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Applying Analytic Hierarchy Process for the Selection of the Requirements of Institute Examination System

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Abstract: Software requirements selection is an important problem in the area of software engineering; and its objective is to select the requirements according to the need of the different types of the stakeholders before actual development takes place. In literature different methods have been developed for the selection of software requirements using different "*multi-criteria decision making*" (MCDM) algorithms like "*Analytic Hierarchy Process*" (AHP). The objective of this paper is to extend our previous work by applying the AHP for the selection of the software requirements of "*Institute Examination System*" (IES). Goal oriented requirements elicitation method has been applied to identify the requirements of IES.

Keywords: Software requirements, functional requirements, non-functional requirements, Analytic hierarchy process, and Institute examination system

1. Introduction

Software requirements elicitation is the first sub-process of requirements engineering (RE) whose objective is to identify different types of the software requirements, i.e., "*functional requirements*" (FR), "*non-functional requirements*" (NFR), and "security requirements" (SR) for the successful development of the software product [1, 2]. There are different techniques which are used to identify the FR, NFR, and SR; but in literature, goal oriented techniques are more popular than the traditional techniques like interview, questionnaire, analysis of existing documents, etc. Knowledge acquisition for automated specification (KAOS) is an important technique for the identification of the FR, while NFR framework is more suitable goal oriented technique for the identification and modeling of the NFRs. Both KAOS and NFR framework are the suitable goal oriented techniques for the elicitation of the FR and NFR; and on the other hand side SR are considered as the NFR, therefore, NFR framework may be used for the identification of the SR [3, 4].

During software requirements elicitation process, requirements analyst identifies thousands of requirements from different stakeholders and each stakeholder has different preference for the same requirements. Under this situation, it is difficult to select those requirements which satisfy the need of all the stakeholders. Therefore, by considering the "multi-criteria decision making" (MCDM) algorithm like AHP, TOPSIS, different methods have been developed by the RE research community for the selection of software requirements. In recent study, Sadiq and Afrin [5] developed "*an integrated approach for the selection of software requirements using fuzzy AHP and fuzzy TOPSIS method*". Their method works well when software requirements are selected under fuzzy environment. Fuzzy-MoSCoW method was developed by Ahmad *et al.* [6] for the prioritization of the software requirements using MoSCoW under fuzzy environment. MoSCoW technique prioritizes the software requirements on the basis of the following criteria: "*Must Have*" (Mo), "*Should Have*" (S), "*Could Have*" (Co), and "Won't Have This Time" (W).

In our previous work, we discuss the applications of the AHP in RE, Software Testing, and Web Development and Internet; and apply the AHP in the area of RE for the selection of the software requirements of IES [7]. In previous work, the FR of IES was evaluated on the basis of only one criterion, i.e. cost. Therefore, in this paper, we extend our previous work by evaluating the FR of the IES on the basis of three different criteria's like Cost, Usability, and Security.

The remaining part of this paper is organized as follows: In section 2, we present a brief introduction about AHP. Section 3 presents the proposed method for the selection of software requirement using AHP. Case study on IES is given in section 4. Finally, section 5, concludes the paper and suggest for future research work.

2. Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is one of the "multi-criteria decision making" (MCDM) algorithms which was developed by the Saaty during 70's for the selection and prioritization of the alternatives after performing the "*pairwise comparisons among alternatives or software requirements*". Researchers have applied AHP in different areas of Science, Technology, and Management [8, 9, 10, 11, 12, 13]. For example, six different methods of software requirements prioritization were evaluated by the Karlsson *et al.* [2]; and after their analysis authors found that "AHP is the most promising method for the prioritization of the software requirements. To apply the AHP in real life problems related with software engineering, there is a need to find out the FR and NFR of the software. After that pairwise comparison matrices are constructed by evaluating the FR on the basis of the NFR [14, 15]. Initially, the diagonal elements of the PCM are one, as shown in Fig. 1.

