An Optimal Soft Computing Based AHP-QFD Model Using Goal Programming for Decision Support System

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Abstract**—** In this paper the current researchers address the quantitative methodology for determining possible implement able optimal solution to project selection problem. The purpose of this paper is to present an application of goal programming as an aid of decision making tool in project selection. The model outputs most advantageous projects to pursue with limited resource keeping in mind multiple constraints to attend the multiple objectives. Here in this paper Quality Function Deployment (QFD) has been used in combination with AHP under fuzziness to select the rank of the project as per customer's requirement primarily. Then the GP model has been considered determines which program to pursue with an effort to maximize the profit under limited budget. The authors have proposed this integrated framework which will help the manager or appropriate decision making authorities to take proper project not only from economic point of view but also can identify technical requirements followed by customer's requirements.

KEYWORDS- QUALITY FUNCTION DEPLOYMENT; AHP; FUZZINESS; PROJECT SELECTION, GOAL PROGRAMMING

1 INTRODUCTION

Research & Development project selection is a critical mediator between the product development strategy of an organization and the process of managing projects. To estimate, evaluate and choose the optimal project, optimization techniques are most fundamental quantitative tools. Project selection procedures can be placed in one of the following domains:

- Unstructured peer review;
- Project's scoring;
- Mathematical programming such as integer programming, Goal programming;
- Economic models, such as Net present value (NPV), Cost-benefit analysis;
- Decision analysis, such as multi-attribute utility theory (MAUT), decision trees, Analytical hierarchy process (AHP) and other tools;
- Artificial intelligence (AI), including expert systems and fuzzy sets;
- Project optimization.

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. Several frameworks have been proposed for solving MCDM problems, namely Analytical Hierarchy Process [AHP] [3], Analytical Network Process [ANP] [4], 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) [5], VIKOR [6], COPRAS [7], with grey number,[8], LINMAP [9] etc.. With these techniques alternative ratings are measured, weight of the criteria are expressed in précised numbers .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

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are dimensions, which are important to determine the performance. Goal programming (GP) is a multi objective optimization technique. It is a special extension of linear programming [10-11]. GP is capable of formulating and solving decision problems that deal with a single goal with multiple sub goals as well as multiple goals with multiple sub goals. While linear programming is one-dimensional, GP techniques are capable of dealing multiple goals with multiple dimensions. There we have no dimension limitation of objective function.

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. And to efficiently utilize the ZOGP technique to simplify budget allocation problems for software company's.

2 RELATED WORKS

In available DSS methods, application of the AHP [12] to the project selection problem is not now in the art. Among formal decision tools' Satty's analytic network process (ANP) model [13] is assumed to be suitable for the project evaluation process. On the contrary, some researchers 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 [14-15]. Fuzzy methods were applied to the multi attribute selection models [16]. Sevkli et al. [17] have proposed a method of project selection combining AHP and fuzzy LP. The weights of the project selection criteria are measured using AHP method. Chang-Shu Tu [18] et al. applied an AHP-QFD Conceptual Model and Zero-One Goal Programming for site selection problem. Gyu C. Kim [19] et al. described an application of zero-one goal programming in project selection.

Several types of integrated QFD technique have been used in determining as well as ranking candidate supplier. Researchers are proposed the introduction of Fuzzy technique [20] 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 [21]. In one such integrated technique, QFD is experimented to develop criteria with corresponding evaluating weights where in AHP is used in two phases. In first phase to measure the relative importance weighting for each project and in second phase to evaluate the score for each of the alternatives to each particular criterion.

3. MAJOR CONTRIBUTIONS

The major contribution of this proposed framework is its unique dealing with three decision making tools.

The QFD Technique has been applied with corresponding evaluation weight for constructing the basic model.

We have used AHP under fuzziness to measure the relative important of each requirement and to asses the evaluation score for each criteria of each of the project.

The goal programming approach has been taken into consideration because of its ability to handle multi dimensional multi-objective function by which under fuzziness a decision maker can take the optimal decision.

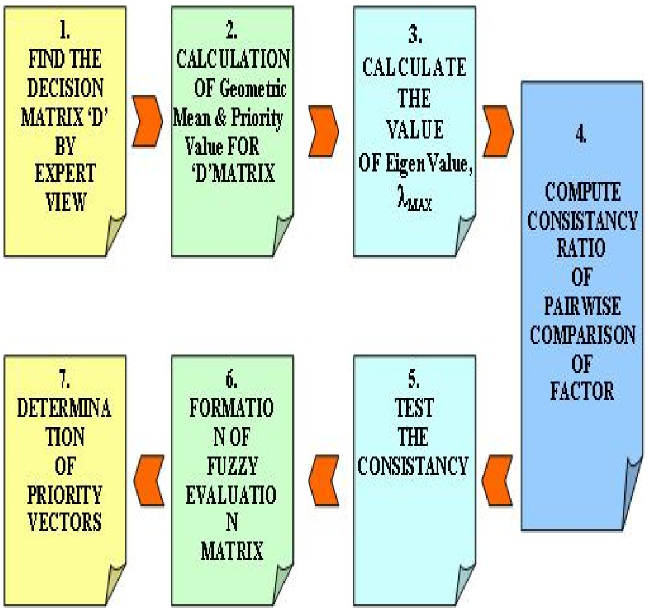
4. PROPOSED WORK & DESIGN FLOW

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. We have used goal programming technique as they allowed us the ordinal solution. In other words it is expressed as a priority of the desired achievement of each goal ranked in ordinal sequence.

