n}^m}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}^m}, \frac{a_{11}^u + a_{12}^u + \cdots + a_{1n}^u}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}^m}\right)$$

(1)

Step4: Determination of composed Crisp column Matrix based on value degree as:

	C_1	C_2	...	C_n	$\tilde{s}_i$	s_i
C_1	(1,1,1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$	s_1
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$	s_2
⋮			⋮	⋮	⋮	...
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)	$\tilde{s}_m = (s_m^l, s_m^m, s_m^u)$	s_m

With

VL:(0,0.5,2); L:(1,2,3); ML:(2,3.5,4); M:(4,5,6); MH (5,6.5,8); H:(7,8,9); VH (8,9.5,10)

$$V(\tilde{A} > \tilde{B}) = \begin{cases} 1 & ; \quad a_m \geq b_m \\ \frac{b_l - a_u}{(a_m - a_u) - (b_m - b_l)} & ; els \end{cases} \qquad (2)$$

$V(\tilde{A} > \tilde{B}, \tilde{C}, \tilde{D}, \ldots) = \text{Min}\{V(\tilde{A} > \tilde{B}), V(\tilde{A} > \tilde{C}), V(\tilde{A} > \tilde{D}), \ldots\} = \alpha$

$V(\tilde{B} > \tilde{A}, \tilde{C}, \tilde{D}, \ldots) = \text{Min}\{V(\tilde{B} > \tilde{A}), V(\tilde{B} > \tilde{C}), V(\tilde{B} > \tilde{D}), \ldots\} = \beta$

$V(\tilde{C} > \tilde{A}, \tilde{B}, \tilde{D}, \ldots) = \text{Min}\{V(\tilde{C} > \tilde{A}), V(\tilde{C} > \tilde{B}), V(\tilde{C} > \tilde{D}), \ldots\} = \gamma$

$V(\tilde{D} > \tilde{A}, \tilde{B}, \tilde{C}, \ldots) = \text{Min}\{V(\tilde{D} > \tilde{A}), V(\tilde{D} > \tilde{B}), V(\tilde{D} > \tilde{C}), \ldots\} = \lambda$

That:

$$s_1 = s_A = \frac{\alpha}{\alpha+\beta+\gamma+\lambda}, \quad s_2 = s_B = \frac{\beta}{\alpha+\beta+\gamma+\lambda}, \quad s_3 = s_C = \frac{\gamma}{\alpha+\beta+\gamma+\lambda}, \quad s_4 = s_D = \frac{\lambda}{\alpha+\beta+\gamma+\lambda}$$

(3)

Step5: Consistency check and deriving priorities and Weighting & Ranking. This step checks for consistency and extracts the priorities from the pair-wise comparison matrices. In existing fuzzy AHP methods, only a few past studies have addressed the issue of checking for inconsistencies in pair-wise comparison matrices. According to Buckley (1985), a fuzzy comparison matrix $\tilde{A} = \tilde{a}_{ij}$ isconsistent if $\tilde{a}_{ik} \otimes \tilde{a}_{kj} \approx \tilde{a}_{ij}$ where $i, j, k = 1, 2, \ldots, n$ and $\otimes$ isfuzzy multiplication, and $\approx$ denotes fuzzy equal to. Oncethe pair-wise comparison matrix, $\tilde{A}$, passes the consistencycheck, fuzzy priorities $\tilde{w}_i$ can be calculated with conventional fuzzy AHP methods. Then, the priority vector $(w_1, w_2, \ldots, w_n)^T$ can be obtained from the comparisonmatrix by applying a prioritization method. Briefly, stages of Consistency check is as below:

Stage1: deviation the fuzzy triangular matrix to tow matrix as;

Interval numbers of triangular judgments: $A^m = [a_{ijm}]$

Geometric average of upper and low limits of triangular numbers: $A^g = \sqrt{a_{iju}a_{ijl}}$

Stage2: Calculating of weight vector for each matrix using saaty's method as below:

$$W_i^m = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ijm}}{\sum_{i=1}^{n}a_{ijm}}; \quad W^m = [W_i^m] \tag{4}$$

$$W_i^g = \frac{1}{n}\sum_{j=1}^{n}\frac{\sqrt{a_{iju}a_{ijl}}}{\sum_{i=1}^{n}\sqrt{a_{iju}a_{ijl}}}; \quad W^g = [W_i^g] \tag{5}$$

