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A PRACTICAL FUZZY DECISION SUPPORT MODEL FOR PERSONNEL SELECTION

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Abstract: *In this paper a fuzzy decision making model for personnel selection problem is presented. Fuzzy rating method and Analytic Hierarchy Process (AHP) are used to model and solve the problem. Relative importance of job related criteria are determined by pairwise comparisons, and candidates are evaluated with six-level linguistic variables with respect to each criterion, final ratings of each candidate are computed by using the fuzzy rating method. Computer software is also developed for the implementation of the proposed approach.*

Özet: *Bu makalede personel seçimi için bulanık mantık temelli pratik bir model geliştirildi ve tanıtıldı. Model* bulanık derecelendirme *ve* analitik hiyerarşi prosesi *tekniklerini kullanarak geliştirildi. İş ile ilgili kriterlerin derecelendirilmesi için karşılaştırma matrisleri kullanıldı. Adaylar altı dereceli dilsel bulanık değişkenler kullanılarak her bir kriter için değerlendirildi ve her bir adayın toplam derecesi bulanık derecelendirme yöntemi ile belirlendi. Önerilen yöntemin uygulanabilmesi için bir bilgisayar programı geliştirildi.*

1. INTRODUCTION

Personnel selection is the search for an optimal match between the job and the amount of any particular characteristic that an applicant may possess (Ivancevich, 2001). This matching can be carried out only if applicants are evaluated according to the correct criteria by proper methods. Otherwise hiring might be a gamble with two possible results: "*true* or *false*". However, personnel selection is not an inconsequential process to take a risk in business environment in which a mistake, like an ineffective management decision, can cause terrible outcomes.

In the literature, some resources recognize personnel selection as a *prediction*; the duty is to predict which applicants will be successful if hired (Robbins and Coulter, 2002). Employees are evaluated as successful if they perform well on the criteria vital for the job and the organization. As an example, in situation of filling a forward football player position in a football team, the selection process should be able to predict which player will score high number of goals if transferred, because goal is vital for the team. Prediction is correct when the applicant was predicted to be successful and

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proved to be successful on the job, or when the applicant predicted to be unsuccessful and would perform accordingly if hired. In the first case, applicant successfully hired; in the second case successfully rejected, these are correct decisions. Rejecting candidates who would have performed successfully on the job and accepting those who ultimately perform poorly are two cases in which decision maker made incorrect decisions.

To make right hiring decisions and to reduce the risk in the selection processes, organizations have to determine criteria and their levels that individuals have to posses for the success of the job and the organization. These criteria can be divided into four sub-categories: *personal characteristics*, *education*, *experience*, and *physical characteristics*. Personal characteristics include marital status, sex, age, some specific aptitudes and skills. And personality type can be also considered in this category. For distinct jobs, employer may use formal education criterion as a stipulation, especially a university degree. As an example, for an open management position, employer may ask for a specific education diploma depending on the position requirements. Even some employers may prefer diploma from a specific university or institute, they may also consider graduation degree as important tool for election of applicants. Next category of criteria is experience which includes past performance. Experience and past performance of a candidate can be considered as indicators for the future performance, not the overall experience, only relevant experience and performance should be taken into consideration by employer during selection process (Ivancevich, 2001). Physical characteristic is a selection criterion if it is directly related to the effectiveness of the position. For example, beauty is important for models; taller men are preferred by security firms as well.

In a typical personnel selection process, candidates applied for the job are evaluated with respect to the criteria determined by the organizations. Important information about candidates' skills and weakness are obtained from these evaluations by using some common tools: application forms, interviews, reference checks, personality and ability tests, and physical examination. Some of these tools are more effective than others depending on the job and the nature of the organization, but the highest degree of benefit can be taken from their combination. Unfortunately there are so many organizations using some of tools instead of well-designed selection process, even there are many organizations making hiring decision with only an application form, interview or a letter of recommendation (Telman and Türetgen, 2004).

