

# **A Novel Integrated AHP-QFD Model for Software Project Selection under Fuzziness**

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## **ABSTRACT**

Now-a-days software manufacturing companies usually try to capture market share with rapid software development. Actually the development of high quality software products can decrease cost by reducing rework and increasing productivity. For that, reason selection of software projects is an important task. Several factors come into consideration while selection of proper project for a specified job. To deal with this typical situation the current researchers combined the much known AHP (Analytic Hierarchy Process) with QFD (Quality Function Deployment). Here the AHP method redefined under fuzziness. Then QFD process is applied to identifying and ranking customer's need and translating them into product / service specification. At the last sensitivity analysis has been done to make the process more robust from the characterization of integration of the fuzzy AHP & QFD.

## **General Terms**

Software project selection; fuzziness; sensitivity analysis.

## **Keywords**

Quality Function Deployment; AHP; Fuzziness; Project selection .

## **1. INTRODUCTION**

Project selection is the process of evaluating individual projects or group of projects and then choosing the most viable project for implementation, so that the objectives of the parent organization will be achieved in due time. This systematic process of project selection can be applied to any area of the organization's business in which choices must be made between competing alternatives. Each project will have different costs, benefits and risks. Rarely these are known with certainty. In the face of such differences, the selection of one project out of a set of projects is a difficult task. Choosing a number of different projects, a portfolio, is even more complex.

Project selection is only one of many decisions associated with project management. The proper choice of investment in projects is crucial to the long-run survival of every organization. This type of decision involves multiple factors such as identification, considerations and analysis of viability. According to Hwang and Yoon [1] Multi-criteria decision making (MCDM) is applied to preferable decisions among available classified alternatives by multiple attributes. So MCDM is one of the most widely used decision methodology in project selection problems [2]. The MCDM is a method that follows the analysis of several criteria, simultaneously. In this method economic, environmental, social and technological factors are considered for the selection of the project and for making the choice sustainable [3-5]. Several framework have been proposed for solving MCDM problems,

namely Analytical Hierarchy Process [AHP] [6, 7, 8], Analytical Network Process [ANP] [9], which deals with decisions in absence of knowledge of the independence of higher level elements from lower level elements and about the independence of the elements within a level. Other framework available are data envelopment analysis (DEA), Technique for order performance by similarity to ideal solution (TOPSIS) [11], VIKOR [12,13], MOORA [14,15], COPRAS [16], with grey number, [17-19], Simple Additive weighting (SAW) etc [20], LINMAP [21]. With these techniques alternative ratings are measured, weight of the criteria are expressed in precise numbers [22]. The projects' life cycle assessment is to be determined and the impact of all actors is to be measured. There are some mandatory axioms that the criteria describing feasible alternatives are dimensions, which are important to determine the performance.

The present work encompasses technical requirements, customer's requirements and economics of the selection of projects in customer's perspective. In this paper, current researchers develop an integrated novel technique for the economics of project selection.

## **2. RELATED WORKS**

In available DSS methods, application of the AHP [23-29] to the project selection problem is not now in the art. Among formal decision tools' Satty's analytic network process (ANP) model [30] is assumed to be suitable for the project evaluation process. On the contrary, some researchers [31-33] have iterated that to integrate the cardinal and ordinal preferences using ANP/ AHP for project selection decisions are not valid. In the research paper, project selection and evaluation studies have been carried under fuzziness [34-37]. Fuzzy methods were applied to the multi attribute selection models [38-39]. Sevkli et al. [40] have proposed a method of project selection combining AHP and fuzzy LP. The weights of the project selection criteria are measured using AHP method.

Several types of integrated QFD technique [41] have been used in determining as well as ranking candidate supplier. Researchers are proposed the introduction of Fuzzy technique [42] for selection of processes. There have been constant efforts to integrate AHP with QFD to establish a framework for prioritizing customer requirements and hence to select appropriate projects [43-45]. In one such integrated technique, QFD is experimented to develop criteria with corresponding evaluating weights where in AHP is used in two phases [46]. In first phase to measure the relative importance's weighting for each project and in second phase to evaluate the score for each of the alternatives to each particular criterion.

