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Contractor Selection in Construction Industry using Fuzzy-Logic System

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***Abstract*— Selection of the most appropriate & potential contractor to deliver a project in time is most significant decision making process to ensure the successful completion of construction projects. The construction industry has witnessed the failure of many contractors due to different reasons like labour problems, financial problems, poor performance, social and political problems, lack of safety considerations at worksite etc. All these incidents have led to the impression that the current scenario of awarding the contracts is inefficient in selecting the contractor capable of meeting the demands and challenges of present times and hence needs to be reviewed accordingly. This work presents contractor selection using Analytic Hierarchy Process & Fuzzy Group Decision making Method and results are evaluated by using an actual case study in infrastructure development.**

Keywords- Bids, Contractors, Parameters, Decision, Analytical Hierarchy Process (AHP), Fuzzy Group Decision Making.

I. INTRODUCTION

Selection of the contractor for the job has been primarily based on bid price alone. The selection of the lowest bidder is one of the major reason for project delivery problem, when contractor faced with a shortage of work, desperately quoted a low bid price simply to remain in business with the expectation to be offset through claims. So, selection of the contractor for construction project should be based on a set of multiple decision criteria both price and non-price related.

In practice, a contractor selection problem can be divided into two stages,

i) A large number of potential contractors are invited and investigated based on a set of predetermined criteria and then a short list of contractors is drawn by the project owner called Prequalification stage.

ii) An appropriate contractor is selected from the short list to execute the construction project called Bid evaluation stage.

Decision making in construction projects is a complicated process and in most cases the value for each criterion is determined roughly by decision makers. In many cases, criteria are examined by linguistic variables such as, very low, low, medium, high and very high. Quantifications of these linguistic variables using fuzzy logic will provide a more realistic approach for evaluation of a construction project. These ambiguities necessitate the use of fuzzy logic in the selection process. Use of fuzzy logic opens the possibility for straight forward translation of the statements in natural language into a fuzzy set, which is very essential for decision making under uncertainties. Fuzzy set theory provide with a respectable inventory of theoretical tools for dealing with concepts expressed in natural language. By fuzzy set of various types we manipulate them in a great variety of ways for various purposes. They enable us to express and deal with various relations, functions and equations.

II. METHODOLOGY

Following methods are described in this work,

A) Analytic Hierarchy Process (AHP)

a. Introduction

Analytic Hierarchy Process (AHP) is an effective decision making technique based on multi-criteria decision making methodology (MCDM). AHP is a method that can be successfully used as it incorporates all the attributes pertaining to contractor selection and then prioritizes each attribute resulting in easy judgment of best contractor. The AHP works on three primary functions namely structuring, measurement and synthesis.

b. How the AHP works

The AHP consider a set of evaluation criteria and a set of alternative options among which the best decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not true in general that the best option is the one which optimizes each single criterion, rather the one which achieves the most suitable trade-off among the different criteria.

The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparison of the criteria, higher the weight, the more important the corresponding criterion. Next, for a fixed criterion, the AHP assigns a score to each option according to the decision maker's pairwise comparison of the options based on that criterion, higher the score, the better the performance of the option with respect to the considered criterion.

Finally, the AHP combines the criteria weights and the option scores, thus determining a global score for each option, and a consequent ranking. The global score for a given option is a weighted sum of the scores it obtained with respect to all the criteria.

c. Steps for contractor selection using AHP

Step 1) Identify the criteria attributing to contractor selection.
Step 2) Structure the decision hierarchy from the top with the goal of the decision, then the criteria on which this goal depends to the lowest level which is a set of the alternatives.
Step 3) Construct a set of pair wise comparison matrices. Each element in the upper level is used to compare the elements in the level immediately below with respect to it. Priorities can be obtained of each criterion and of alternatives with respect to each criterion using these comparison matrices by normalization. The scale used for these comparisons is given in Table No.1
Step 4) Final priorities of the alternatives can be obtained using priorities derived from step 3. Priority of criteria and priority of contractors are then multiplied and added for each of the contractor to obtain the final scores.

