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Evaluation of Contribution and Ranking of Software Quality Attributes by using FAHP

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Abstract*— Different authors propose different models and methods to define and estimate software quality. From these models and methods, we can conclude that quality of software depends upon number of attributes and their sub-attributes. But very little or less effort has been devoted to evaluate the contribution of these attributes to the quality of a software product. Therefore, this study proposes the implementation of ISO 9126 quality model along with Fuzzy Analytical Hierarchy Process (FAHP) to develop a framework for the ranking of different quality attributes in order to evaluate the contribution of these attribute of software to the quality of software product.

***Index Terms*— Quality attributes, FAHP, Linguistic variables, Crisp Score, Fuzzy numbers.**

I. INTRODUCTION

Quality is concept which cannot be understood as a single entity. It depends upon number of attributes and all these attributes constitute the quality of a software product. There are number of quality models which define the different attributes and sub-attributes of quality [1], [2], [3] different authors also propose different methods to estimate the software quality based on these models [4]. Despite of all the methods to define and estimate the software quality, there is still a problem. The problem is, if quality of a software product is estimated as 85 or best but the attributes which is most important for that software product is contributing very less to the overall quality, then what? It is very clear from the above discussion that we need to know the contribution of each attribute to the quality of a software product. Therefore, this study, develop a framework to rank the different attributes of quality so that contribution of each attribute to the quality can be evaluated.

ISO 9126 Quality Model International Organization for Standardization (ISO) defines six attributes of software quality in ISO 9126 quality model. These attributes of quality are given below.

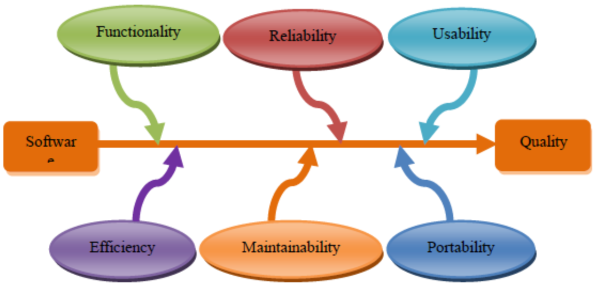

Figure1. Attributes define by ISO 9126.

Each of these attributes consists of several sub-attributes as given below.

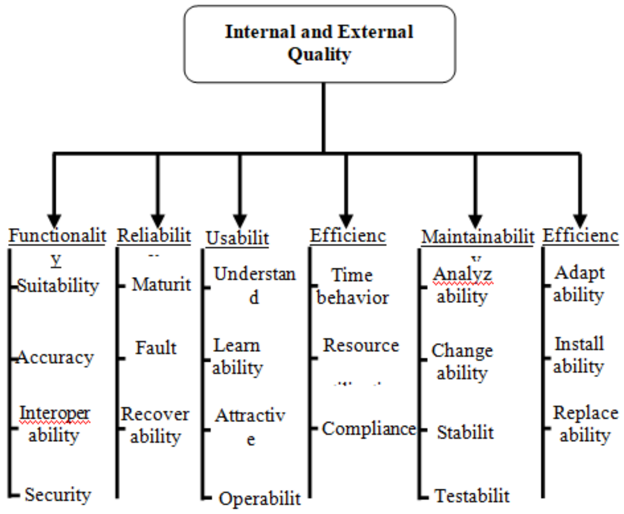

Figure2. Show Attributes & Sub-attributes define by ISO.

These quality attributes are defined as:-

1) Functionality: - A set of attribute that relate to the existence of set of functions and their s Functionality specified properties. The functions are those that satisfy stated or implied needs.
2) Reliability: - A set of attributes that relate to the capability of software to maintain its level of performance under stated conditions for a stated period of time.
3) Usability: - A set of attributes that relate to the effort needed for use, and on the individual assessment of such use, by a stated or implied set of user.
4) Efficiency: - A set of attributes that relate to the relationship between the level of performance of the software and the amount of resource used, under stated conditions.
5) Maintainability: - A set of attributes that relate to the effort needed to make specified modification.
6) Portability: - A set of attributes that relate to the ability of software to be transformed from and environment to another.

This study uses ISO 9126 Quality Model because ISO is widely accepted standard and this model includes both internal and external quality of a software product [5].

