International Journal of Computer and Communication Technology

Volume 4 | Issue 2 Article 9

April 2013

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Available online at www.interscience.in

An Intrigrated Novel Approach in MCDM under Fuzziness

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Abstract - Multiple Criteria Decision Making (MCDM) shows promising areas of applications in the field of computational technique of proper project selection. There are four distinct families of methods in MCDM: (a) the outranking,(b) the theory based on value and utility, (c) the multiple objective programming and (d) collaborative decision and negotiation theory based method. An Analytical way to reach the best possible solution of project selection is most desirable. Analytical Hierarchy Process (AHP) is one of the best ways for deciding among the complex criteria structure in different levels. Fuzzy AHP is a synthetic extension of classical AHP method under fuzziness. A fuzzy decision may be viewed as an intersection of the given goals and constraints. A maximizing decision is defined as a point in the space of alternatives at which the membership function of a fuzzy decision attains its maximum value. This paper aims at the integration of fuzzy AHP and Additive Ratio Assessment Method (ARAS). It actually deals with a novel integrated approach of dual synthesis of project selection. At first fuzzy AHP, method is used to find the criteria coefficient with the performance evaluation in a certain environment where triangular fuzzy number describes the subjectivity of vagueness of the criteria. In the second phase, ARAS method is used to determine the rank of the final project selection.

Keywords- *Fuzzy AHP, ARAS & Project selection, Multi-criteria decision support system,*

I. INTRODUCTION

Being a temporary attempt, a project needs to create a unique product, service or result. Temporary signifies that a particular project has a definite dead line, reaching the dead line the project objectives has been gained or it becomes clear that the project objective will not be made or the necessity of the project no longer exists. In real world, there can be multiple alternative projects. A decision maker (DM) has to choose one alternative, which must be the best option. Therefore, it is a very difficult task [1]. Selection and evaluation of a project involves decisions those are critical to profitability, growth and survival of organization in the competitive world. This type of decision involves multiple factors such as identification, considerations and analysis of viability. According to Hwang and Yoon [2] 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. 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) [10],VIKOR [11], COPRAS [12], with grey number,[13-15],Simple Additive weighting (SAW) etc [16], LINMAP [17].With these techniques alternative ratings are measured, weight of the criteria are expressed in précised numbers [18]. 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.

II. TAXONOMY OF MCDM FOR PROBLEM SOLUTION

Evaluating a finite set of alternatives for finding the best one and to rank them from best towards, a decision maker, has to cluster them into predefine homogeneous classes. Pareto in 1986 [19] was the first to apply multi criteria optimization and determination of priority and utility function on problem set. Under pre-referential and utility independence assumption, Keeny and Raiffa [20] offered the theorem for determining multiple criteria utility function. For solving problems with conflicting goals of global importance, Satty [21] presented decision-making models with incomplete information.

In MCDM approach, it is necessary to define the problem first and there after to identify realistic alternatives. It is very important to determine the actors involve in decision-making, evaluation criteria selection and evaluate all the alternatives according to the set of criteria. Guiton and Martel [22] gave an approach to select the appropriate MCDM method to a specific decision making situation.

Broadly, MCDM methods are classified into two types- quantitative measurement and qualitative measurement. The method based on multi-criteria utility theory of first kind are TOPSIS (Technique for order preference by similarity to ideal solution) [23], SWA (Simple Additive Weighting), [24], LINMAP (Linear Programming Techniques for Multidimensional Analysis of Preference) [25], ARAS [26].

The second type is qualitative measurement. These include two widely known group of methods AHP [27-32] and Fuzzy set theory method [33].

In this paper, the current researchers have dealt with an integrated framework comprising with fuzzy AHP and ARAS. With fuzzy AHP, weights of the criteria have been determined. Thereafter, those weights have been used as the input in the ARAS method by which the final ranking of the projects has been decided.

A. *Fuzzy AHP Method*

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) [34] 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 :

$$M_{g_i}^1 \text{ , } M_{g_i}^2 \text{ , } M_{g_i}^3 \text{ , } M_{g_i}^4 \text{ , } M_{g_i}^5 \text{ .... } M_{g_i}^m$$

where g_i is the goal set (i = 1,2,3,4,..................n) and all $M_{g_i}^j$ (j = 1,2,3,4,........m) are Triangular Fuzzy Numbers(TFNs). 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):-

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

To obtain

$$\sum_{j=1}^{m} M_{g_i}^j$$

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:-

$$\sum_{j=1}^{m} M_{g_i}^j = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \quad (2)$$

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

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

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

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = (\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i) \quad (3)$$

and then compute the inverse of the vector in the equation (3) and equation (4) is then obtained as:-