TABLE 1 THE FUNDAMENTAL SCALE

Intensity of importance on an absolute scale	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favour one activity over another
5	Essential or Strong importance	Experience and judgment strongly favour one activity over another
7	Very Strong importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j* then *j* has the reciprocal value when compared with *i*	
Rationales	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

B) Fuzzy Group Decision-Making Method (FGDM)

a. Introduction

Conflict always occurs in group decision making since members in a group generally do not reach the same decision. Resolving conflicts becomes an important issue in group decision making. For group decision making, the main approach is collective individual decision making. A Fuzzy Delphi method is used to adjust the fuzzy rating of every expert to achieve the consensus and to tackle this type of problems.

b. The basic concepts of fuzzy numbers

A fuzzy number is a fuzzy set $\tilde{A}$ on R which possesses as the following three properties:
(i) $\tilde{A}$ is a normal fuzzy set, i.e. Ht.=1
(ii) The α -cut $\tilde{A}^{\alpha}$ of $\tilde{A}$ is a closed interval for every α Ɛ (0, 1], i.e. lower limit is '0'& upper limit is '1'
(iii) The support of $\tilde{A}$ is bounded. i.e. all values have upper bound to the value '1'
Special cases of fuzzy numbers include crisp real number and intervals of real numbers. Although there are many shapes of fuzzy numbers, the triangular and trapezoidal shapes are used most often for representing fuzzy numbers. The following describes and definitions show that membership function of triangular and trapezoidal fuzzy number and its operations.

Definition A: fuzzy number $\tilde{A}$ is convex, if

$$\mu_{\tilde{A}}[\lambda x_1 + (1-\lambda)x_2] \geq \min[\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)],$$
$$x_2, x_2 \in X, \quad \lambda[0,1].$$

Alternatively, a fuzzy set is convex if all α-level sets are convex.

Definition B: A fuzzy set $\tilde{A}$ in the universe of discourse X is normal, if

$$\sup_{x} \mu_{\tilde{A}}(x_1) = 1.$$

A nonempty fuzzy set $\tilde{A}$ can always be normalized by,

$$\mu_{\tilde{A}}(x) / \sup_{x} \mu_{\tilde{A}}(x).$$

Definition C: A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal.
One of the most important concepts of fuzzy sets is the concept of an α-cut and its variant. It is a bridge from well-defined structure to fuzzy environment.

Definition D: For a fuzzy set $\tilde{A}$ defined on X and for any number a α Ɛ (0, 1]; the α cut, $\tilde{A}^{\alpha}$, and the strong α cut, $\tilde{A}^{\alpha+}$ are defined as:

$$\tilde{A}^{\alpha} = \{x \mid \mu_{\tilde{A}}(x) \geq \alpha\},$$
$$\tilde{A}^{\alpha+} = \{x \mid \mu_{\tilde{A}}(x) > \alpha\}.$$

That is, the α -cut (or the strong α -cut) of a fuzzy set $\tilde{A}$ is the crisp set $\tilde{A}^{\alpha}$ (or the crisp set $\tilde{A}^{\alpha+}$) that contains all the elements of the universal set X whose membership grades in $\tilde{A}$ are greater than or equal to (or only greater than) the specified value of α.

Definition E: A triangular fuzzy number can define as a triplet (a1, a2, a3). Its membership function is defined as,

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1, \\ (x-a_1)/a_2 - a_1, & a_1 \leq x \leq a_2, \\ (a_3 - x)/a_3 - a_2, & a_2 \leq x \leq a_3, \\ 0, & x < a_3. \end{cases}$$

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Let $\tilde{A}$ and $\tilde{B}$ be two fuzzy numbers parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively. Then the operations of triangular fuzzy numbers are expressed as,

$\tilde{A}$ (+) $\tilde{B}$ = (a_1, a_2, a_3) (+) (b_1, b_2, b_3) = ($a_1 + b_1$, $a_2 + b_2$, $a_3 + b_3$)

$\tilde{A}$ (-) $\tilde{B}$ = (a_1, a_2, a_3) (-) (b_1, b_2, b_3) = ($a_1 - b_3$, $a_2 - b_2$, $a_3 - b_1$)

$\tilde{A}$ (x) $\tilde{B}$ = (a_1, a_2, a_3) (x) (b_1, b_2, b_3) = (a_1b_1, a_2b_2, a_3b_3)

$\tilde{A}$ (÷) $\tilde{B}$ = (a_1, a_2, a_3) (÷) (b_1, b_2, b_3) = (a_1/b_3, a_2/b_2, a_3/b_1)