	FR-1	**FR-2**	**FR-3**	**FR-4**
FR-1	**1**			
FR-2		**1**		
FR-3			**1**	
FR-4				**1**

Fig. 1: Initially the diagonal elements of PCM are one

In Fig.1, there are four FR, i.e., FR1, FR2, FR3, and FR4. When these FR were compared with itself then according to the Saaty rules, one will come in the corresponding position. Therefore, in the Fig.1, the diagonal elements are one.

3. Proposed Method

In this section, we present the proposed method for the selection of the requirements of IES using AHP. Proposed method includes the following steps:

- **Step 1:** Identify the functional and non-functional requirements of IES
- **Step 2:** Evaluate the FR on the basis of Cost, Usability, and Security and construct the Pairwise Comparison Matrices (PCM) on the basis of Cost, usability, and Security
- **Step 3:** Add the column of the PCM and store the results into Add_Column matrix
- **Step 4:** Normalize the Add_Column and store the results into Add_Column_Normalized matrix

- **Step 5:** Compute the average of each row from the Add_Column_Normalized matrix. Now, we shall get the ranking values of the FR of IES and store the results into Priority 1, Priority 2, ... Priority $_{N.}$ Here, N is the number of FRs.
- **Step 6:** Multiply the first column of PCM with Priority 1 value, second column with priority 2 value and similarly, tenth column with priority 10 value. As a result a new matrix would be created and we call it weight_matrix.
- **Step 7:** No add the values of the weight_matrix row wise and sort the results into variable WS, i.e., weighted sum. For example, the sum of the first row of weight matrix would be stored into WS-1, WS-2, ...WS-10.
- **Step 8:** Calculate the values of the lambda
  $\lambda_1 = \frac{WS_1}{P_1}, \lambda_2 = \frac{WS_2}{P_2}, \ldots \lambda_{10} = \frac{WS_{10}}{P_{10}}$

- **Step 9:** Calculate the average of $\lambda_1, \lambda_2, \ldots \lambda_{10}$ and store the results into λ_{max}
- **Step 10:** Calculate the consistency index (CI) as:

$$CI = \frac{\lambda_{max} - N}{N - 1}$$

- **Step 11:** Now calculate the consistency ratio (CR) by using the following equation:

$$CR = \frac{CI}{RI}$$

Here, RI is the consistency index and it value varies on the basis of the number of requirements. Table 1, present the values of the RI for different values of the N, where N is the number of FRs. It is given that "*If the value of Consistency Ratio is smaller or equal to 10%, the subjective judgements are acceptable. If the Consistency Ratio is greater than 10%, we need to consider revising our subjective judgments*". The steps of the proposed method are explained with the help of a case study, which is given in Section 4.

Table 1: RI values for different values of N [16]

N	RI
2	0.00
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.51

4. Case Study

In this section, we apply the proposed method to select the software requirements of IES.

Step 1: In this step, we adopt the set of the FR of IES form the work of [4]. Therefore, the list of the FR is given below:

- "fr1: students fee receipt
- fr2: recording of student's marks, i.e., Sessional test marks and end semester marks;
- fr3: check semester result;

- fr4: generation of seating plan;
- fr5: online examination;
- fr6: completion of examination form; and after complete submission of the examination form,
- IES will display the following information, i.e., roll number of the student, name of the students, name of examination, code of different papers, name of the subject(s), backlogs papers information, if any, detail of examination fee(s)
- fr7: upload all the information related to semester examination;
- fr8: generation of hall ticket;
- fr9: examination form approved by Controller of Examination Department;
- fr10: payment of online examination fee"

The NFRs for IES is given below:

- nfr1: Cost
- nfr2: Usability
- nfr3: Security

Step 2: In this step, FRs are evaluated on the basis of the Cost. The corresponding PCM is exhibited in Table 2. Here, we assume that only one decision maker (DM) is participating in the decision making process. Therefore, the pairwise comparison matrix by DM-1 is given in Table 2. In Table-2, FR1 is compared with FR2 on the basis of cost then on the basis of the cost, DM-1, find out that FR2 is more costly than FR1, therefore, FR1 (row) and FR2 (column) contains 1/5 and on the other hand side, FR2 (row) and FR1 (column) contains 5. In the similar way, entire FRs are evaluated by the DM-1 in order to fill all the entries of Table 2.

