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Selection of Construction Contractor by Analytical Hierarchy Process (AHP)

Prolay Das*Dr P Siva Prasad**

*(Post Graduate Student, Department of Architecture – MBEM, School of Planning and Architecture,Vijayawada, 520008, India,Email: prolay.das24@gmail.com)

**(Assistant Professor, Department of Architecture – MBEM, School of Planning and Architecture,Vijayawada, 520008, India,Email: psp2607@gmail.com)

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Abstract:

Selection of a contractor is one of the most important decisions for any construction project. Contractor's prequalification criteria is generally used for shortlisting a contractor based on qualification. A general prequalification process is performed in the bidding stage to identify the best one amongst the applicants by evaluating their economic and technical aspects, quality standards, reputations, financial stability and other aspects. AHP is used as multi-criteria based decision-making tools to provide ranking or weighting of each criterion. This paper discusses a case of the best contractor selections by performing AHP method having four alternatives under six criteria of selection in Indian Context for bid evaluation such as experience, financial stability, quality, technical and management ability, reputation and health safety, human resources. These six factors were deduced from thirteen papers. The AHP analysis was done manually in MS excel. Technical and management ability (0.35) and quality (0.34) resulted as top two criteria and contractor 3 (0.4202) is likely to get the award of contract.Moreover, this kind of research helps the decision-maker making use of appropriate decision support tool for selection of contractor in bid evaluation process.

Keywords **—AHP, Multi-criteria decisions, Contractor selection, Bid evaluation**

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I. INTRODUCTION

Any construction work is generally carried out through a contract – an Agreement enforceable by law. For completing the construction project successfully, the selection of a contractor plays a significant role. Any construction projects fail due to financial problems, or poor performance or accidents for having a lack of safety consideration or having poor management-related issues. The selection of a proper construction contractor increases the chances of successful completion of a construction project (Alhazmi, 2000) However, contactor selection is a complicated decision-making process involving multiple criteria with various alternatives. It can likewise satisfy the customer objectives and maintain the schedule of the cost, time and quality. That is why difficulty arises while selecting an appropriate contractor in the process of construction management.

In general, Contractor is selected by tendering process. In an open tender, anyone can participate whereas, only limited Contractor can participate in limited Tender. Two types of bidding are considered such as technical and financial bid. First, the bids will be accepted and then evaluated,

then the lowest bidder L1 is selected as a Contractor majorly. There are also different stages in bidding process. In single stage bidding, the technical and financial bid are invited through single envelope as the work assigned is clear to the bidder. If the assigned work is not clear to bidder, then two stage bidding is carried out. In first stage bidders have to submit the technical bid, if qualifies, then the financial bid will open in the next stage and the lowest bidder L1 will get the award. In this paper, the selection process is done by AHP method. Generally three prime causes are there for inadequate contractor selection. Firstly, inappropriate prequalification criteria is taken for selecting the contractor. Secondly, inappropriate bid price is given in the tender stage. Thirdly, an unsuitable methodology is applied in the bid evaluation stage. This paper is focused on the contractor evaluation or selection criteria by using AHP method. In this paper, the evaluation criteria is deduced from the literature surveys and final AHP method is applied to prioritise those criteria.

The Analytic Hierarchy Process (AHP) was developed by Thomas Saaty in the1970's proposed a multiple criteria decision-making process for the evaluation of alternatives. The application and the use of AHP method is perfectly described in his further papers. (R. W. Saaty, 1987). AHP is well formed technique for analysing the complicated decision which is based on psychology as well as mathematics. This is an effective methodology that combines judgment and data to rank options as well as predict outcomes. This method is used to arrive at a cardinal ranking of multi-attribute decision problems alternative (T. L. Saaty, 2008). Several outstanding works based on AHP have been published: they include AHP applications in various fields, such as preparation, choosing the best alternative, resource allocation, conflict resolution, optimization, etc and AHP numerical extensions. In many areas of the AEC industry, AHP has been widely used, such as the choice of contractors(Fong & Choi, 2000), procurement (Khalil, 2002), maintenance (Shen et al., 1998), project management (Al-harbi, 1990), risk factors prioritisation (Baha et al., 2013) , supply chain decisions (De Felice & Petrillo, 2012) and facility management decisions (Gilleard & Wong Yat-lung, 2004).