### 3. THEORY OF FUZZY AHP & QFD

#### 3.1 Fuzzy Sets Theory and Fuzzy AHP

Zadeh [47] first introduced the fuzzy set theory to deal with vagueness of human thought, which was oriented to the rationality of uncertainty due to imprecision or vagueness. The fuzzy sets actually represent the vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. Fuzzy sets consist of a class of objects with a continuum of grades of membership functions. Such membership functions are ranging between zero and one. A tilde ‘:’ will be placed above a symbol for representing a fuzzy sets. Therefore  $\tilde{x}, \tilde{y}, \tilde{z}$  are fuzzy sets. The membership functions for these fuzzy sets will be denoted by  $\mu(p|\tilde{x})$  and  $\mu(p|\tilde{z})$  respectively. A triangular fuzzy number (TFN),  $\tilde{\mu}$  is shown in fig1. A TFN is denoted as  $(m_1, m_2, m_3)$ . The parameters  $m_1$  denotes the smallest possible value,  $m_2$  the most promising value and  $m_3$  describes the largest possible value of a fuzzy event.

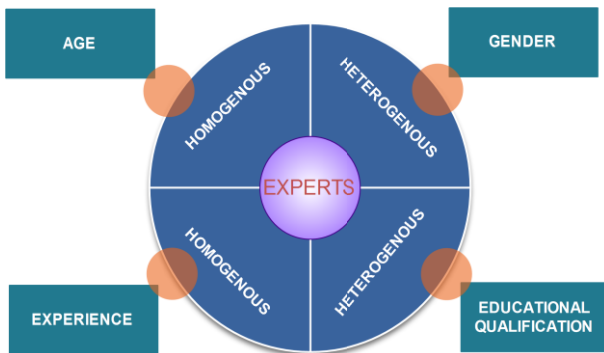


Fig 1: Classification of Experts

AHP is a useful technique for analyzing complex multiple criteria alternatives using subjective judgment. For calculating the importance of the criteria a decision-maker determines the weight of the alternatives by conducting pair-wise comparisons between criteria. But the conventional AHP can not fully reflect the human thinking style [48]. Linguistic and vague descriptions could not be solved easily by AHP until the recent development in fuzzy decision –making [49]. The fuzzy AHP approach can be used as an advanced analytical method developed from the traditional AHP. The first study of fuzzy AHP was proposed by Van Laarhoven and Pedrycz [50] in which triangular fuzzy numbers are used. Later on Chang [51] introduced a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. Fuzzy pair-wise comparisons are more rational to represent decision- makers’ or experts’ uncertain judgments with comparison to crisp ones. In our present project selection approach the decision makers’ tend to give assessments based on their expertise knowledge of the domain. In general linguistic variables such as “most important”, “important”, “less important” are used to make the experts’ assessments. Experts are categorized as described in figure 1. In conclusion, it can be said that by incorporating fuzzy set theory with AHP, fuzzy AHP allows a more accurate description of the decision making process.

#### 3.2 QFD (Quality Function Deployment)

Historical background on QFD has depicted that it was originally evaluated in 1972 in Japan, as a technique that was used to improve product quality in Japanese firms, such as Toyota, Mitsubishi and their suppliers [52]. Toyota was able to decrease startup production costs by 60% from 1977 to 1984 and shortened the time required for its development by one-third through the use of QFD [52-53].

The basic concept of QFD is to deliver a means of defining, customer requirements and translating them into the appropriate technical requirements and actions for each stage of the product / software development cycle, and a customer satisfactory product can be gained by coordinating every activity in an organization. Generally QFD process consists of two stages : capturing customer requirement and the waterfall decomposition process of the customer requirements. In the first phase, the QFD team members (experts) use all technique available to gather or collect the customer requirements i.e, what the customer really wants and expects for the product or model being designed, and then analyze them. This phase is the most critical and also the most difficult part of the QFD process. In the second phase, the QFD team members use a graphic- based tool known as House of Quality (HOQ) to translate the customer’s requirements into technical requirements. House of Quality (HOQ) used in each translation is a chart that is made up of information on “What to do in relation to CRs”, “How CRs are related to TRs” and relationships between CRs and TRs. It includes among the TRs, benchmarking data, attributes’ data and prioritization information. The typical structure of the HOQ is shown as fig1 below:

