Erciyes Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, Sayı 26, Ocak- Haziran 2006, ss

A DECISION MAKER SYSTEM FOR ACADEMICIAN SELECTION WITH FUZZY WEIGHTING AND FUZZY RANKING

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ABSTRACT

In this study an academician selection system has been developed for universities using fuzzy weighting and fuzzy ranking. In the system, effects of many criteria and views of many experts are evaluated for selection. Number of criteria, number of linguistic variables of criteria, names of linguistic variables, membership functions of linguistic variables, number of experts and alternatives can be changed in our system. Experts can determine importances of criteria and performance of each alternative for each criter as linguistic or numerical. The system weights the alternatives using standard fuzzy arithmetic and ranks as fuzzy. In our system maximizing set and minimizing set method has been used for ranking alternatives.

Keywords*:* Personal selection, academician selection, fuzzy logic, fuzzy weighting, fuzzy ranking.

INTRODUCTION

Principal goals of personnel selection, participation a person to an organization, who performs high performance, works with his/her colleagues by motivating them, works at the job for a long time and improves work yield. For a reliable personnel selection, firstly, properties of job have to be defined then alternatives have to be chosen according to these properties. A reliable job analysis is the basic necessity of personnel selection and performance evaluation. In order to the job analysis is the basic of most studies in organizations, this study have to be done perfectly firstly. And then the selection tools, which are experts and criteria of selection, must be defined carefully.

Universities are organizations, which are consists of various units and aim to train proper manpower for needs of humanity by doing education at different

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Makalenin geliş tarihi: Haziran 2005, kabul tarihi: Ekim 2006

levels, academic studies, publication and consultancy (Constitution of Republic of Turkey 1982:130). In this subject, academicians undertake most important duty. Since the academicians have to have lots of qualities, lots of criteria have to be considered in academician selection. In addition, for an objective selection, alternatives must be evaluated by more than one expert. In this case, academician selection problem becomes a multi-experts, multi-criteria decision making (ME-MCDM) problem. For solving a ME-MCDM problem, firstly, criteria is defined, importances of criteria are determined and performances of alternatives are evaluated by experts and then decision maker (DM) weights and ranks alternatives (Chen and Klein, 1997:57; Ribeiro, 1996:162).

In this study we have developed a multi-experts and multi-criteria academician selection system using fuzzy weighting and fuzzy ranking. We have used a method which is intuitive in nature, computationally simple and easy to implement. In this method the fuzzy weights of the alternatives are arrived at with the help of the fuzzy information supplied by several experts on alternatives and various important criteria considered in the study. The process of obtaining the fuzzy weights is detailed in the works of Buckley (1984:28; 1985:24) and we have adopted same process in this paper. Then the final ranking of the alternatives have been determined using the maximizing set and minimizing set proposed by Chen (1985:116-119). In the study, a software has been prepared using Borland Delphi 5. DM obtains ranked results by entering required information to the software.

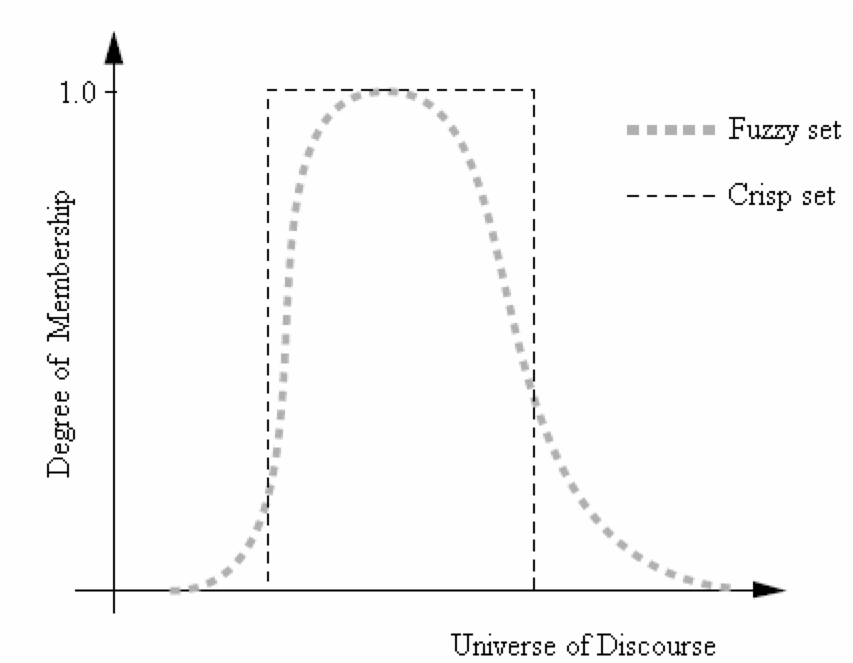
I. FUZZY SET

Fuzzy Set, was initiated in 1965 by Lotfi A. Zadeh (1965:338; 1968:97-101; 1973:37), is a multivalued logic, that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers (Zadeh 1984:28). Classical, or a crisp set, is one which assigns grades of membership of either 0 or 1 to objects within their universe of discourse. A fuzzy set is one which assigns grades of membership between 0 and 1 to objects within its universe of discourse (Fig. 1). If X is a universal set whose elements are $\{x\}$, then, a fuzzy set $\tilde{A}$ is defined by its membership function,

$$m_{\tilde{A}} : X \rightarrow [0,1], \tag{1}$$

which assigns to every x a degree of membership $m_{\tilde{A}}$ in the interval [0,1]. A fuzzy set can be represented by a continuous membership function $m_{\tilde{A}}(x)$, or by a set of discrete points (Simonovic, 2001).

Figure 1: Illustration of a crisp and a fuzzy set.



A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal, and satisfying the following conditions:

(1) $m_{\tilde{A}}(x)$ is interval continue.

(2) $m_{\tilde{A}}(x)$ is a convex.

