# DEVELOPING A SOFTWARE FOR FUZZY GROUP DECISION SUPPORT SYSTEM: A CASE STUDY

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## ABSTRACT
The complex nature and uncertain information in social problems required the emergence of fuzzy decision support systems in social areas. In this paper, we developed user-friendly Fuzzy Group Decision Support Systems (FGDSS) software. The software can be used for multi-purpose decision making processes. It helps the users determine the main and sub evaluation criteria, their weights, and evaluate the performance according to the number of decision makers and evaluation weights of criteria. It also allows the user to use two different fuzzy inference methods. In the fuzzyfication unit, universe of discourse is made up of three different membership functions. The software, which has four main screens, is developed by using Delphi programming language and is used for the purpose of performance assessment of research assistants at Marmara University, Technical Education Faculty.

**Keywords:** Fuzzy logic, Multi-criteria decision making, Performance evaluation

## INTRODUCTION
In real world systems, the decision–making problems are often uncertain or vague in a number of ways. However in many areas of daily life, such as engineering, manufacturing education, human judgment or performance assessment often employ natural language to express thinking so it is likely to come up with a subjective perception. In these natural languages the meaning of a word might be well defined, but when using the word as a label for a set, the boundaries within the objects which belong to the set become fuzzy or vague. Furthermore, based on individuals' subjective perceptions or personality, human judgment of events may be different (Chiou & Tzeng 2002). Therefore, we combined fuzzy sets theory and natural language in our software for performance evaluation.

Fuzzy multi-criteria decision making technique has been one of the fastest growing areas in decision making and operations research during the last three decades. A major reason for the development of fuzzy multi-criteria decision making is that the decision makers can incorporate a large number of criteria in their actions and FGDSS overcomes the difficulty of expressing decision makers' opinions by crisp value in practice. Group decision making pays attention to the way people work together in reaching a decision (Ruan, et al.,2007). Fuzzy logic allows computers to make decisions as human being do, so it can be used in any area where human decision is necessary. Fuzzy set theory (Zadeh 1965) can play a significant role in this kind of decision situation. Fuzzy logic combines the decision ability of human beings and speed of the computers, and through this combination, an excellent decision making progress is obtained under imprecise, vague and uncertain conditions. The complexity of today's socio-economic problems requires more complex decision making processes. That's why decision makers have to consider many aspects of a problem. The necessity of considering all relevant aspects of a problem forces them to use fuzzy multi-criteria decision making systems.

The most important thing in Fuzzy Group Decision Support Systems is to determine the evaluation criteria and their weights in decision process. The knowledge and experience of a human expert is the best source for such kind of information. This can be considered as the design of an expert system. In other words, it is the simulation of the expert's knowledge and experience in a digital environment. Human beings make decisions in fuzzy environments by using fuzzy variables. In order to simulate human decision making in computer environment, fuzzy variables should be represented to computer. This requires the use of fuzzy set theory. Therefore, fuzzy set theory plays a significant role in expert systems which can think and give decisions just like a human being as a result of their inferences (Parsaye, 1988).

There are many studies on multi-criteria decision making process in many social areas. Kwok, Ma, Vogel (2001) developed and applied a fuzzy set approach to collaborative assessment in university classroom contexts. Rasmani and Shen (2005) classified student academic performance using fuzzy techniques. Feng, Rozenblit and Hamilton (2008) developed a novel objective performance assessment module for the minimally invasive surgical trainers. Biswas (1995) presented a fuzzy set approach to evaluating students' answerscripts.

In this study, a user-friendly Fuzzy Group Decision Support Systems software was developed by using Delphi programming. It gives the users the opportunity to determine the main and sub evaluation criteria and their weights, and to evaluate the performance according to evaluation weights. More than one assesse can take place in this assessment procedure. That's why it can be used for multi-purpose decision making processes, such as assessing projects or performance of students, teachers, employees, journals, etc. The software has four modules such as a Fuzzfication, Fuzzy Grading1, Fuzzy Grading2 and Assessment and Report. In order to test the effectiveness of the software the performance of research assistants in the Technical Education Faculty was evaluated. For the fuzzy evaluation process, five main criteria and twenty three sub-criteria was set by lecturers in the department.

