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DEVELOPMENT OF A FUZZY DECISION MAKING MODEL FOR PERSONNEL SELECTION

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DEVELOPMENT OF A FUZZY DECISION MAKING MODEL FOR PERSONNEL SELECTION

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

DEVELOPMENT OF A FUZZY DECISION MAKING MODEL FOR PERSONNEL SELECTION

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In this thesis, a fuzzy decision making model has been developed and implemented for personnel selection, which is a matching process of individuals' properties with job/position and organizational requirements. Matching process is carried out by evaluating applicants according to the criteria important to perform job successfully, of course these evaluations contains vague and imprecise information. It is very difficult to manipulate these kinds of information with classical statistical methods; however "Fuzzy logic" is more successful to model "personnel selection" like other real-life problems include uncertainties. "Fuzzy rating" method is mainly used in order to solve the problem in this thesis together with Pairwise Comparison technique based on the Analytic Hierarchy Process (AHP). Relative importance of job related criteria are determined by pairwise comparison, candidates are evaluated with six-level linguistic variables with respect to each criterion, final ratings of each candidate are computed by fuzzy rating method.

The developed model is implemented through a computer program which is prepared by using Microsoft Visual Studio .NET along with Microsoft Access as database. The program has been tested with real life "personnel selection" problems as well, with positive results. The results are also discussed.

Key Words: Personnel Selection, Fuzzy Logic, Analytic Hierarchy Process

ÖZET

PERSONEL SEÇİMİ İÇİN BULANIK KARAR VERME MODELİ GELİŞTİRİLMESİ

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Bu çalışmada, personel seçimi için bulanık karar verme modeli geliştirilmiştir. Personel seçimi, organizasyon ve işin gerekleri ile kişi özelliklerinin eşleştirilmesine dayanır. Bu eşleştirme sırasında adaylar, işin başarıyla yürütülebilmesi için gerekli olan kriterler doğrultusunda değerlendirmeye tabi tutulurlar. Bu değerlendirmeler belirsiz ve kesin olmayan bir takım bilgiler içerir. Klasik istatistik araçları, bu çeşit bilgilerle bir sonuca ulaşma konusunda yetersiz kalmaktadır. Ancak "bulanık mantık", personel seçimi gibi belirgin olmayan bilgiler içeren ve günlük hayatta sıkça karşılaşabilecek problemlerin çözümünde daha başarılıdır. Bu çalışmada, problemin çözümü için "Bulanık değerlendirme" metodu Analitik Hiyerarşi Prosesi'ne dayanan "İkili Karşılaştırma" tekniğiyle beraber kullanılmıştır. İşin yürütülebilmesi için gerekli olan kriterlerin önem dereceleri "ikili karşılaştırma" tekniğiyle hesaplanmış, adaylar bu kriterler baz alınarak altı-dereceli bulanık değişkenlerle değerlendirilmiş, adayların sonuç puanları ise bulanık değerlendirme metoduyla hesaplanmıştır.

Önerilen model ile, Microsoft Visual Studio .NET ve Microsoft Access veritabanı programları kullanılarak bir bilgisayar programı hazırlanmıştır. Hazırlanan program çeşitli gerçek "personel seçimi" problemlerinde denenmiş ve sonuçlar irdelenmiştir.

Anahtar Kelimeler: Personel Seçimi, Bulanık Mantık, Analitik Hiyerarşi Prosesi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Structure of Personnel Selection

Individuals have different personality characteristics, abilities, skills, behaviours and perceptions; however every job/position has particular requirements at different levels. Then, personnel selection is a process of matching job requirements and individuals' characteristics. If process contains incorrect matching, individual will probably has health and performance problems that prevent him/her to perform job successfully. People are the most important benefit for the organizations; and they have most important role in organizational success. And, hiring the right person for the job may be the most critical decision for managers during their working life.

Information about candidates' skills and weakness can be obtained from a suitable selection process which generally consists of some common tools: application, interviews, reference checks, personality and ability tests, 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 the common 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.

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 more consistent in any situation and away from subjective evaluations.

There are some works in the literature to form consistent models on personnel selection, but most works deal with just mathematical side of the topic or intensify on theory bases, and there is no a strong relationship between researchers and practitioners. This poor relationship causes researchers lack of real life knowledge and makes practitioners uninformed about new development.

This thesis aims to develop a fuzzy decision making model for personnel selection. Fuzzy logic provides a mathematical strength to capture the uncertainties associated with human cognitive process, such as thinking and reasoning. Since the introduction of fuzzy logic in 1965 a number of fuzzy methods have been developed, fuzzy rating method is one of them and suitable for multi criteria decision making problems. *Fuzzy Rating method* is used in this study in combination with pairwise comparison of selection criteria based on the original *Analytic Hierarchy Process*. Education, foreign language, work experience, personality test, ability test, employment interview, reference and background check are used as 7 criteria to evaluate candidates applied for a job/position.

The developed model is implemented through a computer program which is prepared by using Microsoft Visual Studio .NET along with Microsoft Access as database which is integrated to a "personnel and performance management system" (Terziakın, 2005).

1.2 Objectives of the Work

The main objective of this thesis is to develop a fuzzy decision making model that can be applied in any personnel selection problem. The study concentrates on the following objects:

- Examination of the literature on personnel selection,
- Investigation of the fuzzy logic and fuzzy ranking method,
- Investigation of the pairwise comparison and analytic hierarchy process,
- Investigation of personnel selection process, methods and tools,

- Development a fuzzy model for the personnel selection,
- Development a computer program prepared by using Microsoft Visual Studio .NET and Microsoft Access,
- Testing the model and the computer program with examples,
- Discussion of the model and the computer program.

1.3 Methodology and Materials

In this thesis, a mathematical model for "personnel selection" problem is developed. A fuzzy ranking method is used together with pairwise comparison based on the analytic hierarchy process, in order to solve the problem.

The proposed model consists of evaluating candidates with six level fuzzy terms according to the selection criteria. These criteria are determined after investigation of literature on personnel selection, books, web sites of some organizations and human resource management firms on internet. And most common seven criteria, which are used by the organizations during the personnel selection process, are determined. Because relative importances of selection criteria vary with respect to the job requirements, weighting coefficients are computed for each position separately. Finally, evaluations of candidates and pairwise comparisons of the selection criteria are combined, then weighted average ratings for each candidate are obtained: results are triangular fuzzy numbers. These fuzzy numbers are ranked based on their middle values. The model is implemented on a computer program prepared with Microsoft Visual Studio .NET and Microsoft Access.

1.4 Organization of the Thesis

After this introduction chapter in which the thesis is framed briefly and objectives, methodology and materials are presented; the literature about the "personnel selection" problem is mentioned in Chapter 2. In Chapter 3, fundamentals of Fuzzy Logic, Fuzzy Sets, Fuzzy Decision Making and Fuzzy Rating Method will be presented. Knowledge about Analytic Hierarchy Process and Pairwise Comparison will be given in Chapter 4. In Chapter 5, personnel selection and its position in

overall human resource management (HRM), steps and tools of personnel selection process will be presented in detail. The developed “fuzzy decision making model” for personnel selection and its applications will be given in Chapter 6. In the last chapter of the thesis, Chapter 7, the developed model will be discussed; capabilities and incapabilities of the model will be investigated based on the results obtained in Chapter 6. And differences between the developed model and some other models on personnel selection will be discussed in the last chapter.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

There are substantial amount of empirical and analytical works about personnel selection in the literature. Some of these works are mentioned in this chapter, and a conclusion part, in which literature is discussed, is presented at the end of the chapter.

2.2 Literature on Personnel Selection

If the literature is searched, it is found that there are many works on personnel selection. When these works are investigated, it is observed that the number of complete works contain both analytic models, empirical studies and practices in real life is not high.

Soyuer and Kocamaz (2005) provided a model that combines knowledge-based decision support systems with management science methods include scoring model and analytic hierarchy process to select the better employee for a job vacancy from a list of applicants in a database. They used Microsoft Access as database and integrated with Microsoft Excel. In this study, it is also claimed that most of internet based applications used by many organizations are computer based communication systems which are not considered as knowledge-based systems. Because, these systems have not functions of data analysis, model using, problem solution, data production and storing.

Tütüncü et al. (2003) tried to determine the workers perception of recruiting process. A field study was made in İzmir particular for the employees working for travel

agencies. Questionnaires were used for that purpose, and results were analysed by using a special programme (Statistical Programme for Social Sciences). Authors found that personality characteristics of candidates applied for a job in a travel agency are most important criterion for organizations in recruiting process. They also recommend human resource managers to evaluate suitability of candidates for the job more effectually. Another finding of the research is that; selection of right person for a position directly related with the education degree of manager, and 82 percentages of agency managers have university degree.

Lievens et al. (2002) made a study on recent developments in personnel selection. First they asked 26 human resource representatives to list current or future trends that they considered to be of most important in personnel selection. Then, recent academic reviews on personnel selection research were investigated. After these two phases a list of trends was prepared from both practice and researches:

- labour market shortages,
- technological developments,
- applicant perceptions of selection procedures
- construct-driven approaches.

In last phase of the study, published and unpublished research studies relevant to trends in the list were searched. They recommend organizations to pick up on some of the issues that presented, and claim that researchers and practitioners should work together on these issues.

Aguinis et al. (2001) exposed the possibility of applying virtual reality technology to personnel selection. And they suggested virtual reality technology being suitable for assessing specific types of job knowledge, skills, abilities, and other characteristic of candidates during selection process. In this research virtual reality is described as virtual environment which is a computer technology that enables users to view or ‘immerse’ themselves in an alternate world, through the use of real-time computer graphics, users experience a computer-generated environment as if it is real and they are part of it. Research states; however this technology has applications of employee

training in different areas more than selection, potential applications of virtual reality technology in personnel selection procedure are open to discovery.

Individual attributes considered for personnel selection are divided in two categories by Liang and Wang (1994): subjective attributes which have qualitative definitions, e.g. personality, leadership, past experience; objective attributes which can be assessed quantitatively, e.g. general aptitude, job related knowledge, analytic ability, etc. Liang and Wang used a fuzzy multi criteria decision making method to integrate linguistic assessments and weights about subjective criteria to obtain fuzzy suitability index and its ranking value, and they claim that the rating for personnel suitability assessment can be conducted by combining the subjective ranking value with the objective ranking value by a subjective criteria weight.

Karsak (2000) presented a fuzzy multiple objective programming approach for personnel selection. He integrated the linguistic assessments about subjective factors and quantitative factors within multiple objective boolean linear programming technique. Karsak's criteria (objectives) of selection procedure are: personality assessment, leadership excellence, excellence in oral communication skills, past experience, computer skills, fluency in foreign language, aptitude test score, and annual salary request. He uses four level linguistic variables as "poor", "fair", "good", and "very good" to express candidates' scores with respect to criteria mentioned above.

Lazarevic-Petrovic aims to minimize subjective judgments in the process of distinguishing between appropriate employees and inappropriate employees, and she believes personnel selection decision process should be carried out with minimal influence of this subjective judgment. For that purpose, Lazarevic-Petrovic proposed a personnel selection fuzzy model (Lazarevic-Pertrovic, 2001). This model consists of analytic hierarchy process of three levels: the lowest level is of preliminary selection or shortlisting, the second level is related to the selection of final candidate, and top level is the expected utility of hiring the successful candidate. Fuzzy variables are used in the lowest level of the model. She claims her model minimizes individual judgments at preliminary selection and hiring decision levels.

Another personnel selection study was made by Butkiewicz (2002). In this study, fuzzy logic was used to describe selection process. Butkiewicz offers possible two methods can be used to select personnel for a work: index of performance (P) and index of demand satisfaction (DS). He also recommends DS when the features exceed demands for the work because it describes better the candidate features.

2.3 Conclusion

Personnel selection is a complex problem, because it consists of many different steps and contains qualitative and quantitative evaluations in the same time. However solution is not easy. To solve this complex problem, the personnel selection should be considered with all aspects. Analytic models without knowledge about overall personnel selection process, its steps, job requirements, labour market conditions, current technological developments are not sufficient alone.

Analytic models in the literature are generally applied for personnel selection problems with low number of applicants, not all of them have proofs that they can be applied for situation include many applicants. Although contemporary practices within "personnel selection" have been influenced by the research literature, but it is obviously that there is not a systematic linear flow from the research literature into the work of practitioners (Robertson and Smith, 2001).

Personnel selection process contains subjective evaluations of individuals; weights of these criteria may vary depending on the conditions of the situations. So, model to be developed for personnel selection should have flexible structure; to obtain that structure a combination of fuzzy logic and analytic hierarchy process are used in this thesis. It is believed that, this kind of combinations which contain different decision making methods may produce more effective and flexible models for the personnel selection problem. Finally, a consistent model is developed which can be used for personnel selection problems with higher number of applicants. The proposed model can also be used for any open position by changing the weights of selection criteria with respect to the position requirements.

CHAPTER 3

FUZZY LOGIC, FUZZY SET THEORY AND FUZZY RATING METHOD

3.1 Introduction

In this chapter, a brief introduction of fuzzy logic and main principles of fuzzy set theory are given. Fuzzy rating method used in personnel selection, which is a multi criteria decision making (FMCDM) technique, is explained.

3.2 Fuzzy Logic

The dominance of statistics to represent/model imprecision and uncertainty was ended by introduction of *fuzzy logic* in 1965 by Lotfi A. Zadeh (Şen, 2001). With this introduction, it was made possible to make decisions by another tool in the presence of vague and imprecise information that humans deal with in real life. Although many real life problems that contain uncertainties can be modelled by both fuzzy logic and statistics, it is clear that fuzzy logic is more successful to manipulate objects have **ill-defined** boundaries. "Ill-defined" means poorly defined, such as "hot weather", "young man", "delicious foods", "cheap goods". Of course *hot*, *young*, *delicious* and *cheap* words are fuzzy terms; their meanings are not clear and can be understood differently by different people. Above fuzzy terms are **linguistic variables** which play a central role in fuzzy logic and underlies most of its applications (Zadeh, 2004). A linguistic variable is a variable whose values are words or sentences in a natural or synthetic language (Zadeh, 1973).

In bivalent logic, truth is bivalent, implying every proposition, is either true or false, with no degrees of truth allowed. In multivalent logic, truth is a matter of degree. In fuzzy logic:

- everything is, or is allowed to be, to be partial, i.e., a matter of degree
- everything is, or is allowed to be, imprecise (approximate)
- everything is, or is allowed to be, granular (linguistic)
- everything is, or is allowed to be, perception based

However fuzzy logic is not in conflict with bivalent logic, it is a generalization of bivalent logic in which everything is, or is allowed to be, a matter of degree. Fuzzy logic provides a foundation for the methodology of computing with words and perceptions (Zadeh, 2004)

3.3 Fuzzy Set Theory

In ordinary mathematics, information is of a crisp kind. It belongs to a set or it does not. The choice of a yes-or-no answer is possible and usually applied, but information could be lost in such a choice, as the degree of belonging is not taken into consideration. A fuzzy model is the idea of a fuzzy set. 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 values in between are used to symbolize intermediate degrees of membership (Fayad and Webb, 1999), (Erkoç et al., 2003).

Definition 1. (*Classical set*)
Classical, or a crisp set, is one which assigns grades of membership of either "0" or "1" to objects within their universe of discourse. Objects belong to or do not belong to a certain class; objects either possess a certain property, or they do not; there is no middle ground (Prodanovic, 2001),

$$\begin{aligned} &X && \text{: universal set} \\ &A && \text{: subset} \\ &x(A){:}X \rightarrow \{0,1\} && (3.1) \end{aligned}$$

x(A) is characteristic function.