Collected information from selection process tools is not sufficient alone, there is still another task: "deciding *which candidate is better*; *whose qualifications fit the job requirements*". This can be done intuitionally or systematically. Obviously systematic way is better, because it is consistent in any situation and away from subjective evaluations.

This paper aims to develop a practical fuzzy decision support model, which provides a systematic approach for the personnel selection problem. *Fuzzy rating method* is mainly used in combination with pairwise comparison of selection criteria based on the *analytic hierarchy process (AHP)*.

2. THEORETICAL FOUNDATION OF THE PRPOSED MODEL

2.1. Fuzzy Logic

Fuzzy Logic was introduced in 1965 by Lotfi A. Zadeh (Şen, 2001). It is a very good tool for decision problems especially when vague and imprecise or partially precise descriptions are possible (Butkiewicz, 2002). In real life, everybody makes decisions that contain alternatives and multiple-criteria. Decision makers select, classify the alternatives or develop new alternatives according to the pre-defined criteria. In many situations, these alternatives are evaluated by using quantitative and qualitative variables; because fuzzy models can manipulate both of them, they are more effective than other models for these kinds of decision making situations. A fuzzy model is the idea of a fuzzy set differs from conventional (crisp) sets in its semi permeable boundary membrane, instead of a characteristic function that has two states: inclusion and exclusion, the fuzzy set has a function that admits a degree of membership in the set from complete exclusion "0" to absolute inclusion "1". The value "0" is used to symbolize complete non-membership, the value "1" is used to symbolize complete membership, and the values in between them are used to symbolize intermediate degrees of membership (Fayad and Webb, 1999). Fuzzy set theory uses also linguistic variables whose values are words or sentences in a natural or synthetic language (Zadeh, 1973) to represent imprecise information and vagueness of human language.

A fuzzy number is a special case of a fuzzy set, and it can be described as a subset of real numbers whose membership function μ_A is a continuous mapping from R (real line) to a closed interval [0,1] (Liang and Wang, 1994), which is also both normal and convex. Triangular, trapezoidal and Gaussian are some types of fuzzy numbers, however triangular and trapezoidal are more common types which are defined by three and four parameters respectively. The membership functions for triangular fuzzy numbers are triangular in shape and can be represented by a triplet (*a*, *b*, *c*), indicating the lower limit of support, the mode (core) and the upper limit of support (Chen, 1996). Triangular fuzzy numbers are most common fuzzy numbers, and the main reason for using them is that decision makers find them intuitively easy to use (Liang and Wang, 1994). Membership function of triangular fuzzy number is linear in both left and right sides and is described as in Equation 1 (see also Figure 1).

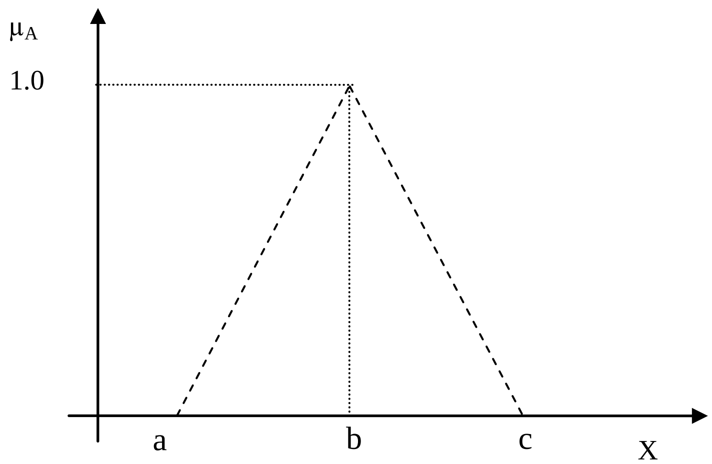

Figure 1. Triangular fuzzy number (*a*, *b*, *c*)

$$\mu_A(x) = \begin{cases} (x-a)/(b-a), & a \le x \le b \\ (c-x)/(c-b), & b \le x \le c \\ 0, & x < a \text{ or } x > c \end{cases} \quad (1)$$