Stage3: Calculating the biggest of specific amount for each matrix as below:

$$\lambda_{max}^m = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}a_{ijm}\left(\frac{W_j^m}{W_i^m}\right) \tag{6}$$

$$\lambda_{max}^g = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}\sqrt{a_{iju}a_{ijl}}\left(\frac{W_j^g}{W_i^g}\right) \tag{7}$$

Stage4: Calculating of consistency index using the relations:

$$CI^m = \frac{(\lambda_{max}^m - n)}{n-1}, \quad CI^g = \frac{(\lambda_{max}^g - n)}{n-1} \tag{8}$$

Stage5: Calculating of consistency rate using the relations:

$$CR^m = \frac{CI^m}{RI^m}, \quad CR^g = \frac{CI^g}{RI^g} \tag{9}$$

If both of indexes were less of 0.10, Then fuzzy matrix is consistent, and if they were most of 0.10, then decision makers should revise the prioritization, and if one of these indexes were most of 0.10, then decision makers should revise the interval amounts of triangular judgments (Buckly, 1985).

4. Data Analysis

4.1. Calculating the Criteria's Weights of Suppliers Evaluation using Fuzzy AHP

Step1: Now we use fuzzy AHP to evaluate the suppliers (Alternatives: three suppliers) of Abzarsazi Company in Iran according to the five criteria's. For this purpose, in first we calculate the Criteria's Weights.

So, set up the analytic hierarchy model of the supplier's evaluation as figure1:

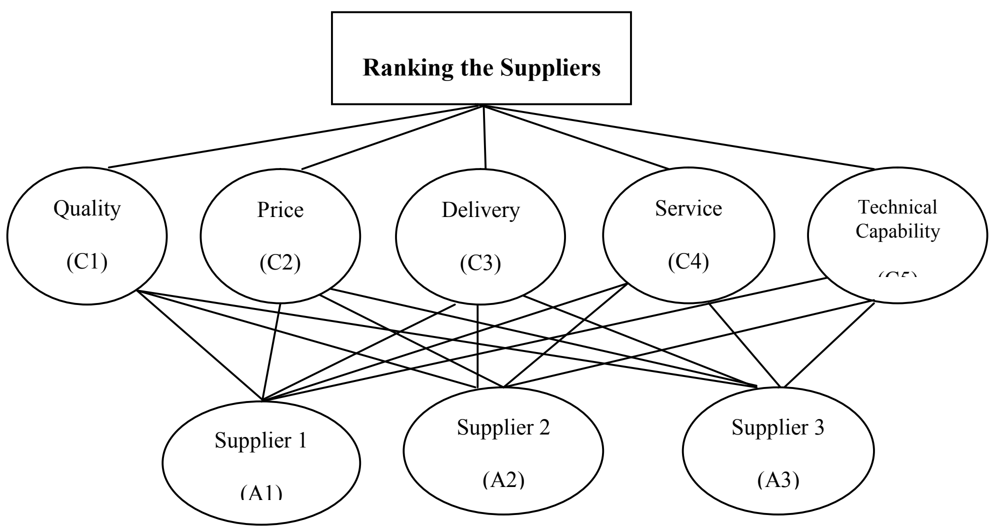

Figure1. The hierarchy model of the supplier's evaluation

Step2: Next, we give the geometric Fuzzy Pair-wise Matrix for Suppliers evaluation. On the other hand, in this step, a questionnaire prepared and twelve experts completed it with linguistic variables. To convert the fuzzy linguistic variables to fuzzy number can use the table5:

Table 5: Linguistic variables for paired comparison criteria

VL (Very low)	0	0.5	2
L (Low)	1	2	3
ML (Medium Low)	2	3.5	4
M (Medium)	4	5	6
MH (Medium High)	5	6.5	8
H (High)	7	8	9

VH (Very High)	8	9.5	10

Finally, the geometric fuzzy pair-wise matrix is calculated as figure2.

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	1.00	2.00	3.00	4.00	5.00	6.00	0.00	0.50	2.00	7.00	8.00	9.00
C2	0.33	0.50	1.00	1.00	1.00	1.00	7.00	8.00	9.00	2.00	3.50	4.00	8.00	9.50	10.00
C3	0.17	0.20	0.25	0.11	0.13	0.14	1.00	1.00	1.00	0.00	0.50	2.00	7.00	8.00	9.00
C4	0.50	2.00	1000.00	0.25	0.29	0.50	0.50	2.00	1000.00	1.00	1.00	1.00	8.00	9.50	10.00
C5	0.11	0.13	0.14	0.10	0.11	0.13	0.11	0.13	0.14	0.10	0.11	0.13	1.00	1.00	1.00