(3) $m_{\tilde{A}}(x)$ is a normalized fuzzy set and $m_{\tilde{A}}(m)=1$, where m is a real number.

Most common types of fuzzy numbers are triangular and trapezoidal. Other types of fuzzy numbers are possible such as generalized bell, gaussian, two-sided composite of two different gaussian, sigmoidal, difference between two sigmoidal, product of two sigmoidal, polynomial (Z, S and Pi curves) fuzzy numbers (Mathworks Inc. 1999:136-143).

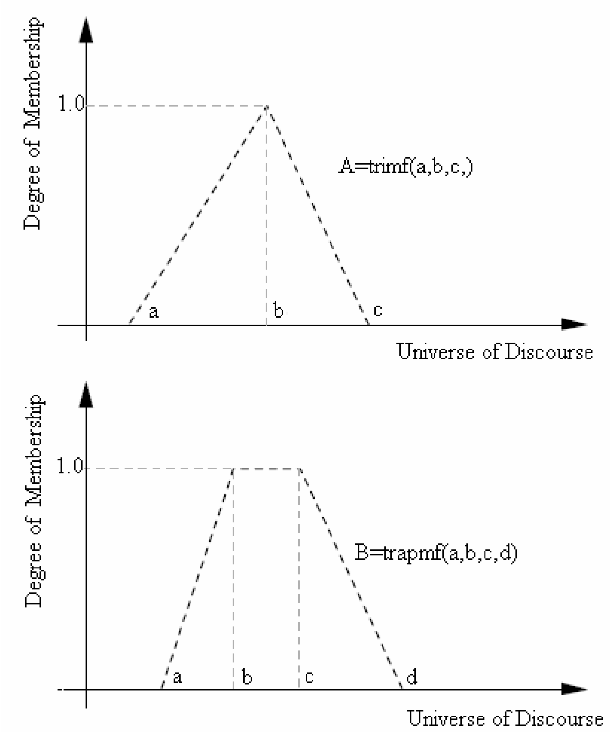
A triangular fuzzy number can be defined as a triplet (a,b,c) and a trapezoidal fuzzy number can be defined as a quartet (a,b,c,d) . The membership functions are shown in Fig. 2 and defined as

$$m_{\tilde{A}}(x) = \begin{cases} 0, & x \le a, \\ \dfrac{x-a}{b-a}, & a \le x \le b, \\ \dfrac{c-x}{c-b}, & b \le x \le c, \\ 0, & x \ge c. \end{cases} \text{, for triangular}$$

(2)

$$m_B(x) = \begin{cases} 0, & x \le a, \\ \dfrac{x-a}{b-a}, & a \le x \le b, \\ 1, & b \le x \le c \\ \dfrac{d-x}{d-c}, & c \le x \le d \\ 0, & x \ge d \end{cases} \text{, for trapezoidal}$$

Figure 2: Triangular and trapezoidal fuzzy numbers



If $\tilde{A}$ and $\tilde{B}$ are two fuzzy numbers parameterized by triplets (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively; then the operations on triangular fuzzy numbers are expressed as

1. Addition operation $\tilde{A} \oplus \tilde{B}$:

$$(a_1, a_2, a_3) \oplus (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3), \tag{3}$$

2. Multiplication operation $\tilde{A} \otimes \tilde{B}$:

$$(a_1, a_2, a_3) \otimes (b_1, b_2, b_3) = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3), \tag{4}$$

where $\oplus$, $\otimes$ represent fuzzy number addition and fuzzy multiplication, respectively.

II. FUZZY WEIGHTING

Consider the problem of ranking m alternatives $(A_i; i = 1,2,...,m)$ by a decision maker. Decision maker wishes to select from amongst m alternatives, with the help of supplied by n experts $(E_j; j = 1,2,...,n)$ about alternatives for each of K criteria $(C_k; k = 1,2,...,K)$ and also the relative importance of each criteria with respect to some overall objective; which one best satisfy criteria. Since mentioned ranking problem including multi-criteria and multi-experts view, decision maker must compute the fuzzy weights $(\tilde{w}_i; i = 1,2,...,m)$ of the alternatives, firstly. The fuzzy weights for each of the alternatives can be arrived at by pooling, averaging or aggregating across experts. This task can be achieved two ways. They are "pool first" and "pool last" procedures (Raj and Kumar 1999:371).

In pool-first procedure, the first step is to find the averages of fuzzy numbers across all the experts first as shown in Eq. (5). For this purpose we use $\oplus$ and $\otimes$ as fuzzy addition and multiplication, respectively, as defined in Eq. (3) and Eq. (4). Then

$$\tilde{p}_{ik} = (1/n) \otimes (\tilde{a}_{i1}^{k} \oplus \tilde{a}_{i2}^{k} \oplus \cdots \oplus \tilde{a}_{in}^{k}) \text{ and}$$

$$\tilde{q}_k = (1/n) \otimes (\tilde{c}_{k1} \oplus \tilde{c}_{k2} \oplus \cdots \oplus \tilde{c}_{kn}), \tilde{p}_{ik}, \tilde{q}_k \in L \tag{5}$$

In Eq. (5), $\tilde{p}_{ik}$ is the fuzzy ranking of A_i for criteria C_k, $\tilde{q}_k$ is the fuzzy ranking of C_k and L is scale of preference structure. The next step is then to determine the fuzzy weights of the alternatives $(\tilde{w}_i)$. To compute these weights multiply $\tilde{p}_{ik}$ and $\tilde{q}_k$ and find the average over all criteria as shown in Eq. (6). That is

$$\tilde{w}_i = (1/KL)\otimes\{(\tilde{p}_{i1}\otimes\tilde{q}_1)\oplus(\tilde{p}_{i2}\otimes\tilde{q}_2)\oplus\cdots\oplus(\tilde{p}_{iK}\otimes\tilde{q}_K)\} \tag{6}$$