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II. METHODOLOGY

FAHP

The analytical Hierarchy Process (AHP) proposed by satty (1980), is a multi-criteria decision making process. AHP is one of the most useful Multi-criteria decision making process. Although AHP is very popular but is inable to deal with uncertainty and imprecision associated with decision maker's perception. To overcome these pitfalls, AHP is combined with fuzzy because fuzzy set theory is capable of representing vague and fuzzy values. Fuzzy AHP, developed from AHP is widely used in solving complicated decision making problems [6], [7]. The method proposed by chen & Hwang (1992) involves following steps:-

Ist Step. Conversion of linguistic terms into fuzzy numbers and then to crisp scores.

Firstly, linguistic variable are converted into fuzzy no. using conversion scales.

We consider 5 points scale to show the conversion of linguistic term to fuzzy Numbers.

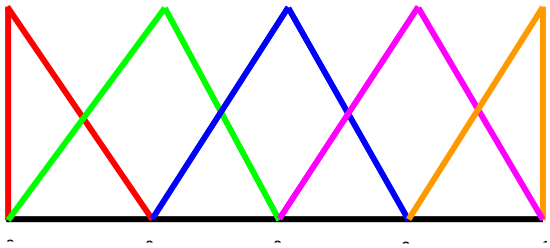

Figure3. Show range of linguistics variables

Table1. Show 5-point conversion scale for linguistic variable to fuzzy number.

Linguistic Variables	Fuzzy Numbers
POOR	M1
ABOVE POOR	M2
GOOD	M3
VERY GOOD	M4
BEST	M5

Fuzzy numbers are then converted into crisp score by using fuzzy scoring approach.

$$\mu\, max(x) = \begin{cases} x, 0 \le x \le 1 \\ 0, otherwise \end{cases}$$

$$\mu\, min(x) = \begin{cases} 1 - x, 0 \le x \le 1 \\ 0, otherwise \end{cases}$$

Then right, left & total score are calculates as given below.

$$\mu R(M) = sup\,[\mu \max(x) \,\hat{}\, \mu M\,(x)]$$

$$\mu L\,(M) = sup[\mu \min(x) \,\hat{}\, \mu M\,(x)\,]$$

$$\mu T\,(M) = [\mu R(M) + 1 - \mu L\,(M)]/2$$

Similarly, crisp values for fuzzy Numbers M1, M2, M3, M4 and M5 are calculated.

$$\mu\, M1(x) = \begin{cases} 1, x = 0 \\ \dfrac{(0.3 - x)}{0.3}, 0 \le x \le 0.3 \end{cases}$$

$$\mu\, M2(x) = \begin{cases} \dfrac{(x - 0)}{0.25}, 0 \le x \le 0.3 \\ \dfrac{(0.5 - x)}{0.25}, 0 \le x \le 0.5 \end{cases}$$

$$\mu\, M3(x) = \begin{cases} \dfrac{(0 - 0.3)}{0.2}, 0.3 \le x \le 0.5 \\ \dfrac{(0.5 - x)}{0.2}, 0.5 \le x \le 0.7 \end{cases}$$

$$\mu\, M4(x) = \begin{cases} \dfrac{(x - 0.5)}{0.25}, 0.5 \le x \le 0.75 \\ \dfrac{(1.0 - x)}{0.25}, 0.75 \le x \le 1.0 \end{cases}$$

$$\mu\, M5(x) = \begin{cases} \dfrac{(x - 0.7)}{0.3}, 0.7 \le x \le 10 \\ 1, x = 1 \end{cases}$$

The right, left & total score for M1 are calculated as

$$\mu R(M1) = sup\,[\mu \max(x) \,\hat{}\, \mu M1\,(x)] = 0.23$$

$$\mu L\,(M1) = sup[\mu \min(x) \,\hat{}\, \mu M1\,(x)\,] = 1.0$$

$$\mu T\,(M1) = [\mu R(M1) + 1 - \mu L\,(M1)]/2 = 0.115$$

Similarly right, left & total Score of M2, M3, M4 & M5 are given below.

	μR	μL	μT
M1	0.25	1.0	0.115
M2	0.39	0.8	0.295
M3	0.58	0.59	0.495
M4	0.79	0.4	0.695
M5	1.0	0.23	0.895

Table2. Show right left & total score for M1, M2, M3, M4 & M5.

