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A Fuzzy Analytical Hierarchy Process Application in Personnel Selection in IT Companies: A Case Study in a Spin-off Company

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Personnel selection is a strategic decision in knowledge-intense enterprises. Choosing the right qualified labor is crucial for IT companies. While evaluating the possible candidates for required positions, many aspects should be considered, such as technical skills, individual skills, etc. Multi-criteria decision making methods give supportive solutions for problems involving multi-dimensional human judgment. Human decisions mostly exhibit gradual judgment, vagueness and imprecision. Fuzzy set theory is a fundamental tool to develop models with uncertainty and relativity. This study aims to build a fuzzy analytical hierarchy process method for personnel selection in IT companies. A case study in a spin-off IT company in Sakarya University, Technology Development Zone was conducted to acquire empirical evidence. Furthermore the proposed study provides a decision support system for human resource departments to relax personnel selection problem.

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1. Introduction

Recruiting qualified employees is one of the most challenging topics in information technology (IT) companies. With each passing day, rising competitive environment and rapid developments in the technology makes this kind of selection problems more complex to solve. Thus conventional techniques in personnel selection (PS) used by human resources departments might not be sufficient to distinguish qualified labor from one another. At this point, if the problem is modeled by a multi-criteria decision making (MCDM) approach, fuzzy analytical hierarchy process (FAHP) can be used as an effective tool for recruitment in IT companies.

There are several studies [1–17] in literature offering solutions to PS problem with different methodologies. Fewer of them focus on FAHP method in PS [1, 12], while other studies focus on MCDM methods, fuzzy TOPSIS methods and other hybrid methods.

As stated before, there are similar studies about PS with MCDM methods in related literature, however only one of the studies by Aggarwal [4], especially focuses on PS in IT companies with AHP-FLP approach. In this study distinctively from literature, FAHP method is used in PS of a spin-off company. One of the other contributions of this study is an empirical evidence of usage of multi criteria decision making method in IT companies. Industrial empirical evidence supports validating usage of FAHP method in PS problems in IT companies.

Within this context, this study investigates qualified PS in IT companies with FAHP by using pairwise comparisons. A critical point in FAHP is the process of determining control criteria for alternatives. In this study, criteria sets which are crucial for IT companies are determined by both literature survey and experts' opinions. Finally, a case study in a spin-off company has been conducted with the proposed criteria set.

2. Fuzzy AHP method

There are many fuzzy AHP methods for calculating weights of criteria and ranking of the alternatives. Author used Chang's extent analysis method [18] for calculations. The extent analysis method is described below.

Let $X = \{x_1, x_2, ..., x_n\}$ be an object set, and $G = \{g_1, g_2, ..., g_m\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained with the following signs:

$M^1_{g_i}$, $M^2_{g_i}$,..., $M^m_{g_i}$, $i = 1, 2, ..., n$, where all $M^j_{g_i}$ $(j = 1, 2, ..., m)$ are triangular fuzzy numbers.

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as

$$S_i = \sum_j^m M^j_{g_i} \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M^j_{g_i}\right]^{-1}. \quad (1)$$

To obtain $\sum_j^m M^j_{g_i}$, one should perform the fuzzy addition operation of m extent analysis values for a particular matrix, such that

$$\sum_j^m M^j_{g_i} = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j\right) \quad (2)$$

and to obtain $\left[\sum_{i=1}^n \sum_{j=1}^m M^j_{g_i}\right]^{-1}$, one should perform the

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fuzzy addition operation of $M_{g_i}^j$ $(j = 1, 2, ..., m)$ values, such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \tag{3}$$

and then compute the inverse of the vector in Eq. (3) such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} l_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} u_i}\right). \tag{4}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = \sup\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right]$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt\left(M_1 \bigcap M_2\right) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise,} \end{cases} \tag{5}$$

where d is the ordinate of the highest intersection point d between μ_{M_1} and μ_{M_2}. Both values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are required in order to compare M_1 and M_2.

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

$$V(M \geq M_1, M_2, ..., M_k) =$$
$$V\left[(M \geq M_1) \wedge (M \geq M_2) \wedge ... \wedge (M \geq M_k)\right] =$$
$$\min V(M \geq M_i), \ i = 1, 2, ..., k. \tag{6}$$

Assuming that

$$d'(A_i) = \min V(S_i \geq S_k) \text{ for } k = 1, 2, ..., n; \ k \neq i, \tag{7}$$

the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), ..., d'(A_n)\right)^T, \tag{8}$$

where $A_i (i = 1, 2, ..., n)$ are n elements.

Step 4: Via the normalization, the normalized weight vectors are

$$W = \left(d(A_1), d(A_2), ..., d(A_n)\right)^T, \tag{9}$$

where W is a nonfuzzy number.

Fuzzy linguistic terms and corresponding triangular fuzzy numbers which are used for pairwise comparisons in Fuzzy AHP method are shown in Table I. The pairwise comparisons are implemented according to Fuzzy AHP method within each main criteria or sub-criteria in order to generate relative importance weights.

TABLE I

The linguistic variables and triangular fuzzy numbers for relative importance weights.

