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EFFECT ON SELECTION PROCESS BY MODERN CRITERIA & PROCESS FOR CONTRACT

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ABSTRACT:
Contractor selection is one of the important aspects in the field of project management as it has a big influence on project and its success. Without a precise method for selecting the best contractor, the choice of contractor for a project may affect the successful completion of project.
Analytical Hierarchy Process (AHP) is one of the decision making techniques used in construction management for selection of contractor. AHP helps the construction sector in two ways; first, the prequalification criteria's focus on degree of importance, and second, it implements a multi-criteria AHP approach which calculates priority vectors for evaluating and selecting the best contractor. The other TOPSIS method (Technique for Order Preference by Similarity to an Ideal Solution) focuses on selecting the most suitable contractor by calculating shortest distance from positive ideal solution and farthest distance from negative ideal solution.
This dissertation work consists of structuring of decision hierarchy for selection of best contractor from various potential alternatives and forming of theoretical model based on methods. Overall six criteria's are considered for research work. Data regarding these criteria's is collected in the form of questionnaire survey from contractors in various fields and project managers. Applying both the methods, best contractor is selected by solving various matrices in the form of theoretical model.

INTRODUCTION:
The Contractor selection is the process of selecting the most appropriate contractor to deliver the project as specified so that the achievement of the best value for money is ensured. Construction clients are becoming more aware of the fact that selection of a contractor based on tender price alone is quite risky and may lead to the failure of the project in terms of time delay and poor quality standards. Evaluation of contractors based on multiple criteria is, therefore, becoming more popular. Contractor selection in a multi criteria environment is, in essence, largely dependent on the uncertainty inherent in the nature of construction projects and subjective judgment of decision makers (DMs).
The construction industry is characterized by cost and duration overruns, serious problems in quality standards and safety measures, and an increased number of claims, counterclaims, and litigation. To minimize or optimize all these risks, selection of an appropriate contractor to deliver the project under consideration as per requirements is the most crucial challenge faced by any construction client.
The aim of this research is to evaluate the various criteria's considered for contractor selection and prequalification process and select the best contractor among various alternatives depending on those criteria's.

OBJECTIVE:
The objectives of proposed work are:
1) To explore and define the potential criteria which affect the selection of contractor.
2) To reduce project risk, maximize the quality and maintain strong relationships between project

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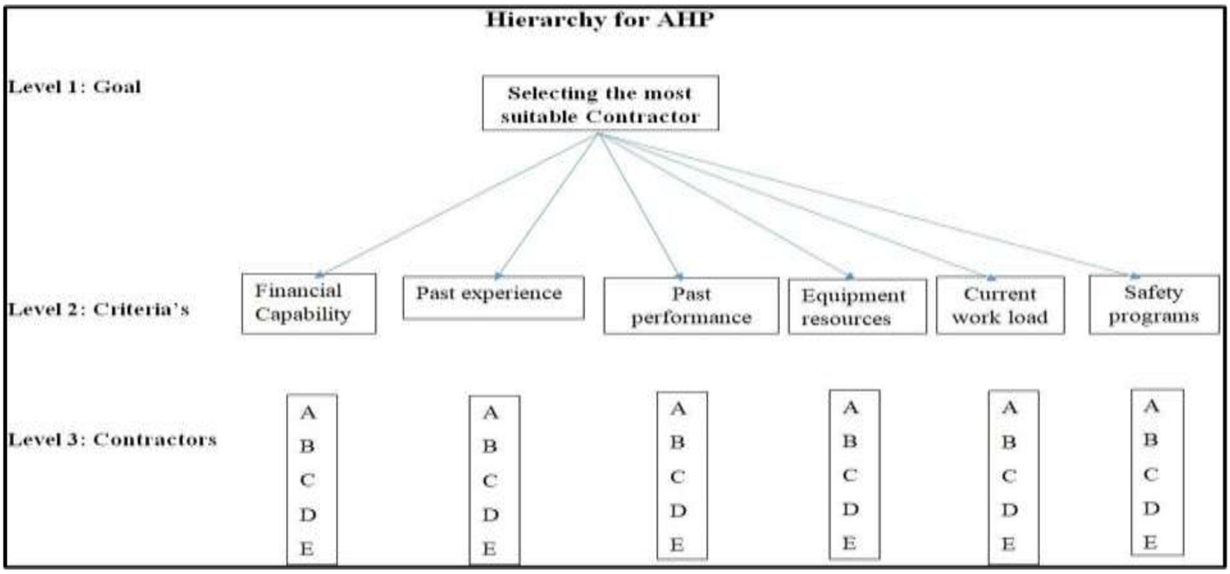
parties.
3) To develop theoretical model that represents the appropriate contractor selection based on AHP process.
4) To develop theoretical model that represents the appropriate contractor selection based on TOPSIS method

PROBLEM STATEMENT:
Based on questionnaire survey carried out, the data regarding past experience, financial status, reputation condition, quality performance, current work load, equipment resources and safety programs collected from contractors is as below. The below data is collected from contractors from various fields to select the best alternative.