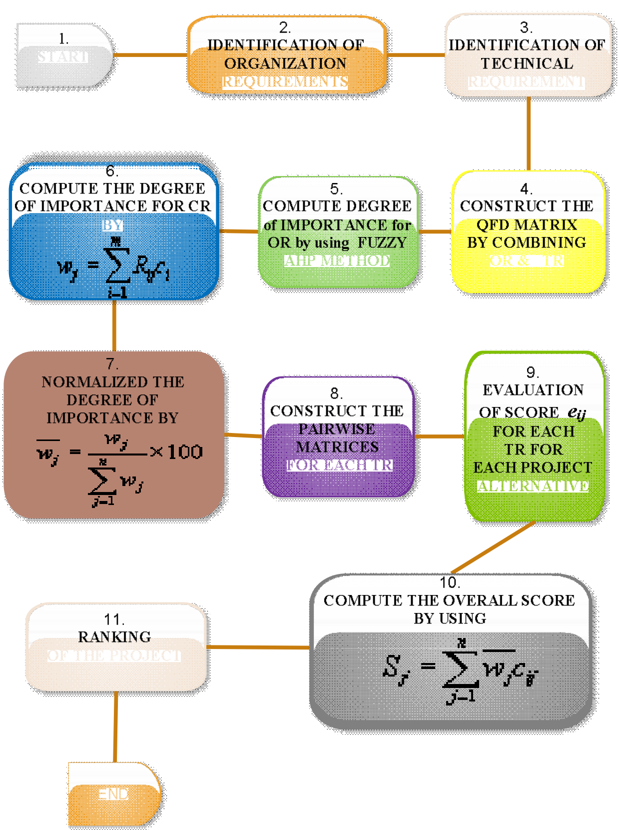
4.1 Fuzzy AHP

Schematic diagram for Fuzzy AHP is given below:



4.2 QUALITY FUNCTION DEPLOYMENT (QFD)

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



5. Goal Programming Model Formulation

5.1 The Zero-one goal programming binary model

Objective Function:

$$\text{Min} \quad \sum_{i=1}^{n} p_i (d_i^-)$$

Goal Constraints:

$$\sum_{j=1}^{m} r_{ij} I_j - d_i^+ + d_i^- = g_i \quad , \quad \forall_i, i = 1, \ldots\ldots\ldots. n$$

$$\sum_{j=1}^{m} c_j I_j \le R \qquad I_j \in (0,1) \text{ and } d_i^+, d_i^- \ge 0$$

5.2 Decision Variables:

I_j = if the j[th] evaluation criteria is selected,

then I_j =1; otherwise I_j =0;

p_i = the priority level;

d_i^+ = the amount by which the i[th] customer's requirement exceeds its target level;

d_i^- = the amount by which the i[th] customer's requirement misses its target level;

g_i = the target level of the i[th] customer's requirement (g_i =1);

C_j = the amount of resource cost required for the j[th] evaluation criteria to reach its target value;

R = the total environmental assessment cost allocation;

r_{ij} = the relationship co-efficient.

n = the number of customer's requirements.

m = the number of technical requirements.

6. Case Study

A case study [22] of a software company dealing with an enormous volume of projects analyzed here to benchmark the proposed method. The identified customer requirements for a particular project selection process are Realism, Capability, Flexibility and cost. These are denoted by r1, r2, r3, r4. Correspondingly, four technical requirement factors have been identified: Project risks, Project time, Adaptability and Project Cost. The factors may be denoted by f1, f2, f3, f4. 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 opinions are 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] T. To check the level of inconsistency the results obtained are: λ_{max} = 4.1287; C.I. = 0.0429; R. I. = 0.99 and C_R = 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 1: Evaluat ion 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 2: 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 [23] theory the following results are obtained:
The weight W = (0.29, 0.34, 0.23, 0.14)
A = Realism, B = Capability, C = Flexibility, D = Cost

Table 3: QFD Matrix for project selection problem

Customer Requirements	Technical Requirements for Project Selection: 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

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.

Matrix -1: 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 -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 -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 -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 4: Overall scores of the four projects

Technical requirements	Importance weight for Projects				
	Weight	P1	P2	P3	P4
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 P2 > P1 > P3> P4 i.e. P2 has precedence over P1 which is more important than P3 and P4 Thus the project P2 is selected, as it has the highest overall score.