In pool-last method, fuzzy weights $(\tilde{w}_{ij})$ for alternative A_i for each of the expert E_j are computed first. This means that $\tilde{w}_{ij}$ is the fuzzy average over all the criteria and is given in Eq. (7).

$$\tilde{w}_{ii} = (1/KL)\otimes\{(\tilde{a}_{ij}^1\otimes\tilde{c}_{1j})\oplus(\tilde{a}_{ij}^2\otimes\tilde{c}_{2j})\oplus\cdots\oplus(\tilde{a}_{ij}^K\otimes\tilde{c}_{Kj})\} \tag{7}$$

The fuzzy weights $\tilde{w}_{ij}$ are then pooled across all the experts to obtain final weights $(\tilde{w}_{ij})$ of the alternatives as shown in Eq. (8). That is

$$\tilde{w}_i = (1/n)\otimes(\tilde{w}_{i1}\oplus\tilde{w}_{i2}\oplus\cdots\oplus\tilde{w}_{in}) \tag{8}$$

In the pool-first procedure, the fuzzy weight w_i can easily be computed using standard fuzzy arithmetic as shown below. Let a_{ik}, b_{ik}, g_{ik} and d_{ik} be averages across experts of $a_{ij}^K, b_{ij}^K, g_{ij}^K$ and d_{ij}^K, respectively. Similarly let e_k, z_k, h_k and q_k be defined as the averages across experts of e_{kj}, z_{kj}, h_{kj} and q_{kj}, respectively. That is

$$a_{ik} = (\sum a_{ij}^K)/n, j=1,2,\ldots,n, \text{ and } e_{ik} = (\sum e_{kj})/n, \quad j=1,2,\ldots,n. \tag{9}$$

Similar expressions can be written for $b_{ik}, g_{ik}, d_{ik}, z_{ik}, h_{ik}$ and q_{ik}. Let the fuzzy weight $\tilde{w}_i$ be described as

$$\tilde{w}_i = (a_i[L_{i1}, L_{i2}]/b_i, g_i/d_i[U_{i1}, U_{i2}]). \tag{10}$$

The graph of the membership function of w_i is: zero to the left of a_i; $L_{i1}y^2 + L_{i2}y + a_i = x$ on $[a_i, b_i]$; horizontal line $(y=1)$ between $[b_i, g_i]$; $U_{i1}y^2 + U_{12}y + a_i = x$ on $[g_i, d_i]$ and zero to the right of d_i. The terms in the Eq. (10) are given in Eqs. (11) and (12). Theorems related to these equations, the proofs and properties are well described in (Buckley 1985:29; Dubois and Prade 1980:192-201).

$$a_i = \left(\sum a_{ik} e_k\right)/KL, \quad b_i = \left(\sum b_{ik} z_k\right)/KL$$
$$g_i = \left(\sum g_{ik} h_k\right)/KL, \quad d_i = \left(\sum d_{ik} q_k\right)/KL \tag{11}$$

$$L_{i1} = \left\{\sum (b_{ik} - a_{ik})(z_k - e_k)\right\}/KL, \quad L_{i2} = \left[\sum \left\{a_{ik}(z_k - e_k) + e_k(b_{ik} - a_{ik})\right\}\right]/KL$$
$$U_{i1} = \left\{\sum (d_{ik} - g_{ik})(q_k - h_k)\right\}/KL, \quad U_{i2} = -\left[\sum \left\{d_{ik}(q_k - h_k) + q_k(d_{ik} - l_{ik})\right\}\right]/KL \tag{12}$$

III. RANKING OF FUZZY NUMBERS

In practical use, ranking of fuzzy numbers is very important. For example, the concept of optimum or best choice to come true is completely based on ranking or comparison. Therefore, how to set the rank of fuzzy numbers has been one of the main problems. To resolve the task of comparing fuzzy numbers, many authors have proposed fuzzy ranking methods which yield a totally ordered set or ranking. These methods range from the trivial to the complex, and from including one fuzzy number attribute to many fuzzy number attributes. A review and comparison of these existing methods can be found in (Chen and Hwang 1992:152-180; Lee and Li 1988:891-893; Zimmermann 1987:83-91). Ranking methods are classified into four major classes according to Chen and Hwang (1992:195), which are listed as follows:

(1) Preference relation

- (a) Degree of optimality.
- (b) Hamming distance.
- (c) a -cut.
- (d) Comparison function.

(2) Fuzzy mean and spread

- (a) Probability distribution.

(3) Fuzzy scoring

- (a) Proportion to optimal.
- (b) Left/right scores.

(c) Centroid index.

(d) Area measurement.

(4) Linguistic expression

(a) Intuition.

(b) Linguistic approximation.

In this paper, we have used maximizing set and minimizing set, which is a fuzzy scoring method to find the order of fuzzy weights. This method distinguishes the alternatives clearly (Chen 1985:121; Raj and Kumar 1999:372). Fuzzy weights can have triangular or trapezoidal or any other appropriate-shaped membership functions. After obtained fuzzy sets, maximizing $\{m_{\tilde{M}}(x)\}$ and minimizing, $\{m_{\tilde{m}}(x)\}$ sets are defined by the following equations:

$$m_{\tilde{M}}(x) = \begin{cases} w\left\{\left(x - x_{\min}\right)/\left(x_{\max} - x_{\min}\right)\right\}^r, & x_{\min} < x < x_{\max,} \\ 0, & otherwise, \end{cases}$$
$$m_{\tilde{m}}(x) = \begin{cases} w\left\{\left(x - x_{\max}\right)/\left(x_{\min} - x_{\max}\right)\right\}^r, & x_{\min} < x < x_{\max,} \\ 0, & otherwise, \end{cases} \qquad (13)$$

where $w = \min_{1<i<m}(w_i)$, $x_{\max} = \sup_{1<i<m}(d_i)$, $x_{\min} = \inf_{1<i<m}(a_i)$, subscripts i and m represent the i^{th} alternative and number of alternatives, respectively (see Eq. 10).