	Contractor A	Contractor B	Contractor C	Contractor D	Contractor E
Experience	5 years experience Two similar projects	2 years experience in similar projects Special procurement experience	3 years experience No similar projects 1 international project	4 years experience Two similar projects	1 year experience No similar projects
Financial Capability	Financially stable with no past loans	Moderately stable	Financially more stable	Financially less stable	Loan taken for 1 project
Quality Performance	Good organization Good reputation Many certificates Safety program	Average organization Two delayed projects Safety program	Good organization Good reputation QA/QC program	Good organization Many certificates Cost raised in some projects	Bad organization Unethical techniques One project terminated
Equipment Resources	4 mixer machines 1 excavator	6 mixer machines 1 excavator 1 bulldozer	1 batching plant 2 concrete transferring trucks	4 mixer machines	2 mixer machines
Current works load	1 big project ending 2 projects in mid (1medium +1 small)	2 projects ending (1 big + 1 medium)	1 medium project started 2 projects ending (1 big + 1 medium)	2 big projects ending 1 medium project in mid	2 small projects started 3 projects ending (2 small + 1 medium)

By following the AHP procedure described, the hierarchy of the problem can be developed. The above hierarchy with three levels is developed to select the most appropriate contractor from various alternatives.
Level 1 shows the problem statement and its goal. Level 2 shows the six criteria's to be considered for solving the decision making problem. Level 3 shows the five alternatives that are A, B, C, D and E amongst which the suitable alternative is required to be selected.



As shown in the above figure 3.6., six criteria considered for the primary objective are evaluated. The criteria used for contractor selection in the model are identified, and the significance of each criterion is determined using a questionnaire. Comparisons are made by ranking the aggregate score of each candidate based on each criterion, and the candidate with the highest score is deemed the best.

METHODOLOGY :

Saaty developed the following steps for applying the AHP:

1.Define the problem and determine its goal.

2.Structure the hierarchy from the top (the objectives from a decision-makers viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.

3.Construct a set of pair-wise comparison matrices (size nxn) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 4.1. The pair-wise comparisons are done in terms of which element dominates the other.

4.There are n (n-1) judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.

5.Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

6.Having made all the pair-wise comparisons, the consistency is determined by using the eigen value, λmax, to calculate the consistency index, as C.I. = $(\lambda max - n)/(n - 1)$, where n is the matrix size.

7.Steps 3 to 6 are performed for all levels in the hierarchy.

LITERATURE REVIEW:

(Balmat 2011)

Both Fuzzy-AHP and AHP methods check the consistency of decision makers' judgments. Utilizing these systems, the qualitative scores of attributes are converted into numerical values. The methods have also the ability to handle scores evaluated by a group. This approach, however, cannot capture the uncertainty of the preference ratings for scoring the contractors.

fuzzy scale, utilized in Fuzzy AHP, overcomes this problem by allowing the decision makers to give their opinions in terms of a range of values in the scale. The biggest disadvantage of AHP, fuzzy AHP and fuzzy AHP-SMART however, is the rank reversal problem. Such a problem is said to occur when the relative ranks of contractors change whenever one or more contractors are either added or deleted from consideration.

Fuzzy set theory is an extension of classical set theory that "allows solving a lot of problems related to dealing the imprecise and uncertain data". It has many advantages. Fuzzy logic "takes into account the insufficient information and the evolution of available knowledge". It allows imprecise input. It allows for a few rules to encompass problems with great complexity. For disadvantages, fuzzy systems can sometimes be difficult to develop. In many cases, they can require numerous simulations before being able to be used in the real world. Fuzzy set theory is established and has been used in applications such as engineering, economic, environmental, social, medical, and management. Many of these types of problems take advantage of the availability of imprecise input. These types of applications favor a method that embraces vagueness and can be tested numerous times before real-world application.