6.2 Using Goal-programming approach for Demonstration example:

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.
For that purpose it is assumed that after several iterations, the QFD team satisfactorily arrived at the outcome of budget decision. Table 5 shows the detailed outcome of the demonstration example. The outcome has four technical requirements for the project selection and uses the Fuzzy-AHP, QFD model and the assessment weights from Table 4. The outcome also reveals the

relationship coefficients indicating each technical requirement to reaching the software company's target and the criterion's contribution to meeting each customer's requirements target level. A budget of $1.2 million was available for the implementation cost of projects. At this stage, the QFD team needed to select the project that most effectively met the company's requirements as well as customer's requirements based on the limited budget. So the final outcome of each technical requirement and the customer's requirements within limited resources are as follows:

Table 5: Final out Come of Each project Evaluation

	PSC1	PSC2	PSC3	PSC4
P1	0.529	0.147	0.074	0.267
P2	0.094	0.280	0.520	0.550
P3	0.314	0.514	0.105	0.054
P4	0.062	0.059	0.300	0.128
Assessment cost for selected criteria	0.1	0.2	0.3	0.3

Note: Assessment budget allocation: $1.2 million.
Four Projects are P1, P2, P3, P4. and

1. PSC1: Project risk,
2. PSC2:Project time,
3. PSC3: Adaptability,
4. PSC4: Project cost.

Selected PSCs decision: using zero-one goal programming model a budget allocation of $1.2 million, the QFD team would choose all four PSCs.
So the final goal programming model.

Objective function :

$$\text{Min } 4.dn1 + 3.dn2 + 2.dn3 + 1.dn4$$

Subject to the constraints:

$$P_1: \quad dn1 + 0.529I_1 + 0.147I_2 + 0.074I_3 + 0.267I_4 - dp1 = 1$$
$$P_2: \quad dn2 + 0.094I_1 + 0.280I_2 + 0.520I_3 + 0.550I_4 - dp2 = 1$$
$$P_3: \quad dn3 + 0.314I_1 + 0.514I_2 + 0.105I_3 + 0.054I_4 - dp3 = 1$$
$$P_4: \quad dn4 + 0.062I_1 + 0.059I_2 + 0.300I_3 + 0.128I_4 - dp4 = 1$$

Budget allocation :

$$0.1I_1 + 0.2I_2 + 0.3I_3 + 0.3I_4 \leq 1.2$$

where I_1, I_2, I_3 and I_4 are binary variables.

Table 6 shows the solution output for this example in which the project selection decision model was implemented using LINGO software. However, a problem as simple as the illustration example given in table 6 can be easily solved with LINGO software.

Global optimal solution found.
Objective value: 0.1280328
Infeasibilities: 0.000000
Total solver iterations: 5

Table 6: Optimal Solution

Variable	Value	Reduced Cost
DN1	0.000000	4.000000
DN2	0.000000	3.000000
DN3	0.000000	1.434426
DN4	0.1280328	0.000000
I1	2.377049	0.000000
I2	0.000000	0.0096803
I3	2.415301	0.000000
I4	0.000000	0.2008443
DP1	0.4361913	0.000000
DP2	0.4793989	0.000000
DP3	0.000000	0.5655738
DP4	0.000000	1.000000
Row	**Slack or Surplus**	**Dual Price**
1	0.1280328	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.000000	-0.5655738
5	0.000000	-1.000000
6	0.000000	1.197951

7. Discussion of Findings

This paper describes application of the AHP-QFD under fuzziness and a zero-one binary goal programming to construct an optimal selection of project. This integrated model provides the analysis of cost benefit criteria's with an opportunity to make the decision from the perspective of customer's requirement

7.1 Graphical Analysis.

From the above graphical analysis, it could be concluded that when the "reduced costs" are zero, the "value"are non zero and the vice-versa.

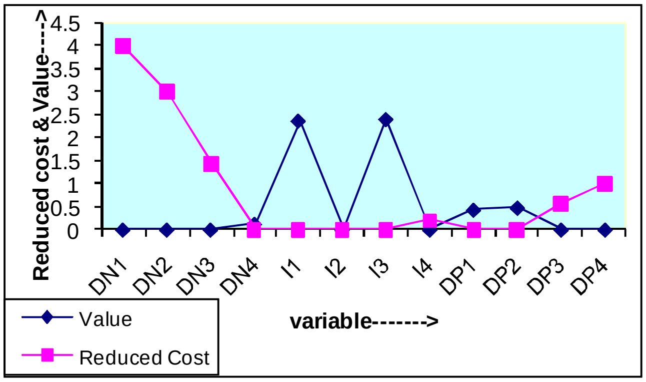


Figure 1

8. 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) ZOGP approach allow for input for highly detailed information on the relationship in the structure, and the approach determined the project evaluation criteria that will maximize the optimal goal while constrained to a limited budget.

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