Linguistic Variables	Fuzzy Numbers	Crisp score
POOR	M1	0.115
ABOVE POOR	M2	0.295
GOOD	M3	0.495
VERY GOOD	M4	0.695
BEST	M5	0.895

Table3. Show linguistic variable along with their fuzzy number & crisp score.

2nd Step. Construct Relative importance matrix.

A matrix (Ar) is developed based on expert reasoning. The weight to this matrix is assigned by comparing criteria with criteria. The diagonal elements of the matrix are always 1 because a criterion is compare with itself.

Table4. Show scale of relative preference based on satty (1980).

Intensity of preference	Reciprocal	Linguistic variable
1	1	JUST EQUAL
3	1/3	SLIGHTLY IMMORTALLY
5	1/5	STRONG IMPORTANT
7	1/7	VERY STRONG IMPORTANT
9	1/9	EXTREMELY IMPORTANT
2,4,6,8	1/2, 1/4, 1/6, 1/8	INTERMEDIATE VALUE (WHEN COMPROMISE IS NEEDED)

3rd Step. Consistency check.

It is performed to check that whether the weights assigned by expert are correct or not. The value less than 0.1 Show that weights are consistent. It further involves following steps.

1. Geometric Mean: - It is calculated by multiplying the elements of each row and then dividing by size of matrix. Then, Total geometric mean is calculated by adding geometric mean for each row.
2. Normalized Weight: - It is calculated for each row by dividing the geometric mean of each row by total geometric mean and then weights obtained are arranged in a matrix denoted by An.
3. A1=Ar X An
   Where Ar = relative importance matrix & An = normalized Matrix.
4. A2=A1/An
5. λ max = Sum of A2 elements / No. of A2 elements
6. CI = λ max-n / n-1
   Where n = size of matrix.
7. CR = CI / RI

Where RI is random index, which is already given for specific number of criteria.
If value of CR is less than 0.1 then, weights are consistent.

4th Step Ranking

Ranking can be obtained by multiplying Decision Making Matrix (DMM) with Normalized Matrix (An) [8], [9], [10].

III. FRAMEWORK DEVELOPMENT

For this study, we choose ISO 9126 quality model. Therefore, the six quality attributes defined by ISO are the input parameters.

Table5. Show number and name of input along with their linguistic variables.

Intensity of preference	Reciprocal	Linguistic variable
1	FUNCTIONALITY	POOR
2	RELIABILITY	
3	USABILITY	GOOD
4	EFFICIENCY	
5	MAINTAINABILITY	
6	PORTABILITY	BEST

Ist Step. Conversion of linguistic terms into fuzzy numbers and then to crisp scores.

Since for this study we choose only three linguistic variables therefore we choose 3 point scale.
From table1 and figure 3, we get fuzzy number for the linguistic variables.

Table6. Show linguistic variables along with their fuzzy numbers.

Linguistic Variables	Fuzzy Numbers
POOR	M1
GOOD	M3
BEST	M5

These fuzzy numbers are then converted into crisp scores by using fuzzy scoring approach. From table 2 and table 3 we get crisp score.

Table7. Show crisp scores and fuzzy numbers.

Linguistic Variables	Fuzzy Numbers	Crisp score
POOR	M1	0.115
GOOD	M3	0.495
BEST	M5	0.895

From above crisp values the decision making matrix (DMM) so formed is given below

$$\begin{vmatrix} 0.115 & 0.495 & 0.115 & 0.495 & 0.115 & 0.495 \\ 0.495 & 0.115 & 0.895 & 0.895 & 0.495 & 0.895 \\ 0.895 & 0.495 & 0.895 & 0.115 & 0.115 & 0.895 \\ 0.895 & 0.115 & 0.895 & 0.495 & 0.115 & 0.115 \\ 0.895 & 0.495 & 0.495 & 0.895 & 0.495 & 0.495 \\ 0.895 & 0.895 & 0.115 & 0.495 & 0.115 & 0.115 \end{vmatrix}$$

2nd Step. Construct Relative importance matrix.