(Wang, T. 2012)

The challenges in using the proposed decision framework would be defining and specifying the types of fuzzy numbers for linguistic variables and establishing the scale of preference structure to be used by DMs. When there are many stakeholders with different interests in the outcomes of the project, it would be more difficult and complicated to establish the preference of scale structure as each of them may have different ideas about the importance of decision criteria and how they should be evaluated making group decision making much more complicated and fuzzier. One of the simple and effective ways to address this issue is use of the fuzzy Delphi method to achieve a group consensus. In this method, a number of industry experts are first asked to express their opinions about the fuzzy numbers for linguistic variables and scale of preference structure for them and results are then aggregated. These aggregated results are sent back to them so that they can change their opinions based on the aggregated results. This process continues until a level of general agreement is achieved. The major disadvantage of the proposed method is that the exhaustive establishment of weights for different combinations of criteria, if there are many, requires consistency and is time consuming.

(Rajiv B. Bhatt 2011)

AHP represents the knowledge acquisition process and transforming the information to a manageable form for developing a theoretical model. The AHP is a decision aiding tools based on multi-criteria decision making for dealing with complex and multi attribute decision. The AHP process is simplifies using a decision support system. The paper is organized as follows: It provides a review of some relevant literature on contractor selection. This literature is utilized to review contractor evaluation methodology and criteria, appropriate investigation issues. The paper introduces a qualitative study that was conducted to address the research issues. It is composed of the investigation objectives and tasks. The AHP has a unique feature in that it measures the quality of the input data, a measure of inconsistency, which enables decision- makers to determine judgments that need reassessment.

(Subramanian N. and Ramanathan N. 2012)

The methodology is capable of Breaking down a complex, unstructured situation into its component parts, arranging these parts into a hierarchic order (criteria, sub-criteria, alternatives etc.) Assigning numerical values from 1 to 9 to subjective judgements on the relative importance of each criterion based on the characteristics Synthesizing the judgements to determine the overall priorities of criteria/sub-criteria/ alternatives.

DISCUSSION:

Overview of data collection

A total of thirty-five (35) sets of questionnaires were distributed to selected construction industry stakeholders in Pune, including clients, consultants, and contractors. Out of these, thirty (30) completed questionnaires were received, resulting in a response rate of 85.71%. The following section presents an analysis of the responses obtained from the survey participants.

Table 1.1. Pair wise Comparison Scale for AHP Preferences (Saaty T. 2012)

Numerical Scale	Verbal judgment of preferences
9	Extremely preferred
8	Very Strongly to Extremely

7	Very Strongly Preferred
6	Strongly to Very Strongly
5	Strongly Preferred
4	Moderately to Strongly
3	Moderately Preferred
2	Equally to Moderately
1	Equally Preferred

4.1.1. Pair wise Comparison Matrix for Criteria's

The average Level 1 scores for the six criteria based on a survey is shown in Table 1.2. The weight of each criterion at the same level was calculated as follows:

Table 1.2. Pair wise Comparison Matrix for Criteria's

Actual pair wise and average values for normalization matrix							
	Financial Capability	Past Performance	Experience	Equipment Resources	Current work load	Safety programs	Average
Financial Capability	1	1	3	0.5	2	3	1.750
Past Performance	1	1	7	1	7	2	3.167
Experience	0.33	0.14	1	0.25	3	1	0.953
Equipment Resources	2	1	4	1	7	1	2.667
Current work load	0.5	0.14	0.33	0.14	1	0.5	0.435
Safety programs	0.33	0.5	1	1	2	1	0.972
SUM	5.16	3.78	16.33	3.89	22	8.5	

Level 1: 1.Calculate the total for each column in the comparison matrix;

1. Divide each score by the sum of its column to form a new matrix ie. Synthesized matrix; and
2. Calculate the average of each row in the new matrix to obtain the priority vector weights of each criterion.

Tables 1.4, 1.6, 1.8, 1.10, 1.12, 1.14 show the new matrix after the weights were calculated. The "Average" column above shows the average values of the normalization matrix and is called the priority vector. The priority vector is usually determined by averaging the row entries in the normalization matrix. Tables 1.3 to 1.14 show the pair wise comparison and normalization matrices for each criterion.

