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Application of Analytical Hierarchy Process (AHP) in Construction Works

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***Abstract*—Over the last decades Indian Construction industry has witnessed threefold growth in the progress of the nation. Though, execution is the heart of any construction project, but sometimes it is seen that execution work being hamper due to previous decisions taken. Bidding is one of those stages, which is core of any contractor's business. Risk and uncertainty are major considerations in bidding decisions for construction projects. Numerous factors need to be considered when making bidding decisions which make them multi-criteria decisions. From previous studies it has been seen that multi-criteria decision making is a tangled process and there are numerous techniques to arrive at a firm decision out of which Analytical Hierarchical Process (AHP) is one of them. AHP aids the stakeholders to identify contractors with the best potential to deliver reasonable outcomes in a final contractor selection process which is not based simply on the lowest bid. The present study focuses on developing multi-criteria decision-making models to assist in bidding decisions and the criteria used for contractor selection in the model have been identified, and the significance of each criterion has been arrived at by conducting a questionnaire survey in public organizations in Mumbai.**

Keywords*—Analytical Hierarchy Process AHP, Ready mix concrete RMC

I. INTRODUCTION

Contractor selection is one of the main activities of clients. Without a proper and accurate method for selecting the most appropriate contractor, the performance of the project will be affected. The multi-criteria decision-making (MCDM) is suggested to be a viable method for contractor selection. The analytic hierarchy process (AHP) has been used as a tool for MCDM. However, AHP can only be employed in hierarchical decision models. The hierarchical structure is constructed for the prequalification criteria and the contractors wishing to prequalify for a project. The contracting firm wishing to bid on a project needs to be qualified before it can be issued bidding documents or before it can submit a proposal. Prequalification of contractors aims at the elimination of incompetent contractors from the bidding process. Prequalification can aid the public and private owner in achieving successful and efficient use of their funds by ensuring that it is a qualified contractor who will construct the project. Furthermore, because of the skill, capability and efficiency of a contractor, completion of a project within the estimated cost and time is more probable

Application of AHP

It is widely used for decision making. AHP technique is widely applied to various fields as given below:

1. Choice - The selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved.
2. Ranking - Putting a set of alternatives in order from most to least desirable.
3. Prioritization - Determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them.
4. Resource allocation - Apportioning resources among a set of alternatives.
5. Benchmarking - Comparing the processes in one's own organization with those of other best of-breed organizations.
6. Quality management- Dealing with the multidimensional aspect of quality and quality improvement
7. Conflict resolution - Settling disputes between parties with apparently incompatible goals or positions

This paper has an objective to develop criteria framework which suggests the technique for Ready Mixed Concrete selection in Indian context.

II. LITERATURE REVIEW

Fir Patrick Sikwah Fong and Sonia Kityung Choi developed a Research classified contractor selection can be divided into two phases: prequalification and nal selection. It aimed in selecting a contractor to whom to award a contract at the latter stage based on 68 criteria, collected from 10 publications, summarized, and grouped into a smaller number of underlying factors. They concluded that, AHP is therefore valid as a model for contractor selection.

Attirawong, and MacCarthy, (2002) developed an Analytical Hierarchy Process model for evaluating an overseas site selection. Factors as direct costs, indirect costs, labour characteristics, infrastructure, proximity to markets, proximity to suppliers and macro- environment were considered to affect the site selection decision. To evaluate the usability of the proposed model, it was presented to two companies with a description of how to use it. Both companies stated that the model was easy to apply and would facilitate the international location decision making process.

El-Mikawi, M. et al (1996) developed an AHP model that allows decision makers to select an optimal structural material for infrastructure repairs and construction. As a case study, this model was applied to test the use of advanced composite materials in the repair of deteriorated and damaged bridge columns in Washington. Two alternative materials were considered, either the use of composites made of carbon fibers or the use of conventional steel jackets. Performance, economic analysis, environmental aspects, codes, material availability and architectural aspects were the factors included in this study. Structural performance was found to be the most important factor and of equal importance to the economic indicators while, architectural aspects was the least important factor. The resulting AHP model recommended the selection of composite materials over the steel jackets.

Al-Harbi (2001) demonstrated the AHP application on the contractor pre-qualification problem by illustrating asimplified project example. He created the AHP model using experience, financial stability, quality performance, manpower resources and current workload as factors affecting contractor pre- qualification. The AHP was implemented using the Expert Choice Software. Results from the Analytical Hierarchy model indicated that experience, financial stability and quality performance were the most important factors as they had the highest ranking weight. The study concluded that the AHP is a powerful tool for decision making.