Methods of operations called as *extended algebraic operations* on fuzzy numbers were developed by Dubois and Prade in 1978 (Chen, 1996). These operations contain some approximations: fuzzy sum, fuzzy subtraction and multiplication of a triangular fuzzy number by a real number produce also triangular fuzzy numbers, although multiplication of two fuzzy numbers does not produce triangular fuzzy number, it is just an approximations (Equation 2).

$$
\begin{aligned}
&A_1 = (a_1, b_1, c_1) \; and \; A_2 = (a_2, b_2, c_2) \\
&A_1 + A_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \\
&A_1 - A_2 = (a_1 - a_2, b_1 - b_2, c_1 - c_2) \qquad (2) \\
&k * A_1 = (ka_1, kb_1, kc_1), \quad k \in R \\
&A_1 * A_2 = (a_1 * a_2, b_1 * b_2, c_1 * c_2), \quad if \; a_1 \geq 0 \; and \; a_2 \geq 0
\end{aligned}
$$

In fuzzy multiple criteria decision support problems, the ratings of different alternatives versus various criteria and the weights of the criteria are usually assessed in linguistic values represented by fuzzy number. Chen (1996) defines fuzzy multiple criteria decision making by rating method as follow: a number of alternatives are denoted as A_1, A_2, …, A_m, the criteria (aspects) that influence all the alternatives are identified as C_1, C_2, …, C_n, then for a given alternative A_i, the relative merit of criterion C_j is assessed by a rating, denoted as r_{ij}. The relative importance of each criterion is assessed by a weighting coefficient, w_j for criterion C_j. In the fuzzy rating method, alternative A_i receives the weighted average rating which can be calculated by Equation 3.

$$\bar{r}_i = \sum_{j=1}^{n} r_{ij} w_j \qquad (3)$$

2.2. Analytic Hierarchy Process (AHP)

AHP is another flexible decision making tool for multi criteria problems and firstly introduced in 1977 by Thomas L. Saaty. AHP contains multi level hierarchical structure: objective (goal), criteria (and sub-criteria), and alternatives (Figure 2). Decision maker provides judgments about relative importance of each criterion and then state a preference on each criterion for each decision alternative. These judgments are made by pairwise comparisons in matrix format which are quantified by using a scale, with values from 1 to 9 (Table 1).

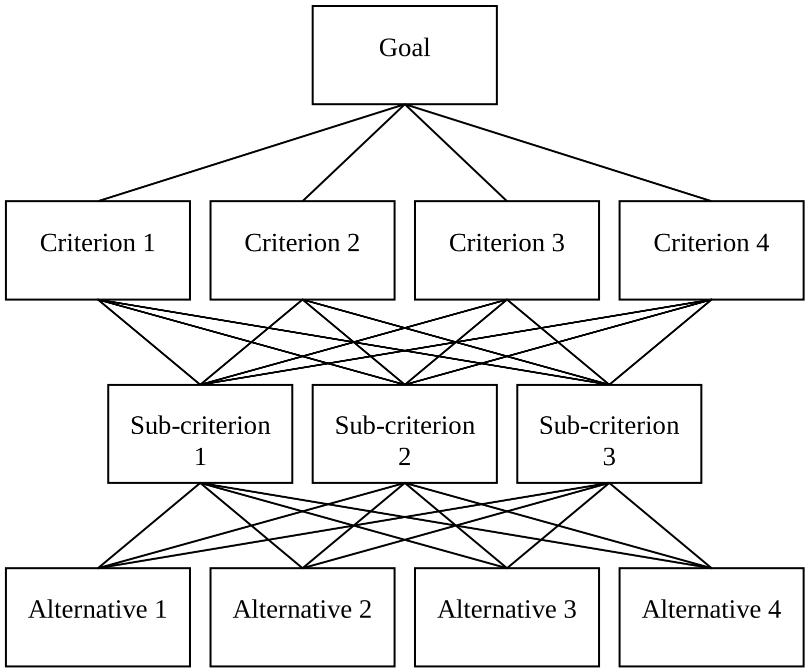

Figure 2. Hierarchical structure of AHP

Table 1. Scale of Relative Importance

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.	