Table 1.3. Pairwise comparison matrix for Experience

Experience	A	B	C	D	E
A	1	0.33	0.5	0.17	2
B	3	1	2	0.5	2
C	2	0.5	1	0.25	2
D	6	2	4	1	7
E	0.5	0.5	0.5	0.14	1

Table 1.4. Synthesized matrix for Experience

Experience	A	B	C	D	E	Priority Vectors
A	0.08	0.08	0.063	0.081	0.141	0.088
B	0.24	0.23	0.25	0.243	0.141	0.221
C	0.16	0.12	0.13	0.122	0.141	0.133
D	0.48	0.46	0.50	0.486	0.51	0.487
E	0.04	0.12	0.06	0.068	0.071	0.071

Table 1.5. Pairwise comparison matrix for Past performance

Past Performance	A	B	C	D	E
A	1	5	0.33	2	8
B	0.2	1	0.25	0.25	2
C	3	4	1	4	9
D	0.5	4	0.5	1	8
E	0.125	0.5	0.11	0.125	1

Table 1.6. Synthesized matrix for Past performance

Past Performance	A	B	C	D	E	Priority Vectors
A	0.207	0.34	0.152	0.27	0.285	0.252
B	0.04	0.07	0.12	0.034	0.071	0.066
C	0.62	0.28	0.46	0.542	0.324	0.444
D	0.10	0.28	0.23	0.136	0.28	0.206
E	0.03	0.03	0.05	0.017	0.036	0.033

Table 1.7. Pairwise comparison matrix for Financial Capability

Financial Capability	A	B	C	D	E
A	1	5	3	3	7
B	0.2	1	0.5	1	3
C	0.33	2	1	0.33	5
D	0.33	1	3	1	8
E	0.14	0.33	0.2	0.125	1

Table 1.8. Synthesized matrix for Financial Capability

Financial Capability	A	B	C	D	E	Priority Vectors
A	0.498	0.54	0.388	0.55	0.292	0.453
B	0.10	0.11	0.064	0.183	0.125	0.116
C	0.17	0.21	0.13	0.06	0.208	0.156
D	0.17	0.11	0.39	0.183	0.33	0.236
E	0.07	0.04	0.03	0.023	0.042	0.039

Table 1.9. Pairwise comparison matrix Equipment Resources

Equipment Resources	A	B	C	D	E
A	1	0.2	0.1	2	3
B	6	1	0.5	5	7
C	7	2	1	9	7
D	0.5	0.2	0.11	1	2
E	0.33	0.14	0.14	0.5	1

Table 1.10. Synthesized matrix for Equipments

Equipment Resources	A	B	C	D	E	Priority Vectors
A	0.067	0.05	0.075	0.114	0.15	0.091
B	0.40	0.28	0.264	0.286	0.35	0.318
C	0.47	0.57	0.53	0.514	0.35	0.487
D	0.03	0.06	0.06	0.057	0.10	0.061
E	0.02	0.04	0.08	0.029	0.05	0.043

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Table 1.11. Pairwise comparison matrix for Current work load

Current work load	A	B	C	D	E
A	1	0.2	0.3	3	3
B	5	1	5	5	7
C	4	0.2	1	2	2
D	0.33	0.2	1	1	2
E	0.33	0.14	0.5	0.5	1

Table 1.12. Synthesized matrix for Current work load

Current work load	A	B	C	D	E	Priority Vectors
A	0.094	0.11	0.034	0.261	0.20	0.141
B	0.47	0.57	0.690	0.435	0.467	0.527
C	0.38	0.11	0.14	0.174	0.133	0.187
D	0.03	0.11	0.07	0.087	0.13	0.087
E	0.03	0.08	0.07	0.043	0.067	0.058

Table 1.13. Pairwise comparison matrix for Safety Programs

Safety Programs	A	B	C	D	E
A	1	3	0.5	1	0.14
B	0.33	1	0.25	5	7
C	2	4	1	3	2
D	2	0.2	0.33	1	5
E	6	0.14	0.5	0.2	1

Table 1.14. Synthesized matrix for Safety Programs

Safety Programs	A	B	C	D	E	Priority Vectors
A	0.088	0.36	0.194	0.052	0.009	0.139
B	0.03	0.12	0.09	0.515	0.467	0.246
C	0.18	0.48	0.39	0.309	0.133	0.297
D	0.18	0.02	0.13	0.103	0.33	0.153
E	0.53	0.02	0.19	0.021	0.067	0.165

1.1.2 Consistency of a Hierarchy

The AHP measures the reliability of judgements of the decision maker by means of a consistency Index. The consistency index (CI) is a function of the maximum eigenvalue (λmax) and the size of the square matrix (n).