The study aims to select the best contractor from four alternatives by evaluating the criteria such as - experience, financial stability, quality, technical and management ability, reputation and health safety, human resources. Statistical tools such as- AHP (analytical hierarchy process) was applied to select the best contractor which is a multi-criteria decision method. To achieve the aim, the following objectives were:

- To select the criteria for contractor selection in Indian context.
- To perform AHP analysis to prioritise the criteria and select the best contractor from four alternatives.

II. LITERATURE REVIEW

From literature review, six main criteria were deduced from 13 papers and described in table 1. (Zala & Bhatt, 2011) considered 10 main factors and for contractor selection in Indian context and suggesting to perform AHP analysis for prioritising those criteria. All those main criteria having different no of sub-criteria, from that best contractor is selected out of three alternatives. (Tiwari, 2015) evaluated 9 factors for selection of Contractor and bid evaluation in Indian context. All the data were taken from top contractors and filled by questioner survey after that an AHP analysis is performed for effective bid evaluation using software. Ultimately, they conclude the most important factor is nothing but the need of work, however the payment method and the company strength also have the high importance among all those criteria. (Paul et al., 2016) selected 70 factors out of 155 factors based on the comprehensive and valuable input from experts. After that they deduced 6 main criteria and 15 no of sub criteria for selection of best contractor from 4 alternatives and then perform TOPSIS and extended Fuzzy TOPSIS methods. Two methods are compared and concluded extended Fuzzy TOPSIS gives better

results. (Krishna Rao et al., 2018) identified 15 factors and considered 6 main criteria from those factors and then an industry- wide questionnaire survey was conducted with the objective of identifying the important criteria for adoption in the selection process. They developed a fuzzy set based model for contractor prequalification/evaluation, by using effective criteria obtained from the percept of construction professionals, taking subjective judgments of decision makers also into consideration. A case study was considered consisting of four alternatives (contractors in the present case) solicited from a public works department of Pondicherry in India and then the final selection of contractor is made based on the Overall Evaluation Score. (Alptekin & Alptekin, 2017) performed TOPSIS analysis to rank 12 identified criteria for contractor selection. Termination of construction work in previous tender resulted as the most important criteria. (Erdogan et al., 2017) performed AHP method and sensitivity analysis for selection of contractor. They identified total of seven criteria having different number of sub criteria and prioritise them with expert choice software. (Salama et al., 2006) identified 5 main criteria and 20 no of sub criteria for contractor's prequalification and bid evaluation process. They performed bid evaluation method and bid price was concluded as the dominant factors in financial evaluation. (Razi et al., 2020) identified six factors and performed AHP analysis to prioritise them in the selection of contractor. Financial capability and past performance resulted as the top two criteria. (Alzober & Yaakub, 2014) proposed an integrated model for the selecting the Contractor. Integrated model consists of three components such as ANN, MCLP and AHP with Web-HIPRE software. They identified 12 criteria with different number of sub criteria from literature survey. (Dave et al., 2017) identified 5 major criteria and a total of 20 sub criteria for Contractors' selection in bid evaluation and prequalification process. (Erdogan et al., 2019) identified 7 criteria having 23 sub criteria and considered 5 alternatives for selection of Contractor. AHP analysis with expert choice software was performed and contractor 3 resulted as the best selection for a case study of pool construction. (Araujo et al., 2016) identified 6 major criteria from 25 literature survey for selecting contractor. They proposed a multi-criteria decision model which was an integration of PROMETHEE GDSS and PROMETHE V for contractor selection. (Chiang et al., 2017) identified 5 criteria and 20 sub criteria for evaluating the contractors' prequalification. AHP method was used to prioritise those factors. Technical ability and management capability resulted as the top two criteria.