Definition 2. *(Fuzzy Set)*

A fuzzy set (class) A in X is characterised by a membership (characteristic) function $\mu_A(x)$ which associates with each point in X a real number in the interval [0,1], with the value of $\mu_A(x)$ at x representing the "*grade of membership*" of x in A. Thus, the nearer the value of $\mu_A(x)$ to unity, the higher the grade of membership of x in A (Zadeh, 1965).

$$\mu_A : X \rightarrow [0,1] \tag{3.2}$$

$$A = \{(x, \mu_A(x))\}, \quad x \in X \tag{3.3}$$

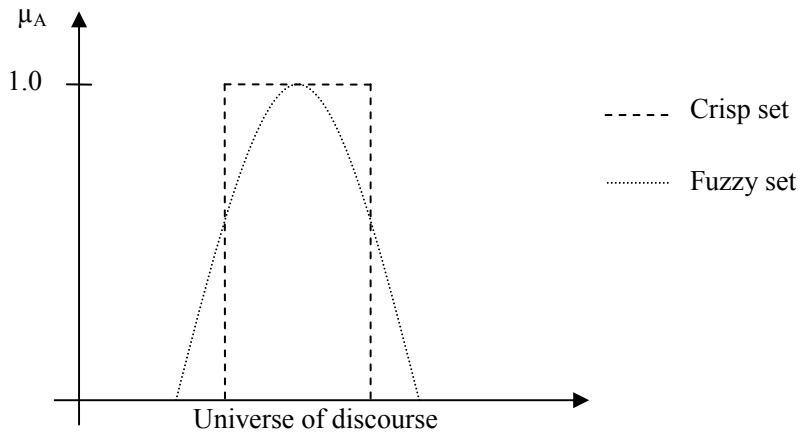


Figure 3.1 Classical (crisp) and fuzzy sets

Definition 3. *(Support, core, α-cut, height)*

The support of a fuzzy set is the crisp subset of X whose elements all have nonzero membership degrees in A (Jantzen, 1998). Support contains boundaries of a fuzzy set. Boundaries have the same elements with the support region except elements having complete membership.

$$\sup(A) = \{x \in X \,|\, \mu_A(x) > 0\} \tag{3.4}$$

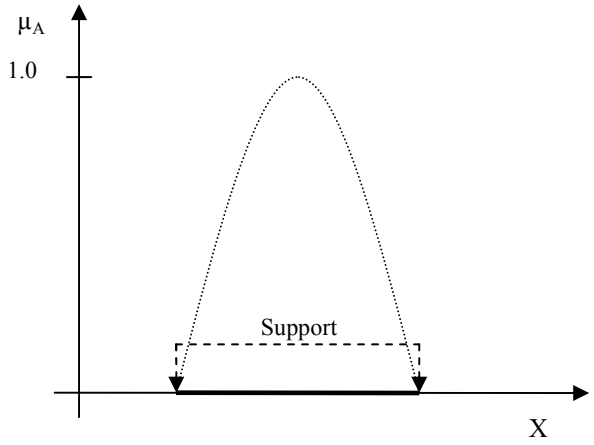


Figure 3.2 Support of a fuzzy set

The core of a fuzzy set is the area where the elements have maximum degree of membership.

$$core(A) = \{x \in X | \mu_A(x) = 1\} \tag{3.5}$$

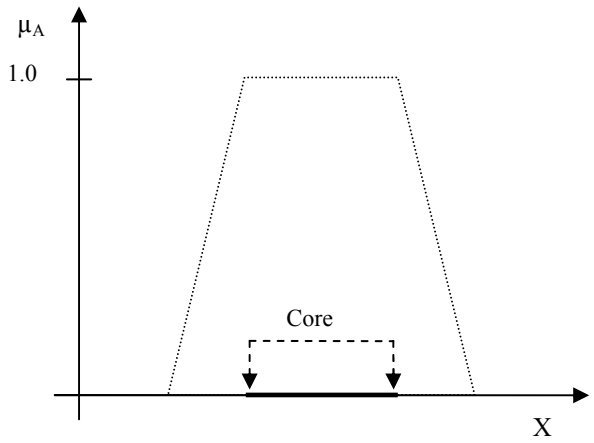


Figure 3.3 Core of a fuzzy set

The α-cut is a crisp set or crisp interval of fuzzy set *A* for a particular degree of membership at height α.

$$\alpha\text{-}cut(A) = \{x \in X | \mu_A(x) \geq \alpha\} \quad A_\alpha = [a_\alpha, b_\alpha] \tag{3.6}$$

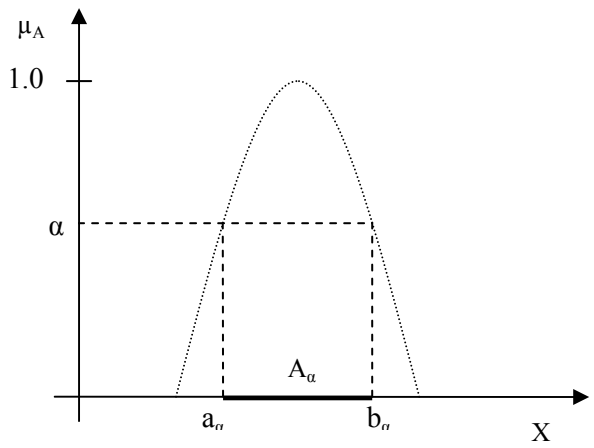


Figure 3.4 α-cut of a fuzzy set (Vanegas and Labib, 2001)

The height of a fuzzy set is the maximum value of membership function of subset *A*.

$$height(A) = \max\{\mu_A(x)\} \tag{3.7}$$

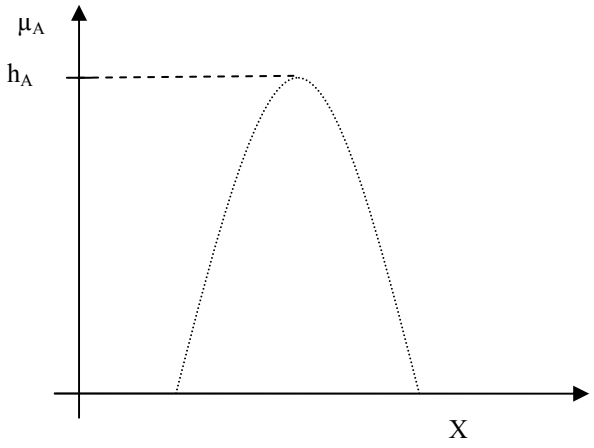


Figure 3.5 Height of a fuzzy set

Definition 4. (*Normal fuzzy set*)

A fuzzy set is called as normal fuzzy set if it has at least one element with a membership degree of 1 ($\mu A(x)$ =1), otherwise it is non-normal.

Definition 5. (*Convex fuzzy set*)

A fuzzy set is convex if and only if it satisfies following property:

$$\mu(x_2) \geq \min(\mu(x_1), \mu(x_2)) \tag{3.8}$$

Above equation should be proved for all elements of the set: $x_1, x_2, x_3 \in X$ and $x_1 < x_2 < x_3$.

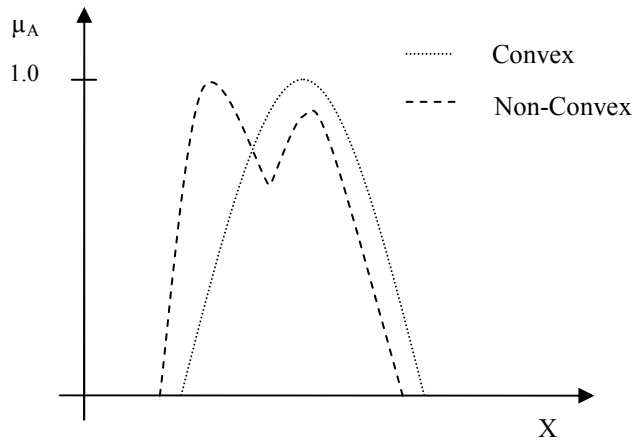


Figure 3.6 Convex and non-convex sets

Definition 6. (*Fuzzy Number*)

A fuzzy numbers 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 most common types which are defined by three and four parameters respectively. Following figures show these fuzzy numbers.

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). They are most common fuzzy numbers, and 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 3.9.

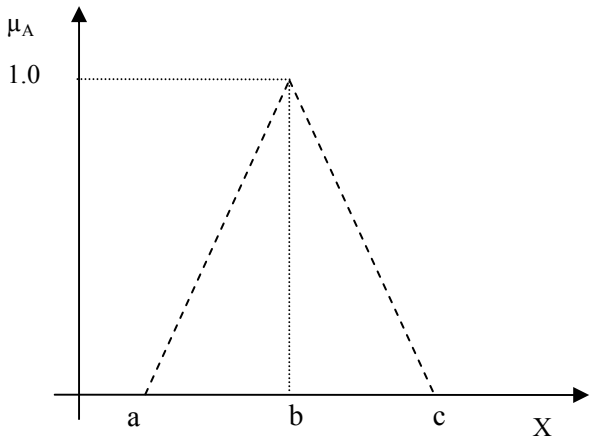


Figure 3.7 Triangular fuzzy number, (a,b,c)

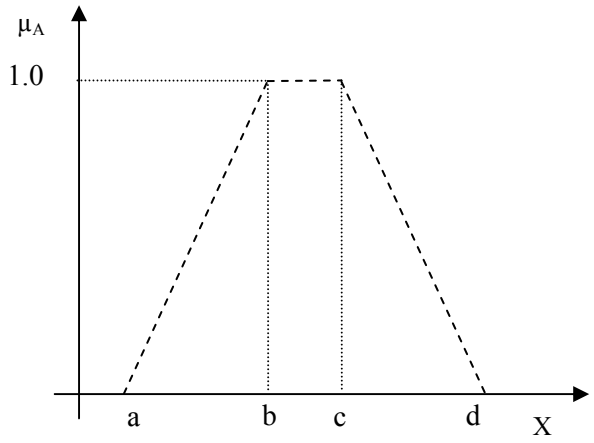


Figure 3.8 Trapezoidal fuzzy number, (a,b,c,d)

$$\mu_A(x) = \begin{cases} (x-a)/(b-a), & a \le x \le b, \\ (c-x)/(c-b), & b \le x \le c, \\ 0, & x < a \ or \ x > c, \end{cases} \tag{3.9}$$

Some methods of operations are called as extended algebraic operations 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.

$$
\begin{aligned}
&A_1 = (a_1, b_1, c_1)\ and\ A_2 = (a_2, b_2, c_2) \\
&A_1 + A_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \\
&A_1 - A_2 = (a_1 - a_2, b_1 - b_2,\ c_1 - c_2) \\
&k*A_1 = (ka_1, kb_1, kc_1), \quad k \in R \\
&A_1*A_2 = (a_1*a_2, b_1*b_2, c_1*c_2), \quad if\ a_1 \geq 0\ and\ a_2 \geq 0
\end{aligned}
\tag{3.10}
$$

3.4 Fuzzy Multi Criteria Decision Making

In real life everybody makes decisions that contain alternatives and criteria. Decision makers have to select, classify the alternatives or develop new alternatives according to the pre-defined criteria. Alternatives are evaluated by using quantitative and qualitative variables, because fuzzy models use both of them, they are more flexible than other decision making models. Fuzzy set theory uses also linguistic variables to represent imprecise information and vagueness of human language; this makes fuzzy models more powerful than others. Of course the main goal in a decision making problem is to select alternative by maximizing the objective function against constraints. This can be done by optimization of both objective function and constraints.

Definition 7. (*Fuzzy decision*)
The fuzzy set of alternatives resulting from the intersection of the fuzzy constraints and fuzzy objective functions (Bellman and Zadeh, 1970).

If $A = \{A_1, A_2, A_3, \ldots\ldots\ldots, A_m\}$ the set of alternatives, $C = \{C_1, C_2, C_3, \ldots\ldots\ldots, C_n\}$ the set of criteria, and $G = \{G_1, G_2, G_3, \ldots\ldots\ldots, G_k\}$ set of goals, then D is the decision:

$$
D = G_1 \cap G_2 \cap G_3 \ldots\ldots\ldots \cap G_k \cap C_1 \cap C_2 \cap C_3 \cap \ldots\ldots\ldots \cap C_n \tag{3.11}
$$

$\mu_D(x)$, $\mu_G(x)$, $\mu_C(x)$ are membership functions, using these functions,

$$
\mu_D(x) = \min(\mu_{G1}(x), \mu_{G2}(x), \mu_{G3}(x), \ldots, \mu_{Gk}(x), \mu_{C1}(x), \mu_{C2}(x), \mu_{C3}(x), \ldots, \mu_{Cn}(x)),\ x \in A \tag{3.12}
$$

and the optimal decision is given by:

$$x_{opt} = \left\{ x \middle| \mu_D(x) \, is \max \right\} \tag{3.13}$$

3.5 Fuzzy Rating and Ranking

Fuzzy decision making methods have two main phases: the aggregation of the performance scores with respect to all attributes for each alternative (rating), the ranking of the alternatives according to the aggregated scores (Morillas et al., 1996).

A decision maker who wants to order fuzzy quantities extracts a specific feature from fuzzy sets and ranks these fuzzy sets according to the feature extracted. So decision maker can reach different ranking orders if he uses different features (ranking methods). In literature ranking methods are categorized into two classes (Prodanovic, 2001):

1. Methods which convert a fuzzy number to a crisp number by applying a mapping function. Fuzzy numbers are then sorted by ranking crisp numbers produced by the mapping.

2. Methods which use fuzzy relations to compare pairs of fuzzy numbers, and then construct a relationship which produces a linguistic meaning of the comparison. The ordering results are something like “fuzzy number A is slightly better than fuzzy number B”.

In fuzzy multiple criteria decision making 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 below:
A number of alternatives are denoted as A_1, A_2, A_3, …, A_m. The criteria (aspects) that influence all the alternatives are identified as C_1, C_2, C_3, …, 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. All above information can be expressed in matrix format:

Table 3.1 Fuzzy rating matrix

	C_1	C_2	…	C_j	…	C_n
A_1	r_{11}	r_{12}	…	r_{1j}	…	r_{1n}
A_2	r_{21}	r_{22}	…	r_{2j}	…	r_{2n}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_i	r_{i1}	r_{i2}	…	r_{ij}	…	r_{in}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_m	r_{m1}	r_{m2}	…	r_{mj}	…	r_{mn}

$W = [w_1, w_2, ..., w_j, \ldots, w_n]$

Then the weighted average rating of alternative A_i can be calculated as below:

$$\bar{r}_i = \frac{\sum_{j=1}^{n} r_{ij} w_j}{\sum_{j=1}^{n} w_j} \tag{3.14}$$

That formula is simplified by not considering the extended division;

$$\bar{r}_i = \sum_{j=1}^{n} r_{ij} w_j \tag{3.15}$$

3.6 Conclusion

Fuzzy logic is much more general than traditional logical systems; it provides a foundation for the methodology of computing with words and perceptions. Fuzzy logic is more successful to make decision in the presence of vague and imprecise information that humans deal with in the real life situations.

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 personnel selection which is a real life problem. Fuzzy rating method is used in this study to compute ratings of each candidate applied for a particular position.

CHAPTER 4

ANALYTIC HIERARCHY PROCESS

4.1 Introduction

In this chapter, analytic hierarchy process (AHP), which is a flexible decision making tool for multi criteria problems, and its structure are presented in detail. AHP is used in this study to determine relative importance of personnel selection criteria. Its applications will be given in later chapters.

4.2 Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) was introduced by Thomas L. Saaty in 1977 to solve complex decision making problems involving multiple criteria. In such problems there are both objective and subjective evaluations. AHP contains multi level hierarchical structure: objective (goal), criteria (and sub-criteria), and alternatives (Kuruüzüm and Atsan, 2001). Decision maker provides judgments about relative importance of each criterion and then state a preference on each criterion for each decision alternative. Output of the process is ranked alternatives according to the preferences. In recent years, combining of the AHP with other methods rises; AHP and Fuzzy Logic, AHP and Goal Programming, AHP and Data Envelopment Analysis combinations are common applications in the literature (Dağdeviren et al., 2004).