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

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 (5):-

$$V (M_2 \geq M_1) = \sup_{y \geq x} [\min (\mu_{M1} (x), \mu_{M2} (y))] \quad (5)$$

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

$V (M_2 \geq M_1) = 1,$ if $m_2 \geq m_1$

$= 0,$ if $l_1 \geq u_2$

$$= \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{ otherwise} \quad (6)$$

Step 3:-

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy number M_i (i= 1,2,3...............k) can be defined by V (M $\geq M_1, M_2, M_3 .... M_k$) = min V (M$\geq M_i$), i = 1, 2 ...k. Assume that equation (9) is

$$d^*(A_i) = \min V(S_i \geq S_k) \quad (7)$$

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

$$W^* = (d^*(A_1), d^*(A_2), ... d^*(A_n))^T \quad (8)$$

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

Step 4:-

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

$$W = (d(A_1), d(A_2), d(A_3) ... d(A_n))^T \quad (9)$$

Where W is non-fuzzy numbers.

B. ADDITIVE RATIO ASSESMENT (ARAS) METHOD

The algorithm consists of the following steps:-

Step 1: - Establishment of Decision Making Matrix (DMM)

The first stage of ARAS method is decision making matrix (DMM) formation. In case of MCDM problem, the problem can be solved by representing the following DMM of preferences for m feasible alternatives (rows) and n sign full criteria (Columns) as:-

$$X = \begin{pmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{pmatrix}$$

Where i = No. of alternatives = 0, 1, 2 ….m. and j = No. of criteria = 1, 2 …n. , and x_{ij} = (Score / performance value for i[th] alternative of j[th] criterion). x_{0j} = optimal value of the j[th] criterion, if optimal value of j[th] criterion is unknown, then x_{0j} will be $(x_{ij})_{max}$ if the criterion is preferable. x_{0j} will be $(x_{ij})_{min}$ if the criterion is non-preferable. The performance values x_{ij} and the criteria weights w_j are viewed in the entries of a DMM. The weights of criteria are determined by the experts in AHP methods where w_j = Weight / importance of j[th] criterion.

$$\sum_{j=1}^{n} wj = 1$$

Step 2:- Normalization of DMM

In the second stage, the initial values of all the criteria of the decision-making matrix are normalized as:

$$\overline{X} = \begin{bmatrix} \overline{x_{01}} & \cdots & \overline{x_{0j}} & \cdots & \overline{x_{0n}} \\ \vdots & \ddots & \vdots & \therefore & \vdots \\ \overline{x_{i1}} & \cdots & \overline{x_{ij}} & \cdots & \overline{x_{in}} \\ \vdots & \therefore & \vdots & \ddots & \vdots \\ \overline{x_{m1}} & \cdots & \overline{x_{mj}} & \cdots & \overline{x_{mn}} \end{bmatrix}$$

Where $\overline{x_{ij}} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}$, for benefit criteria.

The criteria whose preferable values are minima are normalized by applying two stage procedures as follows:

$$x_{ij} = \frac{1}{x_{ij}^*}$$

$$\overline{x_{ij}} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}$$

Step 3:- Calculation of Criteria

Calculation of the importance of criteria by AHP / Logic Method / Modified Logic Method.

Step 4:- Calculation of Weighted Normalized Matrix

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \cdot^{\cdot^{\cdot}} & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \cdot^{\cdot^{\cdot}} & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix},$$

where $x_{ij} = \overline{x_{ij}} * w_j$

Step 5:- Optimal Values

The optimal value is determined as follows:

$$S_i = \sum_{j=1}^{n} x_{ij}$$

where S_i = value of the optimality function of i^{th} alternative.

Step 6:- Final Result

$K_i = Si / S_0$, where K_i = degree of utility for i^{th} alternative and S_0 = the best or optimal one.

The largest value of K_i is the best and the smallest one is the worst. In addition, the optimality function S_i has a direct and proportional relationship with the values of x_{ij} and weights w_j and their relative influence on the final result.

III. CRITERIA SELECTION OF MODEL

The proposed model for the project selection problem, composed of Fuzzy AHP and ARAS methods [35-36], consists of three basic stages: identification of properties, weight assigning and evaluation of alternatives and determine final rank. Based on proposed methodology, the present researcher selects some criteria like:

A. *Net Present Value*

The Net Present Value (NPV) is defined as the sum of the present values (PVs) of the individual cash flows. Actually, NPV is an indicator of how much value a project adds to the organization. So it is treated as the benefit criteria of the project. In financial theory, if there is a choice between two mutually exclusive alternatives, the one yielding the highest NPV should be selected. So if the value of NPV is positive, the project may be accepted.