Figure2. The geometric Fuzzy Pair-wise Matrix

Step3: Next, we calculate the composed Fuzzy column Matrix in excel software as figure3:

	$\tilde{S}_i$		
C_1	0.01	0.25	0.41
C_2	0.01	0.35	0.49
C_3	0.00	0.15	0.24
C_4	0.00	0.23	39.22
C_5	0.00	0.02	0.03

Figure3. The composed Fuzzy column Matrix

Step4: In this step, we determinate the composed Crisp column Matrix based on value degree as figure4:

Criteria's	C1	C2	C3	C4	C5
C1	1	1	0.696463	0.999329	0.092892
C2	0.812904	1	0.544446	0.996986	0.061244
C3	1	1	1	1	0.167957
C4	1	1	0.756384	1	0.108786
C5	1	1	1	1	1
V(Ci>C1,C2,C3,C4,C5)	0.812904	1	0.544446	0.996986	0.061244

Figure4. The composed Crisp column Matrix based on value degree

Step5: Consistency check and deriving priorities and Weighting as figure5:
In this paper, Fuzzy AHP is implemented in the software Excel. Calculated consistency ratio by software is 0.04 and 0.03 for tow indexes, next that represents the relative consistency of decision makers' judgments.

Criteria's	C_1	C_2	C_3	C_4	C_5
	Quality	Price	Delivery	Service	Technical Capability
Weight	0.238	0.29278	0.1594	0.29189	0.01793
Rank	3	1	4	2	5

Figure5. The Weighting of Criteria's

4.2. Ranking the Alternatives According to Weights of Criteria's using Fuzzy AHP

Now we use fuzzy AHP to rank the suppliers (Alternatives: three suppliers) of Abzarsazi Company in Iran according to the five criteria's as below steps:
Step1: First, we give the geometric Fuzzy Pair-wise Matrix of alternatives base on criteria's. For example the geometric Fuzzy Pair-wise Matrix of alternatives according to criteria 1 is as below:

Geometric (C1)	A1			A2			A3		
A1	1.00	1.00	1.00	2.00	3.27	4.16	6.26	7.47	8.65
A2	0.24	0.31	0.50	1.00	1.00	1.00	7.32	8.47	9.32
A3	0.12	0.13	0.16	0.11	0.12	0.14	1.00	1.00	1.00

Figure6. The geometric Fuzzy Pair-wise Matrix base on C1

Step2: Next, we calculate the composed Fuzzy column Matrix in excel software as figure7:

C1	Si		
A1	0.36	0.52	0.73
A2	0.33	0.43	0.57
A3	0.05	0.05	0.07

Figure7. The composed Fuzzy column Matrix

Step3: In this step, we determinate the composed Crisp column Matrix based on value degree as figure8:

C1	A1	A2	A3
A1	1	0.710737	-1.683201
A2	1	1	-2.32808
A3	1	1	1
V(Ai>A1,A2,A3)	1	0.710737	-2.32808

Figure8. The composed Crisp column Matrix based on value degree

Step4: Consistency check and deriving priorities and Weighting as figure9:

In this paper, Fuzzy AHP is implemented in the software Excel. Calculated consistency ratio by software is 0.05 and 0.04 for tow indexes, next that represents the relative consistency of decision makers' judgments.

C1	A1	A2	A3
Weight	-1.619845	-1.151283	3.771128

Figure9. The Weighting of Alternatives

Such, the composed crisp column matrix based on value degree and weighting of alternatives according to C2, C3, C4, C5 are as figures (10-13):

C2	A1	A2	A3
A1	1	1	0.350197
A2	0.89476	1	0.198218
A3	1	1	1
V(Ai>A1,A2,A3)	0.89476	1	0.198218
Weight	0.427506	0.477788	0.094706

Figure10. The composed crisp column matrix based on value degree and weighting of alternatives

C3	A1	A2	A3
A1	1	1	0.81515
A2	0.7309	1	0.573371
A3	1	1	1
V(Ai>A1,A2,A3)	0.7309	1	0.573371
Weight	0.317193	0.433977	0.24883

Figure11. The composed crisp column matrix based on value degree and weighting of alternatives

C4	A1	A2	A3
A1	1	0.803941	0.034949
A2	1	1	0.040357
A3	1	1	1
V(Ai>A1,A2,A3)	1	0.803941	0.034949
Weight	0.543807	0.437188	0.019005