4.2.1 Structure of the AHP

AHP can be applied to a decision making problem after structured hierarchically at different levels: objective, criteria, and alternatives. The first level is the goal of the

decision maker, several different factors combine the second level, and the last level of the hierarchy contains all the alternatives (Figure 4.1).

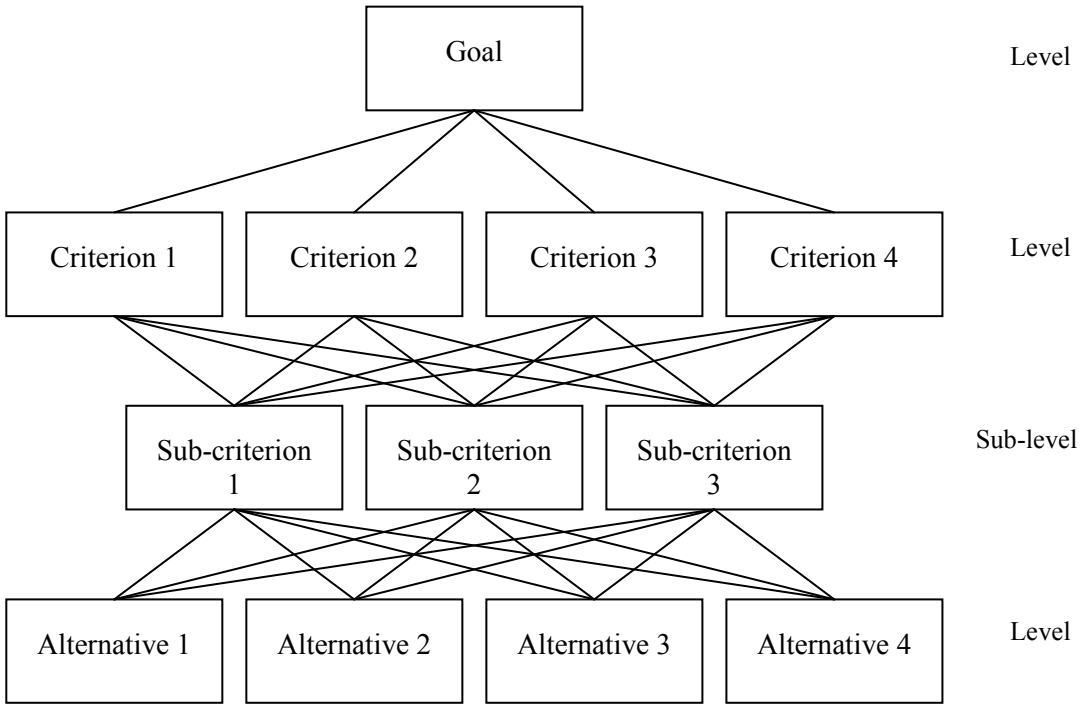


Figure 4.1 Hierarchical structure of AHP

Table 4.1 Analytic Hierarchy Process matrix

	C_1	C_2	…	C_j	…	C_n
	w_1	w_2	…	w_j	…	w_n
A_1	x_{11}	x_{12}	…	x_{1j}	…	x_{1n}
A_2	x_{21}	x_{22}	…	x_{2j}	…	x_{2n}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_i	x_{i1}	x_{i2}	…	x_{ij}	…	x_{in}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_m	x_{m1}	x_{m2}	…	x_{mj}	…	x_{mn}

Mathematically, Analytic Hierarchy Process is a simple matrix-based technique (Jandric and Srdjevic, 2000). This matrix (Table 4.1) is formed by alternatives, decision criteria, performance values of alternatives and weights of criteria.
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:

4.2.2 Process of the AHP

The AHP divides the decision problem into the following main steps (Saaty, 1994):

1. Problem structuring.
2. Assessment of the local priorities.
3. Calculation of global priorities.

Decision problem is structured by defining the overall goal, decision criteria and sub-criteria, all possible alternatives, and putting them into the different levels of hierarchy (Figure 4.1).

The weights of the criteria and scores of the alternatives, which are called local priorities, are considered as decision elements in the second step of the decision process. The last step of the AHP aggregates all local priorities to obtain the global priorities used for ranking of the alternatives and selection of the best one (Mikhailov, 2002).

4.2.3 Pairwise Comparison

Analytic Hierarchy Process, like other decision making methods, needs to quantify qualitative data, and it uses pairwise comparison matrix for that purpose. AHP takes pairwise comparisons as inputs and converts them into relative weights as outputs. Pairwise comparisons are quantified by using a scale, with values from 1 to 9 to rate the relative preferences, proposed by Saaty (1980). There are some other 1-5, 1-7, 1-15, and 1-20 scales in the literature, however the most accepted and used one is Saaty's scale depicted in Table 4.2.

According to the scale decision maker can use the values for the pairwise comparison from the set: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}.

Table 4.2 Scale of Relative Importance (Triantaphyllou and Mann, 1995)

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*.	

After constitution of the pairwise comparison matrixes for criteria and alternatives in terms of each criterion, decision maker has to extract the relative importance of criteria and scores of the alternatives from those judgment matrixes. 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 of for all elements at the same level of hierarchy. Unfortunately it is reality that achieving perfect consistency in pairwise comparison for real life situations is unusual. If decision maker evaluates that element *A* is much more important than element *B*, *B* slightly more important than element *C*, and *C* slightly more important than *A*, then judgments are inconsistent and decisions made by decision maker are distrustfully.

Consistency of comparison 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). Consistency ratio (*CR*) is calculated by dividing consistency index (*CI*) by random consistency index (*RCI*).

$$CR = \frac{CI}{RCI} \tag{4.1}$$

To solve the above equation consistency index (CI) should be obtained first by using the formula:

$$CI = \frac{(\lambda_{\max} - N)}{(N-1)} \tag{4.2}$$

λ_{max} and N represent the maximum eigenvalue and number of elements compared respectively. The maximum eigenvalue λ_{max} is calculated by multiplying the original judgment matrix by priority vector and then summing these values over the rows. The next step is done by dividing the weighted sum vector by elements of the priority vector. The average value of this resultant vector is λ_{max} (Zaim et al., 2005). Random consistency index (*RCI*) values are given in Table 4.3.

Table 4.3 RCI values for different values of N.

N	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

4.2.4 Computing the Final Ranking

After the pairwise comparisons of criteria and alternatives in terms of each decision criterion, decision maker obtains relative importances of criteria (weight vector) and scores of the alternatives (priority vectors). Then the final step is the calculation of the overall scores (global priorities) of the alternatives to be used for ranking them. Final priority for alternative i can be calculated with the formula:

$$\sum_{j=1}^{n} x_{ij}\, w_j\,, \quad for\, i = 1,2,3,...m \tag{4.3}$$

This formula is used for each alternative at the third level of the hierarchy. Another representation of calculation of final priorities is possible with matrixes:

$$\begin{vmatrix} x_{11} & x_{12} & \dots & x_{1j} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2j} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \dots & x_{ij} & \dots & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mj} & \dots & x_{mn} \end{vmatrix} \text{X} \begin{vmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{vmatrix} \tag{4.4}$$

First matrix is combined with priority vectors; each column shows priority of alternatives for criterion j. Second matrix is weight vector of criteria. Multiplication these two matrixes yields a decision matrix containing final priorities of all

alternatives. Decision maker uses these priorities for a final selection or combining with another decision making method for further applications.

4.3 Conclusion

Analytic hierarchy process is a method designed to solve complex problems involving multi criteria. The process is based on the judgments of decision maker about the relative importance of each criterion and then specifying a preference on each criterion for each decision alternative.

Overall Analytic hierarchy process is not used in this study, it is only processed to obtain relative importance of personnel selection criteria; the relative importance for each criterion is not same for each position applied. Because each position/job has different characteristics and requirements to be performed by individuals, level of these characteristics and requirements should be determined particularly for each selection problem. Finally, AHP pairwise comparison is suitable for that purpose and proposed in the study.

CHAPTER 5

"*There are many ways to improve productivity, but none is more powerful than making the right hiring decision*" (Mondy et al., 2002).

PERSONNEL SELECTION

5.1 Introduction

In this chapter, overall personnel selection process is given. Although details of the process are discussed in later parts of the chapter, following definitions can summarize personnel selection: "*personnel selection* is the process by which an organization chooses from a list of applicants the person or persons who best meet the selection criteria for the position available, considering current environmental conditions"; by another explanation, "it is the search for an optimal match between the job and the amount of any particular characteristic that an applicant may possess" (Ivancevich, 2001).

5.2 Personnel Selection in Human Resource Management (HRM)

In 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 job and organization. As an example in 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 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.

Human resource management process of an organization consists of eight activities. The first three activities ensure that competent employees are identified and selected; the next two activities involve providing employees with up-to-date knowledge and skills; and the final three activities entail making sure that the organization retains competent and high performing employees who are capable of sustaining high performance (see Figure 5.1)

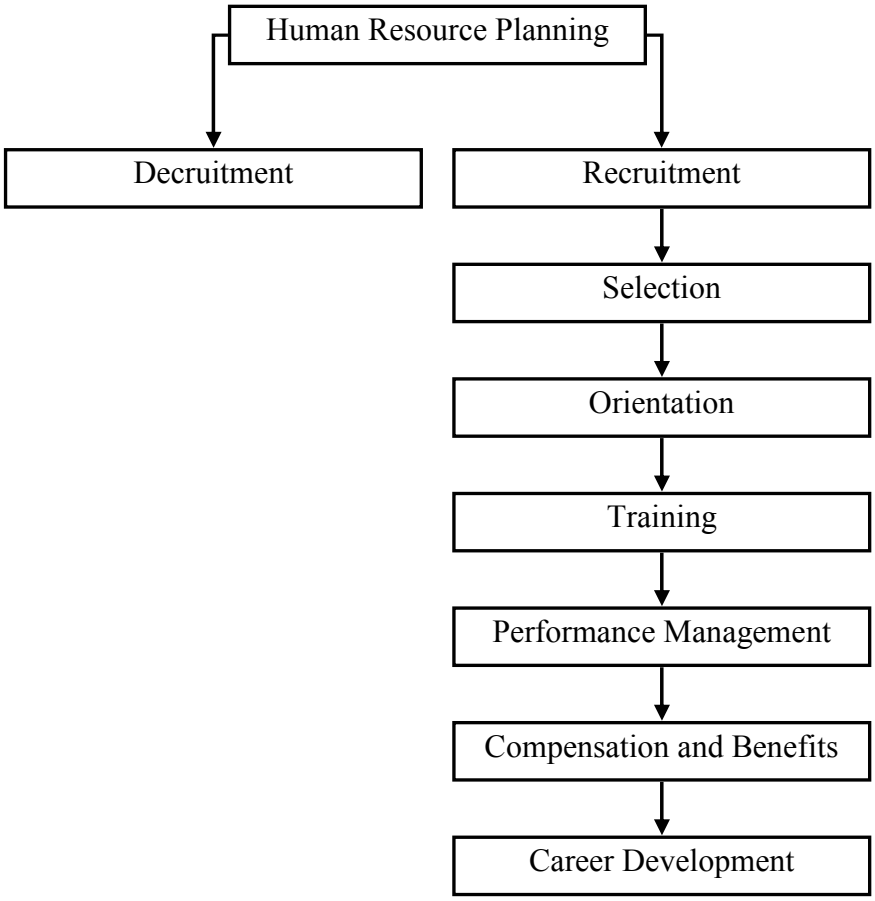


Figure 5.1 Human Resource Management Process (Robbins and Coulter, 2002)

Human resource planning is the first step of the HRM system. Organization should be analysed totally about number and kind of people in the right departments and at the right times. This can be done for developing current resources, planning future human resource needs according to the organization's goals and strategies.

Recruitment is the following step, consists of locating, identifying, and attracting capable applicants. These applicants can be supplied from different sources: internal search, employee referrals, internet, advertisements, public and private employment agencies. On the other hand, decruitment process is operated if management wants to reduce the number of people working for the organization.

Selection process is after recruitment that has produced an applicant pool in which best qualified candidate is elected for the job. Selected employee is introduced to job and organization. This introduction, which is called as orientation, has two types: work unit orientation familiarizes the employee with the goals of work unit, clarifies how his or her job contributes to the unit's goal, and introduces to his or her new co-workers; organizational orientation informs the employee about organization's objectives, history, philosophy, procedures and rules (Robbins and Coulter, 2002).

Jobs need changes while scientific and technological innovations are increasing, then employee skills have to be updated. Therefore organizations train employees to improve their technical, interpersonal and problem solving skills.

Performance management is another part of HRM, because managers of the organizations need information about employees' performances on their jobs if they are performing their jobs efficiently or not. A performance management system is established based on the performance appraisal methods: written essay, critical incidents, graphic rating scales, multi-person comparison and 360 degree feedback.

All information obtained from performance management is used in compensation system of the organization. Appropriate and effectively working compensation system, including many types of rewards and benefits, is important to motivate people, retain and attract competent employees. This is definitely important for mission and goals of the organization.

Career development is the last step of the overall HRM system. Generally career development programs are designed by organization to help employees for their work lives within a specific organization (Robbins and Coulter, 2002). Organizations do this for benefits of organizations and employees; they consider working life of the employee just within the organization, although career contains all the positions held by a person during the overall lifetime. Person has responsibility for planning and developing his own career, and can take helps from advisors if necessary.

5.3 Personnel Selection Process

Today, world is smaller than it was, science and technology are in everywhere and many firms can take and use them after paying cost-price. Then, main difference between the firms is the person, and the organization having more effectual human resources has a distinctive advantage in a competitive business environment. The target of the personnel selection process is to match people with criteria of the job and the organization. If individuals are overqualified, underqualified, or for any reason do not fit either job or the organization's culture, they will probably leave the firm. For that reason, organization has to determine criteria and their levels that individuals have to posses for the success of the job and 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 university 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. 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.

Figure 5.2 shows overall selection process that may be varied by organizations depending on the conditions. It begins with preliminary interview and/or application form; unqualified employees are rejected before selection tests. After a series of selection tests, employment interview, reference and background checks, suitable individual receives physical examination, if successful, he/she is employed.

5.3.1 Preliminary Interview

The most common first step in any selection process involves preliminary interview which has a main purpose of screening of applicants by eliminating who obviously do not meet the position's basic requirements. For example position may require a specific certification, such as driving licence; interviewer wants to know if applicant possesses this licence or not. If the applicant does not have driving licence, he/she will be rejected. During the interview, a few straight forward questions are asked to the applicant in different ways: meeting, telephone, or computer.

5.3.2 Review of Applications

Review of applications and résumés is one of the most common early steps of overall selection process; it can precede or follow the preliminary interview. Almost all applications forms contain enough questions; answers of these questions are information to be compared to the job description; to determine the applicant is minimally qualified for the position. In a typical application form, applicants give their name, address, telephone number, personal history profile, personal activities, skills and accomplishments. By using this information, employer can make a preliminary elimination which is necessary for reducing cost and saving time of overall selection process. Moreover this information establishes a base for the following selection steps.

Today, many companies have computer terminals to take application forms completed by applicants, especially internet is used. Applications can be screened

firstly by a scanning program which can scan for not only a specific position, for all positions in the organization as well.