**FUZZY SET THEORY**

In decision making process, it is difficult to make an exact evaluation because of the vagueness of human feeling and recognition. Therefore, fuzzy set theory, which provides reliable and objective results, can play a significant role in our evaluation process. Zadeh (1988) proposed a computational procedure for fuzzy logic inference, which consists of an implication function and inference rule. Given that $A$ and $B$ are both fuzzy sets defined over $U$ and $V$ respectively, a fuzzy rule $A \rightarrow B$ is first transformed into a fuzzy relation $R_{A \rightarrow B}$ that represents the correlation between A and B. The developed software has two relation methods, max-min and max-product relation methods, as the compositional rule of inference. Max-min relation is defined as follows (Chiueh 1992):

$$\mu_R(x,y) = \min_{x \in U,\, y \in V}(\mu_A(x), \mu_B(y))$$

where min is an implication function. Given a fact is $A'$ and a rule is $A \rightarrow B$, Zadeh's composition rule says

$$B' = A' \circ R_{A \rightarrow B}$$

$$\mu_{B'}(y) = \max_x \min (\mu_{A'}(x)\ \mu_{RA \rightarrow B}(x,y))$$

This computation can be viewed as a vector-matrix product with multiplication and addition replaced by min and max. Consequently, when a rule is $A \rightarrow B$ and an input is A', the membership function of the inferred output $B'$ is calculated as follows:

$$\mu_{B'}(y) = \max_{x \in U} \min (\mu_{A'}(x)\ \mu\ \mu_{RA \rightarrow B}(x,y))$$

$$\mu_{B'}(y) = \max_{x \in U} \min (\mu_{A'}(x), \min(\mu_A(x), \mu_B(y)))$$

$$\mu_{B'}(y) = \min \max_{x \in U} [\ \min(\mu_{A'}(x), \mu_A(x)), \mu_B(y)\ ]$$

$$\mu_{B'}(y) = \min (\alpha, \mu_B(y))$$

where

$$\alpha = \max \min (\mu_{A'}(x), \mu_A(x))$$

The max-product as the compositional rule of inference multiplication operation ($\cdot$) is used instead of the min operation. The max-product inference, $\mu_{B'}(y)$, is performed as follows:

$$\mu_{B'}(y) = (\alpha \cdot \mu_B(y))$$

where

$$\alpha = \max (\mu_{A'}(x) \cdot \mu_A(x))$$

Since value of α and the final centroid change more smoothly depending on inputs (observation), the inference based on the max-product method is more sensitive than the max-min. method (Zadeh, & Kacpyrzyk, 1992).

When more than one fuzzy output is enabled, the consequents of all fuzzy outputs are combined. Supposing that $B'_1, B'_2, \ldots B'_n$ are derived results, the combined result is the individual fuzzy result (Baba, 2004).
Final step is defuzzification which converts fuzzy results into a single value that best represents the whole sets. One useful method computes the centroid or center of area is shown in below:

$$G = \frac{\sum_{i=1}^{N} \mu_{Bi} w_i}{\sum_{i=1}^{N} \mu_{Bi}}$$

Where, $w_i$ is the support value, the membership function reaches the maximum value $\mu_{Bi.}$

**FUZZY DECISION SUPPORT SYSTEM SOFTWARE**
The whole decision process mainly includes four stages; determination of fuzzy variables, selection of main and sub decision criteria, determination of decision criteria weights, and fuzzy grading (Ma, &Duanning, 2000). The developed user friendly software can also be used for different and multiple assessment purposes such as assessing the performance of students, lecturers, employees etc. In the system, user accessibility was enhanced for users to input or change the shape and values of membership functions in fuzzyfication unit. The main and sub criteria and their weights in decision systems can also be changed by the user. At the fuzzy inference system the user can also choose either max-product inference method or min-max inference method. The software works in a windows environment. It has four windows; Fuzzfication, Fuzzy Grading1, Fuzzy Grading2 and Assessment and Report. Contents of the menu window vary according to the chosen window in the menu. When one of the windows is selected, it replaces the menu window.