This study performs AHP method to evaluate those criteria for selecting contactors. Some important equation are described below.

Total no of comparisons is referred in equation 1, Where n is the total number of criteria.

$$Totalnoofcomparison = (\boldsymbol{n^2 - n}) \,/\, \mathbf{2} \qquad \text{Eq. 1}$$

In Pairwise comparison process, a square matrix has to be formed as depicted in equation 2 and numerical rating is given as per table 3.

$$A = a_{ij} = \begin{bmatrix} a_{1,1} & \cdots & a_{1,n} \\ \cdots & \cdots & \cdots \\ a_{n,1} & \cdots & a_{n,n} \end{bmatrix} \qquad \text{Eq. 2}$$

Equation 3 showed the formula to get the principal eigen value (λ_{max}) and to get each matrix normalised.

$$Aw = \lambda_{max} w \qquad \text{Eq. 3}$$

To measure the consistency of the data, equation 4 and 5 were performed where CI is the Consistency index. After getting CI, consistency ratio (CR) has to be calculated with the help of random index (RI) which is followed in table 4.

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \qquad \text{Eq. 4}$$

$$CR = \frac{\text{CI}}{RI} \qquad \text{Eq. 5}$$

Consistency ratio (CR) should always be less than or equals to 10%. Otherwise, the pairwise comparison must be repeated.

TABLE ICONTRACTOR SELECTION CRITERIA

Sl no	Criteria	Articles
C1	Experience	[23];[22];[16];[15];[3];[10];[17];[4];[8];[5];[7]
C2	Financial Stability	[23];[22];[16];[15];[3];[10];[17];[4];[8];[5];[7];[20];[11]
C3	Quality	[23];[22];[16];[15];[3];[4];[5];[7];[11]
C4	Technical & Management Ability	[23];[15];[3];[10];[4];[8];[5];[7];[20];[11]
C5	Reputation & Health safety	[23];[3];[10];[17];[4];[8];[5];[7];[20];[11]
C6	Human Resources	[22];[16];[15];[17];[4];[8];[7];[11]

TABLE II DESCRIPTIONS OF SELECTION CRITERIA

Sl no	Criteria	Descriptions
C1	Experience	Considered as type, size and number of past projects completed
C2	Financial Stability	Consists of financial stability, credit ratings, banking arrangements and bonding.
C3	Quality	Refers quality control, quality assurance, tender quality and query response timeliness.
C4	Technical & Management Ability	Consists of qualification, experience and knowledge of staff, plant and equipment, past performance and quality, project management organisation.
C5	Reputation & Health safety	Considered as Relationship with sub-contractors and suppliers, Cooperation with contractors, health and safety system, records, performance and insurance policy, OSHA incidence rate.
C6	Human Resources	Refers number of staffs and numbers of direct workers available for the project, Labour and Equipment.

From the literature survey, six main criteria were deduced from 13 papers described in table 1. Four Contractors are considered in Indian context and the pairwise comparison of those criteria is carried away by construction industry expert. The hierarchy of the AHP analysis is followed in Figure 1. The description of each criteria is referred in Table II.