Decision maker has to extract the relative importance of criteria and scores of the alternatives from these judgments in the comparison matrix. The next step is to estimate the right principal eigenvector of the judgment matrix. Corresponding maximum left eigenvector is approximated by using the geometric mean of each row. That is, the elements in each row are multiplied with each other and then the n^{th} root is taken (where n is the number of elements in the row). Next the numbers are normalized by dividing them with their sum. Hence priority vector for a judgment matrix is obtained (Triantaphyllou and Mann, 1995). Priority vector consists of weighting coefficients for all elements at the same level of hierarchy. Consistency of comparisons in a judgment matrix can be controlled by consistency ratio (*CR*), and comparison is considered to be sufficiently consistent if corresponding *CR* is less than %10 (Saaty, 1980). Triantaphyllou and Mann (1995) give *CR* calculation in details.

If A_1, A_2, A_3, …, A_m and C_1, C_2, C_3, …, C_n indicate alternatives and criteria respectively. Then x_{ij} is the performance value of i^{th} alternative in terms of j^{th} criterion, and w_j is the weight of the criterion C_j, then final priority for alternative A_i can be calculated by Equation 4.

$$\sum_{j=1}^{n} x_{ij} w_j \qquad for\ i = 1,2,3,...,m \qquad (4)$$

3. FUZZY DECISION MAKING MODEL FOR PERSONNEL SELECTION

Overall personnel selection procedure contains evaluations of candidates with respect to criteria necessary to perform job successfully. Some or all of the evaluations are made with subjective judgments including vague and imprecise information. These kinds of information make fuzzy logic necessary for the personnel selection problem which is a real life problem. *Fuzzy Rating method* is mainly used in the proposed model, in combination with pairwise comparisons of selection criteria based on the original *Analytic Hierarchy Process* to compute the ratings of each candidate who are applied for a particular position. The model has three main parts:

- Determining relative importance of selection criteria (design requirements),
- Evaluation of applicants (alternatives),
- Computation of weighted ratings for each applicant.

The main steps of the proposed approach are shown in Figure 3.