The participation of the decision maker is controlled by the constant r in Eq. (13). If we assume $r = 1$, we consider maximizing and minimizing sets with linear membership functions and decision maker is neutral (Fig. 3a). If $r = 2$, we consider maximizing and minimizing sets with convex-curved (risk prone) membership functions (Fig 3b), which denotes that decision maker tends to have an adventurous character, i.e., as the value gets larger, the degree of preference of decision maker increases rapidly and if $r = 0.5$, we consider maximizing and minimizing sets with concave-curved (risk averse) membership functions (Fig 3c), which denotes that the decision maker possesses a conservative preference. In this case, as concavity becomes larger, the degree of preference of decision maker increases more slowly than the previous case. In general these three cases cover the three types of preferences: fair, adventrous, conservative of human beings (Raj and Kumar 1999:373). Here we present the case when r =1.

Then the right utility value {U_M(i)} and left utility value {U_m(i)} of fuzzy weight $(\tilde{w}_i)$ are respectively, defined as

$$U_M(i) = \sup_x \{m_{\tilde{w}_i}(x) \cap m_{\tilde{M}}(x)\} \text{ and } U_m(i) = \sup_x \{m_{\tilde{w}_i}(x) \cap m_{\tilde{m}}(x)\}. \tag{14}$$

It is seen from Fig. 3 that the right utility value is the membership value at the intersection point of $m_{\tilde{M}}(x)$ with the right-hand side of $m_{\tilde{w}_i}(x)$ and the left utility value is the membership value at the intersection point of $m_{\tilde{m}}(x)$ with the left-hand side of $m_{\tilde{w}_i}(x)$, respectively.

In Eq. (14), U_M(i), the higher the order of fuzzy weight $\tilde{w}_i$ and U_m(i), the smaller the order of fuzzy weight $\tilde{w}_i$. Therefore, we take the average of U_M(i) and $\{w - U_m(i)\}$ in order to find the total utility or order value U_T(i) as shown below

$$U_T(i) = \{U_M(i) + w - U_m(i)\}/2 \tag{15}$$

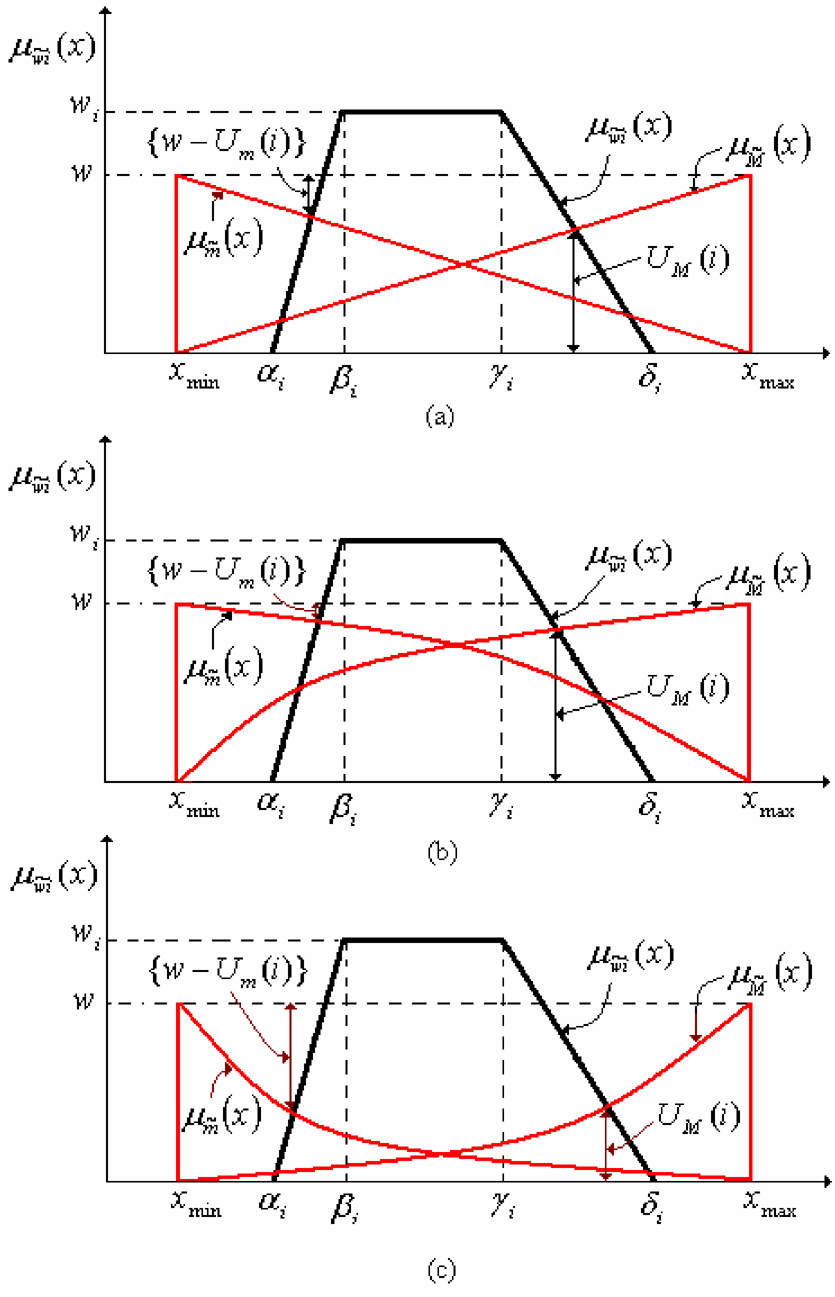
In the expanded from U_T(i) can be written as