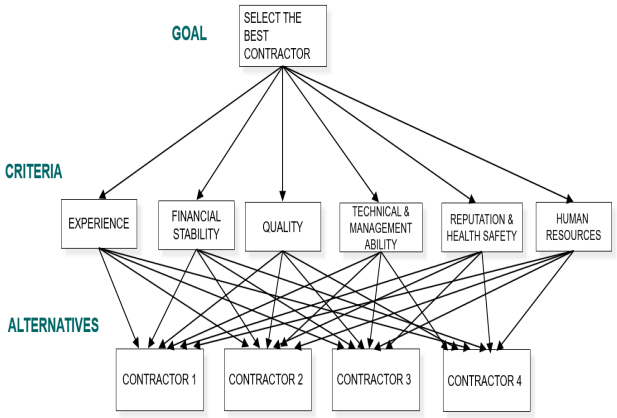
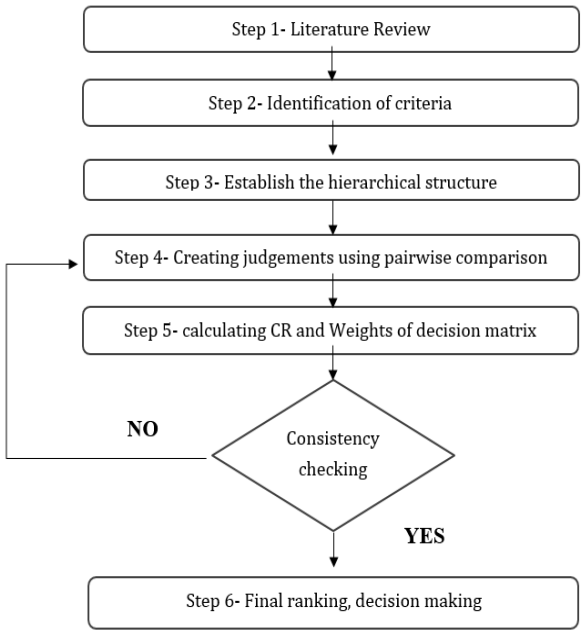


FIGURE 1 HIERARCHY OF CONTRACTOR SELECTION

III. METHODOLOGY



IV. RESULTS

TABLE III PAIRWISE COMPARISON FOR AHP PREFERENCE

Numerical ratings	Verbal judgement preference
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

TABLE IV RANDOM CONSISTENCY INDEX

Size of matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

TABLE V PAIRWISE COMPARISON MATRIX FOR CRITERIA

factor	experience	Financial stability	quality	Technical and management ability	Reputation and health safety	Human resources	Weighted criteria
experience	1	7	1/3	1/3	5	3	0.16
Financial stability	1/7	1	1/9	1/7	3	1/3	0.04
quality	3	9	1	1	7	7	0.34
Technical and management ability	3	9	1	1	7	9	0.35
Reputation and health safety	1/5	1/3	1/7	1/7	1	1/5	0.03
Human resources	1/3	3	1/7	1/9	5	1	0.08

λ max = 6.57 ; CI = 0.114 ; CR = 0.09 ≤ 0.1

TABLE VI PAIRWISE COMPARISON MATRIX FOR ALTERNATIVES

experience	Con1	Con2	Con3	Con4	Weighted criteria
Con1	1	4	3	7	0.54
Con2	0.25	1	0.33	3	0.13
Con3	0.33	3	1	5	0.27
Con4	0.14	0.33	0.20	1	0.06

CI = 0.040 ; CR = 0.044 ≤ 0.1

Financial stability	Con1	Con2	Con3	Con4	Weighted criteria
Con1	1	5	0.33	3	0.27
Con2	0.20	1	0.14	0.20	0.05
Con3	3	7	1	3	0.51
Con4	0.33	5	0.33	1	0.17

CI = 0.077 ; CR = 0.085 ≤ 0.1

quality	Con1	Con2	Con3	Con4	Weighted criteria
Con1	1	3	0.50	3	0.29
Con2	0.33	1	0.33	3	0.16
Con3	2	3	1	5	0.47
Con4	0.33	0.33	0.20	1	0.08

CI = 0.044 ; CR = 0.049 ≤ 0.1

Technical and management ability	Con1	Con2	Con3	Con4	Weighted criteria
Con1	1	0.50	0.33	0.14	0.08
Con2	2	1	0.14	3	0.19
Con3	3	7	1	3	0.50
Con4	7	0.33	0.33	1	0.22

CI = 0.055 ; CR = 0.061 ≤ 0.1

Reputation and health safety	Con1	Con2	Con3	Con4	Weighted criteria
Con1	1	5	0.33	0.20	0.14
Con2	0.20	1	0.11	0.14	0.04
Con3	3	9	1	2	0.46
Con4	5	7	0.50	1	0.35