Definition F: A trapezoidal fuzzy number $\tilde{A}$ = (a_1, a_2, a_3, a_4), $a_1 \le a_2 \le a_3 \le a_4$, (if $a_2 = a_3$, $\tilde{A}$ is a triangular fuzzy number) its membership function is defined by,

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1 \\ (x - a_1)/(a_2 - a_1), & a_1 \le x \le a_2 \\ 1 & a_2 \le x \le a_3 \\ (x - a_4)/(a_3 - a_4), & a_3 \le x \le a_4 \\ 0, & x > a_4 \end{cases}$$

c. A Fuzzy Group Decision-Making Method

In this section, we will summarily introduce Fuzzy Delphi method ranking fuzzy numbers procedure, and the defuzzification value of the trapezoidal fuzzy number.

Fuzzy Delphi Method -

The fuzzy Delphi method consists of the following steps.

Step 1) Experts E_i, i=1,…,n provide the possible realization time (or rating) of a certain event: the earliest time (or the pessimistic rating) $a_1^{(i)}$, the most plausible time (or rating) $(a_2^{(i)}, a_3^{(i)})$, and the latest time (or the optimistic rating) $a_4^{(i)}$. The time given by each expert E_i are presented in the form of a trapezoidal fuzzy number

$$\tilde{A}^{(i)} = \left(a_1^{(i)}, a_2^{(i)}, a_3^{(i)}, a_4^{(i)}\right), \; i = 1, \dots n$$

Step 2) First, the average (mean) $\tilde{A}_m$ of all $\tilde{A}^{(i)}$ is computed. This requires computation of the average of all $a_1^{(i)}, a_2^{(i)}, a_3^{(i)}$, and $a_4^{(i)}$, i=1,…, n. Hence

$$\tilde{A}_m = (a_{m1}, a_{m1}, a_{m1}, a_{m1})$$
$$= \left(\frac{1}{n}\sum_{i=1}^{n} a_1^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_2^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_3^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_4^{(i)}\right).$$

Then for each expert E_i the differences

$$\left(a_{m1} - a_1^{(i)}, a_{m2} - a_2^{(i)}, a_{m3} - a_3^{(i)}, a_{m4} - a_4^{(i)}\right)$$
$$= \left(\frac{1}{n}\sum_{i=1}^{n} a_1^{(i)} - a_1^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_2^{(i)} - a_2^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_3^{(i)} - a_3^{(i)}, \frac{1}{n}\sum_{i=1}^{n} a_4^{(i)} - a_4^{(i)}\right)$$

are found and sent back to the expert E_i for re-examination.

Step 3) Each expert E_i presents a revised trapezoidal fuzzy number

$$\tilde{B}^{(i)} = \left(b_1^{(i)}, b_2^{(i)}, b_3^{(i)}, b_4^{(i)}\right), \qquad i = 1, \dots n$$

This process starting with Step 2 is repeated. The average $\tilde{B}_m$ is calculated by above formula (9) with the differences that now $a_1^{(i)}, a_2^{(i)}, a_3^{(i)}, a_4^{(i)}$ are substituted correspondingly by $b_1^{(i)}, b_2^{(i)}, b_3^{(i)}, b_4^{(i)}$. If it still necessary new trapezoidal fuzzy numbers $\tilde{C}^{(i)} = \left(c_1^{(i)}, c_2^{(i)}, c_3^{(i)}, c_4^{(i)}\right)$ are presented, and their average $\tilde{C}_m$ is calculated. The process could be repeated again and again until to successive means $\tilde{A}_m, \tilde{B}_m, \tilde{C}_m, \dots$ become reasonably close (we can define the distance of two fuzzy numbers, $d_i \le 0.2$)

Step 4) At a later time, the same process may re-examine the ratings, if there is important information available due to new discoveries.

d. Ranking fuzzy numbers procedure

a) Intuition ranking method. From membership function curves of fuzzy numbers, many fuzzy numbers can easily rank its orderings by intuition ranking method. Human intuition would favor a fuzzy number with the following characteristics: higher mean value and at the same time lower spread.

b) If it's ordering cannot rank by intuition ranking method. We can rank fuzzy numbers by α-cut method, fuzzy mean and spread, or other methods. We use the defuzzification value of the trapezoidal fuzzy number to do the necessary rank orderings. We take trapezoidal fuzzy number to represent experts' opinion.

e. The defuzzification value of the trapezoidal fuzzy number

Definition: For a trapezoidal fuzzy number, $\tilde{A} = \left(a_1^{(i)}, a_2^{(i)}, a_3^{(i)}, a_4^{(i)}\right)$, its defuzzification value is defined to be, C = ($a_1 + a_2 + a_3 + a_4$) / 4 of the trapezoidal fuzzy number to do the necessary rank orderings. We take trapezoidal fuzzy number to represent experts' opinion.