B. *Rate of Return*

Rate of return (ROR) is the ratio of money gained or lost on a project relative to the amount of money invested. ROR is usually expressed as a percentage. So ROR is also the benefit criteria for any project selection.

C. *Payback Period*

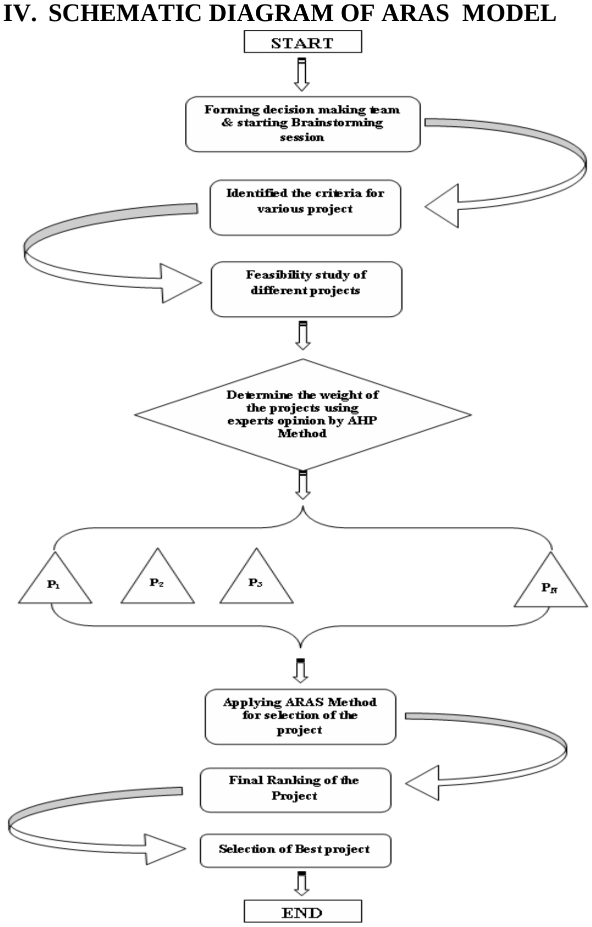
Payback period is the period required for the return on an investment or project. Payback period has no explicit criteria for decision-making. Any project yielding the quickest Payback Period should be selected.

D. *Project Risk*

There may be some external circumstances or event that cannot occur for the project to be successful. The external events are called project risks. If such type event is likely to happen, then it would be a risk. The aim of project selection is to minimize the risk criteria.

After identifying these criteria, their weights are found by Fuzzy AHP method. Five homogeneous experts help us to specify the weight.

IV. SCHEMATIC DIAGRAM OF ARAS MODEL



V. CASE STUDY OF PROPOSED MODEL

The survey data of the expansion of optical fiber for Telecommunication sector in one part of IRAN [37] is reused.

According to expert's decision, the following matrix is formed and then by using Triangular Fuzzy Number the Fuzzy evaluation matrix is formed

EVALUATION MATRIX

Criteria	NPV	ROR	PB	PR
NPV	1	1	2	1
ROR	1	1	2	2
PB	0.5	1	1	1.33
PR	0.5	0.5	0.75	1

FUZZY EVALUATION MATRIX

Criteria	NPV	ROR	PB	PR
NPV	(1,1,1)	(0.75,1,1.25)	(1,2,3)	(0.75,1,1.25)
ROR	(0.8,1,1.33)	(1,1,1)	(1,2,3)	(1.33,2,4)
PB	(0.33,0.5,1)	(0.8,1,1.33)	(1,1,1)	(1,1.33,2)
PR	(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 [34] theory the following results are obtained:

S_{NPV} = (3.5, 5, 6.5) $\otimes$ (0.04, 0.057, 0.078)= (0.14, 0.28, 0.51)

S_{ROR} =(4.13, 6, 9.33) $\otimes$ (0.04, 0.057, 0.078)=(0.17, 0.34, 0.73)

S_{PB} =(3.13, 3.83, 5.33) $\otimes$ (0.04, 0.057,0.078)=(0.13,0.22, 0.42)

S_{PR} =(2.08, 2.75, 3.75) $\otimes$ (0.04,0.057,0.078)= (0.08,0.16, 0.29)