Linguistic variables	Fuzzy num.	Triangular fuzzy number	Triangular fuzzy reciprocal num.
Equally important (EI)	$\tilde{1}$	(1, 1, 1)	(1, 1, 1)
Weakly important (WI)	$\tilde{3}$	(1, 3, 5)	(1/5, 1/3, 1)
Strongly important (SI)	$\tilde{5}$	(3, 5, 7)	(1/7, 1/5, 1/3)
Very important (VI)	$\tilde{7}$	(5, 7, 9)	(1/9, 1/7, 1/5)
Absolutely import. (AI)	$\tilde{9}$	(7, 9, 9)	(1/9, 1/9, 1/7)

3. IT personnel selection using fuzzy AHP approach

In this section FAHP method with author's proposed criteria set has been illustrated with a case study in a spin-off IT company in Sakarya University Technology Development Zone. Recruitment process started with application of the candidates for "junior developer" position. Three of the candidates who applied for the available position have been recalled for a "two-staged interview" process. First stage was about technical skills and qualifications (basic technical skills) and was conducted by IT director of the company. Second stage was about general competencies (individual and auxiliary skills) and was conducted by general manager.

TABLE II

Set of main criteria.

C1	Basic technical requirements
C2	Individual skills
C3	Auxiliary skills

TABLE III

Set of sub-criteria.

C11	Programming capabilities (Front end development languages HTML, CSS, JS/JQ)
C12	Past development experience (Domain specific knowledge)
C13	Education (B.Sc., B.Eng., M.Sc. etc. degrees and certificates)
C14	Foreign language
C21	Analytical thinking (Swift learning capabilities)
C22	Communication and reporting skills (written and oral)
C23	Teamwork adaptation
C31	Willingness (open minded for innovation)
C32	Crisis handling (decision making and problem solving)
C33	Effective time management (planning, organizing and controlling resources over time)

Before the interview, the importance of main criteria and sub-criteria as listed in Table II and Table III, respectively, were pairwise compared for junior developer position with the linguistic variables listed in Table I. While both stages of interviews were being conducted, possible candidate listed in Table IV were pairwise compared according to each sub-criteria listed in Table III.

After acquiring the required knowledge from candidates and weighting the criteria and sub-criteria set, candidates were rated according to the hierarchy in Fig. 1.

TABLE IV

Possible candidates who applied for junior developer position.

P1	Possible candidate 1
P2	Possible candidate 2
P3	Possible candidate 3

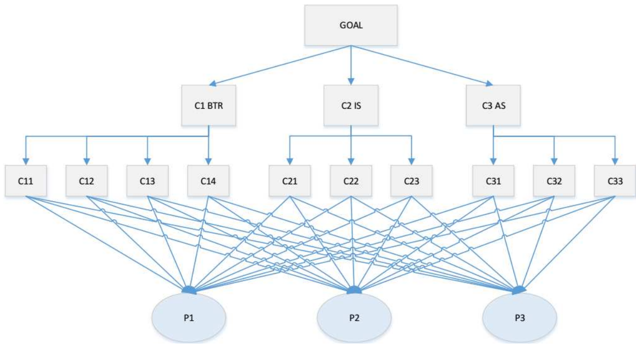

Fig. 1. Hierarchical representation of goal (PS), criteria, sub-criteria and alternatives.

As it can be seen in Table V, most important main criteria was determined as "C1: Basic technical requirements".

TABLE V

Weights of main criteria.

Criteria	Weights	Rank
C1	0.573	1
C2	0.375	2
C3	0.051	3

Sub-criteria weights are determined as shown in Table VI. C11, C12 and C21 were listed as the top three important criteria.

The performance data for each possible candidate for junior developer position is listed in Table VII. As it is clearly seen from Table VII, P1 is ranked as the best and is recommended for employment.

4. Conclusions

Personnel selection is a critical strategic decision in many industries as well as in IT industry. PS process determines the input quality of human resource, which involves some uncertainties of the performances and weights. In this study PS has been considered as a fuzzy MCDM problem. Fuzzy AHP was applied in a spin-off IT company in Sakarya University Technology Development Zone.

The proposed FAHP approach is not meant to replace the people who work in human resource departments. On the contrary, it is a decision support system for decision makers in the related area.

As a future work of this study, human-machine interfaces should be developed for industrial usage, because computers and solely software applications (MATLAB, MS Excel, Superdecisions, Expertchoice etc.) may not be time efficient in terms of data input, especially when dimensions of the comparison matrices increase. Reprogrammable hand-held devices or smartphone applications (preferable built-in voice recognition and natural language processing) can overcome this inefficiency problem. While evading long time Q&A sessions, these application solutions can lead to more consistent results.

TABLE VI

Weights of sub-criteria.

Criteria	Weights	Rank
C11	0.244	1
C12	0.218	2
C13	0.094	5
C14	0.017	8
C21	0.214	3
C22	0.161	4
C23	0	10
C31	0.021	6
C32	0.009	9
C33	0.021	7

TABLE VII

Ratings of possible candidates.

Criteria	Weights	Rank
P1	0.521	1
P2	0.181	3
P3	0.299	2

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