Table 2: Evaluating FRs on the basis of Cost

	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10
FR1	1	1/5	3	7	3	9	3	5	1	1/9
FR 2	5	1	3	1	5	7	3	7	5	1/7
FR 3	1/3	1/3	1	5	1/7	9	1/9	5	1/3	5
FR 4	1/7	1/1	1/5	1	5	1/3	7	1/3	1/7	1/1
FR 5	1/3	1/5	7	1/5	1	1/1	1	5	1/5	7
FR 6	1/9	1/7	1/9	3	1	1	3	1/7	9	1/9
FR 7	1/3	1/3	9	1/7	1	1/3	1	7	1/5	3
FR 8	1/5	1/7	1/5	3	1/5	7	1/7	1	7	1/3
FR 9	1/1	1/5	3	7	5	1/9	5	1/7	1	5
FR 10	9	7	1/5	1	1/7	9	1/3	3	1/5	1

Step 3: In this step, we add the column of Table 2; and the results are given in Table 3.

Table 3: Column addition

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10
FR1	1.000	0.200	3.000	7.000	3.000	9.000	3.000	5.000	1.000	0.111
FR 2	5.000	1.000	3.000	1.000	5.000	7.000	3.000	7.000	5.000	0.143
FR 3	0.333	0.333	1.000	5.000	0.143	9.000	0.111	5.000	0.333	5.000
FR 4	0.143	1.000	0.200	1.000	5.000	0.333	7.000	0.333	0.143	1.000
FR 5	0.333	0.200	7.000	0.200	1.000	1.000	1.000	5.000	0.200	7.000
FR 6	0.111	0.143	0.111	3.000	1.000	1.000	3.000	0.143	9.000	0.111
FR 7	0.333	0.333	9.000	0.143	1.000	0.333	1.000	7.000	0.200	3.000
FR 8	0.200	0.143	0.200	3.000	0.200	7.000	0.143	1.000	7.000	0.333
FR 9	1.000	0.200	3.000	7.000	5.000	0.111	5.000	0.143	1.000	5.000
FR 10	9.000	7.000	0.200	1.000	0.143	9.000	0.333	3.000	0.200	1.000
Add_Column	17.453	10.552	26.711	28.343	21.486	43.777	23.587	33.619	24.076	22.698

Step 4: Here, we normalise the above matrix; and the results are shown in Table 4.

Table 4: Normalized Matrix

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10
FR1	0.057	0.019	0.112	0.247	0.140	0.205	0.127	0.149	0.041	0.005
FR 2	0.286	0.095	0.112	0.035	0.233	0.160	0.127	0.208	0.208	0.006
FR 3	0.019	0.031	0.037	0.176	0.007	0.205	0.005	0.199	0.014	0.220
FR 4	0.008	0.095	0.007	0.035	0.233	0.008	0.297	0.010	0.006	0.044
FR 5	0.019	0.019	0.262	0.007	0.046	0.023	0.042	0.149	0.008	0.308
FR 6	0.006	0.013	0.004	0.106	0.046	0.023	0.127	0.004	0.374	0.005
FR 7	0.019	0.031	0.337	0.005	0.046	0.008	0.042	0.208	0.008	0.132
FR 8	0.111	0.013	0.007	0.106	0.009	0.160	0.006	0.030	0.291	0.015
FR 9	0.057	0.019	0.112	0.247	0.233	0.002	0.212	0.004	0.041	0.220
FR 10	0.037	0.663	0.007	0.035	0.007	0.205	0.014	0.089	0.008	0.044

Step 5: The results of this step is given in Table 5.