CI = 0.076 ; CR = 0.084 ≤ 0.1

Human resources	Con1	Con2	Con3	Con4	Weighted criteria
Con1	1	0.20	3	5	0.23
Con2	5	1	5	7	0.60
Con3	0.33	0.20	1	2	0.10
Con4	0.20	0.14	0.50	1	0.06

CI = 0.064 ; CR = 0.071 ≤ 0.1

Decision Matrix

TABLE VII

Criteria weights	0.16	0.04	0.34	0.35	0.03	0.08
Factors	experience	Financial stability	quality	Technical & management ability	Reputation & health safety	Human resources
Con1	0.54	0.27	0.29	0.08	0.14	0.23
Con2	0.13	0.05	0.16	0.19	0.04	0.60
Con3	0.27	0.51	0.47	0.50	0.46	0.10
Con4	0.06	0.17	0.08	0.22	0.35	0.06

From Decision matrix (Table VII), the priority of the contractor is calculated, the final results obtained from AHP are expressed in the following Table:

TABLE VIII

Factors	Experience	Financial stability	quality	Technical & management ability	Reputation & health safety	Human resources	Priority value	Rank
Con 1	0.0864	0.0108	0.0986	0.0280	0.0042	0.0184	0.2464	2nd
Con 2	0.0208	0.0020	0.0500	0.0665	0.0012	0.0480	0.1969	3rd
Con 3	0.0432	0.0204	0.1598	0.1750	0.0138	0.0080	0.4202	1st
Con 4	0.0096	0.0068	0.0272	0.0770	0.0105	0.0048	0.1359	4th

V. CONCLUSIONS

Selecting a construction contractor is more complex process since contactor plays a crucial role in success or failure of any construction project. To maintain Cost quality and time, an effective selection process is required for the successful completion. Construction clients majorly accept the lowest bids from the prequalified contractor. This study used AHP method to select the contractor. 6 criteria were collected from 13 papers and four alternatives were also considered in this model. The results we got after performing AHP analysis appears in a way that the technical and management ability (0.35) and quality (0.34) are top two criteria and contractor 3 (0.4202) is likely to get the award of contract because of having higher priority value. Further research must focus on creating more no of sub criteria to the main criteria and using other MCDM methods for effective pairwise comparison.