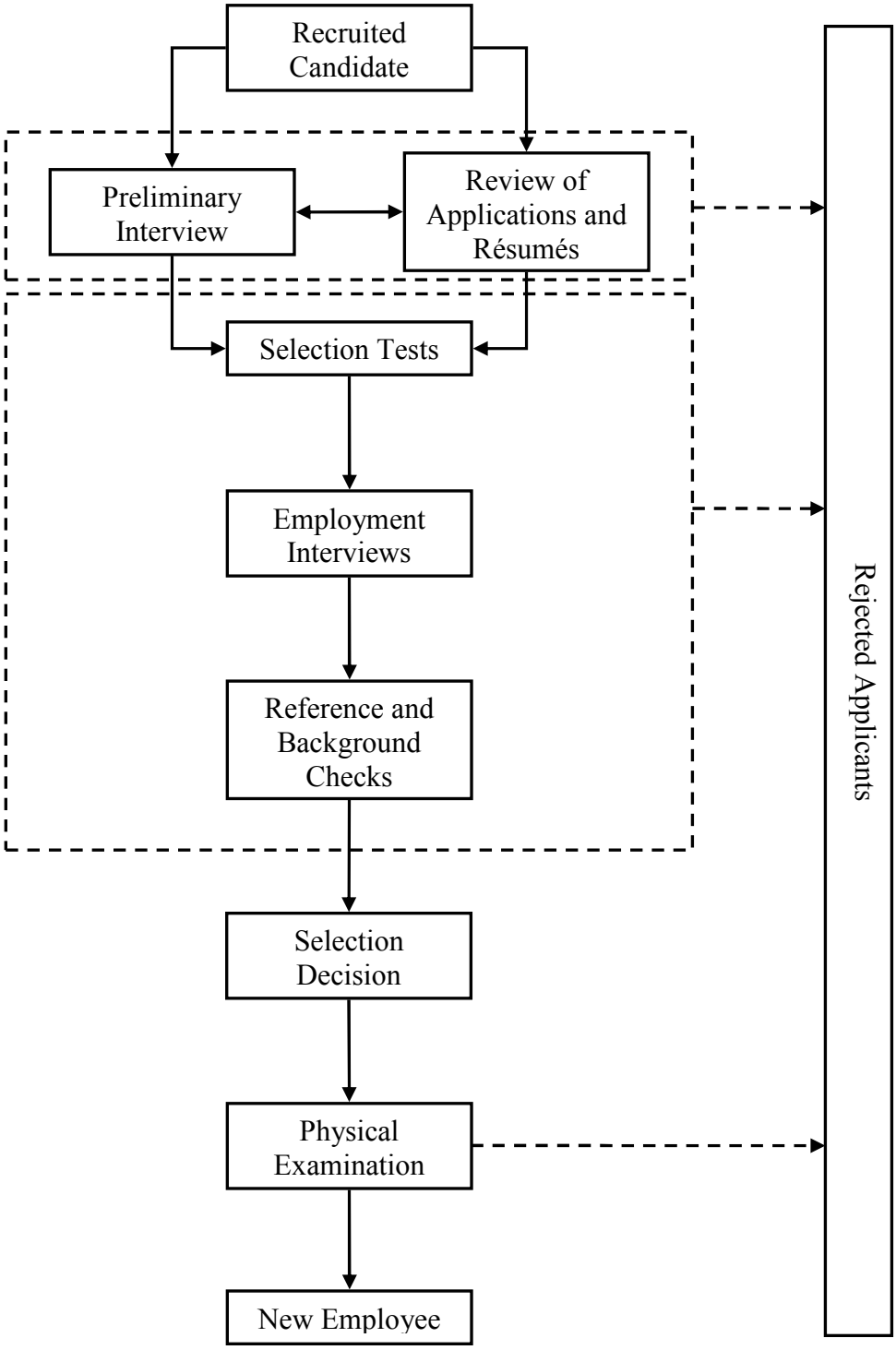


Figure 5.2 Selection Process (adapted from Mondy et al., 2002)

5.3.3 Selection Tests

Employment selection test is a mechanism that attempts to measure certain characteristics of individuals. These characteristics range from aptitudes, to intelligence to personality. There are many types of test used for that purpose, and a number of factors are taken into consideration to decide which test or tests will be used; budgetary constraints of the organization, the complexity and difficulty of the job, the size and quality of applicant populations, knowledge, skills, abilities, and other characteristics required by the job (Ivancevich, 2001). Tests can be classified with respect to the characteristics to be measured:

1. Intelligence tests
2. Integrity/Honesty tests
3. Ability tests
4. Skill tests
5. Personality tests

Intelligence tests, in some resources called as mental ability tests, are used to take an indication of individual's overall mental capacity (Torrington et al., 2002). In such tests, individual has to answer the questions about vocabulary, analogies, similarities, opposites, arithmetic, number extension and general information. *Cattel* and *Beta* tests are intelligence tests not based on the verbal ability, and contain figure completion, finding mistakes, similarities and differences. *Wechsler adult intelligence scale* is another intelligence test evaluating different mental processes, has two main parts: verbal and performance. There are general information, understanding, number repetition, arithmetic, similarities and word capacity tests in the first part. Performance part contains figure completion, wooden figures, figure arranging, parts combination and code tests. Wechsler test is used in special cases (e.g. occupational rehabilitation). Kohs blocks, Lever / Hebel test, Alexander are other intelligence tests having industrial applications (Telman and Türetgen, 2004).

Honesty or integrity tests are designed to measure individuals' level of honesty; employers particularly use these tests when hiring employees whose job responsibilities include handling cash or merchandise. *Polygraph* is an instrument,

used for measuring honesty, that records changes in breathing, blood pressure, pulse, and skin response associated with sweating of palms, and then plots these reactions on paper (Ivancevich, 2001). Also there are some other paper-and-pencil honesty tests to screen applicants in some stages of personnel selection process.

Ability tests are used to determine individuals' attention, concentration, mathematical, mechanical, and duplication abilities. These tests measure individual's potential to develop, but skill tests measure skills of an individual has already acquired. *Revision Test* is an example to ability tests; it has 4 versions (addition, subtraction, multiplication, and division) for mathematical attention, mainly used in personnel selection for accounting and banking organizations, and others working with numbers. Test of Synonyms is applied by a milimetric paper; individual has to duplicate a geometrical shape. This test is suitable for textile and other sectors in which modelling is necessary. Other ability test can be seen in Telman and Türetgen (2004) in detail.

Skill tests are mainly carried out by means of some instruments and devices: Chronoscope, Turner, Disc test, Omega, Aesthesiometer, Flicker Fusion, Tachistoscope, Attention Diffuse, Match Board, Threading Tester, Ribbon Test, Wooden Pims, Metal Pims, Colour Blind Test, and Simulators are some of them. In personnel selection applications, if position require some special skills, it is necessary to evaluate applicants according to these skills. As an example, Match Board can be used to measure hand skill and speed of an individual applied for an assembler position. Colour Blind Test is used to determine the individuals who can not distinguish one or more colours from others. It contains funds made of coloured specks, individual asked to read number in the funds. This test is suitable for transport firms looking for drivers, chemical industry, and textile firms.

Personality tests attempt to assess non-cognitive, basic characteristics of individuals; these tests measure the emotional adjustment, social relations, motivations and interests of the individual who is test taker. Personality tests, try to predict behaviours of an individual in a particular future situation by measuring different dimensions of his/her personality. Some organizations use these tests to classify personnel according to the personality types to create teams or to select new

personnel for a job vacancy. There are many different instruments and techniques used to evaluate personality; Özgüven (2000) categorizes them into 4 groups:

1. Observational Techniques
2. Self-Reporting Techniques
3. Projective Techniques
4. Situational Techniques

Observational techniques are tools to determine personality of an individual by numerical degrees. Technique collects information from another person (evaluator) has observed individual whose personality to be evaluated. Because all informations are subjective, they are converted into numbers by a rating scale. Observational techniques can be used to determine different sides of personality, and its application is simple.

Next technique used to evaluate personality is Self-Reporting; informations about individual are taken directly from him/her, interviews, inventories, questionnaires, autobiographies are main ways to get these informations. This technique may be the most important one, because individual is most true and natural information resource about his/her personality. A sample test developed by Littauer and Littauer (2003) is given in Appendix 1.

A different technique, not as direct as self-reporting, utilizes incomplete sentences, vague figures, and ink blots as stimulant, called as Projective technique in which the test taker interprets ambiguous stimuli that may elicit a number of different responses evidencing the test taker's fantasies and emotional associations. The responses to stimulants provide data on which psychologists base their assessment and interpretation of a personality. Rorschach Inkblot Test, Thematic Apperception Test, Human Figure Drawing Test are some examples to projective tests.

Situational tests are structured to observe individual's behaviours in a particular situation. In-basket Test, Role-playing, Leaderless Group Discussion are situational tests that require a person to perform a given task or react to a given real life situation. Individual is then evaluated on the way in which he or she responds. All

observations are analysed by psychologists, and final personality profile of individual is obtained.

5.3.4 Employment Interview

Some resources consider employment interview as an art rather than a science. Telman and Türetgen (2004) state that interviewers search answers of the three main questions:

- Can applicant do the job?
- Does applicant want to do the job offered?
- What is accomplishment degree of the applicant among others?

During the interview, it is not the purpose to take information from the applicant, however some information about position and organization is given, and this information makes applicant feel a desire for the job.

As a one of the main steps in the personnel selection process, an interview folder is prepared for each individual, consists of application form completed before, résumé, references, and test results. There are three types of interviews: structured, unstructured, and situational interviews. Interviewer uses a standardized list of job related questions to ask each applicant for a particular job in a structured interview. On the other hand, open-ended questions are used in unstructured interview in which different information may be obtained from each applicant and it is more time consuming then structured interview. Although highly skilled interviewers can get useful insights about an applicant (Ivancevich, 2001), Mondy et al. (2002) claim that using structured interview increases reliability and accuracy by reducing the subjectivity and inconsistency of unstructured interviews. Another type of interview, which has an increasing usage in last years, is situational interview. It has a purpose to evaluate applicants with respect to job knowledge and motivation like other types of interviews, additionally some hypothetical questions are asked to the applicants to measure the responses to job related hypothetical situations. There are also some methods can be used to conduct interviews: one-to-one interview, group interview, board interview, stress interview.

5.3.5 Reference and Background Checks

Almost all candidates applied for a job are asked to make a list of references to be contacted to get information about them. Obviously, prepared list is generally made of people who will give positive information about candidate, and some people consider checking this list is worthless and references in this list are of little or no value to the hiring procedure. However, reference checks will probably make available additional judgment about candidate. Background check is done by investigation of following elements: previous employment, education, personal references, criminal history, driving record, civil litigation, workers' compensation history, credit history etc. (Mondy et al., 2002). That investigation, regardless of which element is controlled, is important for verifying the information given by candidate in application form and during interviews, and for getting additional information could not be taken from candidate directly. Investigation is carried out by telephone, letter, meeting or internet.

5.3.6 Selection Decision

After all preceding steps, selection decision is the most crucial step of the overall selection procedure. Successful candidates not rejected until decision step, who may be called as finalists, are now in a final evaluation. In this evaluation, one or more candidates will be selected according to their information obtained from preliminary interview, review of application form, selection tests, employment interview, reference and background checks. Candidate, whose qualifications most closely to match the position's requirements, is more advantageous to be selected.

Managers have all responsibility to hire most qualified candidate for benefit of the organization. For that purpose, managers should be away from subjective judgments about candidates, and provide a method to minimize these subjective judgments in hiring decision. Fuzzy Logic, AHP and some other multi-criteria decision making models are used in recent years with increasing popularity.

5.3.7 Physical Examination

Physical examination is the last step just before hiring new employee. Some organizations may use this examination to differentiate between successful and less-successful candidates, but this is not a common situation. Generally physical examination is required after a conditional offer of employment; it means that if the conditionally offered individual has a physical examination result with a disability to perform work, he/she will not be hired.

Physical examination has following objectives:

- To screen out individual with infectious disease.
- To determine certain physical capabilities of individual to perform work.
- To determine physical situation of individual before hiring, to protect insurance claims for injuries or illnesses of individual during work life in the organization.
- To prove suitable individual will be employed for a particular position reserved for disabled people according to the legal rules.

5.4 Conclusion

Personnel selection is the most important step of overall human resource management systems; because malfunction and success of the organizations in business environment usually depend on their human resources. Also, hiring the right person for a job/position will probably reduce the costs of turnover, training and monitoring the personnel.

As mentioned in preceding sections, personnel selection is a matching process of individuals' properties with job and organizational requirements. This matching can be carried out only if applicants are evaluated according to the correct criteria by proper methods. These selection criteria and selection methods should be determined by investigation of the position requirements, structure of the organization, number

and profile of the candidates, current environmental and economic conditions. Also, the personnel selection process should be supported by well-designed decision making models. By this way, the selection process is made consistent and away from subjective effects. Also, right people are hired for right job/positions.

CHAPTER 6

FUZZY DECISION MAKING MODEL FOR PERSONNEL SELECTION

6.1 Introduction

In this chapter, *personnel selection model*, which consists of two main multi criteria decision making techniques: *Fuzzy Rating* and *Analytic Hierarchy Process*, is described. Model is applied by using developed computer program for three different examples.

All individuals have different characteristics and abilities; moreover all jobs have different requirements. Then personnel selection for a particular job is a searching procedure to match job requirements and individual's characteristics and abilities. Developed model aims to determine requirement levels and to predict best individual who will perform job successfully.

6.2 Fuzzy Decision Making Model for Personnel Selection

The model developed for *personnel selection* is mainly based on *fuzzy rating method*, and model has three principal parts:

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

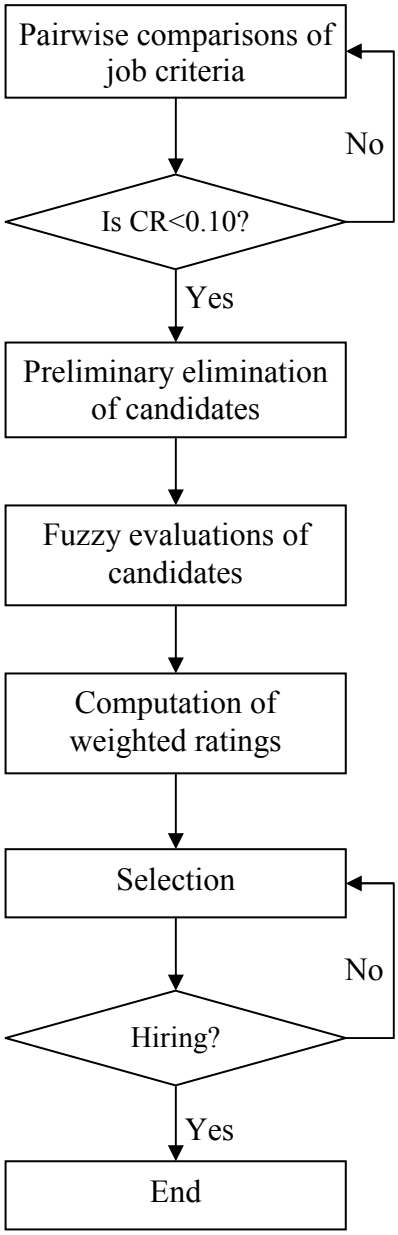


Figure 6.1 Personnel selection flowchart

6.2.1 Determining Relative Importance of Criteria

Relative importances of criteria are determined based on pairwise comparison of the original Analytic Hierarchy Process.

Education, Foreign Language, Work Experience, Personality Test, Ability Test, Employment Interview, Reference and Background Check are designated as job criteria and symbolized as in Table 6.1.

Table 6.1 Job criteria and symbols

Criterion	**Symbol**
Education	C_1
Foreign Language	C_2
Work Experience	C_3
Personality Test	C_4
Ability Test	C_5
Employment Interview	C_6
Reference and Background Check	C_7

All job criteria are located into comparison matrix (Table 6.2), and compared pairwisely by using 1-9 scale: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}. These comparisons are done with respect to the position (open position that candidates applied) 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.