$$\begin{aligned} U_T(i) = [&-U_{i2}/2U_{i1} - \{(-U_{i2}/2U_{i1})^2 + (X_{iR} - d_i)/U_{i1}\}^{1/2} + w + L_{i2}/2L_{i1} - \\ &\{(L_{i2}/2L_{i1})^2 + (X_{iL} - a_i)/L_{i1}\}^{1/2}]/2 \end{aligned} \tag{16}$$

where

$$\begin{aligned} X_{iR} = [&2x_{\min} - U_{i2}(x_{\max} - x_{\min})/U_{i1}w + ((x_{\max} - x_{\min})/w)^2/U_{i1} - ((x_{\max} - x_{\min})/w) \\ &\{(-U_{i2}/U_{i1} + (x_{\max} - x_{\min})/U_{i1}w)^2 + 4(x_{\min} - d_i)/U_{i1}\}^{1/2}]/2 \\ X_{iL} = [&2x_{\max} + L_{i2}(x_{\max} - x_{\min})/L_{i1}w + ((x_{\max} - x_{\min})/w)^2/L_{i1} - ((x_{\max} - x_{\min})/w) \\ &\{(L_{i2}/L_{i1} + (x_{\max} - x_{\min})/L_{i1}w)^2 + 4(x_{\max} - a_i)/L_{i1}\}^{1/2}]/2 \end{aligned} \tag{17}$$

Figure 3: Graphical representation of $m_{\tilde{w}_i}(x), m_{\tilde{M}}(x)$ and $m_{\tilde{m}}(x)$. a) r=1, b) r>2, c) r<1



Using Eqs. (14)-(17), the total utility or order values are calculated and with these values alternatives can be ranked. If two alternatives have the same utility values, we may use the vertices of the graphs of the corresponding membership functions to make the distinction. That is, the vertex further right is the largest, with decreasing size from right to left (Raj and Kumar 1999:373).

IV. ACADEMICIAN SELECTION SYSTEM

In this study we have developed a multi-experts and multi-criteria academician selection system using fuzzy weighting and fuzzy ranking. Number of criteria, number of linguistic variables of criteria, names of linguistic variables, membership functions of linguistic variables, number of experts and alternatives can be changed in our system.

Research assistant exam of Department of Electronics in Atatürk University Erzincan Vocational High School has been given as example while the system has been explained. 5 alternatives have applied to the exam. In the system, 3 experts' views have been evaluated by the DM, because it is necessary that academician exam have to be done by 3 experts according to local regulations.

In the system, selection examination for graduate studies (SEGS), science exam (SE), hand skill exam (HSE), average grade of bachelor's degree (BD), foreign language exam (FLE) and interview (INT) have been used as selection criteria. Among these criteria, SEGS, SE, BD and FLE are obligatory criteria to evaluate and HSE and INT are optional criteria for selection. Decision maker decides either use optional criteria or not. SEGS is determines general culture and general capability of a person and a central exam, which is done by student selection and placement center (OSYM). Limit mark of SEGS is 45 over 80 and applicants have to take at least 45 to apply academician selection exam. Both a local foreign language exam and national (UDS, KPDS etc.) or international (TOEFL) acceptable foreign language exams can be allowed for FLE criter according to local regulations. Limit mark of FLE is 50 over 100 and applicants have to take at least 50 to apply academician selection exam. SE questions are prepared by experts and answers of alternatives are evaluated by experts separately. In vocational high schools, both theoretical (%60) and practical (%40) education are given to students because aim of these schools to educate technical personnel for industry. Therefore, practical sufficiency of academicians is desired and used as a criter for academician selection.

Linguistic variables and those membership functions of each criter are determined taking views of 78 academicians in Erzincan campus of Atatürk University. In our system, SE and INT criteria have been defined with 9 linguistic variables, BE has been defined with 7 linguistic variables and SEGS, HSE and FLE have been defined with 5 linguistic variables. Boundary values of membership functions have been determined by taking average values of boundary values defined by academicians (See Table 1-3).

Table 1: Linguistic variables and membership functions for SE and INT criteria

	SE	INT
Worst (W)	(0,0,10)	(0,0,9)
Very Poor (VP)	(3,12,23)	(4,12,21)
Poor (P)	(13,25,35)	(16,25,35)
Below Average (BA)	(26,37,50)	(28,37,47)
Average (A)	(43,52,62)	(40,50,61)
Above Average (AA)	(60,69,76)	(56,64,72)
Good (G)	(71,75,85)	(67,75,84)
Very-Good (VG)	(83,87,95)	(79,88,95)
Best (B)	(91,100,100)	(92,100,100)

Table 2: Linguistic variables and membership functions for BD criteria

	BD
Very Poor (VP)	(1,1,1.3)
Poor (P)	(1.2,1.5,1.8)
Below Average (BA)	(1.7,2.1,2.3)
Average (A)	(2,2.6,2.9)
Above Average (AA)	(2.8,3.1,3.4)
Good (G)	(3.2,3.5,3.8)
Very-Good (VG)	(3.6,4,4)

Table 3: Linguistic variables and membership functions for SEGS, HSE and FLE criteria

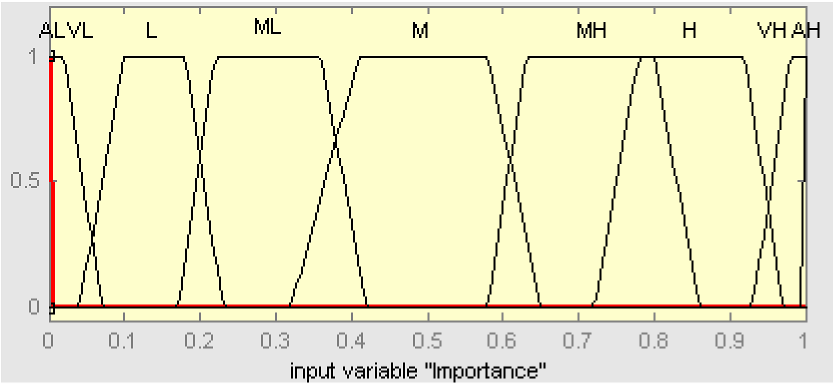
	SEGS	HSE	FLE
Very Poor (VP)	(40,40,50)	(0,0,1)	(50,50,58)
Poor (P)	(46,52,59)	(0.4,1.3,2.3)	(55,63,72)
Average (A)	(56,61,71)	(2,2.8,3.7)	(67,76,85)
Good (G)	(68,73,75)	(3.4,4,4.6)	(81,90,96)
Very-Good (VG)	(74,80,80)	(4.3,5,5)	(91,100,100)