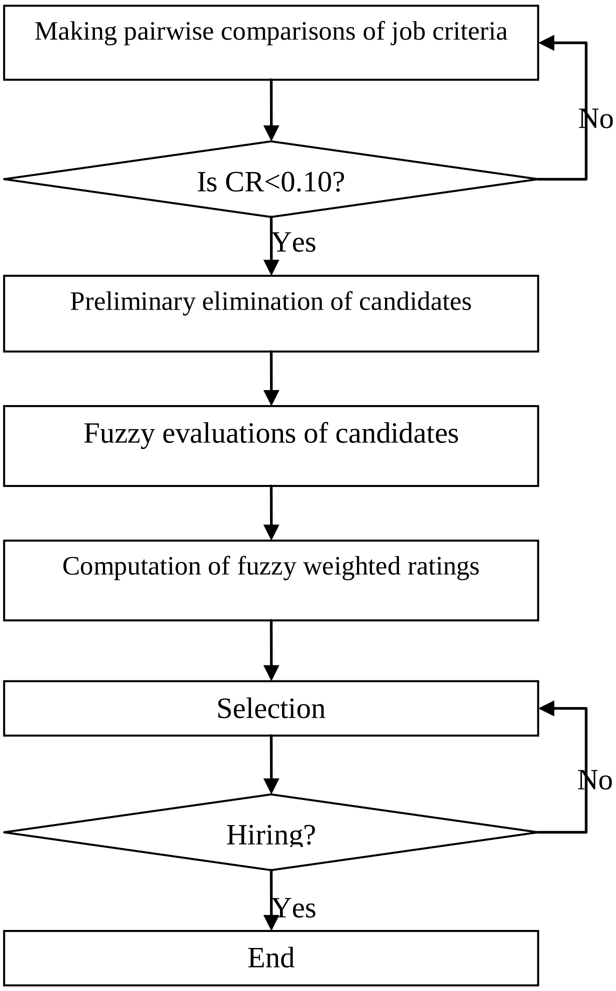

Figure 3. Personnel selection flowchart

Education, *foreign language*, *work experience*, *personality test*, *ability test*, *employment interview*, *reference and background check* are designated as job criteria. In the first step of the model, their relative importances are determined based on pairwise comparisons. These comparisons of criteria are done with respect to the position requirements. As an example: for a position in a research and development department, education may be more important criterion than reference and background check; for a management position, work experience may have higher importance degree.

Applicants are evaluated with respect to the seven job criteria in the second step. Then fuzzy ratings r_{ij} for each applicant A_i with respect to each criterion C_j are obtained by fuzzy evaluations. The following fuzzy terms are used in the evaluations:

VL	very low	(k = 1)
L	low	(k = 2)
ML	medium low	(k = 3)
M	medium	(k = 4)
MH	medium high	(k = 5)
H	high	(k = 6)

The fuzzy terms are converted into numerical values by using the triangular membership functions which are defined by the following equations (Chen, 1996):

For k = 1:

$$\mu_1(x) = \begin{cases} 0, & x \le 0 \text{ or } x \ge 1/5 \\ 1-5x, & 0 \le x \le 1/5 \end{cases} \qquad (5)$$

For k = 2, 3, 4, and 5:

$$\mu_k(x) = \begin{cases} 0, & x \le (k-2)/5 \text{ or } x \ge k/5 \\ 5x-(k-2), & (k-2)/5 \le x \le (k-1)/5 \\ k-5x, & (k-1)/5 \le x \le k/5 \end{cases} \qquad (6)$$

For k = 6:

$$\mu_6(x) = \begin{cases} 0, & x \le 4/5 \text{ or } x \ge 1 \\ 5x-4, & 4/5 \le x \le 1 \end{cases} \qquad (7)$$

Now, the model is processed by using weighting coefficients of criteria and fuzzy ratings of applicants to compute the final weighted average ratings. If w_1, w_2, …, w_j, …, w_n are weighting coefficients of criteria C_1, C_2, C_3,…,C_j,…, C_n, and r_{ij} is fuzzy rating of applicant A_i with respect to criterion C_j, then weighted average rating for A_i is calculated by using Equation 3. Final ratings are in triangular fuzzy number form, and ranking of applicants is carried out based on the middle values of the fuzzy numbers. Higher values of ratings mean higher suitability of the individuals for the particular position.

4. NUMERICAL EXAMPLE

A hypothetical personnel selection problem is designed to demonstrate the computational process of the fuzzy decision support model. Suppose that there are a number of candidates applied for an open *plant manager* position in a company. Some of them, who don't meet the position's basic requirements are eliminated, and the total number of candidates is reduced to seven.

Step 1: Selection criteria (education, foreign language, work experience, personality test, ability test, employment interview, reference and background check) are compared based on the position requirements to determine the weighting coefficients for them (Table 2).

Table 2. Criteria pairwise comparison matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	1	3	1/2	4	5	2	4
C_2	1/3	1	1/3	3	4	1/2	1/2
C_3	2	3	1	5	6	3	3
C_4	1/4	1/3	1/5	1	3	1/3	1/3
C_5	1/5	1/4	1/6	1/3	1	1/5	1/4
C_6	1/2	2	1/3	3	5	1	3
C_7	1/4	2	1/3	3	4	1/3	1

Table 3. Criteria weights

Criterion	**Symbol**	**Weights (w_j)**
Education	C_1	0.241
Foreign Language	C_2	0.094
Work Experience	C_3	0.316
Personality Test	C_4	0.052
Ability Test	C_5	0.031
Employment Interview	C_6	0.162
Reference and Background Check	C_7	0.104
CR = 0.055 **0.055**		

Because CR is lower than 0.10, comparisons are not renovated. It is found that *work experience* is the most important criterion, and *ability test* is the least one.
Step 2: Candidates are evaluated with respect to each criterion with six level fuzzy terms of *VL*, *L*, *ML*, *M*, *MH* and *H*. Evaluations are given in Table 4. Fuzzy ratings of each candidate are obtained in this step.