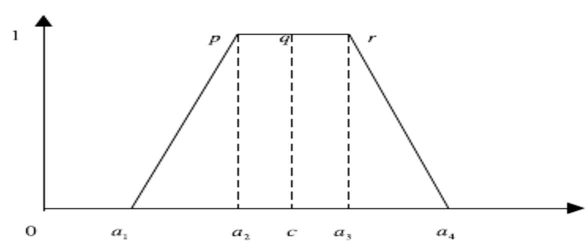

Fig. 1 The defuzzification value of the Trapezoidal fuzzy number

From above Fig.1 we can see that if the left area Δa_1pa_2 + □a_2pqc is equal to the right area □$cqra_3$ + Δa_3ra_4 then,

(1) $(a_2 - a_1)/2 + (c - a_2)(1) = (a_3 - c)(1) + (1)(a_4 - a_3)/2$

=> c = ($a_1 + a_2 + a_3 + a_4$)/4

Therefore, we obtain the defuzzification value of the trapezoidal fuzzy number is,

$$c = (a_1 + a_2 + a_3 + a_4) / 4$$

III. DATA COLLECTION

For evaluation process, a case study of a Tender work of "Establishment of Ground Control Points, Carrying out Engineering survey and Preparation of Master Plan with necessary Detailed Project Report of Infrastructure" for

Urun-Islampur Municipal Council, Tal - Walawa, Dist – Sangali, Maharashtra, India has been propose.

TABLE 2 DATA FROM CASE STUDY

Parameter	***Notation***	***Unit***	***Bidder A***	***Bidder B***	***Bidder C***
Bid Value	C1	Rs.	3875500	4185540	4456825
Financial Stability	C1	%	100	31	41
Technical capability	C3	%	85	90	80
Management Skill	C4	%	80	90	85
Reputations & Safety	C5	%	90	90	90
Quality	C6	%	90	70	80

IV. EVALUATIONS

a. Using AHP

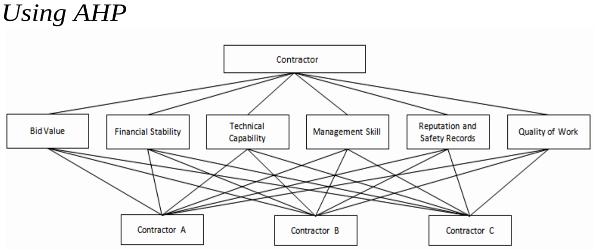

Fig.2 Hierarchy structure for Contractor Selection

The criteria used for contractor selection and hierarchy structure are obtained for the Analytic Hierarchy Process given in Table 2 and Figure 2 respectively. Carry out pair-wise comparison matrix is obtained by comparing all criteria attributing to contractor selections according to the importance of one criterion over the other criterion. The following matrices (Table 3 and 4) show pair-wise comparison. The Fundamental scale used is given in Table 1.

TABLE 3 PAIRWISE COMPARISON MATRIX

	C1	**C2**	**C3**	**C4**	**C5**	**C6**
C1	1	5	7	9	9	9
C2	0.2	1	5	5	7	7
C3	0.14	0.2	1	3	7	7
C4	0.11	0.2	0.33	1	5	5
C5	0.11	0.14	0.14	0.2	1	0.33
C6	0.11	0.14	0.14	0.2	3	1
Sum	**1.67**	**6.68**	**13.61**	**18.4**	**32**	**29.14**

TABLE 4 SUMMARIES OF CRITERIA PRIORITIES

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**Priority**
C1	0.599	0.749	0.514	0.489	0.281	0.309	0.490
C2	0.120	0.150	0.367	0.272	0.219	0.240	0.228
C3	0.084	0.030	0.073	0.163	0.219	0.240	0.135
C4	0.066	0.030	0.024	0.054	0.156	0.172	0.084
C5	0.066	0.021	0.010	0.011	0.031	0.011	0.025
C6	0.066	0.021	0.010	0.011	0.094	0.034	0.039