Each attribute is compared with other attributes and weights are assigned based on expert reasoning, using table 4 Diagonal elements are always 1 because compared with it themselves. It is denoted by Ar.

$$\mathbf{Ar} = \begin{array}{c|cccccc} & \mathbf{A1} & \mathbf{A2} & \mathbf{A3} & \mathbf{A4} & \mathbf{A5} & \mathbf{A6} \\ \hline \mathbf{P1} & 1 & 2 & 5 & 3 & 3 & 2 \\ \mathbf{P2} & 0.5 & 1 & 3 & 5 & 5 & 5 \\ \mathbf{P3} & 0.2 & 0.3 & 1 & 3 & 2 & 3 \\ \mathbf{P4} & 0.3 & 0.2 & 0.3 & 1 & 3 & 3 \\ \mathbf{P5} & 0.3 & 0.2 & 0.5 & 0.3 & 1 & 3 \\ \mathbf{P6} & 0.5 & 0.2 & 0.3 & 0.3 & 0.3 & 1 \end{array}$$

3rd Step. Consistency check.

For checking the correctness of weights assigned by experts consistency check is performed .

1. Geometric Mean: -

GM1 = (1 X 2 X 5 X 3 X 3 X 2) / 6 = 2.3761
GM2 = (0.5 X 1 X 3 X 5 X 5 X 5) / 6 = 2.3923
GM3 = (0.2 X 0.3 X 1 X 3 X 2 X 3) / 6 = 1.0129
GM4 = (0.3 X 0.2 X 0.3 X 1 X 3 X 3) / 6 = 0.73833
GM5 = (0.3 X 0.2 X 0.5 X 0.3 X 1 X 3) / 6 = 0.54772
GM6 = (0.5 X 0.2 X 0.3 X 0.3 X 0.3 X 1) / 6 = 0.3731
GM = GM1+GM2+GM3+GM4+GM5+GM6 = 7.4406

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2. Normalized Weight: -

N1 = GM1 / GM = 2.3761 / 7.44406 = 0.3193
N2 = GM2 / GM = 2.3923 / 7.44406 = 0.3215
N3 = GM3 / GM = 1.0129 / 7.44406 = 0.1361
N4 = GM4 / GM = 0.73833 / 7.44406 = 0.0992
N5 = GM5 / GM = 0.54772 / 7.44406 = 0.0736
N6 = GM6 / GM = 0.3731 / 7.44406 = 0.0501

An =

0.3193
0.3215
0.1361
0.0992
0.0736
0.0501

3. A1 = Ar X An

1	2	5	3	3	2		0.3193
0.5	1	3	5	5	5		0.3215
0.2	0.3	1	3	2	3	*	0.1361
0.3	0.2	0.3	1	3	3		0.0992
0.3	0.2	0.5	0.3	1	3		0.0736
0.5	0.2	0.3	0.3	0.3	1		0.0501

A1 =

2.2618
2.00455
0.67147
0.67147
0.48201
0.36682

4. A2 = A1 / An

	2.2618		0.319		7.082
	2.00455		0.321		6.234
=	0.67147	/	0.1361	=	4.9325
	0.67147		0.0992		6.766
	0.48201		0.7361		6.548
	0.36682		0.05015		7.31435
			Total Sum =		38.879

5. λmax=Total sum of A2 / Size of A2
= 38.879 / 6
=6.4798

6. CI = λmax-n / n-1, n = size of matrix
= (6.4798 – 6) / (6-1)
=0.09596

7. CR = CI / RI, for 6 criteria RI=1.25
= 0.09596 / 1.25
= 0.076

Since value of CR is less then 0.1, therefore weights are consistant

4th Step. Ranking

It is obtained by multiplying Decision Making Matrix DMM and Normalized matrix An.

0.115	0.495	0.115	0.495	0.115	0.495		0.3193
0.895	0.495	0.895	0.115	0.115	0.895	*	0.3215
0.895	0.115	0.895	0.495	0.115	0.115		0.1361
0.895	0.495	0.495	0.895	0.495	0.495		0.0992
0.895	0.895	0.115	0.495	0.115	0.115		0.0736
							0.0501

Ranking

1.338070474	R1
0.839189935	R2
0.464206501	R3
0.336386389	R4
0.134996703	R6
0.150954711	R5

IV. CONCLUSION

The proposed work is concluded as the development of the framework for the ranking of different quality attributes, so that contribution of each quality attribute to the overall quality can be evaluated. For choosing different quality attributes, ISO 9126 quality model is selected and for ranking, FAHP is selected which is an effective problem solving multi-attribute decision making method. By following ISO 9126 quality model along with different steps and calculations of FAHP, ranking of different quality attributes is obtained which clearly shows the contribution of each attribute to the quality of software product.

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