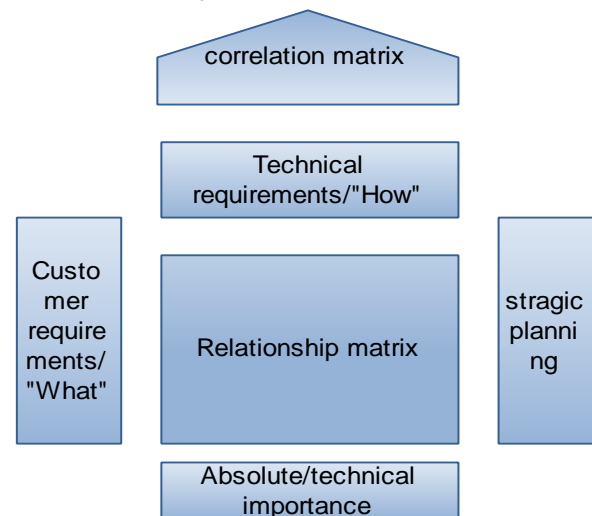


Fig 2: Diagram of QFD

Taking into consideration, the first HOQ as an example, the process of constructing a HOQ includes the following tasks:

- Identify the customer requirements ( “Whats”), their relative importance, their improvement ratios and target levels;
- Identify the technical requirements ( “Hows”);
- Identify the relationship between “Whats” and “Hows”;
- Identifying the corelation between “Hows”;
- Determining the importance, improvement ratios and target values for product / software characteristics.

So, it can be inferred that QFD provides a structure to the front end process. It is a systematic procedure for identifying

and ranking customer needs, translating those needs into product / service specifications and tracking those customer needs throughout the product / service realization process.

#### 4. PROPOSED WORK

The methodology adopted in this research work is directed to determine as well as rank the projects among a set of alternative projects. The current researchers have considered the project selection technique from the perspective of customer requirement combining the technical feasibility and economic profitability. The current researchers have used AHP under fuzziness for determining the degrees of relative importance for customer requirement and QFD for determining the degrees of relative importance and normalized importance of each technical requirement. An overall score for individual project is then calculated for the decision maker to choose most appropriate based upon multiple criteria that may be conflicting in nature.

Though the basic reasons for the implementation of a project selection system in customer's perspective are to enhance profitability and quality, the ultimate justification is to be made in economic terms. For that purpose there is a need to make the proposed combined Fuzzy AHP/ QFD model more robust. Understanding the affect of change in criteria values and model structure an optimum solution is derived by sensitivity analysis. The current researchers have considered cost factors as parametric values for sensitivity analysis.

#### 5. ALGORITHM

##### 5.1 Fuzzy AHP

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. According to the method of Chang's (1992) [51] extent analysis, each criterion is taken and extent analysis for each criterion,  $g_i$ 's performed on, respectively. Therefore, m extent analysis values for each criterion can be obtained by using following notation :

$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, M_{g_i}^4, M_{g_i}^5, \dots, M_{g_i}^m$ , where  $g_i$  is the goal set ( $i = 1, 2, 3, 4, \dots, n$ ) and all  $M_{g_i}^j$  ( $j = 1, 2, 3, 4, \dots, m$ ) are Triangular Fuzzy Numbers (Tens). The steps of the analysis can be given as follows:

**Step 1:-** The fuzzy synthetic extent value ( $S_i$ ) with respect to the  $i$ th criterion is defined as equation (1):-

$$S_i = \sum_{j=1}^m M_{g_i}^j \otimes (1 / [\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j]) \quad (1)$$

$$\text{To obtain (2):-} \quad \sum_{j=1}^m M_{g_i}^j \quad (2)$$

Perform the fuzzy addition operation of m extent analysis values for a particular matrix given in equation (3) below, at the end step of calculation, new (l, m, and u) set is obtained and used for the next:-

$$\sum_{j=1}^m M_{g_i}^j = (\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j) \quad (3)$$

Where l is the lower limit value, m is the most promising value and u is the upper limit value and to obtain (4):-

$$(1 / [\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j]) \quad (4)$$

Perform the fuzzy addition operation of  $M_{g_i}^j$  ( $j = 1, 2, 3, 4, \dots, m$ ) values given as equation (5):-

$$\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j = (\sum_{i=1}^n l_i, \sum_{i=1}^n m_i, \sum_{i=1}^n u_i)$$

And then compute the inverse of the vector in the equation (5) and equation (6) is then obtained as:-

$$\left( \frac{1}{\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j} \right) = \left( \frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right) \quad (6)$$