Now, Pair wise comparison matrices are obtained by comparing contractors with respect to each criterion (Table 5 to 10)

TABLE 5 PAIR WISE COMPARISON W.R.T. C1

Criteria	**A**	**B**	**C**	**A**	**B**	**C**	**Priority**
A	1	2	3	0.546	0.571	0.500	0.539
B	1/2	1	2	0.273	0.286	0.333	0.297
C	1/3	1/2	1	0.182	0.143	0.167	0.164
Sum	1.83	3.5	6				

TABLE 6 PAIR WISE COMPARISON W.R.T. C2

Criteria	**A**	**B**	**C**	**A**	**B**	**C**	**Priority**
A	1	5	3	0.652	0.556	0.693	0.634
B	1/5	1	1/3	0.13	0.111	0.077	0.106
C	1/3	3	1	0.217	0.333	0.231	0.260
Sum	1.53	9	4.33				

TABLE 7 PAIR WISE COMPARISON W.R.T. C3

Criteria	**A**	**B**	**C**	**A**	**B**	**C**	**Priority**
A	1	1	1/2	0.25	0.25	0.25	0.25
B	1	1	1/2	0.25	0.25	0.25	0.25
C	2	2	1	0.5	0.5	0.5	0.5
Sum	4	4	2				

TABLE 8 PAIR WISE COMPARISON W.R.T. C4

Criteria	**A**	**B**	**C**	**A**	**B**	**C**	**Priority**
A	1	1/3	1/3	0.143	0.143	0.143	0.143
B	3	1	1	0.429	0.429	0.429	0.429
C	3	1	1	0.429	0.429	0.429	0.429
Sum	7	2.33	2.33				

TABLE 9 PAIR WISE COMPARISON W.R.T. C5

Criteria	A	B	C	A	B	C	Priority
A	1	1	1	0.333	0.333	0.333	0.333
B	1	1	1	0.333	0.333	0.333	0.333
C	1	1	1	0.333	0.333	0.333	0.333
Sum	3	3	3				

TABLE 10 PAIR WISE COMPARISON W.R.T. C6

Criteria	A	B	C	A	B	C	Priority
A	1	3	3	0.6	0.6	0.6	0.6
B	1/3	1	1	0.2	0.2	0.2	0.2
C	1/3	1	1	0.2	0.2	0.2	0.2
Sum	1.667	5	5				

Final ranking is obtained by multiplying priority of criteria and priority of contractors followed by addition to obtain the final scores and presented in Table 11

TABLE 11 FINAL RANKING FOR CONTRACTORS

Criteria	C1	C2	C3	C4	C5	C6	
Priority	0.490	0.228	0.135	0.084	0.025	0.039	Rank
A	0.539	0.634	0.250	0.143	0.333	0.600	0.497
B	0.297	0.106	0.500	0.429	0.333	0.200	0.256
C	0.164	0.260	0.500	0.429	0.333	0.200	0.259

The Final scores obtained in Table 11 lead us to the conclusion that Contractor A has better final score than Contract C and B.

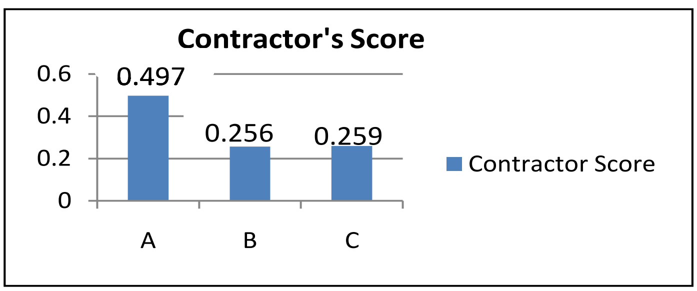

Fig. 3 Ranking of Bidders by AHP

b. Using Fuzzy Group Decision making Method

TABLE 12 LINGUISTIC VARIABLES OF THE IMPORTANCE WEIGHT

Very low (VL)	(0, 0, 0.1, 0.2)
Low(L)	(0.1,0.2,0.2,0.3)
Medium low (ML)	(0.2,0.3,0.4,0.5)
Medium (M)	(0.4,0.5,0.5,0.6)
Medium high(MH)	(0.5,0.6,0.7,0.8)
High(H)	(0.7,0.8,0.8,0.9)
Very high(VH)	(0.8,0.9,1,1)