Figure12. The composed crisp column matrix based on value degree and weighting of alternatives

C5	A1	A2	A3
A1	1	0.850342	0.01925

A2	1	1	0.004652
A3	1	1	1
V(Ai>A1,A2,A3)	1	0.850342	0.004652
Weight	0.539085	0.458407	0.002508

Figure13. The composed crisp column matrix based on value degree and weighting of alternatives

Finally, scoring and ranking of alternatives is as figure14:

Alternatives	Score	Rank
A1	-0.05595	3
A2	0.062754	2
A3	0.993193	1

Figure14. Final ranking of alternatives

For example the score (0.062754) of A2 is calculated as below:
0.243564

$$0.062754 = (0.243564 \times -1.151283) + (0.256314 \times 0.477788) + (0.186953 \times 0.433977) + (0.188093 \times 0.437188) + (0.125076 \times 0.458407)$$

CONCLUSION

Supply chain management is an important concept and discipline which enables business partners to integrate products and services effectively and to build long-term relationships. SCM can be extensively defined as effective coordination on material, product, delivery, payment, and information flows between enterprises and trading partners (Wu and Chuang , 2010). Supplier Evaluation is of increasing importance for companies and their further business development due to the fact that companies are concentrating on their core competencies.
In this study, we first identified the evaluation criteria's of suppliers through the research literature. In finally, the suppliers of Abzarsazi industries in Iran are ranked using Fuzzy AHP.

REFERENCES

[1] Ballou, H. R. 1992. Basic Business Logistics, Prentice-Hall, Inc. Englewood Cliffs, USA.
[2] Chopra, S., Meindl, P., 2001. Supply Chain Management: Strategy, Planning and Operation, Prentice Hall Inc.,
[3] Dickson, G. W., 1996. An analysis of vendor selection systems and decision. Journal of Research, 141, 70–87.
[4] Dooley K., 1995. Purchasing and supply, Operational Research, 8, 3, 21-25
[5] Fazel Zarandi, H. M. et al., 2002. Supply chain: Crips and fuzzy aspects, Int. J. Appl. Math. Computer, Sci., 12, 3, 423-435.
[6] Gharakhani D., 2012. The Evaluation of Supplier Selection Criteria by Fuzzy DEMATEL Method, Journal of Basic and Applied Scientific Research, 2(4)3215-3224.
[7] Harun B., 2011, Multi-criteria approach to ranking suppliers in the supply chains concept, Technical Gazette, 18, 3, 393-401
[8] Ho, W., Xu, X., Dey, P. K. 2009. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review, European Journal of Operational Research, 202 (1), 16-24, p. 1
[9] Li, X., & Wang, Q., (2007). Coordination mechanisms of supply chain systems. European Journal of Operational Research, 179(1), pp.1–16.
[10] Oliveria, R.C. and Lourenc¸o, J.C. (2002), "A multi-criteria model for assigning new orders to service suppliers", European Journal of Operational Research, Vol. 139, 390-399.
[11] Pi, W. N., & Low, C. (2006). Supplier evaluation and selection via Taguchi loss functions and an AHP. The International Journal of Advanced Manufacturing Technology, 27(5), 625–630.
[12] Thomas, D. J., Griffin P. M., 1996. Invited review coordinated supply chain management, European Journal of Operation Research, 94, 1-15.
[13] Tilanus, B., 1997. Information Systems in Logistics and Transportation, Elsevier, Science Ltd., UK.
[14] Wang, S. J., & Hu, H. A., (2005). Application of rough set on supplier's determination. Paper presented at the third annual conference on uncertainty.
[15] Wu, I-L, Chuang , C-H., (2010), examining the diffusion of electronic supply chain management with external antecedents and firm performance: A multi-stage analysis, Decision Support Systems, 50, PP.103–115.
[16] Yan, H., Yu, Z. and Cheng, T.C.E. (2003), A strategic model for supply chain design with logical constraints: formulation and solution, Computers & Operations Research, Vol. 30, 2135-55.
[17] Bellman, R., &Zadeh, L. A., 1970. Decision making in a fuzzy environment. Management science, 17(4), 141–164.
[18] Beynon, M., Cosker, D., & Marshall, D., 2001. An expert system for multi-criteria decision making using Dempster Shafer theory. Expert Systems with Applications, 20(4), 357–367.
[19] Boender C.G.E., deGraan J.G., F.A. 1989. Lootsma, Multi-criteria decision analysis with fuzzy pairwise comparisons, Fuzzy Sets and Systems 29, 133–143.