Table 4. Candidate evaluations

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	*M*	*L*	*MH*	*M*	*M*	*MH*	*MH*
A_2	*MH*	*MH*	*L*	*M*	*MH*	*M*	*L*
A_3	*H*	*H*	*VL*	*MH*	*M*	*ML*	*ML*
A_4	*MH*	*M*	*MH*	*MH*	*M*	*MH*	*MH*
A_5	*MH*	*MH*	*ML*	*M*	*MH*	*M*	*M*
A_6	*H*	*MH*	*L*	*MH*	*M*	*M*	*MH*
A_7	*ML*	*L*	*VL*	*MH*	*MH*	*MH*	*M*

Step 3: Weighted average rating for each candidate is calculated by using Equation 3. Results are in triangular fuzzy number form.

r_1 = (0.479, 0.679, 0.879)
r_2 = (0.305, 0.505, 0.705)
r_3 = (0.365, 0.502, 0.635)
r_4 = (0.575, 0.775, 0.975)
r_5 = (0.410, 0.610, 0.810)
r_6 = (0.420, 0.620, 0.772)
r_7 = (0.237, 0.374, 0.574)

According to these results, applicant who has the highest weighted average rating is candidate 4 (shown with dashed line in Figure 4). This means that, candidate 4 meets position's requirements better than the others, at the same time candidate *7* is the worst. The approximate triangular plot of the membership functions are shown in Figure 4.

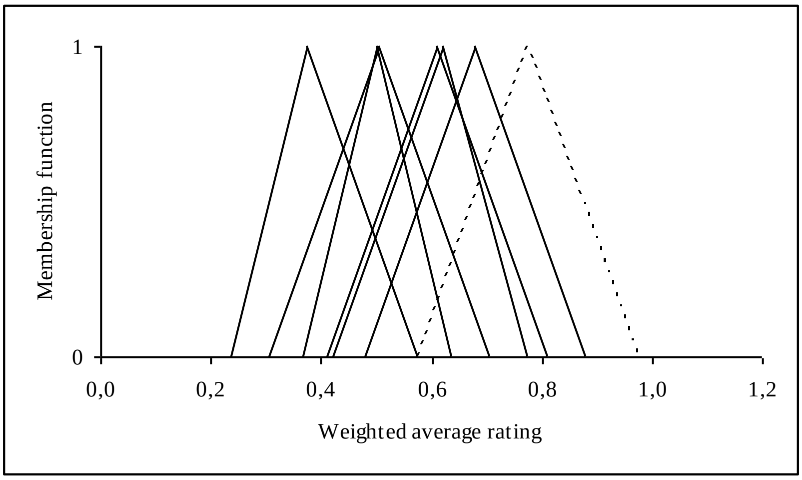

Figure 4. Membership functions of the candidates.

In order to automate the computations a computer program is also developed during the study. The program is written in Microsoft Visual Studio.NET and Microsoft Access. Snapshots from the developed program are presented in Appendix 1. In the program the user is prompted to input relevant data then the program generates all results and reports within seconds. The program also acts as a database for future reference.

5. CONCLUSION

Personnel selection which is an important step of human resource management (HRM) includes evaluation of candidates with respect to the criteria necessary for the job. All or some of these evaluations are subjective and contain vague and imprecise information. Fuzzy logic is an effective tool to manipulate these kinds of information and objects with ill-defined boundaries. In the present study a practical methodology is proposed to help managers in personnel selection. The present approach makes use of AHP and fuzzy rating methods for evaluating candidates. A computer program is also developed during the study which automates the proposed methodology.

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