The fuzzyfication window, shown in Figure 1, is used to define main and sub criteria and their weights in decision support systems. The program provides users maximum five main criteria, each of which can consist at most five sub criteria. In this window, the universe of discourse is made up of maximum five fuzzy sets representing the defined linguistic variables. Three shapes of membership function; triangle, trapezoid and bell can be selected. The user can enter the value of the membership functions and build the universe of discourse. Moreover, membership functions can be seen graphically on this window. In the figure trapezoid type of membership functions are selected.

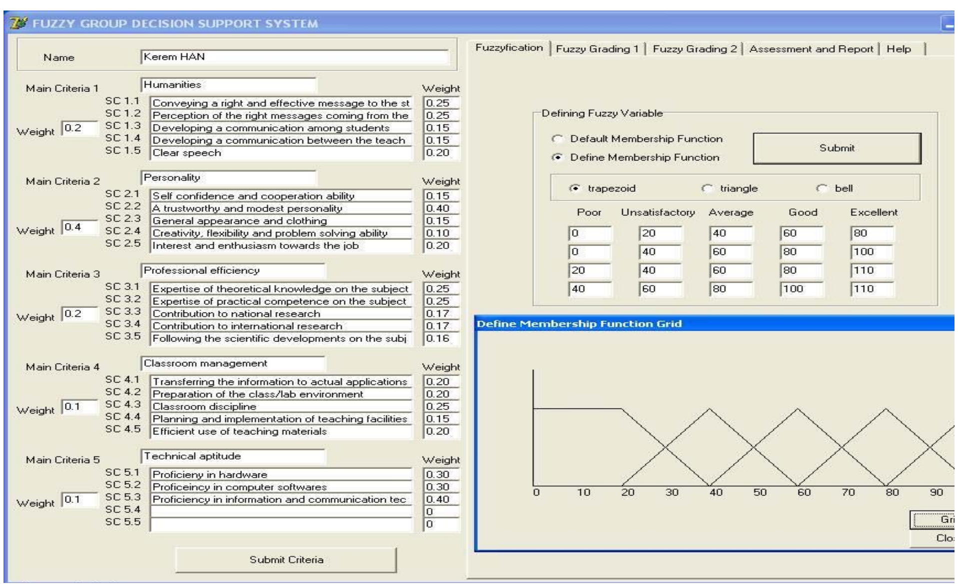



Figure 1. The Fuzzyfication window

In the Fuzzy Grading 1 window shown in Figure 2, the fuzzy linguistic evaluation results of each decision maker between 1 and 5 (Poor:1, Unsatisfactory:2, Avarage:3, Good:4, Excelent:5) gives the opportunity to determine the quantity and evaluation weights. The window in Figure 2 displays evaluation results of five decision makers attaining 0.2 weights. The software enables the user define maximum fifteen decision-makers. For the decision process, fuzzy inference method can choose either Max-Min inference or Max-Product inference.