Saaty identified the Consistency lndex as: $C1 = (\lambda max - n)/(n-1)$. In the case of inconsistency, λmax will be greater than n. The more inconsistent the decision maker is, the greater the value of λmax. As perfect consistency cannot be expected, Saaty simulated the random pair wise comparisons for different size matrices, calculating the consistency indices, and arriving at an average consistency index for random judgments for each size matrix. Table (1.15) shows the value of the random consistency index (RI) for matrices of order 1 to 13 obtained by approximating random indices using a sample size of 500.

Table 1.15. Average Random Index (RI) Based on Matrix Size (Al-Harbi and Kamal M. 2001)

Size of Matrix (n)	Random Consistency Index (RI)
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48

13	1.56

He then defined the consistency ratio of the consistency index (Cl) for a particular set of judgments to the average consistency index for random comparisons for a matrix of the same size. Consistency Ratio (CR) - Consistency Index (CI) / Random Index (RI) Where RI = reciprocal of C.I. In general, if the consistency ratio is 0.10 or less, the inconsistency is considered to be acceptable for evaluation of the decision hierarchy
(Saaty 1980).

1.1.2 Causes of Inconsistency

The most common cause of inconsistency is a clerical error. When entering one or more judgments into a computer, the wrong value, or perhaps the inverse of what was intended is entered. A second cause of inconsistency is lack of information. If one has little or no information about the factors being compared, then judgments will appear to be random and a high inconsistency ratio will result. Another cause of inconsistency is lack of concentration. A final cause of inconsistency is an “inadequate-model structure.” Ideally, one would structure a complex decision in a hierarchical fashion such that factors at each level are comparable of other factors at that level.
(Anagnostopoulos K.P. and Vavatsikos A.P. 2006)

1.1.2 Consistency Ratio Calculation

The consistency ratio for each criterion at the same level was calculated as follows:
Level 1: • Multiply the “Weight” column by the Level-1 matrix in Table 1.2, and then obtain a new matrix,

- Find the sum of each row, as shown in Table 1.16;

Table 1.16. Consistency Ratio Calculation

Priority vectors (Consistency Ratio Calculation)								
	Financial Capability	Past Performance	Experience	Equipment Resources	Current work load	Safety programs	Average	Sum
Financial Capability	0.194	0.265	0.184	0.129	0.091	0.353	0.202	1.214
Past Performance	0.194	0.265	0.429	0.257	0.318	0.235	0.283	1.698
Experience	0.064	0.037	0.061	0.064	0.136	0.118	0.080	0.481
Equipment Resources	0.388	0.265	0.245	0.257	0.318	0.118	0.265	1.590
Current work load	0.097	0.037	0.020	0.036	0.045	0.059	0.049	0.294
Safety programs	0.064	0.132	0.061	0.257	0.091	0.118	0.121	0.723

The above table shows calculations for consistency ratio using the formula given in 1.1.4. Divide the “Sum” column by the “Weight” column to find the average of that column (λmax),

- Find the average of the column that was obtained in the previous step;
- Calculate the consistency index using the following formula: CI = $(\lambda max - n)/(n-1)$

where n = 6 represents the number of factors and λmax is the average of the sum column.
The consistency ratio is found using the following formula: CR = CI / RI = where RI = 1.24 for matrix of size 6x6.

Discussion of result

The final priorities were determined by multiplying the overall priority vectors of the criteria by the priorities for each alternative decision for each objective. The overall priority vectors (Average) obtained from Table 4.16 for various criteria's are as follows 1. Financial Capability- 0.202, Past Performance – 0.283, Experience – 0.080, Equipment Resources -0.265, Current work load – 0.049 and for Safety programs is 0.121.

1.1.1.1 Priority vectors for various alternatives

The priority vectors for all alternatives like Contractor A, Contractor B, etc are calculated to rank them accordingly to decide the best contractor. The final ranking is given in descending order from highest priority vector to the lowest one.