[20] Buckley J.J., Feuring T., Hayashi Y., 2001. Fuzzy hierarchical analysis revisited, European Journal of Operational Research 129 (1), 48–64. References

[21] Buckley J.J., Fuzzy hierarchical analysis, Fuzzy Sets and Systems 17 (1985) 233–247.

[22] Cathy M., Johan S., Klaas D.B., Alain V., PROMETHEE and AHP: The design of operational synergies in multi-criteria analysis. Strengthening PROMETHEE with ideas of AHP, European Journal of Operational Research 153 (2004) 307–317.

[23] Chang D.-Y., Applications of the extent analysis method on fuzzy AHP, European Journal of Operational Research 95 (1996) 649–655.

[24] Chen M.-F., Tzeng G.-H., C.G. Ding, 2008. Combining fuzzy AHP with MDS in identifying the preference similarity of alternatives, Applied Soft Computing, 8,110–117.

[25] Chen, S. J., & Chen, S. M., 2005. A prioritized information fusion method for handling fuzzy decision-making problems. Applied Intelligence, 22(3), 219–232.

[26] Chen, S. M., & Lee, L. W., 2010. Fuzzy multiple attributes group decision-making based on the interval type-2 TOPSIS method. Expert Systems with Applications, 37(4), 2790–2798.

[27] Chen, S. M., & Wang, C. H., 2009. A generalized model for prioritized multicriteria decision making systems. Expert Systems with Applications, 36(3), 4773–4783.

[28] Csutora R., Buckley J.J., 2001. Fuzzy hierarchical analysis: the Lambda-Max method, Fuzzy Sets and Systems 120 (2), 181–195.

[29] Dagdeviren, M., 2008. Decision making in equipment selection: an integrated approach with AHP and PROMETHEE. Journal of Intelligent Manufacturing, 19, 397-406.

[30] Deng H., 1999. Multi-criteria analysis with fuzzy pairwise comparison, International Journal of Approximate Reasoning 21 (3), 215–231.

[31] Duran, O., &Aguilo, J., 2007. Computer-aided machine-tool selection based on a fuzzy-AHP approach. Expert Systems with Applications, 34(3), 1787–1794.

[32] Enea M., T. Piazza, 2004. Project selection by constrained fuzzy AHP, Fuzzy Optimization and Decision Making 3, 39–62.

[33] Erensal Y.C., Öncan, T., Demircan M.L., 2006. Determining key capabilities in technology management using fuzzy analytic hierarchy process: A case study of Turkey, Information Sciences 176 (18), 2755–2770.

[34] Ferreira, L., Lake, M., 2002. Towards a methodology to evaluate public transport projects. Physical Infrastructure Centre. Research report 02-03, School of Civic Engineering, Queensland University of Technology, Brisbane.

[35] Fu, G., 2008. A fuzzy optimization method for multicriteria decision making: An application to reservoir flood control operation. Expert Systems with Applications, 34(1), 145–149.

[36] Gogus O., Boucher T.O., 1997. A consistency test for rational weights in multi-criterion decision analysis with fuzzy pair-wise comparisons, Fuzzy Sets and Systems 86, 129–138.

[37] Gogus O., Boucher T.O., 1998. Strong transitivity and weak monotonicity in fuzzy pairwise comparisons, Fuzzy Sets and Systems 94, 133–144.

[38] Göleç A., Tas kın H., 2007. Novel methodologies and a comparative study for manufacturing systems performance evaluations, Information Sciences 177 (23), 5253–5274.

[39] Hua, Z., Gong, B., &Xu, X., 2008. A DS–AHP approach for multi-attribute decision making problem with incomplete information. Expert Systems with Applications, 34(3), 2221–2227.

[40] Janic, 2003. Multi-criteria evaluation of high-speed rail, trans rapid maglev and air passenger transport in Europe. Transportation planning and technology 26 (6), 491-512.

[41] Kahraman, C., &Cebi, S., 2009. A new multi-attribute decision making method: Hierarchical fuzzy axiomatic design. Expert Systems with Applications, 36(3), 4848–4861.

[42] Konidari, P., Mavrakis, D., 2007. A multi-criteria evaluation method for climate change mitigation policy instruments. Energy Policy 35, 6235-6257.

[43] Kulak O., Kahraman C., 2005. Fuzzy multi-attribute selection among transportation companies using axiomatic design and analytic hierarchy process, Information Sciences 170 (2–4), 191–21

[44] Kwon, O., & Kim, M., 2004. MyMessage: Case-based reasoning and multicriteria decision making techniques for intelligent context-aware message filtering. Expert Systems with Applications, 27(3), 467–480.