**Step 2:-** The degree of possibility of

$M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$  is defined as equation (7):-

$$V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (7)$$

And x and y are the values on the axis of membership function of each criterion. This equation can be written as :

$$\begin{aligned} V(M_2 \geq M_1) &= 1, \quad \text{if } m_2 \geq m_1 \\ &= 0, \quad \text{if } l_1 \geq u_2 \\ &= \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{ otherwise} \end{aligned} \quad (8)$$

**Step 3:-** The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers  $M_i$  ( $i = 1, 2, 3, 4, 5, \dots, k$ ) can be defined by

$$V(M \geq M_1, M_2, M_3, \dots, M_k) = \min V(M \geq M_i), i = 1, 2, \dots, k. \text{ Assume that equation (9) is}$$

$$d^*(A_i) = \min V(S_i \geq S_k) \quad (9)$$

For  $k = 1, 2, 3, \dots, n; k \neq i$ . Then the weight vector is given by equation (10):-

$$W^* = (d^*(A_1), d^*(A_2), \dots, d^*(A_n))^T \quad (10)$$

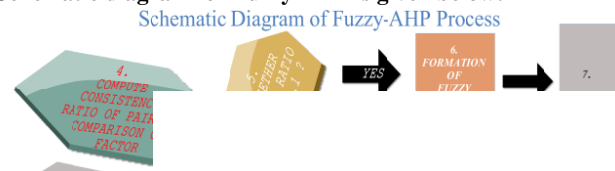
Where  $A_i$  ( $i = 1, 2, 3, \dots, n$ ) are n elements.

**Step 4:-** Via normalization, the normalized weight vectors are given in equation 11:-

$$W = (d(A_1), d(A_2), d(A_3), \dots, d(A_n))^T \quad (11)$$

Where W is non-fuzzy numbers.

**Schematic diagram for Fuzzy AHP is given below:**



**Figure 3. Diagram for Fuzzy AHP**

## 5.2 Quality Function Deployment:-

**Step1:-** Construction of central relationship matrix using expertise knowledge of QFD team by combining the Customer's requirements and the technical requirements.

**Step 2:-** Compute the degree of importance for Customer's requirements by Fuzzy AHP method.

**Step 3:-** Compute the degree of technical requirements using

$$w_j = \sum_{i=1}^m R_{ij} c_i, \text{ where } w_j \text{ is the degree of importance for the}$$

$j^{\text{th}}$  technical requirement (  $j=1,2,\dots,n$ );  $R_{ij}$  is the relationship between the  $i^{\text{th}}$  customer requirement and the  $j^{\text{th}}$  technical criteria in the central relationship matrix; and  $C_i$  is the importance weighing of the  $i^{\text{th}}$  customer requirement.

**Step 4:-** Normalize the degree of importance of technical criteria by

$$\bar{w}_j = \frac{w_j}{\sum_{j=1}^n w_j} \times 100$$

**Step 5:-** Construct the pair wise comparison matrices for each technical requirement using Satty's [42,43] nine –point scale.

**Step 6:-** Evaluation of score,  $C_{ij}$  , for each technical requirement for each alternative project.

**Step 7:-** Compute the overall score by

$$S_j = \sum_{i=1}^n \bar{w}_j c_{ij}, \text{ where } S_j \text{ is the overall score for the } j^{\text{th}}$$

alternative project(  $j = 1,2,\dots,n$ );  $\bar{w}_j$  is the normalized importance degree of the  $j^{\text{th}}$  technical criteria (  $j = 1,2,\dots,n$ ); and  $c_{ij}$  is the PV value of the  $j^{\text{th}}$  alternative on the  $i^{\text{th}}$  technical criteria.

**Step 8:-** Ranking of all the alternative projects and select the best one using the analogy 'the higher the score, the better the selection' [54].