Table 6.2 Criteria pairwise comparison matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}
C_2	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}	x_{26}	x_{27}
C_3	x_{31}	x_{32}	x_{33}	x_{34}	x_{35}	x_{36}	x_{37}
C_4	x_{41}	x_{42}	x_{43}	x_{44}	x_{45}	x_{46}	x_{47}
C_5	x_{51}	x_{52}	x_{53}	x_{54}	x_{55}	x_{56}	x_{57}
C_6	x_{61}	x_{62}	x_{63}	x_{64}	x_{65}	x_{66}	x_{67}
C_7	x_{71}	x_{72}	x_{73}	x_{74}	x_{75}	x_{76}	x_{77}

It should be noted that comparison matrix is reciprocal; that is, if criterion C_1 is twice as preferred to criterion C_7, criterion C_7 receives a score of ½ when compared to criterion C_1. Additionally, when comparing any criterion to itself, evaluation scale is 1; representing equally preferred criteria, so main diagonal of the matrix consists of 1s.

To calculate the relative importances of criteria, scores in each row are multiplied with each other and then 7-th root is taken. Next, numbers are normalized by dividing them with their sum.

$$v_1 = \sqrt[7]{(x_{11})(x_{12})(x_{13})(x_{14})(x_{15})(x_{16})(x_{17})} \tag{6.1}$$

v_2, v_3, v_4, v_5, v_6 and v_7 are calculated in the same way,

$$w_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \tag{6.2}$$

w_1, w_2, …, w_j, …, w_n are weighting coefficients of criteria C_1, C_2,…, C_j, …, C_n. Before using these coefficients in computation of ratings for alternatives, consistency ratio (CR) of pairwise comparisons is checked (calculation of CR is given in Chapter 4). If CR is less than 0.10, ratio indicates a reasonable level of consistency in the pairwise comparisons; if CR is equal or grater than 0.10, it indicates inconsistent judgments, then comparisons are renovated.

6.2.2 Evaluation of Applicants (Alternatives)

In Chapter 5, overall personnel selection process and its main steps are discussed in detail. *Preliminary interview* and *Review of applications* are two early steps in which applicants who obviously do not meet the position's basic requirements are eliminated. After these two steps, successful candidates are evaluated with respect to the 7 criteria mentioned in the former part. Each criterion has its own procedure and evaluation.

In this model, it is proposed to make evaluations with fuzzy terms. And six level fuzzy numbers are used:

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	($k = 6$)

In numerical form, their membership functions are defined by the following equations (Chen, 1996):

For $k = 1$:

$$\mu_1(x) = \begin{cases} 0, & x \le 0 \ or \ x \ge 1/5 \\ 1 - 5x, & 0 \le x \le 1/5 \end{cases} \tag{6.3}$$

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

$$\mu_k(x) = \begin{cases} 0, & x \le (k-2)/5 \ or \ x \ge k/5 \\ 5x - (k-2), & (k-2)/5 \le x \le (k-1)/5 \\ k - 5x, & (k-1)/5 \le x \le k/5 \end{cases} \tag{6.4}$$

For $k = 6$:

$$\mu_6(x) = \begin{cases} 0, & x \le 4/5 \ or \ x \ge 1 \\ 5x - 4, & 4/5 \le x \le 1 \end{cases} \tag{6.5}$$

All above membership functions represent *triangular fuzzy numbers* as shown in Figure 6.2.

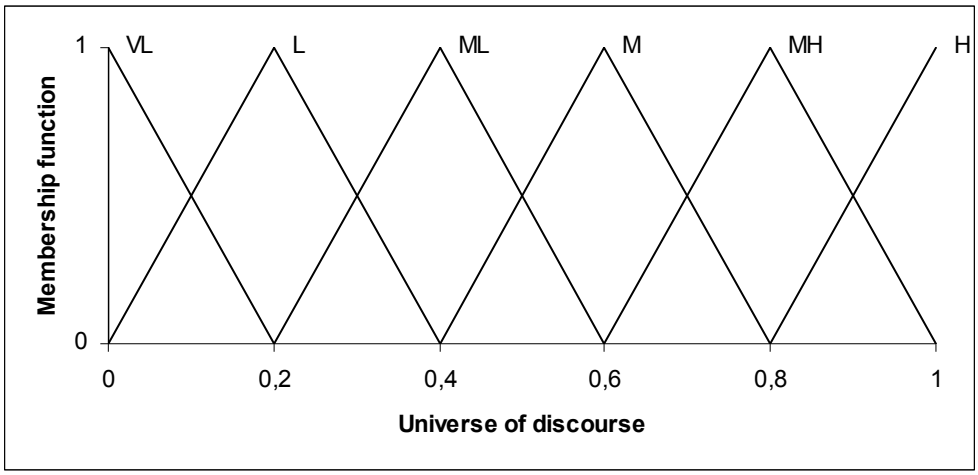


Figure 6.2 Membership functions of fuzzy numbers

Then fuzzy ratings r_{ij} for each applicant A_i with respect to each criterion C_j are obtained. An example evaluation of A_i for C_j is shown in Table 6.3.

Table 6.3 Candidate evaluation example

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

6.2.3 Computation of weighted ratings for each alternative

This part of the model uses outputs coming from preceding two parts: *determining relative importance of criteria* and *evaluation of applicants*. Now, model is processed by using weighing coefficients of criteria and fuzzy ratings of applicants for ranking them. This ranking is done after computing final weighted average ratings of applicants/alternatives.

If $w_1, w_2, \ldots, w_j, \ldots, w_n$ are weighing coefficients of criteria $C_1, C_2, C_3, \ldots, C_j, \ldots, C_n$, 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 3.15. Table 6.4 shows this calculation in detail.

Table 6.4 Weighted average rating calculation

A_1	$(r_{11} \text{ x } w_1) + (r_{12} \text{ x } w_2) + \ldots + (r_{1j} \text{ x } w_j) + \ldots + (r_{1n} \text{ x } w_n)$
A_2	$(r_{21} \text{ x } w_1) + (r_{22} \text{ x } w_2) + \ldots + (r_{2j} \text{ x } w_j) + \ldots + (r_{2n} \text{ x } w_n)$
⋮	⋮
A_i	$(r_{i1} \text{ x } w_1) + (r_{i2} \text{ x } w_2) + \ldots + (r_{ij} \text{ x } w_j) + \ldots + (r_{in} \text{ x } w_n)$
⋮	⋮
A_m	$(r_{m1} \text{ x } w_1) + (r_{m2} \text{ x } w_2) + \ldots + (r_{mj} \text{ x } w_j) + \ldots + (r_{mn} \text{ x } w_n)$

Calculated weighted average ratings are in triangular fuzzy number forms (a, b, c), then ranking is carried according to middle values.

6.3 Applications

In this section, applications of developed model to different personnel selection problems are presented. Additionally, Analytic Hierarchy Process without fuzzy numbers and evaluations is compared with the developed model in Application 3.

6.3.1 Application 1

In this example, 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 reduced to seven.

To solve the problem, relative importance of selection criteria should be determined firstly. For that purpose, selection criteria are located into comparison matrix, and compared pairwisely by using 1-9 scale: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}. Comparisons are made according to the position's requirements.

Table 6.5 Criteria pairwise comparison matrix in Application 1

	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

Scores in each row are multiplied with each other, and 7-th root is taken according to the Equation 6.1.

$$v_1 = \sqrt[7]{(1)(3)(1/2)(4)(5)(2)(4)} = 2.19$$

$$v_2 = \sqrt[7]{(1/3)(1)(1/3)(3)(4)(1/2)(1/2)} = 0.85$$

$$v_3 = \sqrt[7]{(2)(3)(1)(5)(6)(3)(3)} = 2.87$$

$$v_4 = \sqrt[7]{(1/4)(1/3)(1/5)(1)(3)(1/3)(1/3)} = 0.48$$

$$v_5 = \sqrt[7]{(1/5)(1/4)(1/6)(1/3)(1)(1/5)(1/4)} = 0.28$$

$$v_6 = \sqrt[7]{(1/2)(2)(1/3)(3)(5)(1)(3)} = 1.47$$

$$v_7 = \sqrt[7]{(1/4)(2)(1/3)(3)(4)(1/3)(1)} = 0.94$$

Next, numbers are normalized by dividing them with their sum, by using Equation 6.2.

$$w_1 = \frac{2.19}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.241$$

$$w_2 = \frac{0.85}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.094$$

$$w_3 = \frac{2.87}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.316$$

$$w_4 = \frac{0.48}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.052$$

$$w_5 = \frac{0.28}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.031$$

$$w_6 = \frac{1.47}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.162$$

$$w_7 = \frac{0.94}{2.19 + 0.85 + 2.87 + 0.48 + 0.28 + 1.47 + 0.94} = 0.104$$

w_1, w_2, w_3, w_4, w_5, w_6, w_7 are weighting coefficients of criteria C_1, C_2, C_3, C_4, C_5, C_6, C_7 (Table 6.6). Before using these coefficients in computation of weighted ratings for each candidate, *CR* of comparisons is checked.

$\lambda_{max} = 7.44$ (Maximum eigenvalue)

$CI = \frac{(7.44 - 7)}{(7 - 1)} = 0.073$ (Consistency index, Equation 4.2)

$CR = \frac{0.073}{1.32} = 0.055$ (Consistency ratio, 1.32 from Table 4.3)

Table 6.6 Criteria weights for Application 1.

Criterion	**Weights**
Education	0.241
Foreign Language	0.094
Work Experience	0.316
Personality Test	0.052
Ability Test	0.031
Employment Interview	0.162
Reference and Background Check	0.104

Because CR is lower than 0.10, comparisons are not renovated. In this problem, it is found that *work experience* is the most important criteria, and *ability test* is the lowest.

Evaluations of candidates are made with respect to each criterion with six level fuzzy terms of *VL*, *L*, *ML*, *M*, *MH* and *H*. Evaluations are given in Table 6.7.

Table 6.7 Candidate evaluations in Application 1

	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*

Then, weighted average rating for each candidate is calculated by using Equation 3.15. Table 6.8 shows this calculation.

Table 6.8 Weighted average rating calculation for Application 1

r_1	*M* x 0.241 + *L* x 0.094 + *MH* x 0.316 + *M* x 0.052 + *M* x 0.031 + *MH* x 0.162 + *MH* x 0.104
r_2	*MH* x 0.241 + *MH* x 0.094 + *L* x 0.316 + *M* x 0.052 + *MH* x 0.031 + *M* x 0.162 + *L* x 0.104
r_3	*H* x 0.241 + *H* x 0.094 + *VL* x 0.316 + *MH* x 0.052 + *M* x 0.031 + *ML* x 0.162 + *ML* x 0.104
r_4	*MH* x 0.241 + *M* x 0.094 + *MH* x 0.316 + *MH* x 0.052 + *M* x 0.031 + *MH* x 0.162 + *MH* x 0.104
r_5	*MH* x 0.241 + *MH* x 0.094 + *ML* x 0.316 + *M* x 0.052 + *MH* x 0.031 + *M* x 0.162 + *M* x 0.104
r_6	*H* x 0.241 + *MH* x 0.094 + *L* x 0.316 + *MH* x 0.052 + *M* x 0.031 + *M* x 0.162 + *MH* x 0.104
r_7	*ML* x 0.241 + *L* x 0.094 + *VL* x 0.316 + *MH* x 0.052 + *MH* x 0.031 + *MH* x 0.162 + *M* x 0.104

Results obtained from the developed model are in triangular fuzzy number form. According to these results, applicant who has the highest weighted average rating is candidate with the number of 4; it meanings that, this candidate meets position's requirements better than others, in the same time candidate with application number of *7* does worst.

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

Same problem is solved by using developed computer program, and same results are obtained. Firstly, all the information and evaluations about candidates are entered into "*Candidate Evaluation Form*", given in Appendix 4. Then, criteria pairwise comparisons repeated in "*Criteria Weights Program*" (Figure 6.3), and recorded. Finally, "*Candidate Evaluation Program*" is started to compute weighted average ratings of candidates (Figure 6.4).

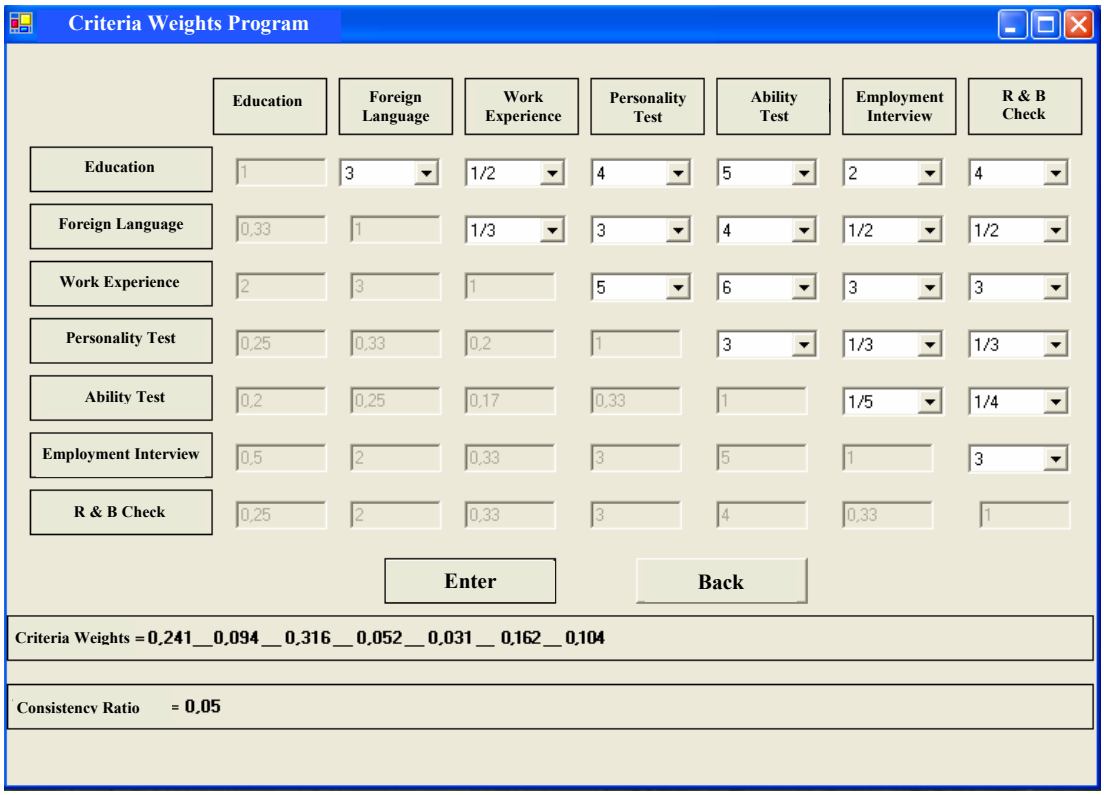


Figure 6.3 Criteria Weights Program results in Application 1

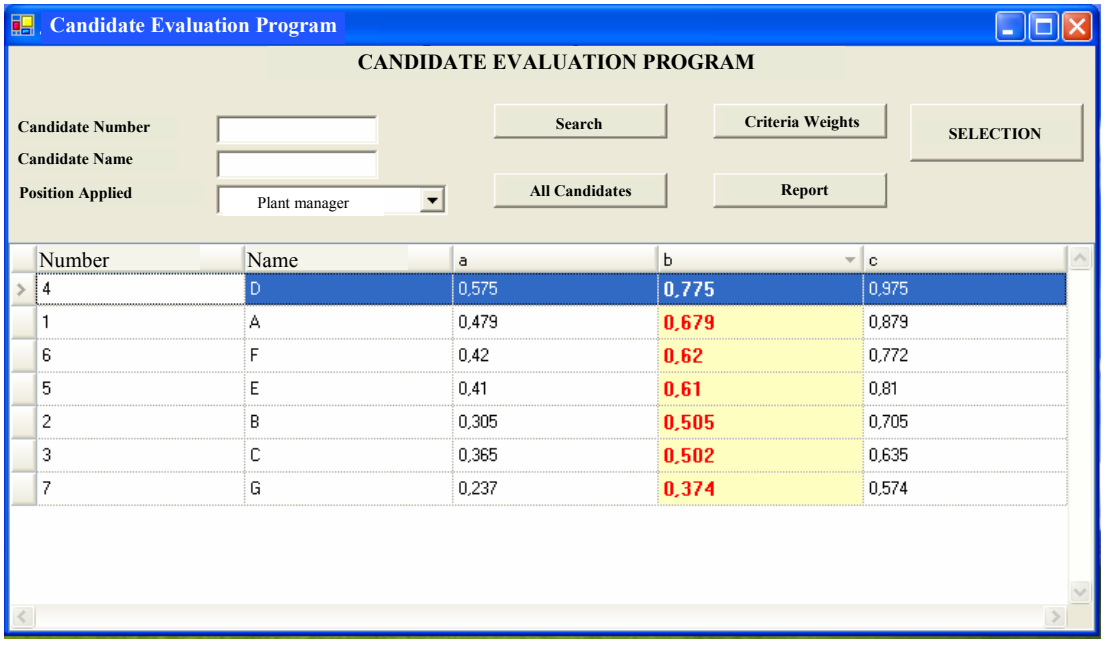


Figure 6.4 Candidate Evaluation Program results in Application 1

6.3.2 Application 2

In this example, there are 13 candidates to be evaluated; applied position is *production operator*. Same procedures in Application 1 are followed in this example. All information and evaluations are entered into "*Candidate Evaluation Form*", and then criteria are compared pairwisely in "*Criteria Weights Program*" (Figure 6.5)