$V(S_{NPV} \geq S_{ROR}) = 0.85$, $V(S_{NPV} \geq S_{PB}) = 1$,

$V(S_{NPV} \geq S_{PR}) = 1$

$V(S_{ROR} \geq S_{NPV}) = 1$, $V(S_{ROR} \geq S_{PB}) = 1$,

$V(S_{ROR} \geq S_{PR}) = 1$

$V(S_{PB} \geq S_{NPV}) = 0.82$ $V(S_{PB} \geq S_{ROR}) = 0.67$,

$V(S_{PB} \geq S_{PR}) = 1$

$V(S_{PR} \geq S_{NPV}) = 0.55$, $V(S_{PR} \geq S_{ROR}) = 0.4$,

$V(S_{PR} \geq S_{PB}) = 0.73$

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

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

PROBLEM DESCRIPTION TABLE FOR ARAS METHOD

Serial No.	Set of criteria for evaluation	Variable	Optimal	Unit of Measuremet	Weight
1	Net Present Value (NPV)	X_1	MAX	Rs. (Rupees)	0.29
2	Rate of Return (ROR)	X_2	MAX	Rs. (Rupees)	0.34
3	Payback Period (PB)	X_3	MIN	Days (Month)	0.22
4	Project Risk (PR)	X_4	MIN	–	0.15

DECISION MATRIX

	NPV (+)	ROR (+)	PB (-)	PR (-)
Project 1	10	3	6	7
Project 2	13	5	7	9
Project 3	9	1	8	1
Project 4	11	3	8	7
Project 5	12	5	10	5

NORMALIZED DMM

	NPV	ROR	PB	PR
Project 1	0.18	0.18	0.15	0.24
Project 2	0.24	0.29	0.18	0.31
Project 3	0.16	0.06	0.20	0.03
Project 4	0.20	0.18	0.20	0.24
Project 5	0.22	0.29	0.26	0.17

INTERMEDIATE TABLE

Alternatives	Criteria			
	X_1	X_2	X_3	X_4
Optimization Direction	*MAX*	*MAX*	*MIN*	*MIN*
Weight of criterion	**0.29**	**0.34**	**0.22**	**0.15**
A_0	1.00	1.00	0.15	0.03
A_1	0.18	0.18	0.15	0.24
A_2	0.24	0.29	0.18	0.31
A_3	0.16	0.06	0.20	0.03
A_4	0.20	0.18	0.20	0.24
A_5	0.22	0.29	0.26	0.17

INITIAL DMM X WITH VALUES, WHICH MUST BE MINIMISED, CHANGED TO MAXIMISED VALUES

Alternatives	Criteria			
	X_1	**X_2**	**X_3**	**X_4**
Optimization Direction	**MAX**	**MAX**	**MIN**	**MIN**
Weight of criterion	**0.29**	**0.34**	**0.22**	**0.15**
A_0	1.00	1.00	6.67	33.33
A_1	0.18	0.18	6.67	4.17
A_2	0.24	0.29	5.56	3.23
A_3	0.16	0.06	5	33.33
A_4	0.20	0.18	5	4.17
A_5	0.22	0.29	3.85	5.88

NORMALISED DMM $\bar{X}$

	X_1	**X_2**	**X_3**	**X_4**
W	*7.5*	*0.34*	*0.22*	*0.15*
A_0	0.50	0.50	0.02	0.40
A_1	0.09	0.09	0.20	0.05
A_2	0.12	0.15	0.17	0.04
A_3	0.08	0.03	0.15	0.40
A_4	0.10	0.09	0.15	0.05
A_5	0.11	0.15	0.12	0.07

SOLUTION RESULT

Weighted normalized DMM X and final result.

	X_1	**X_2**	**X_3**	**X_4**	**S**	**K**	**Rank**
A_0	0.145	0.17	0.044	0.06	0.105	1	
A_1	0.026	0.031	0.044	0.008	0.027	0.257	4
A_2	0.034	0.051	0.037	0.006	0.032	0.304	1
A_3	0.023	0.010	0.033	0.06	0.031	0.295	2
A_4	0.029	0.031	0.033	0.008	0.025	0.238	5
A_5	0.032	0.051	0.026	0.010	0.029	0.276	3

So, $\mathbf{A_2 > A_3 > A_5 > A_1 > A_4}$.

So among the five projects: $\mathbf{P_2 > P_3 > P_5 > P_1 > P_4}$ and **P2** is the best project among all five projects.

VI. CONCLUSION

The traditional approaches of optimization used within the engineering context are based on assumption. The modeling of engineering problem is based on a different kind of logic, taking into consideration the existence of multicriteria, conflicting aims of decision maker, the complex nature of evaluation process.

Above all, the main advantage of MCDM provides taking decision by analyzing complex problem; possibilities to aggregate criteria in evaluation process; chances of taking appropriate decisions; scope for decision maker to participate actively in the process of decision making.

According to the proposed method, the degree of alternative is made by comparison of variables that are analyzed with ideally best one.

In conclusion, the proposed method provides a simple approach of complex theory to access alternative projects and select the best set of project by using the described integrated approach of Fuzzy AHP and ARAS method. This integrated approach has a great future in project management field.

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