**Schematic diagram for Proposed Fuzzy AHP/ QFD Model is given below:**

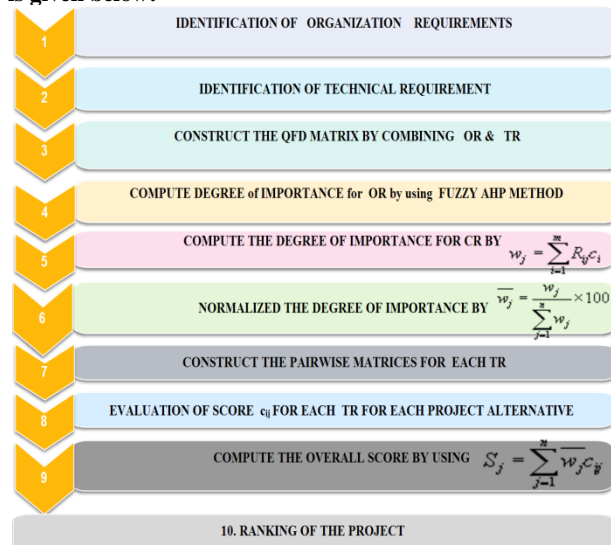


Figure 4. Diagram for Proposed Fuzzy AHP/ QFD Model

## 6. CASE STUDY

A case study of a software company dealing with an enormous volume of projects analyzed here to benchmark the proposed method [55]. The identified customer requirements for a particular project selection process are Realism, Capability, Flexibility and cost.

- **Realism:** - The project should reflect the reality of the customer's decision situation, including the multiple objectives of both the organization and its customer. It includes the factors that reflect project risks (technical risks and implementation risks)

- **Capability:** - The project should deal with multiple time periods, simulate various situations both internal and external to the project.

- **Flexibility:** - The project should have the ability to be easily modified or to be self-adjusting in response to changes in the customer requirement.

- **Cost:** - All types of costs (Design cost, Implementation cost, Installation Cost, Maintenance cost) should be low and must surely be less than the potential benefits of the project.

These are denoted by  $r_1, r_2, r_3, r_4$ . Correspondingly, four technical requirement factors have been identified: Project risks, Project time, Adaptability and Project Cost. The factors may be denoted by  $f_1, f_2, f_3, f_4$ . The job is to select the best one of four projects.

The central relationship matrix displaying the degree of relationship between each customer requirement and the corresponding technical requirement is constructed. A decision matrix (table1) and a Fuzzy evaluation matrix (table2) by expert's opinion is constructed to measure the relative degree of importance for each customer requirement, based on the proposed methodology.

The PV values of this decision matrix is obtained as [0.29, 0.34, 0.23, 0.14]<sup>T</sup>. To check the level of inconsistency the results obtained are:  $\lambda_{\max} = 4.1287$ ; C.I. = 0.0429; R. I. = 0.99 and  $CR = 0.43$ . The QFD team puts the PV values into the transformation matrix shown in table 3.

### 6.1 Calculation of PV values by Fuzzy AHP

TABLE I. EVALUATION MATRIX

Criteria	A	B	C	D
A	1	1	2	1
B	1	1	2	2
C	0.5	1	1	1.33
D	0.5	0.5	0.75	1

TABLE II. FUZZY EVALUATION MATRIX

Criteria	A	B	C	D
A	(1,1,1)	(0.75,1,1.25)	(1,2,3)	(0.75,1,1.25)
B	(0.8,1,1.33)	(1,1,1)	(1,2,3)	(1.33,2,4)
C	(0.33,0.5,1)	(0.8,1,1.33)	(1,1,1)	(1,1.33,2)
D	(0.25,0.5,0.75)	(0.33,0.5,1)	(0.5,0.75,1)	(1,1,1)

Now calculating all the values by applying Chang's [51] theory the following results are obtained:

$$S_A = (3.5, 5, 6.5) \otimes (0.04, 0.057, 0.078) = (0.14, 0.28, 0.51)$$

$$S_B = (4.13, 6, 9.33) \otimes (0.04, 0.057, 0.078) = (0.17, 0.34, 0.73)$$

$$S_C = (3.13, 3.83, 5.33) \otimes (0.04, 0.057, 0.078) = (0.13, 0.22, 0.42)$$

$$S_D = (2.08, 2.75, 3.75) \otimes (0.04, 0.057, 0.078) = (0.08, 0.16, 0.29)$$

$$V(S_A \geq S_B) = 0.85, V(S_A \geq S_C) = 1,$$

$$V(S_A \geq S_D) = 1$$

$$V(S_B \geq S_A) = 1, V(S_B \geq S_C) = 1,$$

$$V(S_B \geq S_D) = 1$$

$$V(S_C \geq S_A) = 0.82, V(S_C \geq S_B) = 0.67,$$

$$V(S_C \geq S_D) = 1$$

$$V(S_D \geq S_A) = 0.55, V(S_D \geq S_B) = 0.4,$$

$$V(S_D \geq S_C) = 0.73$$

Minimum of all values (0.85, 1, 0.67, and 0.4)

The weight W = (0.29, 0.34, 0.23, 0.14)

A = Realism B = Capability C = Flexibility D = Cost

The next job of the QFD team is to find out the ranking of the four given projects based upon the four conflicting TR. The following four pair wise comparison matrices are produced based on the information on each TR.