Table 5. Calculation of priorities: row averages

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10	**Priority**
FR1	0.057	0.019	0.112	0.247	0.140	0.205	0.127	0.149	0.041	0.005	**0.110**
FR 2	0.286	0.095	0.112	0.035	0.233	0.160	0.127	0.208	0.208	0.006	**0.147**
FR 3	0.019	0.031	0.037	0.176	0.007	0.205	0.005	0.199	0.014	0.220	**0.086**
FR 4	0.008	0.095	0.007	0.035	0.233	0.008	0.297	0.010	0.006	0.044	**0.074**
FR 5	0.019	0.019	0.262	0.007	0.046	0.023	0.042	0.149	0.008	0.308	**0.088**
FR 6	0.006	0.013	0.004	0.106	0.046	0.023	0.127	0.004	0.374	0.005	**0.071**
FR 7	0.019	0.031	0.337	0.005	0.046	0.008	0.042	0.208	0.008	0.132	**0.084**
FR 8	0.111	0.013	0.007	0.106	0.009	0.160	0.006	0.030	0.291	0.015	**0.075**
FR 9	0.057	0.019	0.112	0.247	0.233	0.002	0.212	0.004	0.041	0.220	**0.115**
FR 10	0.037	0.663	0.007	0.035	0.007	0.205	0.014	0.089	0.008	0.044	**0.159**

Table 6: Presentation of result: original judgments and priorities

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10	**Priority**
FR1	1.000	0.200	3.000	7.000	3.000	9.000	3.000	5.000	1.000	0.111	**0.110**
FR 2	5.000	1.000	3.000	1.000	5.000	7.000	3.000	7.000	5.000	0.143	**0.147**
FR 3	0.333	0.333	1.000	5.000	0.143	9.000	0.111	5.000	0.333	5.000	**0.086**
FR 4	0.143	1.000	0.200	1.000	5.000	0.333	7.000	0.333	0.143	1.000	**0.074**
FR 5	0.333	0.200	7.000	0.200	1.000	1.000	1.000	5.000	0.200	7.000	**0.088**
FR 6	0.111	0.143	0.111	3.000	1.000	1.000	3.000	0.143	9.000	0.111	**0.071**
FR 7	0.333	0.333	9.000	0.143	1.000	0.333	1.000	7.000	0.200	3.000	**0.084**
FR 8	0.200	0.143	0.200	3.000	0.200	7.000	0.143	1.000	7.000	0.333	**0.075**
FR 9	1.000	0.200	3.000	7.000	5.000	0.111	5.000	0.143	1.000	5.000	**0.115**
FR 10	9.000	7.000	0.200	1.000	0.143	9.000	0.333	3.000	0.200	1.000	**0.159**

Step 6: Here, the first column of the PCM is multiplied with priority 1, i.e, 0.110, see Table 7. Similarly, all the respective columns are multiplied with the corresponding priority values; and the results are summarized in Table 8.

Table 7: Priorities as factors

0.110	**0.147**	**0.086**	**0.074**	**0.088**	**0.071**	**0.084**	**0.075**	**0.115**	**0.159**
1.000	0.200	3.000	7.000	3.000	9.000	3.000	5.000	1.000	0.111
5.000	1.000	3.000	1.000	5.000	7.000	3.000	7.000	5.000	0.143
0.333	0.333	1.000	5.000	0.143	9.000	0.111	5.000	0.333	5.000
0.143	1.000	5.000	1.000	5.000	0.333	7.000	0.333	0.143	1.000
0.333	0.200	1.000	0.200	1.000	1.000	1.000	5.000	0.200	7.000
0.111	0.143	0.200	3.000	1.000	1.000	3.000	0.143	9.000	0.111
0.333	0.333	3.000	0.143	1.000	0.333	1.000	7.000	0.200	3.000
0.200	0.143	0.143	3.000	0.200	7.000	0.143	1.000	7.000	0.333
1.000	0.200	3.000	7.000	5.000	0.111	5.000	0.143	1.000	5.000
9.000	7.000	0.200	1.000	0.143	9.000	0.333	3.000	0.200	1.000