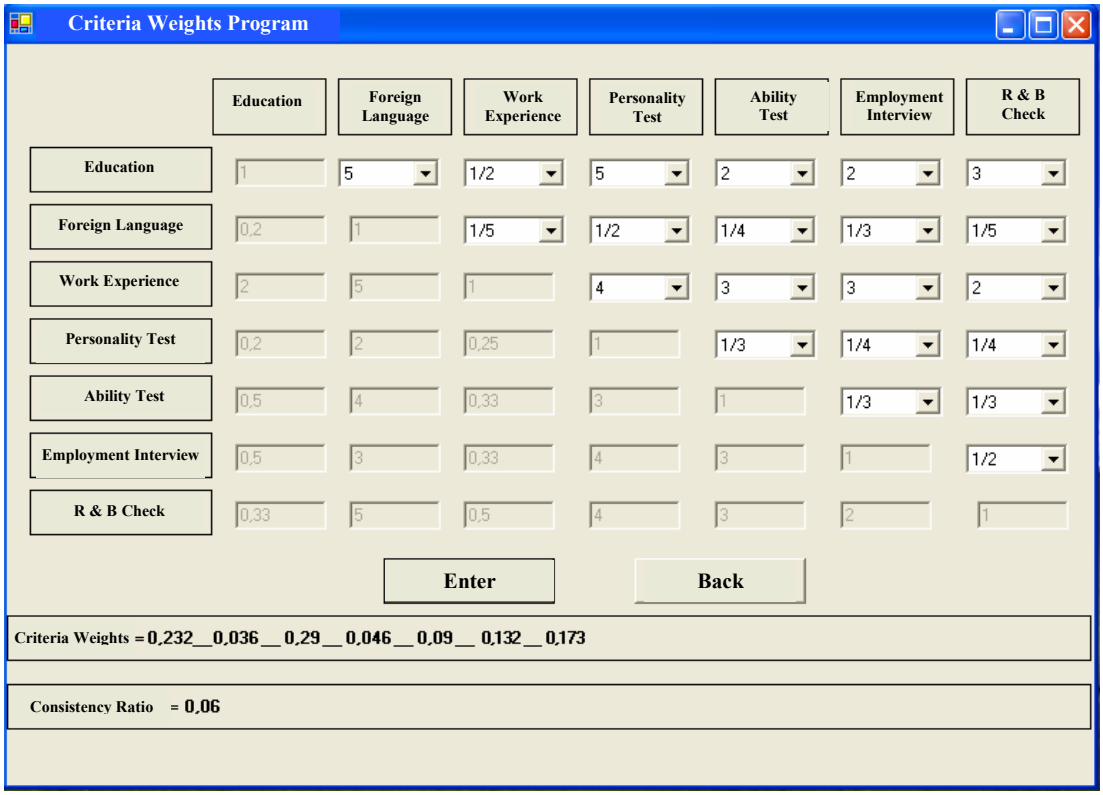


Figure 6.5 Pairwise comparisons of criteria in Application 2

Program calculated that most important criterion is *work experience* with a weight of 0.290; foreign language is requirement which has the least importance for plant operator position. Evaluations of all candidates can be seen entirely in Table 6.9.

Table 6.9 Candidate evaluations in Application 2

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_8	VL	L	MH	ML	M	M	MH
A_9	MH	M	L	MH	MH	M	L
A_{10}	VL	VL	H	L	M	ML	M
A_{11}	MH	M	VL	M	MH	M	L
A_{12}	M	VL	MH	L	L	MH	ML
A_{13}	M	ML	ML	MH	MH	MH	MH
A_{14}	L	L	H	ML	M	M	MH
A_{15}	M	L	M	MH	MH	MH	ML
A_{16}	MH	ML	VL	MH	MH	M	VL
A_{17}	MH	ML	ML	MH	L	L	MH
A_{18}	VL	VL	L	MH	H	H	H
A_{19}	H	M	M	VL	VL	ML	VL
A_{20}	L	L	L	M	ML	ML	ML

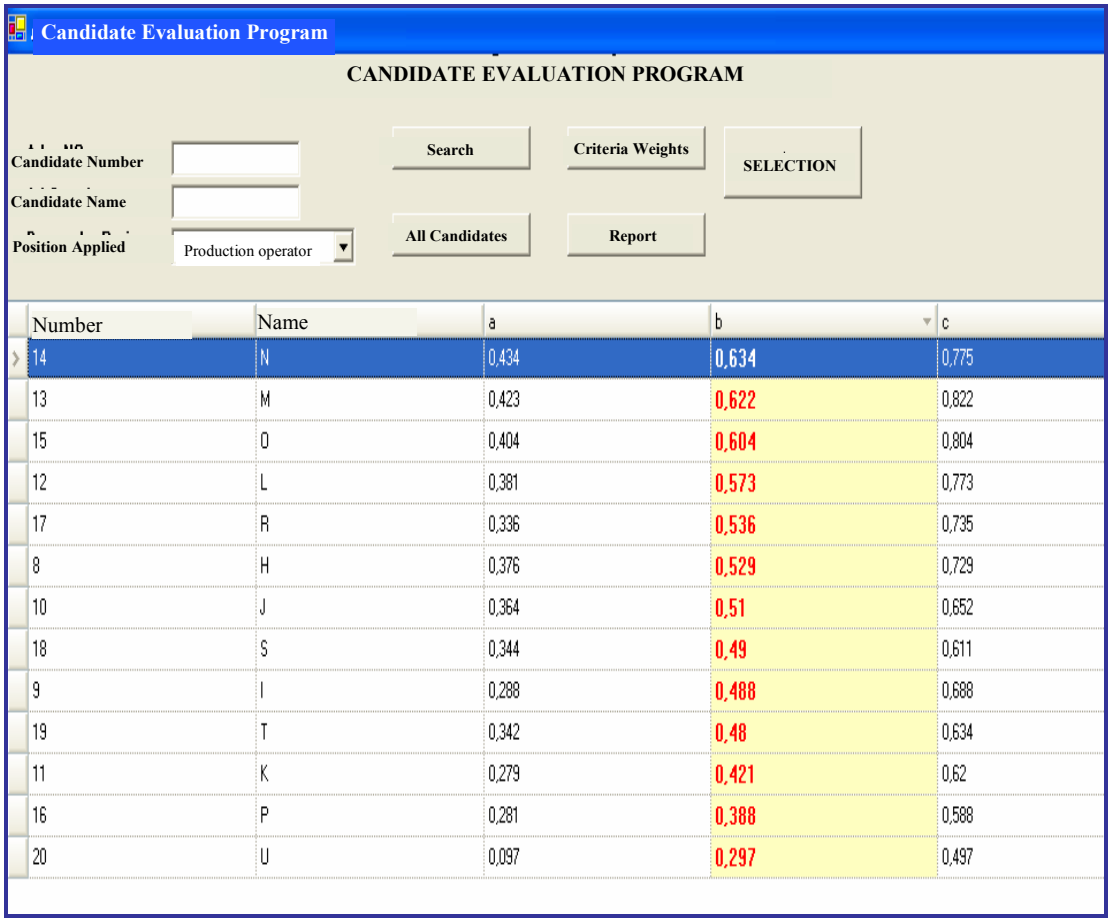


Figure 6.6 Arranged list of candidates in Application 2.

Finally, program is worked to find which applicant is better than others. 14th candidate is the answer, because its weighted rating is the highest one. And arranged list of candidates according to their ratings is given in Figure 6.6.

6.3.3 Application 3

In this application, Analytic Hierarchy Process is used to solve problems in which there are 7, 9, 11 and 13 candidates to be evaluated. AHP is applied without fuzzy evaluations and numbers, all comparisons and evaluations are made by using 1-9 scale. In the same time, the problems are solved by the developed model and the computer program. The first problem containing 7 candidates is the same problem in Application 1, and applied open position is *plant manager*, then criteria weights same as in Application 1 are used. Table 6.10 shows fuzzy evaluations of candidates. Performance values of candidates according to the AHP are given in Appendix 5, 6, 7, 8 for 7, 9, 11, 13 candidates respectively.

Table 6.10 Candidate evaluations in Application 3

	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*
A_8	*MH*	*MH*	*L*	*M*	*L*	*ML*	*MH*
A_9	*MH*	*MH*	*VL*	*MH*	*L*	*MH*	*M*
A_{10}	*ML*	*L*	*MH*	*H*	*M*	*M*	*L*
A_{11}	*L*	*MH*	*MH*	*MH*	*M*	*M*	*M*
A_{12}	*M*	*M*	*H*	*VL*	*M*	*MH*	*L*
A_{13}	*M*	*M*	*MH*	*MH*	*L*	*ML*	*M*

The developed model results are normalized by dividing them with their sum to make them similar to the AHP results (Table 6.11).

Table 6.11 Weighted average ratings and normalized values in Application 3

	Weighted average ratings	Normalized values of 7 candidates	Normalized values of 9 candidates	Normalized Values of 11 candidates	Normalized values of 13 candidates
C_1	0.679	0.167	0.133	0.109	0.090
C_2	0.505	0.124	0.099	0.081	0.067
C_3	0.502	0.123	0.099	0.080	0.066
C_4	0.775	0.191	0.152	0.124	0.103
C_5	0.610	0.150	0.120	0.098	0.081
C_6	0.620	0.153	0.122	0.099	0.082
C_7	0.374	0.092	0.073	0.060	0.049
C_8	0.517		0.102	0.083	0.068
C_9	0.508		0.100	0.081	0.067
C_{10}	0.557			0.089	0.074
C_{11}	0.596			0.095	0.079
C_{12}	0.686				0.091
C_{13}	0.629				0.083

Table 6.12 The AHP results for Application 3

	7 Candidates	9 Candidates	11 Candidates	13 Candidates
C_1	0.172	0.145	0.114	0.104
C_2	0.127	0.090	0.058	0.049
C_3	0.125	0.105	0.086	0.079
C_4	0.174	0.166	0.133	0.112
C_5	0.154	0.107	0.086	0.069
C_6	0.147	0.127	0.108	0.090
C_7	0.102	0.074	0.065	0.046
C_8		0.088	0.070	0.056
C_9		0.098	0.076	0.074
C_{10}			0.102	0.069
C_{11}			0.102	0.071
C_{12}				0.112
C_{13}				0.069

Table 6.12 shows Analytic Hierarchy Process results for 7, 9, 11 and 13 candidates. The results obtained from two different methods are put together into the same graphs for 7, 9, 11, and 13 candidates separately (Figure 6.7, 6.8, 6.9, 6.10 respectively). As shown in these comparative graphs, preference values obtained

from the two different methods are similar. However, this similarity decreases with increasing number of candidates.

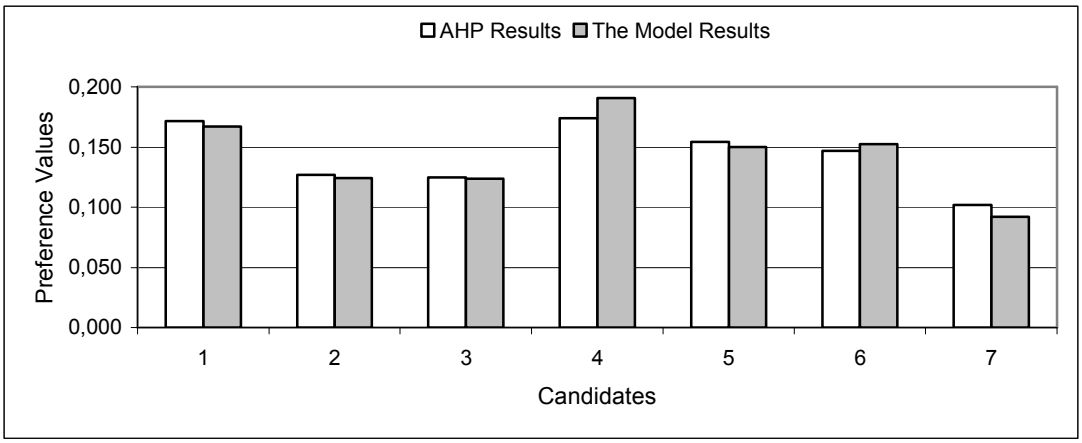


Figure 6.7 Comparative results of the developed model and AHP for 7 candidates.

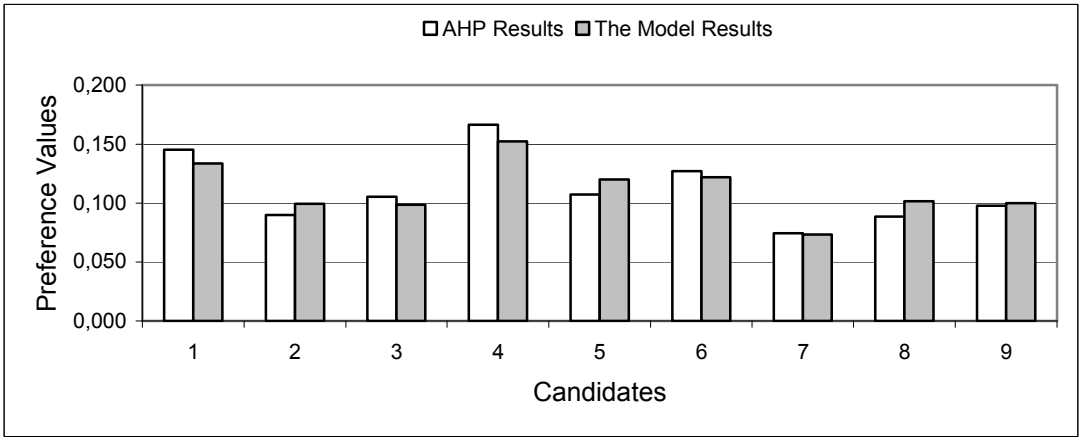


Figure 6.8 Comparative results of the developed model and AHP for 9 candidates.