TABLE13 LINGUISTIC VARIABLES FOR THE RATINGS

Very poor (VP)	(0, 0, 1,2)
Poor(P)	(1,2,2,3)
Medium poor (MP)	(2,3,4,5)
Fair(F)	(4,5,5,6)
Medium good(MG)	(5,6,7,8)
Good(G)	(7,8,8,9)
Very good(VG)	(8,9,10,10)

TABLE 14 THE IMPORTANCE WEIGHT OF THE LINGUISTIC CRITERIA AND ITS MEAN

Parameters	Weight of criteria	Fuzzy value
Bid Value	M	(0.4,0.5,0.5,0.6)
Financial Stability	M	(0.4,0.5,0.5,0.6)
Technical Capability	H	(0.7,0.8,0.8,0.9)
Management Skill	H	(0.7,0.8,0.8,0.9)
Reputation and Safety Records	M	(0.4,0.5,0.5,0.6)
Quality of Work	VH	(0.8,0.9,1,1)

TABLE 15 THE RATINGS OF ATTRIBUTE PERFORMANCE FOR THREE TYPES OF BIDDERS

Parameters	A	B	C
Bid Value	G	MG	F
Financial Stability	VG	MG	G
Technical Capability	G	G	G
Management Skill	MG	G	G
Reputation and Safety Records	G	G	G
Quality of Work	VG	MG	G

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TABLE 16 NORMALIZING THE RATINGS OF ATTRIBUTE PERFORMANCE FOR THREE BIDDERS

	Bid Value	**Financial Stability**	**Technical Capability**	**Management Skill**	**Reputation and Safety Records**	**Quality**
A	0.7,0.8,0.8,0.9	0.8,0.9,1,1	0.7,0.8,0.8,0.9	0.5,0.6,0.7,0.8	0.7,0.8,0.8,0.9	0.8,0.9,1,1
B	0.5,0.6,0.7,0.8	0.5,0.6,0.7,0.8	0.7,0.8,0.8,0.9	0.7,0.8,0.8,0.9	0.7,0.8,0.8,0.9	0.5,0.6,0.7,0.8
C	0.4,0.5,0.5,0.6	0.7,0.8,0.8,0.9	0.7,0.8,0.8,0.9	0.7,0.8,0.8,0.9	0.7,0.8,0.8,0.9	0.7,0.8,0.8,0.9

From Tables 12 to 16, we get Fuzzy weight matrix $\widetilde{W}$ and fuzzy decision matrix $\tilde{X}$ respectively,

$$\tilde{X} = \begin{bmatrix} 0.7,0.8,0.8,0.9 & 0.8,0.9,1,1 & 0.7,0.8,0.8,0.9 & 0.5,0.6,0.7,0.8 & 0.7,0.8,0.8,0.9 & 0.8,0.9,1,1 \\ 0.5,0.6,0.7,0.8 & 0.5,0.6,0.7,0.8 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0. & 0.5,0.6,0.7,0.8 \\ 0.4,0.5,0.5,0.6 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 \end{bmatrix}$$

$$\widetilde{W} = \begin{bmatrix} 0.4,0.5,0.5,0.6 \\ 0.4,0.5,0.5,0.6 \\ 0.7,0.8,0.8,0.9 \\ 0.7,0.8,0.8,0.9 \\ 0.4,0.5,0.5,0.6 \\ 0.8,0.9,1,1 \end{bmatrix}$$

Aggregate the fuzzy evaluations by $\tilde{A}_{(i)}$= [$\tilde{x}_{ij}$] . [$\widetilde{w}_j$]^t, i= 1,…,m, j=1,…,n where '*'denote composition operation of fuzzy numbers.

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 0.7,0.8,0.8,0.9 & 0.8,0.9,1,1 & 0.7,0.8,0.8,0.9 & 0.5,0.6,0.7,0.8 & 0.7,0.8,0.8,0.9 & 0.8,0.9,1,1 \\ 0.5,0.6,0.7,0.8 & 0.5,0.6,0.7,0.8 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.5,0.6,0.7,0.8 \\ 0.4,0.5,0.5,0.6 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 & 0.7,0.8,0.8,0.9 \end{bmatrix} * \begin{bmatrix} 0.4,0.5,0.5,0.6 \\ 0.4,0.5,0.5,0.6 \\ 0.7,0.8,0.8,0.9 \\ 0.7,0.8,0.8,0.9 \\ 0.4,0.5,0.5,0.6 \\ 0.8,0.9,1,1 \end{bmatrix}$$