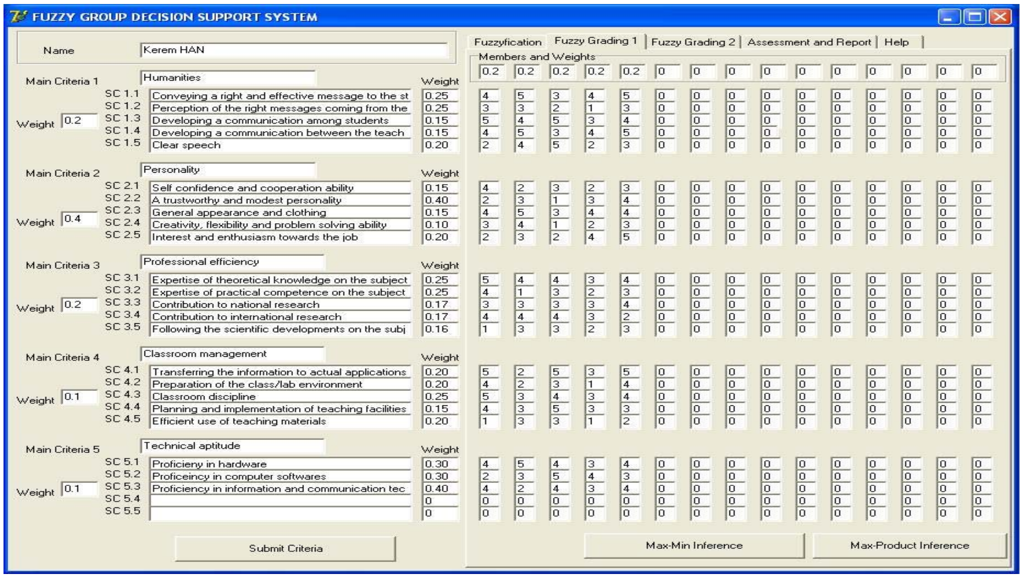



Figure 2. The Fuzzy Grading 1 window

Fuzzy Grading 2 window shown in Figure 3 makes it easy to computerize the evaluation scores of the decision makers when all decision makers have the same evaluation weights.

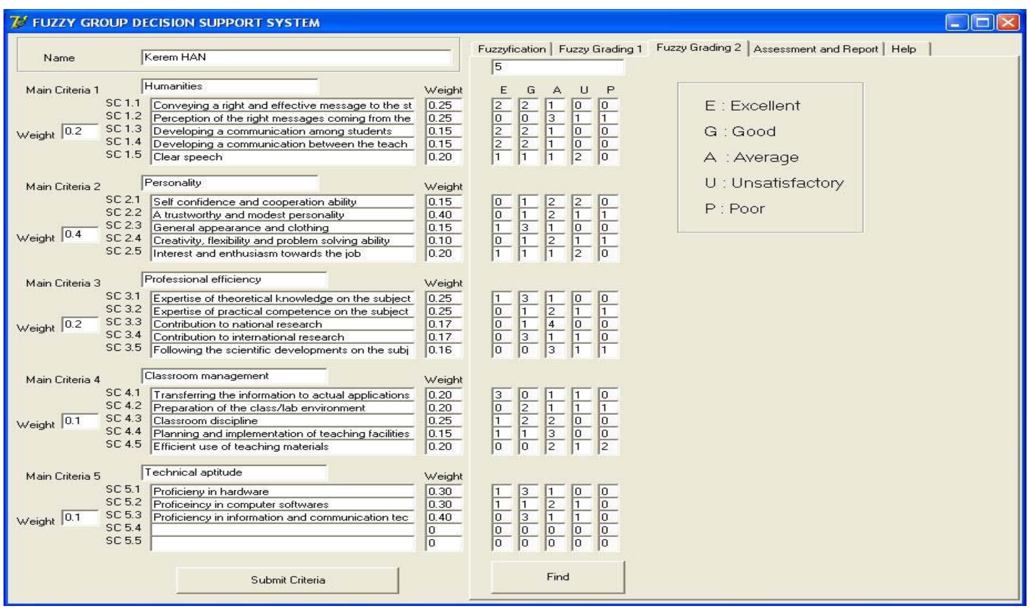



Figure 3. Fuzzy Grading 2 window

The assessment and report window is shown in Figure 4. Fuzzy and crisp evaluation scores of both inference methods can be seen. The grade of the candidate for each main criterium and final score is displayed. The evaluated grades are listed either according to the total score or one of the chosen main criteria score. The evaluation final report can be printed by using the print button. In Figure 5, the candidates are listed according to their final scores.