Fong and Choi (2000) applied the AHP method to develop a model for contractor selection in order to help construction clients to identify contractors with the best potential to deliver satisfactory outcomes. Eight factors involved in contractor selection were used to form the required model: tender price, financial capability, past performance and past experience, resources, current workload, past client/contractor relationship and safety performance. They concluded their study by identifying the tender price as the most significant factor affecting the contractor selection and the validity of AHP method for this particular decision.

I. METHODOLOGY

This paper proposes the RMC's plant model based on the Analytic Hierarchy Process (AHP) to improve the efficiency of contractor bidding decisions. The essence of the AHP method is to make pairwise comparisons of available options against all evaluation criteria. The results of these comparisons are recorded in a matrix in which symmetrical elements are reciprocal. In the expert opinion, a 9-step, verbal scale was used so that the symmetry of the response was maintained. For contractors, the choice of the right tender in which the participation influences their image, financial condition, and their aspiration to succeed. The bid/no bid decision depends on numerous factors associated with the company itself, the environment, and the project concerning the tender. When facing tough competition, contractors search for a solution which increases their chances of winning the tender. The original element of the model involves 6 original criteria and 17 sub-criteria for the assessment of investment decision projects to the selection of the most advantageous contract, i.e. the contractor's participation in the bid.

Ready Mixed Concrete Contractor selection is a multi-criteria decision making problem and hence AHP fits to it. It is suggested to use AHP technique for Ready Mixed Concrete selection. So, a survey questionnaire can be prepared based on AHP technique. It will require the experts to compare various criteria and sub-criteria on 1 to 9 scales. While doing this comparison they have to use their past knowledge and information of criteria as well as available Ready Mixed Concrete Plants.

Detailed proposed AHP based on Ready Mixed Concrete selection process is explained below.

Criteria Framework for ready mixed Concrete Plant Selection

1. Experience
   a) Length of time in business.
   b) Past client relationship.
   c) Daily requirements of RMC.
2. Health and safety
   a) Management review
   b) Accident statistics
3. Material and Resources
   a) Manpower
   b) Equipment
   c) Materials
4. Technical ability
   a) Technical/ lab staff
   b) Software used for estimation

c) Test performed to check quality

5. Financial stability
   a) Turnover
   a) Profitability
   b) Credit rating
   c) Liquidity
6. Quality control and Qualityassurance
   a) Quality status.
   b) Average time ofdelivery.

Steps for Methodology for RMC plant selection.

i. Selection of criteria
ii. Preparation of survey form based on selected criteria.
iii. Collection of responses within selected region
iv. Allotment of weights to the respective criteria's and RMC contractors.
v. Pairwise comparison of selected criteria's
vi. Pairwise comparison of RMC contractors for each selected criteria
vii. Calculation of priority vector for each criteria
viii. Calculation of Consistency index and Consistency ratio.
ix. Calculation of overall priority for each RMC contractors.
x. Selection of contractor based on above process

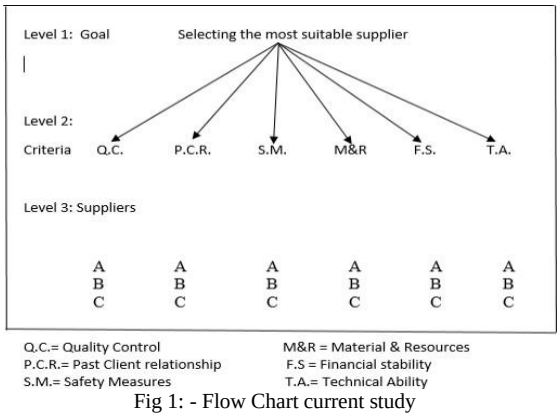

Fig 1: - Flow Chart current study

We have selected 3 RMC suppliers out of the 10 suppliers on the basis of judging criteria such as Experience, safety Measures, Material & Resources etc. The suppliers we have selected are Navdeep Contractor Company (NCC), Prism Johnson Limited (PJL), Kratos RMC plant (KRMC).

Table 1: - Fundamental scale of Pairwise Comparison

Intensity of importance	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Very strong or demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values
1/3, 1/5, 1/7, 1/9	Values for inverse comparison

The table above rubrics used for judging various criteria for the present study for the criteria's.