Table 8: Calculation of weighted columns

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10
FR1	0.110	0.029	0.258	0.518	0.264	0.639	0.252	0.375	0.115	0.018
FR 2	0.550	0.147	0.258	0.074	0.440	0.497	0.252	0.525	0.575	0.023
FR 3	0.037	0.049	0.086	0.370	0.012	0.639	0.009	0.375	0.038	0.795
FR 4	0.016	0.147	0.017	0.074	0.440	0.023	0.588	0.025	0.016	0.159
FR 5	0.037	0.029	0.602	0.015	0.088	0.071	0.084	0.037	0.023	1.113
FR 6	0.012	0.021	0.009	0.222	0.088	0.071	0.252	0.011	1.035	0.018
FR 7	0.037	0.049	0.774	0.010	0.088	0.639	0.084	0.525	0.023	0.477
FR 8	0.022	0.021	0.017	0.222	0.018	0.497	0.012	0.075	0.805	0.053
FR 9	0.550	0.029	0.026	0.518	0.440	0.008	0.420	0.011	0.115	0.795
FR 10	0.990	1.029	0.017	0.074	0.012	0.639	0.028	0.022	0.023	0.159

The results of **step 7** are given in Table 9.

Table 9: Calculation of weighted sum

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10	**Sum**
FR1	0.110	0.029	0.258	0.518	0.264	0.639	0.252	0.375	0.115	0.018	2.578
FR 2	0.550	0.147	0.258	0.074	0.440	0.497	0.252	0.252	0.575	0.023	3.431
FR 3	0.037	0.049	0.086	0.370	0.012	0.639	0.009	0.009	0.038	0.795	2.410
FR 4	0.016	0.147	0.017	0.074	0.440	0.023	0.0.588	0.037	0.016	0.159	1.505
FR 5	0.037	0.029	0.602	0.015	0.088	0.071	0.084	0.011	0.023	0.159	2.099
FR 6	0.012	0.021	0.009	0.222	0.088	0.71	0.252	0.525	1.035	1.113	1.739
FR 7	0.037	0.049	0.774	0.010	0.088	0.639	0.084	0.755	0.023	0.047	2.706
FR 8	0.022	0.021	0.017	0.222	0.018	0.497	0.012	0.075	0.805	0.053	1.742
FR 9	0.550	0.029	0.026	0.518	0.440	0.008	0.420	0.011	0.011	0.795	2.912
FR 10	0.990	1.029	0.017	0.074	0.012	0.639	0.028	0.222	0.023	0.159	2.993

The results of **step 8** are given in Table 10.

Table 9: Calculation of λ_{max}

Weighted Sum	Priority	
2.578 /	0.110 =	23.436
3.341 /	0.147 =	22.728
2.410 /	0.086 =	28.023
1.505 /	0.074 =	20.338
2.099 /	0.088 =	23.852
1.739 /	0.071 =	24.493
2.706 /	0.084 =	32.214
1.742 /	0.075 =	23.227
2.912 /	0.115 =	25.322
2.993 /	0.159 =	18.824
	Total	242.66
	Divide total by 10 to obtain lambda$_{max}$ =	24.266

Step 9: The value of the λ_{max} is calculated as:

$\lambda_{max=}$ (23.436+22.728+28.023+20.338+23.852+24.493+32.214+23.227+25.322+18.824) / 10= 24.246

Step 10: In the step, we calculate the value of the CI by using the following equation:

$$C.I. = (\lambda_{max-n}) / (n-1)$$

where n is the number of compared elements (in our example n = 10).

Therefore,

$$C.I = (\lambda_{max} - n) / (n-1) = (24.246-10) / (10-1)$$

$$= 14.246 / 9$$

$$= 1.583/1.49$$

Step 11: Now we can calculate the consistency ratio

$$CR=CI/RI$$

$$C.R = CI / RI = 1.062$$

Similarly, we apply the same steps for the usability and security also. The results are given in Table 11 and Table 12, respectively.