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 2.36 & 3.18 & 3.55 & 4.21 \\ 2.06 & 2.82 & 3.08 & 3.92 \\ 2.26 & 3.05 & 3.13 & 3.96 \end{bmatrix}$$

$\tilde{A}_A$ = (2.36, 3.18, 3.55 And 4.21)
$\tilde{A}_B$ = (2.06, 2.82, 3.08 And 3.92)
$\tilde{A}_C$ = (2.26, 3.05, 3.13 And 3.96)

Ranking aggregate fuzzy number $\tilde{A}_{(i)}$, i = A, B, C and determining the best alternatives

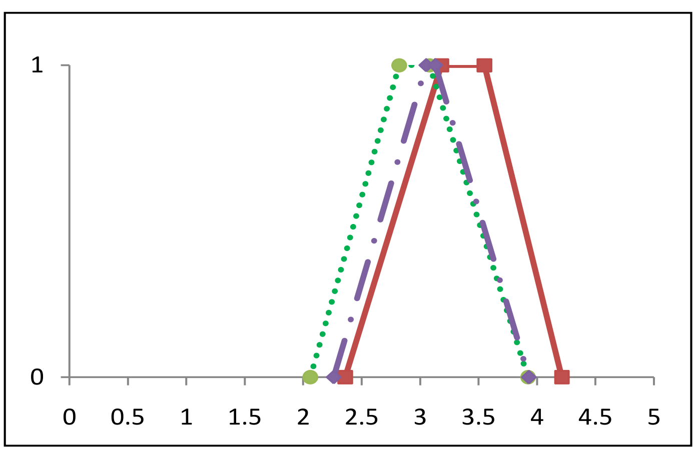

Fig. 4 The defuzzification value of the Trapezoidal fuzzy number A, B, C by Fuzzy methodology

Hence, we can defuzzify, $\tilde{A}_A$, $\tilde{A}_B$ and $\tilde{A}_C$ as in the following:

$$\tilde{A}_A = (2.36 + 3.18 + 3.55 + 4.21) / 4 = 3.325$$
$$\tilde{A}_B = (2.06 + 2.82 + 3.08 + 3.92) / 4 = 2.970$$
$$\tilde{A}_C = (2.26 + 3.05 + 3.13 + 3.96) / 4 = 3.100$$

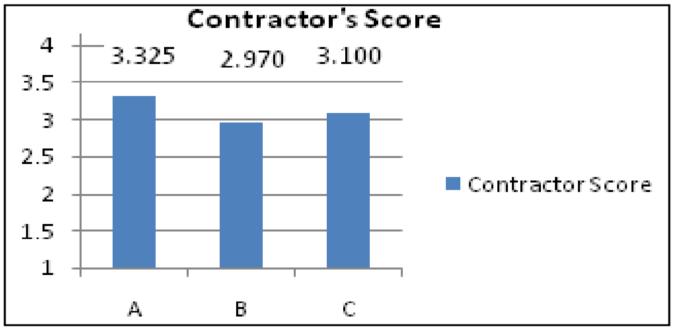

Fig. 5 Ranking of Bidders by Fuzzy methodology

V. RESULTS

Table 17 FINAL RESULTS

Methodology	A	B	C
AHP	0.497	0.256	0.259
FGDM	3.325	2.970	3.100

Therefore, as per above 2 methods, The Ranking of Bidders is, A> C > B

VI. CONCLUSION

Analytic Hierarchy Process is an effective decision making technique based on multi-criteria decision making. AHP is a method successfully used as it incorporates all the attributes pertaining to contractor selection and then prioritizes each attribute resulting in easy judgment of best contractor. In this method important parameters regarding procurement procedure are considered & rating is given to the criterion according to the question, “How important is one criterion compared to other criterion” and ranking procedure to contractor carried out as per given scale. But, in some complex decision problems, it is difficult for the decision maker to compare between alternatives with crisp value, because of the ambiguity in human experience and knowledge. Fuzzy methodology used to tackle this type of problem. Consistency of the outcome regarding the selection of the contractor in the AHP checked in FGDM, the uncertainty involved in rating a contractor overcome using Fuzzy methodology.

Finally, we can concluded that, the suitability of these methods depends on the input regarding various attributes of contractors and attributes of selection criteria obtained from the decision makers.

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