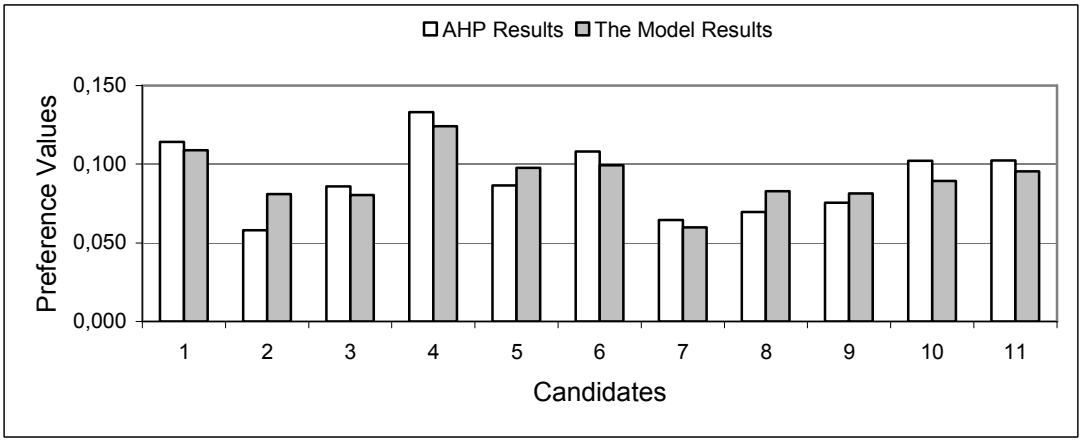


Figure 6.9 Comparative results of the developed model and AHP for 11 candidates.

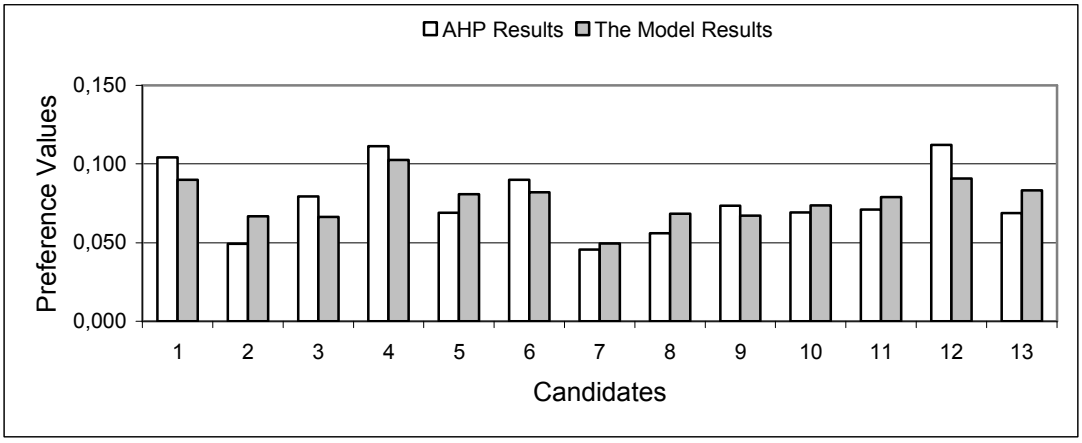


Figure 6.10 Comparative results of the developed model and AHP for 13 candidates.

To show that situation clearly, AHP results are subtracted from normalized results of the model; differences are converted into absolute values. The totals of these values are averaged by dividing them with the numbers of candidates (Table 6.13).

Table 6.13 Differences between the results of the model and AHP

	7 Candidates	**9 Candidates**	**11 Candidates**	**13 Candidates**
C_1	0.005	0.012	0.005	0.014
C_2	0.003	0.009	0.023	0.017
C_3	0.001	0.007	0.005	0.013
C_4	0.017	0.014	0.009	0.009
C_5	0.004	0.013	0.011	0.012
C_6	0.006	0.005	0.009	0.008
C_7	0.010	0.001	0.005	0.004
C_8		0.013	0.013	0.012
C_9		0.002	0.006	0.006
C_{10}			0.013	0.004
C_{11}			0.007	0.008
C_{12}				0.021
C_{13}				0.014
Total	*0.045*	*0.076*	*0.106*	*0.144*
Average	*0.0064*	*0.0084*	*0.0096*	*0.0111*

These average values of differences rise from 0.0064 to 0.0111 with increasing numbers of candidates from 7 to 13. This increase in the differences between the results of two methods is caused mainly from the AHP. The developed model gives consistent results even number of candidates is increased in a personnel selection

problem. However, the results of the AHP are not consistent when high number of candidates present.

6.4 Conclusion

In this chapter, the proposed model is presented mathematically with three principal steps in arranged order. The model and the implemented computer program are tested with two different applications in which better individuals are selected from the lists of candidates. These applications prove that both of the model and the computer program work without any problem. And, the results obtained from the proposed model are not affected from the number of candidates who applied for the same position.

Analytic hierarchy process without fuzzy evaluations and the proposed model are compared in application 3. Same problems are solved with two methods; number of candidates is increased from 7 to 9, 11 and 13. In the same time, it is observed that average difference between the results of two methods rise from 0.0064 to 0.0111. This situation is mainly caused by the structure of the analytic hierarchy process which contains pairwise comparisons matrices; possibility of inconsistencies generally rises with the size of the judgment matrices (Srdjevic, 2005). It is proved that individuals can not simultaneously compare more than seven objects (plus or more minus two) (Miller, 1956), that is also another reason of inconsistency.

CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 Introduction

Discussion and conclusions presented in this chapter are about fuzzy decision making model developed for personnel selection.

7.2 Discussion

7.2.1 The need for the present work

Because personnel selection is a real life situation, many researchers have been interested in that subject; however there are high numbers of works in the literature deal with personnel selection. On the analytical side, most of multi criteria decision making methods are applied to solve this complex problem; especially Fuzzy Logic and Analytic Hierarchy Process are used. Both of them can be used in such real life problems contain uncertainties. But, Analytic Hierarchy Process is not proposed in this thesis to model personnel selection even it can be used for selection with low number candidates. Also psychological experiments show that individuals can not simultaneously compare more than seven objects (plus or minus two) (Miller, 1956), this is the main reason of using *9* as upper limit in 1-9 scale by Saaty; because people are unable to make choices from an infinite set and they cannot distinguish objects with very close values of importance (Triantaphyllou and Mann, 1995), AHP is not proper for personnel selection situations contain high number of candidates and properties of candidates are very close to each other.

Almost all works in the literature approach to the problem from just one side, these are not complete works prepared by associated groups of researchers deal with different sides of the subject. So, developed models are not consistent.

The main aim of this work was to provide a consistent model for the solution of personnel selection problem implemented through a computer program.

7.2.2 The structure of the present work

Personnel selection as an important step of human resource management includes evaluation of candidates with respect to criteria necessary for the job; of course these evaluations contain vague and imprecise information. Fuzzy logic is also a successful tool to manipulate objects with ill-defined boundaries. In that respect, it is employed in this study.

Fuzzy Ranking method is combined with Analytic Hierarchy Process which is not sufficient alone for problems with high number of objects. AHP is used to determine relative importance of criteria. Six-level fuzzy numbers are employed to differentiate candidates with close properties; lower-level scales may cause problems if high number of applicants present.

Model is implemented through computer program prepared by using Microsoft Visual Studio .NET along with Microsoft Access as database, by this way model is made more useful and quick to apply.

7.3 Contributions and Concluding Remarks

It is believed that the combinations of different decision making methods may produce more effective models for the solution of personnel selection problem. By this way, more consistent models can be developed. In this thesis, fuzzy ranking method is combined with analytic hierarchy process, and a consistent model is obtained independent from the number of candidates applied for any position. The proposed model can be used for any personnel selection problem contains even high

number of applicants and for any position by determining the criteria weights based on the position requirements.

The proposed model is implemented through a computer program which is integrated with another computer program developed for "personnel and performance management system" by Terziakın (2005). A complete "personnel selection-personnel and performance management" system is obtained by this integration.

7.4 Future Works

The proposed "fuzzy decision making model for personnel selection" is designated for situations in which personnel selection decisions are made by single decision-maker. However, there are many organizations in which personnel selection decisions are made by multiple decision-makers (selection committee). Then, the current model can be modified for multiple decision-makers' usage.

In this thesis, to develop a more effective model for the solution of personnel selection problem, fuzzy ranking method is combined with analytic hierarchy process. Different combinations of fuzzy logic with other decision making methods may produce more effective models, this is an important future work should be considered.

Now, the most of the organizations have internet sites, they receive applications from any individual in any place of the world, and they make eliminations according to the information received. They use internet and information technology (IT) as tools for their human resource management systems. Therefore, the developed model and program can be integrated with these tools.

Although the current model and the computer program were developed with common personnel selection criteria, they can be customized for particular organizations with specific details. For example, special skill or ability tests, interview forms, may be integrated to the computer program.

APPENDIX 1. Personality Profile Test

Direction: In each of the following rows of four words across, place an X in front of the one word that most often applies to you. Continue through all forty lines. Be sure each number is marked. Transfer all your X's to the corresponding words on the scoring chart and add up your totals.

1		Adventurous		Adaptable		Animated		Analytical
2		Persistent		Playful		Persuasive		Peaceful
3		Submissive		Self-sacrificing		Sociable		Strong-willed
4		Considerate		Controlled		Competitive		Convincing
5		Refreshing		Respectful		Reserved		Resourceful
6		Satisfied		Sensitive		Self-reliant		Spirited
7		Planner		Patient		Positive		Promoter
8		Sure		Spontaneous		Scheduled		Shy
9		Orderly		Obliging		Outspoken		Optimistic
10		Friendly		Faithful		Funny		Forceful
11		Daring		Delightful		Diplomatic		Detailed
12		Cheerful		Consistent		Cultured		Confident
13		Idealistic		Independent		Inoffensive		Inspiring
14		Demonstrative		Decisive		Dry Humour		Deep
15		Mediator		Musical		Mover		Mixes Easily
16		Thoughtful		Tenacious		Talker		Tolerant
17		Listener		Loyal		Leader		Lively
18		Contented		Chief		Chart maker		Cute
19		Perfectionist		Pleasant		Productive		Popular
20		Bouncy		Bold		Behaved		Balanced
21		Blank		Bashful		Brassy		Bossy
22		Undisciplined		Unsympathetic		Unenthusiastic		Unforgiving
23		Reticent		Resentful		Resistant		Repetitious
24		Fussy		Fearful		Forgetful		Frank
25		Impatient		Insecure		Indecisive		Interrupts
26		Unpopular		Uninvolved		Unpredictable		Unaffectionate
27		Headstrong		Haphazard		Hard to Please		Hesitant
28		Plain		Pessimistic		Proud		Permissive
29		Angered Easily		Aimless		Argumentative		Alienated
30		Naive		Negative Attitude		Nervy		Nonchalant
31		Worrier		Withdrawn		Workaholic		Wants Credit
32		Too Sensitive		Tactless		Timid		Talkative
33		Doubtful		Disorganized		Domineering		Depressed
34		Inconsistent		Introvert		Intolerant		Indifferent
35		Messy		Moody		Mumbles		Manipulative
36		Slow		Stubborn		Show-off		Sceptical
37		Loner		Lord-over-others		Lazy		Loud
38		Sluggish		Suspicious		Short-tempered		Scatterbrained
39		Revengeful		Restless		Reluctant		Rash
40		Compromising		Critical		Crafty		Changeable

Scoring Sheet

Strengths

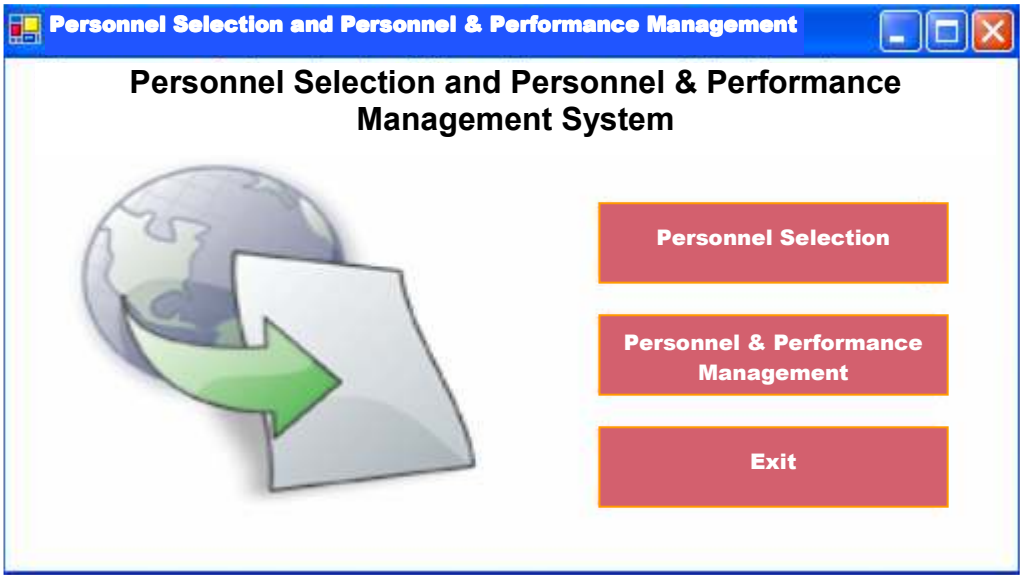
	SANGUINE POPULAR		CHOLERIC POWERFUL		MELANCHOLY PERFECT		PHLEGMATIC PEACEFUL
1		Animated		Adventurous		Analytical		Adaptable
2		Playful		Persuasive		Persistent		Peaceful
3		Sociable		Strong-willed		Self-sacrificing		Submissive
4		Convincing		Competitive		Considerate		Controlled
5		Refreshing		Resourceful		Respectful		Reserved
6		Spirited		Self-reliant		Sensitive		Satisfied
7		Promoter		Positive		Planner		Patient
8		Spontaneous		Sure		Scheduled		Shy
9		Optimistic		Outspoken		Orderly		Obliging
10		Funny		Forceful		Faithful		Friendly
11		Delightful		Daring		Detailed		Diplomatic
12		Cheerful		Confident		Cultured		Consistent
13		Inspiring		Independent		Idealistic		Inoffensive
14		Demonstrative		Decisive		Deep		Dry Humour
15		Mixes Easily		Mover		Musical		Mediator
16		Talker		Tenacious		Thoughtful		Tolerant
17		Lively		Leader		Loyal		Listener
18		Cute		Chief		Chart maker		Contented
19		Popular		Productive		Perfectionist		Pleasant
20		Bouncy		Bold		Behaved		Balanced
		TOTALS		**TOTALS**		**TOTALS**		**TOTALS**

Weaknesses

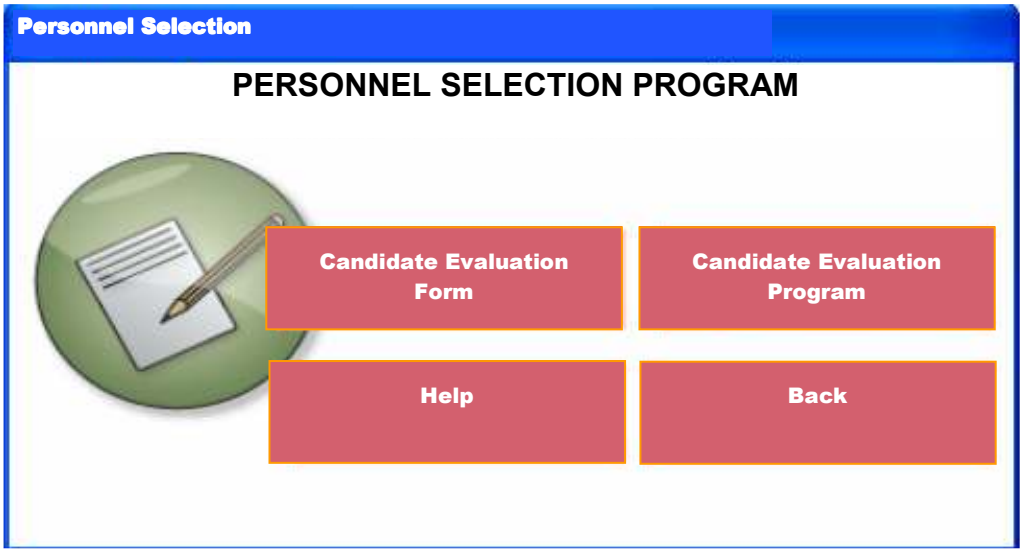
		SANGUINE POPULAR		CHOLERIC POWERFUL		MELANCHOLY PERFECT		PHLEGMATIC PEACEFUL
21		Brassy		Bossy		Bashful		Blank
22		Undisciplined		Unsympathetic		Unforgiving		Unenthusiastic
23		Repetitious		Resistant		Resentful		Reticent
24		Forgetful		Frank		Fussy		Fearful
25		Interrupts		Impatient		Insecure		Indecisive
26		Unpredictable		Unaffectionate		Unpopular		Uninvolved
27		Haphazard		Headstrong		Hard-to-please		Hesitant
28		Permissive		Proud		Pessimistic		Plain
29		Angered-easily		Argumentative		Alienated		Aimless
30		Naive		Nervy		Negative Attitude		Nonchalant
31		Wants Credit		Workaholic		Withdrawn		Worrier
32		Talkative		Tactless		Too Sensitive		Timid
33		Disorganized		Domineering		Depressed		Doubtful
34		Inconsistent		Intolerant		Introvert		Indifferent
35		Messy		Manipulative		Moody		Mumbles
36		Show-off		Stubborn		Sceptical		Slow
37		Loud		Lord-over-others		Loner		Lazy
38		Scatterbrained		Short-tempered		Suspicious		Sluggish
39		Restless		Rash		Revengeful		Reluctant
40		Changeable		Crafty		Critical		Compromising
		TOTALS		**TOTALS**		**TOTALS**		**TOTALS**