Chen's nine numbers fuzzy scale has been used for relative weighting of criteria. Linguistic expressions and fuzzy numbers of criteria weights have been shown in Table 4. Chen's fuzzy numbers of linguistic variables for criteria importances have been represented as graphical in Fig. 4.

Table 4: Linguistic variables and fuzzy numbers for criteria weights

Linguistic Variable	Fuzzy Number
Absolutely Low (AL)	(0,0,0,0)
Very Low (VL)	(0,0,0.02,0.07)
Low (L)	(0.04,0.1,0.18,0.23)
Medium-Low (ML)	(0.17,0.22,0.36,0.42)
Medium (M)	(0.32,0.41,0.58,0.65)
Medium-High (MH)	(0.58,0.63,0.8,0.86)
High (H)	(0.72,0.78,0.92,0.97)
Very High (VH)	(0.93,0.98,1,1)
Absolutely High (AH)	(1,1,1,1)

Figure 4: Graphical representations of Chen's fuzzy numbers of linguistic variables for criteria importances



Importances of criteria, which are given by E1, E2 and E3 experts and have been used for academician selection, have been shown in Table 5. Experts can use linguistic expressions given in Table 4 to define criteria importances. In addition this, experts, who want to assign different importance from Chen's fuzzy numbers, can use different triangular or trapezoidal fuzzy numbers defined by them.

Table 5: Criteria importances given by experts for academician selection

	E1	E2	E3
SEGS	AH	0.75,0.77,0.82,0.85	M
SE	VH	0.6,0.63,0.67,0.7	L
HSE	M	0.05,0.06,0.08,0.1	H
BD	ML	0.7,0.74,0.76,0.8	AH
FLE	H	0.8,0.8,0.9,0.9	H
INT	0.01,0.02,0.02,0.03	0.03,0.05,0.06,0.07	MH

Linguistic evaluations of E1, E2 and E3 experts for A1, A2, A3, A4 and A5 alternatives have been shown in Table 6-11 for each criter.

Table 6: Evaluation of alternatives for SE criteria by experts

SE	E1	E2	E3
A1	G	AA	AA
A2	G	G	AA
A3	AA	A	AA
A4	G	VG	AA
A5	G	VG	AA

Table 7: Evaluation of alternatives for INT criteria by experts

INT	E1	E2	E3
A1	A	G	BA
A2	A	AA	BA
A3	A	AA	AA
A4	AA	G	AA
A5	AA	VG	AA

Table 8: Evaluation of alternatives for BD criteria by experts

BD	E1	E2	E3
A1	G	G	AA
A2	AA	A	A
A3	AA	AA	AA
A4	VG	VG	G
A5	VG	VG	VG

Table 9: Evaluation of alternatives for SEGS criteria by experts

SEGS	E1	E2	E3
A1	A	A	A
A2	G	A	G
A3	P	P	A
A4	G	VG	G
A5	VG	VG	G

Table 10: Evaluation of alternatives for HSE criteria by experts

HSE	E1	E2	E3
A1	G	VG	VG
A2	VG	VG	A
A3	VG	G	G
A4	P	A	P
A5	A	G	A

Table 11: Evaluation of alternatives for FLE criteria by experts

FLE	E1	E2	E3
A1	P	P	P
A2	P	A	P
A3	P	P	P
A4	A	G	G
A5	A	A	P

A software has been prepared for ranking alternatives with information obtained from experts (Table 1-11) using Borland Delphi 5. In the software firstly, number of criteria, number of experts and number of alternatives are entered to user interface of the software (Fig. 5). After entered number of criteria, names of each criter and number of linguistic variables of each criter are entered to the interface (Fig. 6). Then, names and membership functions of each linguistic variable are entered to interface with a different screen for each criter (Fig. 7). After these tasks, importances of criteria defined by experts are entered (Fig. 8). Since importances of criteria can be given as both linguistic variable and fuzzy number by experts, two different type fields have been prepared for two types input in this screen. If data is entered to either of these fields, the other field is disabled.

Figure 5: Input screen for numbers of criteria, number of experts and number of alternatives

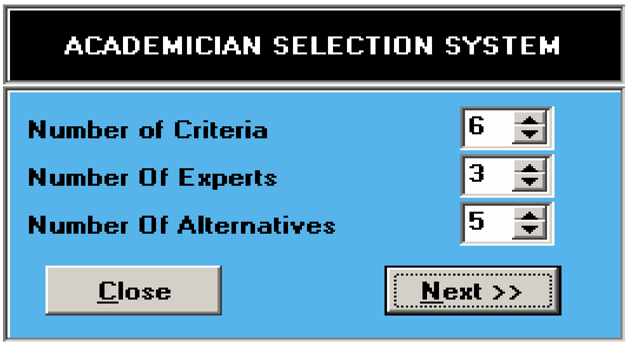


Figure 6: Input screen for names of criteria and number of linguistic variables of criteria.