Matrix1: For 'Project risk' criterion:

$$A_1 = \begin{pmatrix} 1 & 5 & 2 & 8 \\ \frac{1}{5} & 1 & \frac{1}{5} & 2 \\ \frac{1}{2} & 5 & 1 & 4 \\ \frac{1}{8} & \frac{1}{2} & \frac{1}{4} & 1 \end{pmatrix}$$

Matrix 3: For 'Adaptability' criterion:

$$A_3 = \begin{pmatrix} 1 & \frac{1}{5} & \frac{1}{2} & \frac{1}{4} \\ 5 & 1 & 4 & 3 \\ 2 & \frac{1}{4} & 1 & \frac{1}{5} \\ 4 & \frac{1}{3} & 5 & 1 \end{pmatrix}$$

Matrix 2: For 'Project time' criterion:

$$A_2 = \begin{pmatrix} 1 & \frac{1}{2} & \frac{1}{4} & 3 \\ 2 & 1 & \frac{1}{2} & 5 \\ 4 & 2 & 1 & 7 \\ \frac{1}{3} & \frac{1}{5} & \frac{1}{7} & 1 \end{pmatrix}$$

Matrix 4 : For 'Project Cost' criterion :

$$A_4 = \begin{pmatrix} 1 & \frac{1}{3} & 5 & 3 \\ 3 & 1 & 6 & 5 \\ \frac{1}{5} & \frac{1}{6} & 1 & \frac{1}{4} \\ \frac{1}{3} & \frac{1}{5} & 4 & 1 \end{pmatrix}$$

TABLE III. QFD MATRIX FOR PROJECT SELECTION PROBLEM

Technical requirements for Project selection						
CUSTOMER REQUIREMENTS		Project risk	Project time	Adaptability	Project cost	Importance weighting of organization's requirement
	Realism					0.29
	Capability					0.34
	Flexibility					0.23
	Cost					0.14
	Degree of importance for selection criteria	5.46	3.11	3.25	4.74	
	Normalized degree of importance for selection criteria	32.97	18.78	19.63	28.62	

STRONG 9: MODERATE 5; WEAK 1; BLANK : NO

TABLE IV. OVERALL SCORES OF THE FOUR PROJECTS

Technical requirements	Importance weight for Projects				
	Weight	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>
Project risk	32.97	0.529	0.094	0.314	0.062
Project time	18.78	0.147	0.280	0.514	0.059
Adaptability	19.63	0.074	0.520	0.105	0.300
Project cost	28.62	0.267	0.550	0.054	0.128
Overall Score		29.30	34.31	23.61	12.70

So  $P_2 > P_1 > P_3 > P_4$  i.e.  $P_2$  has precedence over  $P_1$  which is more important than  $P_3$  and  $P_4$  Thus the project  $P_2$  is selected, as it has the highest overall score.

## 6.2 Involvement of cost-factor measures

Though the basic reasons for the implementation of selection of projects are to enhance profitability and quality, the ultimate justification is to made in economic terms. Thus, there is a need to make the proposed combined Fuzzy AHP / QFD model more robust. Project selection should consider

cost factors. The sensitivity analysis is done to prove the robustness of the project selection.

The total cost of the project selection system described in the present case study may be broken down as shown in table 5. The cost factors in table 5 involve two types of costs, both fixed and recurring types. The attributes of the cost components are listed in table 6 for four different projects.