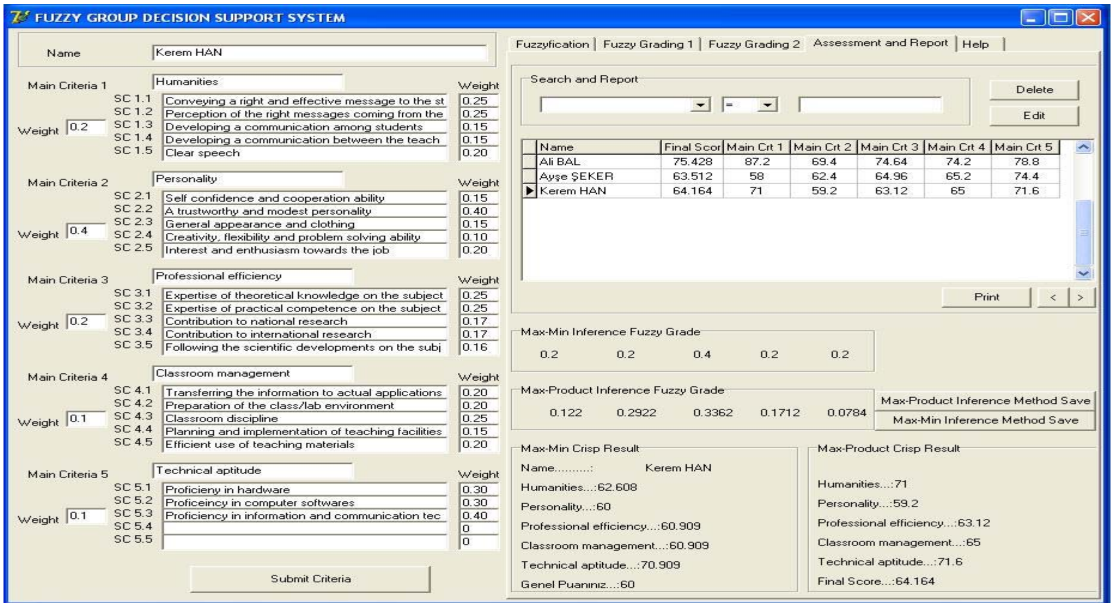



Figure 4. Assessment and Report window

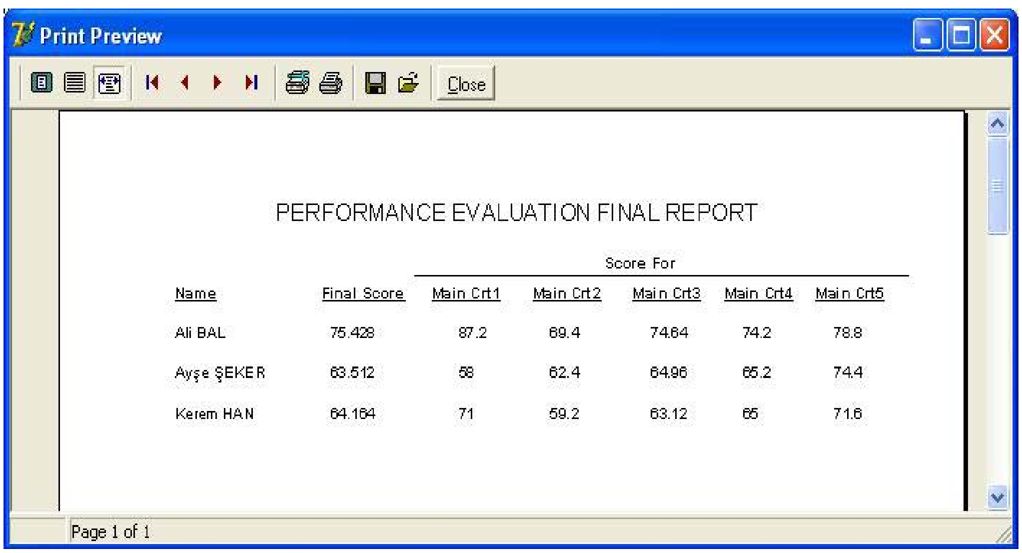



Figure 5. Final Report Window

**CASE STUDY**

Fuzzy decision support systems were applied to university teachers (Kuo, & Chen, 2002), administrators (Li et al., 2004) and students (Rasmani and Shen, 2005) for performance assessment. We used the developed software to evaluate the performance of research assistants at Technical Education Faculty. The selection criteria are represented by a hierarchical structure shown in Figure 6. This hierarchical structure consists of five main criteria and twenty three sub-criteria.

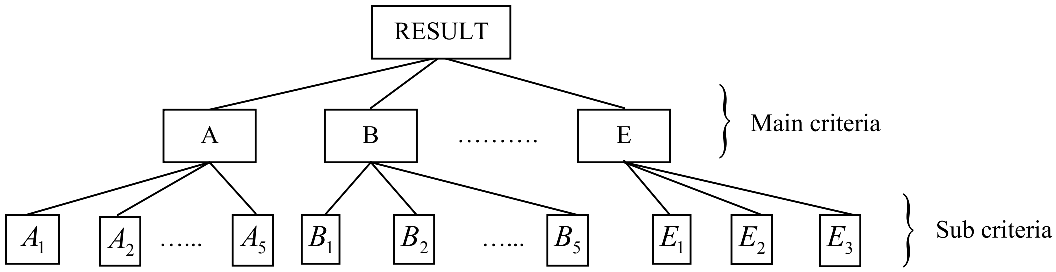



Figure 6. Hierarchical structure of performance evaluation

The main and sub criteria and their weighs are shown in Table 1. These evaluation criteria and their weights are composed of interviews carried out by the head of departments, professors and research assistants.

Table 1. Evaluation criteria and weights (Kuscu,2007)

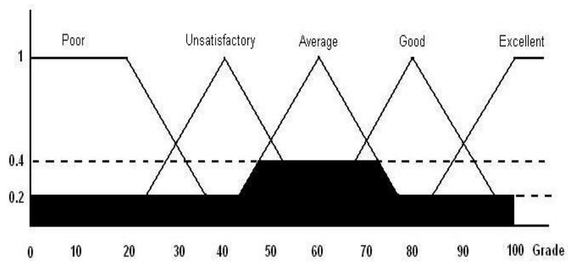
| Main Criteria | Wgt | Sub-Criteria | Weight |
|---|---|---|---|
| Humanities | 0.2 | Conveying a right and effective message to the students | 0.25 |
| | | Perception of the right messages coming from the students. | 0.25 |
| | | Developing a communication among students | 0.15 |