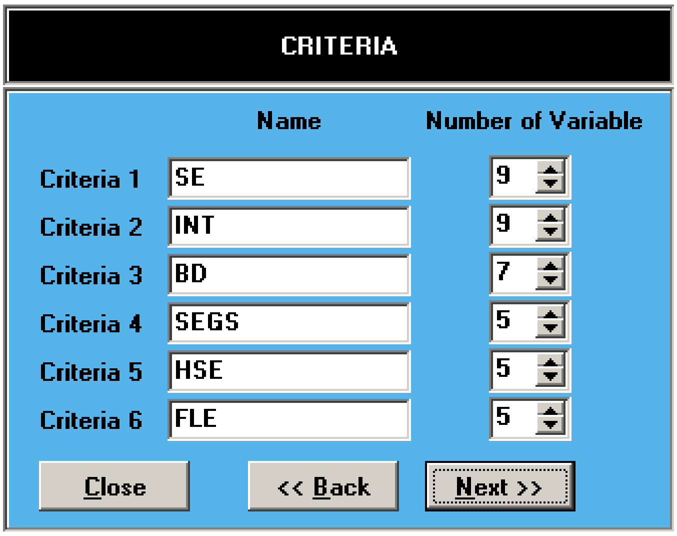


Figure 7: Input screen for names and membership Functions of linguistic variable of SE criteria

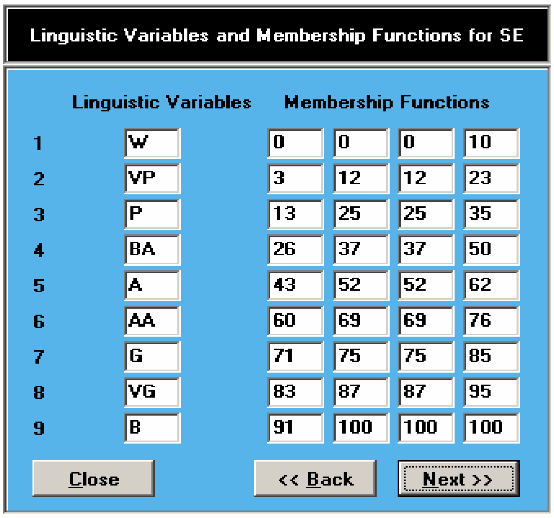
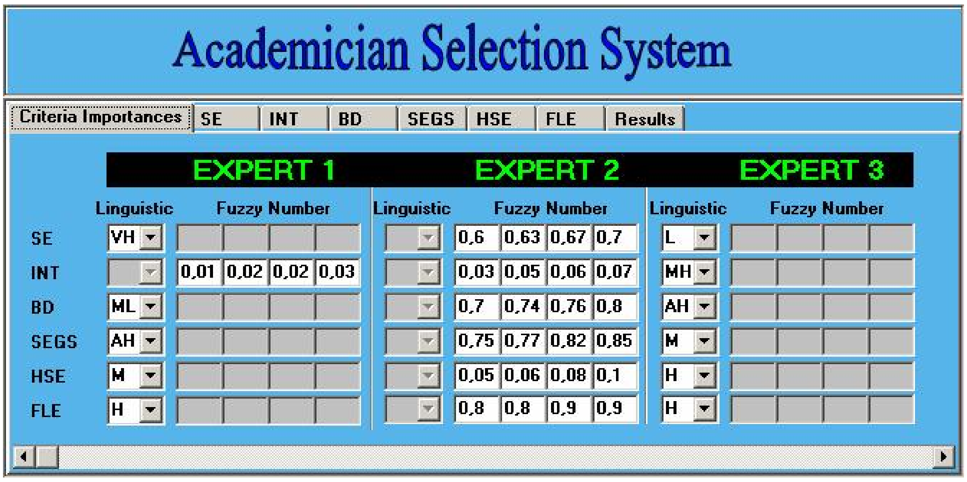
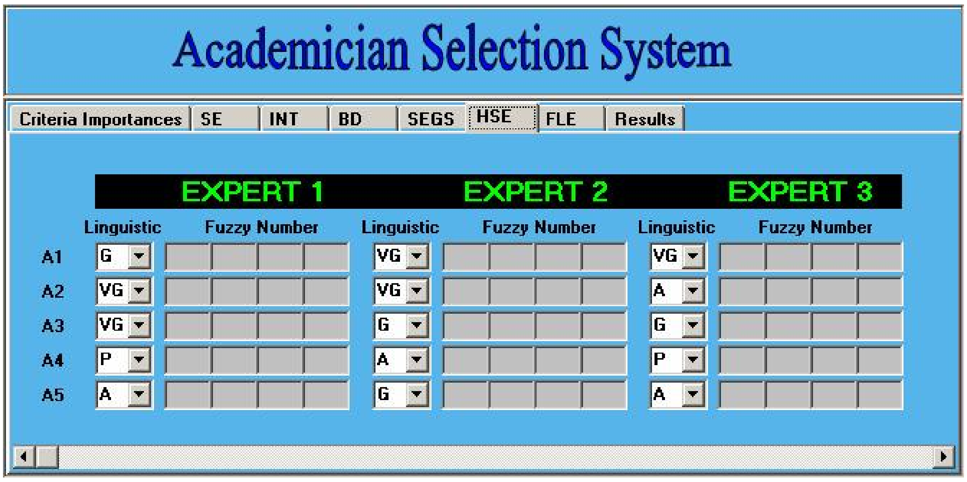


Figure 8: Input screen for criteria importances



Later, evaluation results, which have been done by experts, for alternatives are entered to interface for each criter (Fig. 9) and result screen is opened by clicking “Result” tabsheet.

Figure 9: Input screen for alternative evaluation of experts for HSE criteria



Software computes fuzzy rankings of alternatives for criteria (p_{ik}) and fuzzy rankings of criteria (q_k) using Eq. 5, firstly. Fuzzy rankings of alternatives for criteria and fuzzy rankings of criteria have been shown in Table 12 and Table 13, respectively. Then, software computes a weight value for each alternatives using Eq. 9,10,11 (Table 14).