Table 1.17. Priority vectors and Ranking of alternatives

Priority vectors for various alternatives								
	Financial Capability	Past Performance	Experience	Equipment Resources	Current work load	Safety programs	Final priority vector	Rank
Contractor A	0.453	0.252	0.088	0.091	0.141	0.139	0.218	2
Contractor B	0.116	0.066	0.221	0.318	0.527	0.246	0.200	3
Contractor C	0.156	0.444	0.133	0.487	0.187	0.297	0.342	1
Contractor D	0.236	0.206	0.487	0.061	0.087	0.153	0.184	4
Contractor E	0.039	0.033	0.071	0.043	0.058	0.165	0.057	5

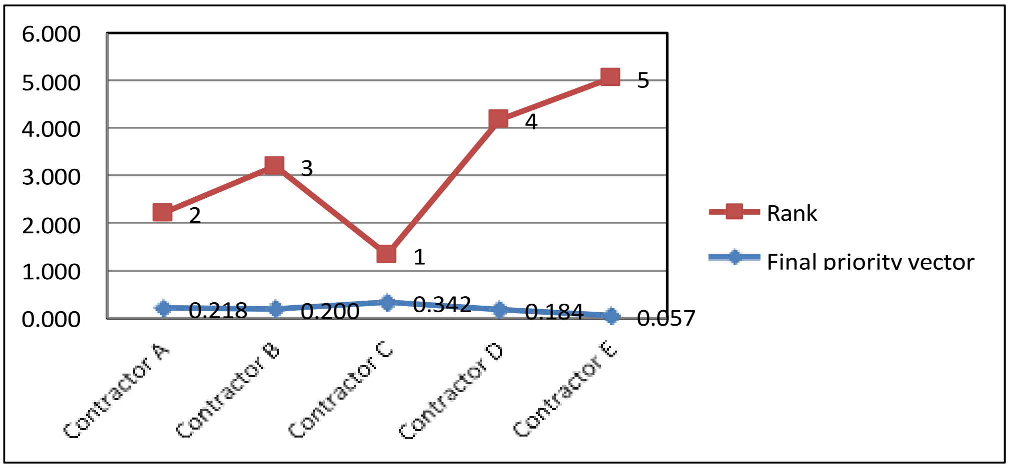

Fig. 1.1. Graph showing Rank & Final Priority vectors

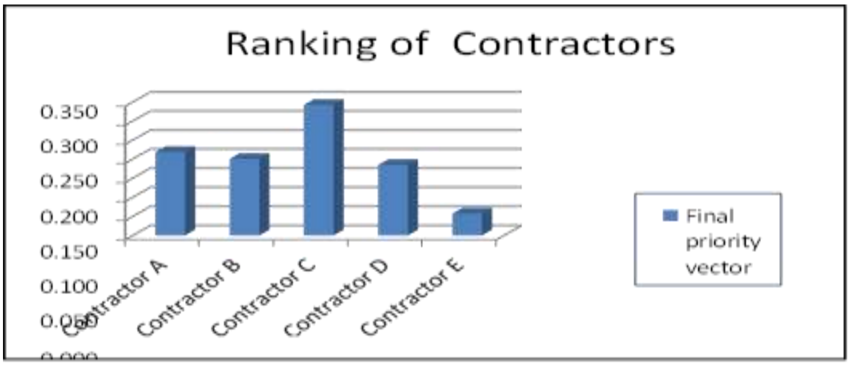

Fig. 1.2. Graph showing ranking with respect to Final Priority vectors

CONCLUSION:

1. Inadequate decision during contractor selection will lead to failure of construction project. Bad quality of work and delay in project duration are some of the causes of improper contractor selection.

2. To reduce such project risks, maximize the quality and maintain strong relationships between project parties, selection of suitable contractor plays an important role.
3. Prequalification of contractors is accounted as important step for contractor selection as it identifies array of eligible contractors as suitable criteria with perfectly matched techniques helps in finding the best solution for selection of contractor.
4. Out of six criteria's considered for prequalification, contractors past experience (in similar or different works) and financial stability have a major impact on prequalification process.
5. AHP has been chosen as a reliable instrument for decision-making particularly in contractor selection because of its flexibility and efficiency.
6. Using the weights obtained in AHP, the proposed study has implemented TOPSIS method too, to rank the alternatives accordingly.
7. In TOPSIS method, the available data, lack of uncertainty, and therefore the option to assign crisp numbers to criteria are the factors that have played a decisive role when choosing a method to select a contractor.
8. The results from both the methods maybe different as both methods work on different principles, assumptions and algorithms.
9. To reduce subjectivity while decision making both the methods should be used in combination. While using combination we just need to make sensitivity analysis ie. at what interval of criteria, change in optimal solution is retained

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