| | | Developing a communication between the teacher and the students | 0.15 |
| | | Clear speech | 0.20 |
| Personality | 0.4 | Self confidence and cooperation ability | 0.15 |
| | | A trustworthy and modest personality | 0.40 |
| | | General appearance and clothing | 0.15 |
| | | Creativity, flexibility and problem solving ability | 0.10 |
| | | Interest and enthusiasm towards the job | 0.20 |
| Professional efficiency | 0.2 | Expertise of theoretical knowledge on the subject | 0.25 |
| | | Expertise of practical competence on the subject | 0.25 |
| | | Contribution to national research | 0.17 |
| | | Contribution to international research | 0.17 |
| | | Following the scientific developments on the subject | 0.16 |
| Laboratory management | 0.1 | Transferring the information to actual applications | 0.20 |
| | | Preparation of the class/lab environment | 0.20 |
| | | Laboratory discipline | 0.25 |
| | | Planning and implementation of teaching facilities | 0.15 |
| | | Efficient use of teaching materials | 0.20 |
| Technical aptitude | 0.1 | Proficiency in hardware | 0.30 |
| | | Proficiency in computer soft wares | 0.30 |
| | | Proficiency in information and communication technology | 0.40 |

To explain the process with an example; Let's assume that the candidate, Kerem Han is evaluated as shown Figure 2. by five professors who have same evaluation weights.