Table 2: - Allotment of weights for Experience

Experience			
Length of time		**Past client relationship**	
Years	**Weightage**	**No**	**Weightage**
>20	9	Excellent	9
15-20	7	Very good	7
10-15	5	Good	5
5-10	3	Satisfactory	3
0-5	1	Poor	1

Table 3: - Pair-Wise Comparison matrix for the Six Criteria's

	Exp.	S.M.	M&R	F.S	Q&D	Q.C
Exp.	1.00	3.00	1.00	3.00	4.00	5.00
S.M.	0.14	1.00	3.00	4.00	2.00	3.00
M&R	1.00	0.33	1.00	1.00	5.00	2.00
F.S	0.33	0.25	1.00	1.00	1.00	4.00
Q&D	0.20	0.50	0.20	1.00	1.00	1.00
Q.C	0.33	0.33	0.11	0.13	0.17	1.00
	3.01	9.42	6.31	10.13	14.17	30.00

Table 4: - Normalization for Six Criteria's

	Exp.	S.M.	M&R	F.S	Q&D	Q.C	P.V
Exp.	0.33	0.74	0.16	0.30	0.28	0.17	0.33
S.M.	0.05	0.11	0.48	0.39	0.14	0.10	0.21
M&R	0.33	0.04	0.16	0.10	0.35	0.07	0.17
F.S	0.11	0.03	0.16	0.10	0.07	0.13	0.10
Q&D	0.07	0.05	0.03	0.10	0.07	0.03	0.06
Q.C	0.11	0.04	0.02	0.01	0.01	0.03	0.04

In the above table P.V stands for priority vector, the calculation of the same is shown in the table below.

Table 5: - Calculation of Priority Vector

0.33	0.64	0.17	0.30	0.24	0.19	1.87
0.05	0.21	0.52	0.40	0.12	0.11	1.42
0.33	0.06	0.17	0.10	0.29	0.08	1.03
0.11	0.05	0.17	0.10	0.06	0.15	0.65
0.07	0.11	0.03	0.10	0.06	0.04	0.40
0.11	0.07	0.06	0.01	0.01	0.04	0.30
5.68	6.66	5.91	6.45	6.88	7.82	

Then **λmax** = (5.68+6.66+5.91+6.45+6.88+7.82)/6 = 6.57

Consistency Index can be defined as index of the consistency of judgments across all pairwise comparisons.

$$CI = \frac{(\lambda max - n)}{(n-1)} = \frac{(6.57-6)}{(6-1)} = 0.1$$

Table 6: - Random Index

Size of the matrix (n)	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$\text{Consistency ratio} = \frac{consistency\ index}{Random\ index} = \frac{0.11}{1.24} = 0.09$$

Therefore, consistency ratio 0.09 ≤ 0.1, Hence o.k.
After finding consistency ratio the next step is analyze pair-wise comparison matrix and normalization matrix for each criteria for all the selected supplier's which is presented below.

Table 7: Pairwise-comparison matrix for Experience

	NCC	PJL	KRMC
NCC	1.00	1.80	0.80
PJL	0.56	1.00	0.44
KRMC	1.25	2.27	1.00
	2.81	5.07	2.24

Normalization matrix for Experience is presented below considering λmax = 3, C.I.=3, C.R. =0.00 ≤ 0.1

Table 8: - Normalization matrix for Experience

NCC	0.36	0.36	0.36	0.36
PJL	0.20	0.20	0.20	0.20
KRMC	0.44	0.45	0.45	0.45

In similar way the normalization was done for other criteria's as well. The next steps are to calculate overall priority matrix before coming to any conclusion.

Overall Priority Vector

$$= \Sigma\{(weight\ of\ alternatives\ w.r.t.\ criteria) \times (importance\ of\ criteria)\}$$
$$= \{(0.33 \times 0.36) + (0.21 \times 0.38) + (0.17 \times 0.14) + (0.10 \times 0.24) + (0.06 \times 0.31) + (0.04 \times 0.22)\}$$
$$= 0.28 \text{ (Navdeep construction company)}$$

Table 9: - Final Results

NCC	PJL	KRMC
0.28	0.23	0.41

For prequalification purposes, the contractors are now ranked according to their overall priorities, as follows: Kratos RMC plant, Navdeep Construction Plant, and Prism Johnson Limited, indicating that Kratos RMC plant is the best qualified contractor to perform the project.

CONCLUSION

By applying the AHP, the prequalification criteria can be prioritized. A descending-order list of contractors can be made in order to select the best contractors to perform the project. A sensitivity analysis can be performed to check the sensitivity of the final decisions to minor changes in judgements. It can easily use by all contractors irrespective of stream or nature of construction and also to determine the contractors' competence or ability to participate in the project bid. The present study has developed a framework of criteria which contributes for Ready Mixed Concrete selection. As Ready Mixed Concrete selection is a multi-criteria decision making problem, Analytic Hierarchy Process is recommended for the solution. AHP based Ready Mixed Concrete selection approach is suggested through this study. Such approach will be more comprehensive and will include the relative importance of criteria in the final decision making. Engineers are encouraged to use such innovative and simple tool like AHP to support their decisions which will finally help the project success achievement. By this study we concluded that the Overall Priority Vector for Kratos RMC plant is highest among others.

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