TABLE V COST-FACTOR COMPONENTS AND THEIR UNITS

Cost-factor components	Range of attribute values ( US \$ )
1. Design Cost	4000-9000
2. Implementation Cost	4000-12000
3. Installation Cost	1000-2100
4. Maintenance Cost	900-2100

Schematic diagram [55] for Sensitivity Analysis is given below

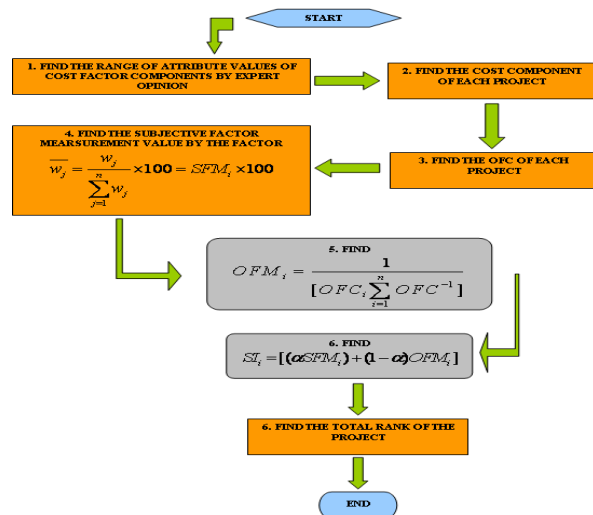


Figure 5 diagram [55] for Sensitivity Analysis

A mathematical model was proposed by Bhattacharya et al. [56-58] to combine cost-factor components with the importance weightings found from Fuzzy AHP, The equation of the stated model is:

$$SI_i = [(\alpha SFM_i) + (1 - \alpha) OFM_i] \dots \dots \dots (1)$$

$$\text{where } OFM_i = \frac{1}{[OFC_i \sum_{i=1}^n OFC^{-1}]} \dots \dots \dots (2)$$

where OFM is the Objective Factor Measure, OFC is the Objective Factor Cost, SFM is the Subjective Factor Measure, SI is the selection Index,  $\alpha$  is the Objective factor decision weight, and n is the number of alternative projects (n=4 in the present case).

TABLE VI. ATTRIBUTES OF COST FACTOR COMPONENTS

Cost Components	Projects			
	$P_1$	$P_2$	$P_3$	$P_4$
1. Design Cost	7500	4000	6800	9000
2. Implementation Cost	8600	4193	6975	12000
3. Installation Cost	1900	1065	1400	2100
4. Maintenance Cost	1487	908	940	2023
Total ( OFC ) (US \$)	19487	10166	16115	25123

SFM values are the ordinal measures of customer requirements found using Fuzzy AHP. OFCs are the total costs of each project. The value of  $\alpha$  depends on the decision-maker's preference regarding the importance of objective and subjective factor measures.

Thus, a sensitivity plot to analyze the effect of  $\alpha$  in the project selection problem is strongly recommended.

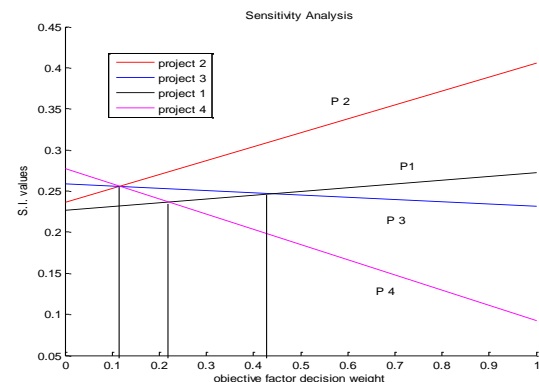


Figure 6 sensitivity plot to analyze

Considering  $\alpha = 0.43$ , the project alternatives are ranked as:  $P_2 > P_1 > P_3 > P_4$ , which is similar to that found from Table 4.

## 7. CONCLUSION

Project selection is a multi-criteria decision making problem. In this paper the selection is performed in three phases. The first phase (i.e., pre-qualification selection), a set of alternatives are selected by the proposed fuzzy method. This method can handle qualitative and quantitative criteria. In the second phase (i.e., final selection) quality function deployment (QFD) is utilized to select the best option. QFD is a unique tool considering the relationship between customer requirement and technical requirement criteria. In addition, linguistic variables and triangular fuzzy numbers are used to overcome the vagueness in human thoughts. Lastly in the third phase (i.e., the post final testing) sensitivity analysis have been derived. It ensures the robustness of the selection methodologies and the viability of the selection from the economic point of view. It is worth to apply this integrated method to compare the



efficiency between project selection criteria and software engineering development characteristics.

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