If the max-min compositional rule of inference is used for inference, Max-Min fuzzy grade is calculated as (0.2, 0.2, 0.4, 0.2, 0.2) as shown in Figure 4. It means that the candidate has the grades of 0.2 Poor, 0.2 Unsatisfactory, 0.4 Average, 0.2 Good and 0.2 Excellent. All these fuzzy grades have to be deffuzzyfied in order to get crisp grade. Figure 7 shows defuzzfication process of the max-min inference. Crisp grade can be calculated as below;

$$G = \frac{(0.2)*20 + (0.2)*40 + (0.4)*60 + (0.2)*80 + (0.2)*100}{0.2 + 0.2 + 0.4 + 0.2 + 0.2} = 60 \quad \text{(Average)}$$



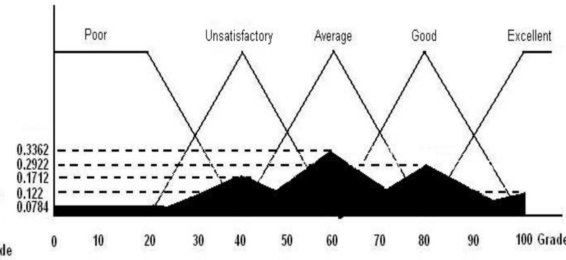




Figure 7. Max-min inference method

Figure 8. Max-product inference method

When the max-product compositional rule of inference is used for inference, Max-Product fuzzy grade can be calculated as (0.0784, 0.122, 0.1712, 0.2922, 0.3362) as shown in Figure 2. It means that the candidate has the grades of 0.0784 Poor, 0.122 Unsatisfactory, 0.1712 Average, 0.2922 Good and 0.3362 Excellent. All these fuzzy grades has to be deffuzzyfied in order to get crisp grade. Figure 8 shows defuzzfication process of the max-product inference. Crisp grade can be calculated as below;

$$G = \frac{(0.0784)*20+(0.1712)*40+(0.3362)*60+(0.2922)*80+(0.122)*100}{0.0784+0.1712+0.3362+0.22922+0.122} = 64.164$$

(Average)

As seen in the example, the performance of the candidate is found by using fuzzy group decision support systems. Crisp grade of candidate is 60 according to the Max-min inference method while it is 64.164 to the Max-product inference method. Although both of the results are averages, the max product compositional rule of inference method is more sensitive and reliable to small changes than the max-min compositional rule of inference method (Zadeh, & Kacpyrzyk, 1992). These two results have been calculated from 115 total fuzzy scores of five decision makers who marked twenty three criteria. It enables us a fair and objective evaluation. It reduces the probable bias of evaluators, minimizes the miscalculations and the assessment procedure gives more reliable results as the number of assesses increases.

## CONCLUSION

In real life, because of the uncertain information as well as the vague human feeling and recognition, it is difficult to make an exact evaluation in social problems. That's why using fuzzy logic set theory helps decision makers deal with complex issues under the fuzzy environment. In this paper we developed user-friendly fuzzy group decision support systems software. This software provides users with the opportunity of determining the main and sub evaluation criteria and their weights, and evaluating the performance according to referees' evaluation weights and numbers. It also allows the user to use two different fuzzy inference methods The developed software can be used for multi-purpose decision making processes such as assessing projects or performance of students, teachers, employees, journals, etc.

In order to test the effectiveness of the software we evaluated the performance of research assistants in the Technical Education Faculty in the light of the criteria above. It enabled us a fair and objective evaluation. We were also able to attain the values and weight of each main criteria according to our priorities. We could prioritize the criteria of performance evaluation according to our needs.

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