Table 11: Priority value of the FR based on Usability

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10	**Priority**
FR1	1.000	3.000	0.200	9.000	7.000	5.000	3.000	0.333	5.000	9.000	**0.192**
FR 2	0.333	1.000	5.000	1.000	1.000	3.000	5.000	0.143	9.000	5.000	**0.115**
FR 3	5.000	0.200	1.000	5.000	1.000	1.000	3.000	0.200	0.111	0.143	**0.098**
FR 4	0.111	1.000	0.200	1.000	3.000	1.000	0.200	7.000	9.000	3.000	**0.123**
FR 5	0.143	1.000	1.000	0.333	1.000	5.000	3.000	1.000	1.000	5.000	**0.080**
FR 6	0.200	0.333	1.000	1.000	0.200	1.000	5.000	1.000	1.000	7.000	**0.060**
FR 7	0.333	0.200	0.333	5.000	0.333	0.200	1.000	3.000	0.200	0.111	**0.056**
FR 8	3.000	7.000	5.000	0.143	1.000	1.000	0.333	1.000	7.000	5.000	**0.155**
FR 9	0.200	0.111	9.000	0.111	1.000	1.000	5.000	0.143	1.000	3.000	**0.080**
FR 10	0.111	0.200	0.143	0.333	0.200	0.143	9.000	0.200	0.333	1.000	**0.038**

Table 12: Priority value of the FR based on Security

FRs	FR 1	FR 2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10	**Priority**
FR1	1.000	5.000	7.000	0.111	3.000	1.000	5.000	0.143	9.000	3.000	0.114
FR 2	0.200	1.000	0.200	3.000	0.143	9.000	9.000	7.000	0.200	0.333	0.123
FR 3	0.143	5.000	1.000	5.000	7.000	0.200	0.333	0.111	1.000	5.000	0.153
FR 4	9.000	0.333	0.200	1.000	5.000	9.000	0.143	5.000	1.000	3.000	0.150
FR 5	0.333	7.000	0.143	0.200	1.000	3.000	5.000	0.143	9.000	5.000	0.195
FR 6	1.000	0.111	5.000	0.111	0.333	1.000	1.000	0.200	7.000	0.333	0.051
FR 7	0.200	9.000	3.000	7.000	0.200	1.000	1.000	1.000	0.200	0.143	0.090
FR 8	7.000	0.143	9.000	0.200	7.000	5.000	1.000	1.000	9.000	0.333	0.147
FR 9	0.111	5.000	1.000	1.000	0.111	0.143	5.000	0.111	1.000	0.200	0.043
FR 10	0.333	3.000	0.200	0.333	0.200	3.000	7.000	3.000	5.000	1.000	0.077

Here, we assume the weight vector for the given set of the NFRs, i.e., cost = 0.3, Usability =0.2, and security = 0.5. Then the final ranking values of the FRs are calculated as:

Table 13: Calculation to calculate the ranking values of the FRs

FR	Cost (0.3)	Usability (0.2)	Security (0.5)
FR1	0.110	0.192	0.114
FR 2	0.147	0.115	0.123
FR 3	0.086	0.098	0.153
FR 4	0.074	0.123	0.150
FR 5	0.088	0.080	0.195
FR 6	0.071	0.060	0.051
FR 7	0.084	0.056	0.090
FR 8	0.075	0.155	0.147
FR 9	0.115	0.080	0.043
FR 10	0.159	0.038	0.077

Table 14: Calculation after multiplying the weight vectors of NFRs

FR	Cost (0.3)	Usability (0.2)	Security (0.5)	Final priority values
FR1	0.033	0.0384	0.057	0.1284
FR 2	0.0441	0.023	0.0615	0.1286
FR 3	0.0258	0.0196	0.0765	0.1219
FR 4	0.0222	0.0246	0.075	0.1218
FR 5	0.0264	0.016	0.195	0.2374
FR 6	0.0213	0.012	0.0255	0.0588
FR 7	0.0252	0.0112	0.045	0.0814
FR 8	0.0255	0.031	0.0735	0.127
FR 9	0.0345	0.016	0.0215	0.072
FR 10	0.0477	0.0076	0.0385	0.0938

In our case study, we identify that FR5 has the highest ranking value. If the clients want to develop the top three requirements during the first release of the software then under this situation, FR5, FR2 and FR1 would be selected during the development process. The other set of requirements can be selected based on their ranking values, as shown in Table 14.