They are found as $x_{\min} = 19.52$ and $x_{\max} = 39.17$ from weight values as shown Table 14. In this study, we have assumed $w = 1$. In our example, it is selected as $r = 1$ to neutral ranking. Thus $m_{\tilde{M}}(x)$ and $m_{\tilde{m}}(x)$ membership functions are determined as triangular like Fig. 3a. Then, the final ranking of alternatives is computed using Eq. 16 and 17 (see Table 15).

Table 12: Fuzzy rankings of alternatives for criteria

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
SE	(63.67,71.00, 71.00,79.00)	(67.33,73.00, 73.00,82.00)	(54.33,63.33, 63.33,71.33)	(71.33,77.00, 77.00,85.33)	(71.33,77.00, 77.00,85.33)
INT	(45.00,54.00, 54.00,64.00)	(41.33,50.33, 50.33,60.00)	(50.67,59.33, 59.33,58.33)	(59.67,67.67 ,67.67,76.00)	(63.67,72.00, 72.00,79.67)
BD	(3.07,3.37, 3.37,3.67)	(2.27,2.77, 2.77,3.07)	(2.80,3.10, 3.10,3.40)	(3.47,3.83, 3.83,3.93)	(3.60,4.00, 4.00,4.00)
SEGS	(56.00,61.00, 61.00,71.00)	(61.00,69.00, 69.00,73.67)	(49.33,55.00, 55.00,63.00)	(70.00,75.33, 75.33,76.67)	(72.00,77.67, 77.67,78.33)
HSE	(4.00,4.67, 4.67,4.87)	(3.53,4.27, 4.27,4.57)	(3.70,4.33, 4.33,4.73)	(0.93,1.80, 1.80,2.77)	(2.47,3.20, 3.20,4.00)
FLE	(55.00,63.00, 63.00,72.00)	(59.00,67.33, 67.33,76.33)	(55.00,63.00, 63.00,72.00)	(76.33,85.33, 85.33,92.33)	(63.00,71.67, 71.67,80.67)

Table 13: Fuzzy rankings of criteria

Criteria	Fuzzy Weight
SE	(0.52,0.57,0.62,0.64)
INT	(0.21,0.23,0.29,0.32)
GMM	(0.62,0.65,0.71,0.74)
PGE	(0.69,0.73,0.80,0.83)
SKE	(0.36,0.42,0.53,0.57)
FLE	(0.75,0.79,0.91,0.95)

Table 14: Fuzzy weights of alternatives

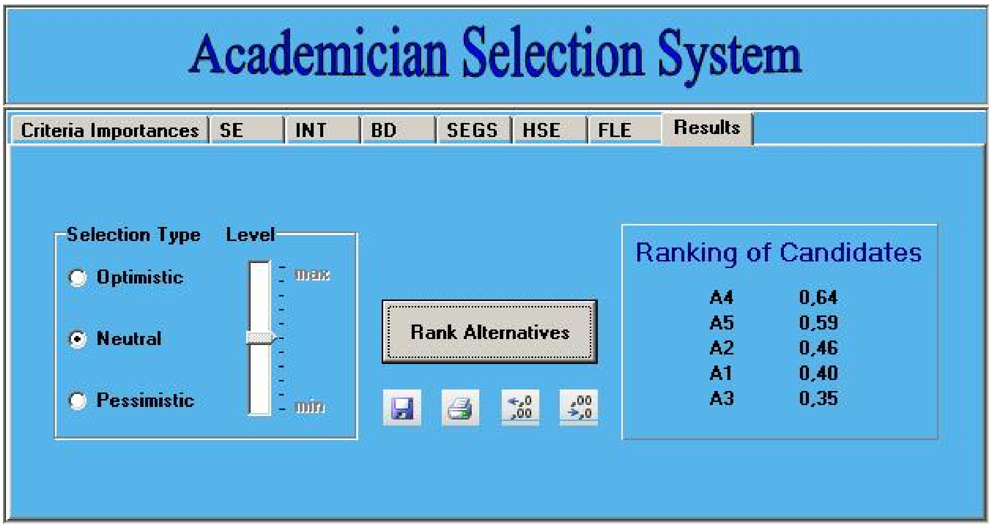
Alternative	Weight
1	(20.95[0.19,4.05]/25.18,28.47/34.02[0.19,-5.74])
2	(22.45[0.18,4.05]/26.67,30.11/35.08[0.16,-5.13])
3	(19.52[0.20,4.16]/13.88,27.08/32.27[0.17,-5.37])
4	(26.24[0.18,4.38]/30.80,34.87/39.17[0.13,-4.43])
5	(25.06[0.18,4.34]/29.58,33.45/37.88[0.13,-4.56])

Table 15: Final ranking of alternatives

Alternative	U_T
1	0.40
2	0.46
3	0.35
4	0.64
5	0.59

Final ranking of alternatives are seen "Result" screen (Fig. 10). Before obtaining results, DM can define own preferences for ranking. For this, DM selects one of neutral, optimistic or pessimistic preferences from selection type section. Also, level of optimism or pessimism preferences can be adjusted with level trackbar. Finally, alternatives are ranked with "Rank Alternatives" button. Obtained results can be saved, printed, and shown in different decimal sensitivity.

Figure 10: Result screen



CONCLUSION

In this study a multi-criteria and multi-experts academician selection system has been developed for universities using fuzzy weighting and fuzzy ranking. A software has been prepared for ranking alternatives using Borland Delphi 5. Number of criteria, number of linguistic variables of criteria, names of linguistic variables, membership functions of linguistic variables, number of experts and number of alternatives can be changed in the software. Software, weights the alternatives using standard fuzzy arithmetic and ranks as fuzzy. In the software, maximizing set and minimizing set method is used for ranking as fuzzy. This selection system will increase objectivity in academicians' selection. Likewise, with flexible structure this system can be easily used in other business areas for personnel selection.

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