Strengths Total				
Weaknesses Total				
GRAND Total				

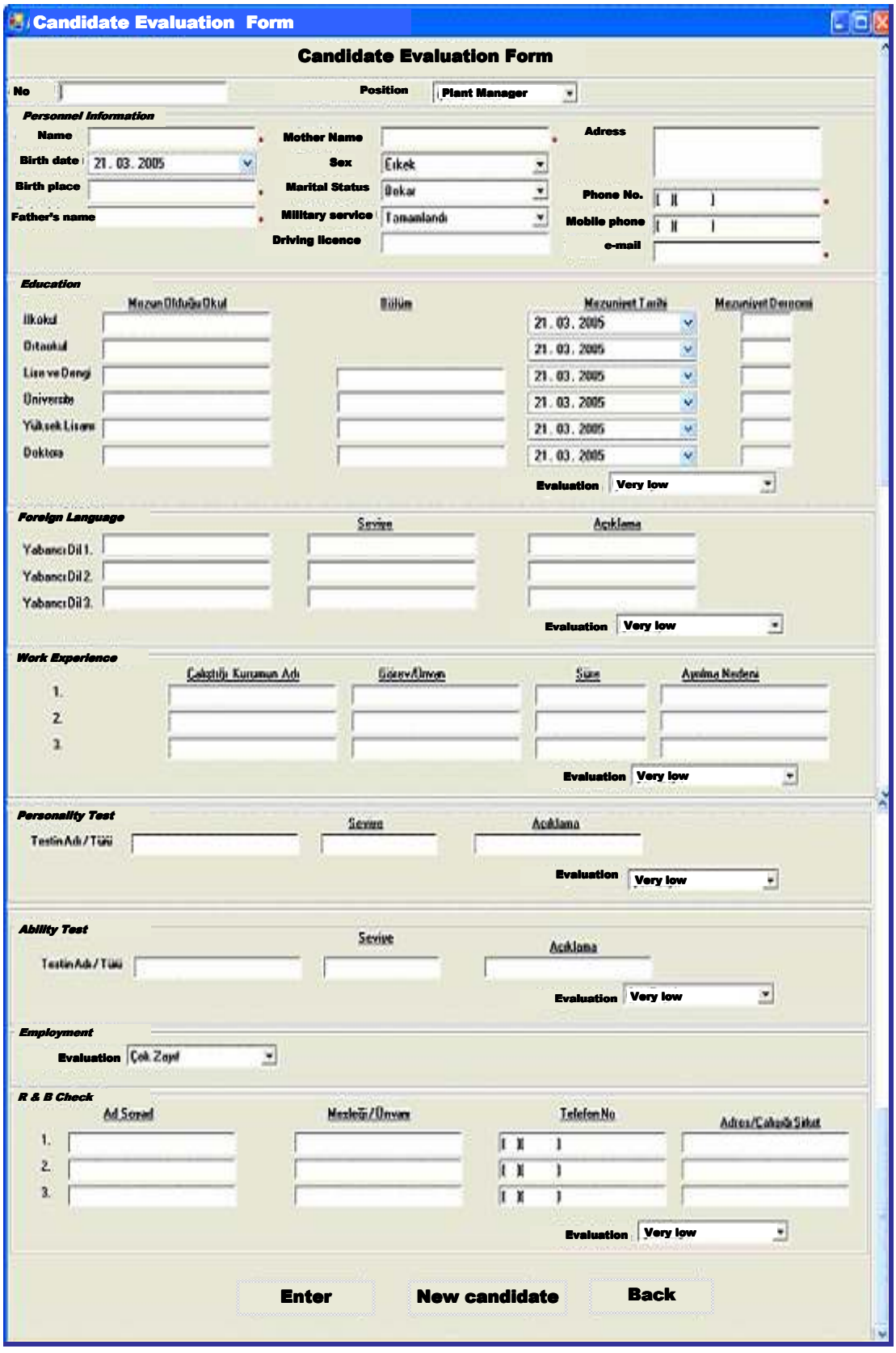
APPENDIX 2. Program Main Screen



APPENDIX 3. Personnel Selection Program



APPENDIX 4. Candidate Evaluation Form



APPENDIX 5. AHP Performance Values of 7 Candidates in Application 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
	0.241	*0.094*	*0.316*	*0.052*	*0.031*	*0.162*	*0.104*
A_1	0.116	0.067	0.260	0.138	0.130	0.162	0.170
A_2	0.146	0.192	0.105	0.124	0.140	0.133	0.077
A_3	0.184	0.231	0.053	0.186	0.136	0.100	0.115
A_4	0.132	0.048	0.266	0.075	0.124	0.173	0.172
A_5	0.152	0.192	0.158	0.133	0.172	0.133	0.154
A_6	0.180	0.192	0.105	0.174	0.130	0.133	0.166
A7	0.091	0.077	0.053	0.170	0.168	0.165	0.146

APPENDIX 6. AHP Performance Values of 9 Candidates in Application 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
	0.241	*0.094*	*0.316*	*0.052*	*0.031*	*0.162*	*0.104*
A_1	0.057	0.042	0.250	0.071	0.091	0.155	0.160
A_2	0.104	0.123	0.084	0.077	0.196	0.080	0.035
A_3	0.192	0.234	0.046	0.142	0.091	0.044	0.048
A_4	0.104	0.068	0.255	0.142	0.096	0.164	0.169
A_5	0.104	0.123	0.122	0.068	0.169	0.087	0.086
A_6	0.201	0.130	0.072	0.142	0.087	0.089	0.182
A_7	0.038	0.038	0.045	0.149	0.196	0.157	0.079
A_8	0.095	0.127	0.080	0.066	0.037	0.042	0.163
A_9	0.104	0.123	0.047	0.142	0.036	0.183	0.079

APPENDIX 7. AHP Performance Values of 11 Candidates in Application 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
	0.241	*0.094*	*0.316*	*0.052*	*0.031*	*0.162*	*0.104*
A_1	0.057	0.028	0.164	0.041	0.069	0.152	0.166
A_2	0.063	0.107	0.041	0.040	0.165	0.063	0.025
A_3	0.173	0.198	0.025	0.102	0.071	0.035	0.042
A_4	0.126	0.054	0.168	0.102	0.072	0.140	0.138
$A5$	0.103	0.112	0.075	0.039	0.170	0.076	0.073
A_6	0.175	0.112	0.049	0.104	0.083	0.087	0.172
A_7	0.048	0.030	0.024	0.106	0.172	0.151	0.070
A_8	0.090	0.116	0.049	0.037	0.027	0.032	0.130
A_9	0.105	0.101	0.025	0.094	0.026	0.119	0.075
A_{10}	0.036	0.028	0.194	0.225	0.074	0.076	0.030
A_{11}	0.023	0.114	0.186	0.111	0.072	0.069	0.079

APPENDIX 8. AHP Performance Values of 13 Candidates in Application 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
	0.241	*0.094*	*0.316*	*0.052*	*0.031*	*0.162*	*0.104*
A_1	0.060	0.045	0.135	0.045	0.105	0.137	0.145
A_2	0.075	0.094	0.032	0.014	0.013	0.058	0.015
A_3	0.169	0.183	0.018	0.091	0.072	0.029	0.037
A_4	0.090	0.049	0.121	0.120	0.155	0.135	0.135
A_5	0.091	0.103	0.049	0.030	0.133	0.058	0.065
A_6	0.159	0.104	0.032	0.093	0.072	0.064	0.134
A_7	0.027	0.023	0.016	0.120	0.110	0.093	0.070
A_8	0.091	0.091	0.020	0.039	0.018	0.018	0.132
A_9	0.090	0.101	0.025	0.110	0.056	0.126	0.065
A_{10}	0.031	0.029	0.113	0.170	0.076	0.058	0.027
A_{11}	0.019	0.088	0.114	0.073	0.060	0.055	0.071
A_{12}	0.047	0.044	0.214	0.021	0.104	0.136	0.027
A_{13}	0.049	0.045	0.110	0.074	0.028	0.032	0.078

APPENDIX 9. Installation Manual of the Computer Program

A. Install the "Microsoft .NET Framework"

1. Double click the "dotnetfx" file
2. Click "Yes" in open screen
3. Click "I agree" in License Agreement
4. Click "Install" to start the installation
5. Click "OK" to finish the installation

B. Install the Developed Computer Program

1. Open the "setup" folder
2. Double click the "setup" file
3. Click "Next"
4. Choose folder in which the program will be installed
5. Click "Next"
6. Confirm installation by clicking "Next"
7. Click "Close" to finish installation

REFERENCES

Aguinis, H., Henle, C.A., Beaty, J.C. (2001). Virtual reality technology: a new tool for personnel selection. *International Journal of Selection and Assessment*, **9**, 70-83

Bellman, R.E., Zadeh, L.A. (1970). Decision-making in a fuzzy environment. *Management Science*, **17**, 141-164

Butkiewicz, B.S. (2002). Selection of staff for enterprise using fuzzy logic. *IEEE SMC TA2N4*

Chen, Y.H. (1996). Fuzzy ratings in mechanical engineering design-application to bearing selection. *Proc. Instn. Mech. Engrs.*, **210**, 49-53

Dağdeviren, M., Akay, D., Kurt, M. (2004). İş değerlendirme sürecinde analitik hiyerarşi prosesi ve uygulaması. *Gazi Üniversitesi Müh. Mim. Fak. Dergisi*, **19**, 131-138

Erkoç, K., Temurtaş, F., Gülbağ, A. (2003). Bulanık mantık kullanarak imza tanıma. *IJCI Proceeding of International Conference on Signal Processing, ISSN*, **1**, 423-428

Fayad, C., Webb, P. (1999). Fuzzy logic based collision avoidance algorithm for a mobile robot. *Workshop on Recent Advances in Soft Computing*. Leicester.

Ivancevich, J.M. (2001). *Human Resource Management*. McGraw-Hill.

Jandric, Z., Srdjevic, B. (2000). Analytic hierarchy process in selecting best groundwater pond. *31st International Geological Congress*. Rio de Janeiro, Brazil

Jantzen, J. (1998). Tutorial on fuzzy logic. *Technical University of Denmark, Technical report*, 98-E 898

Karsak, E.E. (2000). A fuzzy multiple objective programming approach for personnel selection. *IEEE*, 2007-2012

Kuruüzüm, A., Atsan, N. (2001). Analitik hiyerarşi yöntemi ve işletmecilik alanındaki uygulamaları. *Akdeniz İ.İ.B.F. Dergisi*, **1**, 83-105

Lazarevic-Petrovic, S. (2001). Personnel selection fuzzy model. *International Transactions in Operational Research*, **8**, 89-105

Liang, G.S., Wang, M.J.J. (1994). Personnel selection using fuzzy MCDM algorithm. *European Journal of Operational Research*, **78**, 22-33

Lievens, F., Van Dam K., Anderson, N. (2002). Recent trends and challenges in personnel selection. *Personnel Review*, **31**, 580-601.

Littauer, F., Littauer, M. (2003). *Personality Puzzle, Understanding the People You Work With* (Çelik, H.B.). Sistem Yayıncılık. (Original work published in 1992).

Mikhailov, L. (2002). Fuzzy analytical approach to partnership selection in formation of virtual enterprises. *The International Journal of Management Science*, **30**, 393-401

Miller, G.A. (1956). The Magical Number Seven Plus or Minus Two: Some Limits on Our Capacity for Processing Information. *Psychological Review*, **63**, 81-97

Mondy, R.W., Noe, R.M., Premeaux, S.R. and Mondy, J.B. (2002). *Human Resource Management*. Prentice Hall.

Morillas, A., Diaz, B., Gonzalez, J. (1996). Fuzzy comparative concordance analysis. Proposal and evaluation by a case study. *LIth International Conference of the Applied Econometric Association*. Lisboa, Portugal

Özgüven, İ.E. (2000). *Psikolojik Testler*. Pdrem Yayınları.

Prodanovic, P. (2001). Fuzzy set ranking methods and multiple expert decision making. *The University of Western Ontario*, Project report

Robbins, S.P., Coulter, M.C. (2002). *Management*. Prentice Hall

Robertson, I.T., Smith, M. (2001). Personnel Selection. *Journal of Occupational and Organizational Psychology*, **74**, 441-472

Saaty T.L. (1994). *Fundamentals of decision-making and priority theory with the Analytic Hierarchy Process*. RWS Publications.

Saaty, T.L. (1980). *The Analytical Hierarchy Process*. McGraw-Hill.

Şen, Z. (2001). *Bulanık Mantık ve Modelleme İlkeleri*. Bilge Kültür Sanat.

Soyuer, H., Kocamaz, M. (2005, last accessed) İşletmelerde Bilgisayar Destekli İnsan Kaynağı Değerlendirme ve Seçme Süreci. http://www.bilgiyonetimi.org/cm/

Srdjevic, B. (2005). Combining different prioritization methods in analytic hierarchy process synthesis. *Computers & Operations Research*, **32**, 1897-1919

Telman, N., Türetgen, İ. (2004). *Eleman Seçimi*. Epilson Yayıncılık.

Terziakın, Y. (2005, under development). An integrated personnel and performance management system. M. Sc. Thesis, Gaziantep University

Torrington, D., Hall, L., Taylor, S. (2002). *Human Resource Management*. Prentice Hall

Triantaphyllou, E., Mann, S.H. (1995). Using the analytic hierarchy process for decision making in engineering applications: Some challenges. *International Journal of Industrial Engineering: Applications and Practice*, **2**, 35-44

Tütüncü, Ö., Tarlan, D., Mamyrkulov, N. (2003). Seyahat acentalarında çalışanların işe alma sürecini algılamaları ve İzmir ili örneği. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, **5**, 113-140

Vanegas, L.V., Labib, A.W. (2001). Application of new fuzzy-weighted average (NFWA) method to engineering design evaluation. *International Journal of Production Research*, **39**, 1147-1162

Zadeh, L. A. (1973). Outline of a new approach to the analysis of complex systems and decision processes. *IEEE Trans. Systems, Man & Cybernetics*, **1**, 28-44

Zadeh, L.A. (1965). Fuzzy sets. *Information and Control*, **8**, 338-353

Zadeh, L.A. (2004). Fuzzy logic systems: origin, concepts, and trends. http://www.cs.berkeley.edu/~zadeh/

Zaim, S., Sevkli, M., Tarim, M. (2005, last accessed). Fuzzy Analytical Hierarchy Based Approach for Supplier Selection. http://www.fatih.edu.tr