5. Conclusions and Future Work:

In this paper, we present a systematic method for the selection of software requirements of IES using AHP. Proposed method has eleven steps which are used to select the requirements from the set of the requirements. In our study, we identify the ten FR and three NFRs of IES. After applying the proposed method it has been observed that if the client wants to develop the top three requirements then based on the ranking values as shown in Table 14, the FR5, FR2, and FR1 would be selected and implemented during the development phase. Future work includes the following:

- To apply the proposed method on some other real life examples
- To select the software requirements using other MCDM methods

References

1. Dabbagh M, Lee S. P., Parizi R. M.: Functional and non-Functional Requirements Prioritization: Empirical Evaluation of IPA, AHP-based, and HAM-based Approaches", Soft Computing, pp-1-24, 2015.
2. Karlsson J., Wohlin C., and Regnell B.: An Evaluation of Methods for Prioritizing Software Requirements. Information and Software Technology, 39, (1998), 939-947
3. Sadiq, M., Afrin, A.: Extending AHP-GORE-PSR by Generating Different Patterns of Pairwise Comparison Matrix. International Conference on Information, Communication and Computing Technology, CCIS, Springer-Verlag, Singapore (2017)
4. Sadiq M.: A Fuzzy-Set Based Approach for the Prioritization of Stakeholders on the basis of the Importance of Software Requirements", IETE Journal of Research, Taylor and Francis, Vol. 63, Issue 5, pp. 616-629, 2017.
5. Sadiq M. and Afrin A., "An Integrated Approach for the Selection of Software Requirements using Fuzzy AHP and Fuzzy TOPSIS Method", IEEE International Conference on Intelligent Computing, Instrumentation, Control, Technologies, pp. 1094-1100, 2017.
6. Ahmad K. S., Ahmad N., Tahir H., Khan S., "Fuzzy_MoSCoW: A Fuzzy Based MoSCoW Method for the Prioritization of Software Requirements", IEEE International Conference on Intelligent Computing, Instrumentation, Control, Technologies, pp. 433-437, 2017.
7. Afzal N and Sadim M., "Software Requirements Selection using AHP", International Journal of Computer Science and Communication, Volume 9, Issue 2, pp. 47-52, 2018.
8. Behzadian, M., Otaghsara, S.K., Yazdani, M., Ignatius, J.: A State-of the –art Survey of TOPSIS Applications, Expert Systems with Applications, Vol. 39. Elsevier (2012) 13051- 13069
9. Lee Y. and Kozar K.: Investigating the Effect of Website Quality on e-Business Success: An Analytic Hierarchy Process (AHP) Approach", Decision Support System, Vol. 42, pp. 1383-1401, 2006.
10. Lin H. F.: An Application of Fuzzy AHP for Evaluating the Course Website Quality", Computer and Education, Vol. 54, pp. 877-888, 2010.
11. Sadiq M. and Sultana S. A Method for the Selection of Software Testing Techniques using Analytic Hierarchy Process", International Conference on Computational Intelligence in Data Mining (ICCIDM), Springer, Vol. 31, pp. pp. 213-220, December 20-21, 2014.
12. Juan Z., WeiQin T., LiZhi C.: An Evaluation Model in Software Testing Based on AHP", IEEE/ACIS 11th International Conference on Computer and Information Science, pp. 601-604, 2012.

13. Tahavili S., Saadatmand M., Bohlin M.: Multi-criteria Test Case Prioritization using Fuzzy Analytic Hierarchy Process", 10th International Conference on Software Engineering Advances, pp. 290-296, 2015.
14. Saaty T. L.: How to Make a Decision: The Analytic Hierarchy Process. European Journal of Operational Research, 48 (1), (1990), 9-26.
15. Min H.: Selection of Software: The Analytic Hierarchy Process. International Journal of Physical Distribution and Logistics Management, 22(1), (1992), 42-52
16. Alonso J. A., "Consistency in the Analytic Hierarchy Process: A New Approach", International Journal of Uncertainty, Fuzziness, and Knowledge Based Systems, Vol. 14, No. 4, pp. 445-459, 2006.
17. Abdulla M. S.: Multi-criteria Decision Making Overlapping Criteria", IIMB Management Review, Vol. 24, pp. 137-142, 2012.
18. Karsak E. E. and Ozogul C. O.: An Integrated Decision Making Approach for ERP System Selection. Expert Systems with Applications, 36(1), (2009), 660-667