REFERENCES

[1] Al-harbi, K. M. A. (1990). The analytic hierarchy process. European Journal of Operational Research, 45(2–3), 378. https://doi.org/10.1016/0377-2217(90)90209-t
[2] Alhazmi, O. B. T. (2000). P p s s m. June, 176–184.
[3] Alptekin, O., &Alptekin, N. (2017). Analysis of Criteria Influencing Contractor Selection Using TOPSIS Method. IOP Conference Series: Materials Science and Engineering, 245(6). https://doi.org/10.1088/1757-899X/245/6/062003
[4] Alzober, W., &Yaakub, A. R. (2014). Integrated Model for Selection the Prequalification Criteria of Contractor. Lecture Notes on Software Engineering, 2(3), 233–237. https://doi.org/10.7763/lnse.2014.v2.128
[5] Araujo, M. C. B., Alencar, L. H., &Mota, C. M. M. (2016). Contractor selection in construction industry: A multicriteria model. IEEE International Conference on Industrial Engineering and Engineering Management, 2016-Janua(December), 519–523. https://doi.org/10.1109/IEEM.2015.7385701
[6] Baha, B. Y., Wajiga, G. M., Blamah, N. V., &Adewumi, A. (2013). Analytical hierarchy process model for severity of risk factors associated with type 2 diabetes. Scientific Research and Essays, 8(39), 1906–1910. https://doi.org/10.5897/SRE12.665
[7] Chiang, F.-Y., F. Yu, V., &Luarn, P. (2017). Construction Contractor Selection in Taiwan Using AHP. International Journal of Engineering and Technology, 9(3), 211–215. https://doi.org/10.7763/ijet.2017.v9.972
[8] Dave, R., Parmar, K., Patel, B., &Prajapati, R. (2017). The Criteria for Contractors ' Selection and Bid Evaluation & Factors Affecting Bidding Strategy in Construction. International Journal of Scientific Development and Research, 2(4), 488–491.
[9] De Felice, F., &Petrillo, A. (2012). Hierarchical Model to Optimize Performance in Logistics Policies: Multi Attribute Analysis. Procedia - Social and Behavioral Sciences, 58, 1555–1564. https://doi.org/10.1016/j.sbspro.2012.09.1142
[10] Erdogan, S. A., Šaparauskas, J., &Turskis, Z. (2017). Decision Making in Construction Management: AHP and Expert Choice Approach. Procedia Engineering, 172(May), 270–276. https://doi.org/10.1016/j.proeng.2017.02.111
[11] Erdogan, S. A., Šaparauskas, J., &Turskis, Z. (2019). A multi-criteria decision-making model to choose the best option for sustainable construction management. Sustainability (Switzerland), 11(8). https://doi.org/10.3390/su11082239
[12] Fong, P. S. W., & Choi, S. K. Y. (2000). Final contractor selection using the analytical hierarchy process. Construction Management and Economics, 18(5), 547–557. https://doi.org/10.1080/014461900407356
[13] Gilleard, J. D., & Wong Yat-lung, P. (2004). Benchmarking facility management: Applying analytic hierarchy process. Facilities, 22(1), 19–25. https://doi.org/10.1108/02632770410517915
[14] Khalil, M. I. Al. (2002). Selecting the appropriate project delivery method using AHP. International Journal of Project Management, 20, 469–474.
[15] Krishna Rao, M. V., Kumar, V. S. S., &Rathish Kumar, P. (2018). Optimal Contractor Selection in Construction Industry: The Fuzzy Way. Journal of The Institution of Engineers (India): Series A, 99(1), 67–78. https://doi.org/10.1007/s40030-018-0271-1
[16] Paul, P., Salini, P. S., & Mohan, S. (2016). Selection of the most optimal contractor in Indian Construction Industry using Topsis and Extended Topsis model. 67–78.
[17] Razi, P. Z., Ramli, N. I., Ali, M. I., &Ramadhansyah, P. J. (2020). Selection of Contractor by Using Analytical Hierarchy Process (AHP). IOP Conference Series: Materials Science and Engineering, 712(1). https://doi.org/10.1088/1757-899X/712/1/012014

[18] Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. Mathematical Modelling, 9(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8
[19] Saaty, T. L. (2008). Relative Measurement and Its Generalization in Decision Making Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factors The Analytic Hierarchy/Network Process (To the Memory of my Beloved Friend Professor Sixto Rios Ga. Rev. R. Acad. Cien. Serie A. Mat. VOL, 102(2), 251–318. https://link.springer.com/content/pdf/10.1007%2FBF03191825.pdf
[20] Salama, M., Abd El Aziz, H., El Sawah, H., & El Samadony, A. (2006). Investigating the criteria for contractor's selection and bid evaluation in Egypt. Association of Researchers in Construction Management, ARCOM 2006 - Procs 22nd Annual ARCOM Conference, 1(September), 531–540.
[21] Shen, H. S., Sundstøl, F., & Ni, D. B. (1998). Studies on untreated and urea-treated rice straw from three cultivation seasons 2. Evaluation of straw quality through in vitro gas production and in sacco degradation measurements. Animal Feed Science and Technology, 74(3), 193–212. https://doi.org/10.1016/S0377-8401(98)00184-9
[22] Tiwari, D. P. D. S. (2015). Efficient Contractor Selection and Bid Evaluation Methods for Construction Industry in India. International Journal of Science and Research (IJSR), 4(8), 1027–1035. https://www.ijsr.net/archive/v4i8/SUB157527.pdf
[23] Zala, M. I., & Bhatt, R. B. (2011). An Approach of Contractor Selection By Analytical Heirarchy Process. National Conference on Recent Trends in Engineering & Technology An, May, 1–6