[45] Kwon, O., Kim, K. Y., & Lee, K. C., 2007. MM-DSS: Integrating multimedia and decision-making knowledge in decision support systems. Expert Systems with Applications, 32(2), 441–457.

[46] Lin, H. Y., Hsu, P. Y., & Sheen, G. J., 2007. A fuzzy-based decision-making procedure for data warehouse system selection. Expert Systems with Applications, 32(3), 939–953.

[47] Macharis, C., Verbeke, A., De Brucker, K., 2004. The strategic evaluation of new technologies through multi-criteria analysis: the Advisors case. Research in Transportation Economics, 8, 443-462.

[48] Mikhailov L., 2000. A fuzzy programming method for deriving priorities in the analytic hierarchy process, Journal of Operational Research Society 51, 341–349

[49] Mikhailov L., 2003. Deriving priorities from fuzzy pairwise comparison judgements, Fuzzy Sets and Systems 134 (3), 365–385.

[50] Mikhailov L., 2003. Deriving priorities from fuzzy pairwise comparison judgements, Fuzzy Sets and Systems 134 (3), 365–385.

[51] Mohanty, B.K. Singh, N., 1994. Fuzzy relational equations in analytical hierarchy process, Fuzzy Sets and Systems 63, 11–19.

[52] Ruoing X., Xiaoyan Z., 1996. Fuzzy logarithmic least squares ranking method in analytical hierarchy process, Fuzzy Sets and Systems 77, 175–190.

[53] Ruoing, X., Xiaoyan Z., 1992. Extensions of the analytic hierarchy process in fuzzy environment, Fuzzy Sets and Systems 52, 251–257.

[54] Ruoning X., 2000. Fuzzy least square priority method in the analytic hierarchy process, Fuzzy Sets System 112, 395–404.

[55] Saaty, 1995. Decision making for leaders. The analytical hierarchy process for decisions in a complex world. RWS publications, Pittsburgh.

[56] Saaty, 2008. Decision making with the analytic hierarchy process. International Journal of Services Sciences 1(1), 83-98.

[57] Saaty, T.L., 1982. Decision making for leaders. Lifetime learning publications. Wadsworth, Belmont.

[58] Saaty, T.L., 1988. The analytical hierarchy process. McGrawHill, New York.

[59] Sharifi, M.A., Boerboom, L., Shamsudin, K.B., Veeramuthu, L., 2006. Spatial multiple criteria decision analysis in integrated planning for public transport and land use development study in Klang Valley Malaysia. ISPRS Technical Commission II Symposium, Vienna, 12-14.

[60] Tacker, E. C., & Silvia, M. T., 1991. Decision making in complex environments under conditions of high cognitive loading: A personal expert systems approach. Expert Systems with Applications, 2(2–3), 121–127.
[61] Tudela, A., Akiki, N., Cisternas, R., 2006. Comparing the output of cost benefit and multi-criteria analysis. An application to urban transport investment. Transportation Research Part A, 40, 414-423.
[62] Tzeng, G.H., Cheng-Wei, L., Opricovic, S., 2005. Multi-criteria analysis of alternative fuel buses for public transportation. Energy Policy 33, 1373-1383.
[63] Vaidya, O.S., Kumar S., 2006. Analytic hierarchy process: an overview of applications, European J. Oper. Res. 169, 1–29.
[64] Van Laarhoven P.J. M, W. Pedrycz, 1983. A fuzzy extension of Saaty's priority theory, Fuzzy Sets and Systems 11, 229–241.
[65] Wang, J.J. and Yang, D.L., 2007. Using a hybrid multi-criteria decision aid method for information systems outsourcing. Computers and Operation Research 34, 3691-3700.
[66] Yager, R. R. (1991). Non-monotonic set theoretic operations. Fuzzy Sets and Systems, 42(2), 173–190.
[67] Yager, R. R. (1992). Second order structures in multi-criteria decision making. International Journal of Man–Machine Studies, 36(6), 553–570.
[68] Yu C.S. A., 2002. GP-AHP method for solving group decision-making fuzzy AHP problems, Computers and Operations Research 29 (14), 1969–2001.
[69] Zhu, K. Jing J. Y., Chang D.Y., 1999. A discussion on extent analysis method and applications of fuzzy AHP, European Journal of Operational Research 116 (2), 450–456.