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Contractor selection using Analytical Hierarchy Process.

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Abstract: *In the last two decades, there has been a steady increase in the range of methods used for the procurement of contracts. . It is based on this that automated methods are employed. Soft computing methods such as Analytic Hierarchy Process (AHP) have been employed to evaluate contractor biddings. The Analytical Hierarchy Process (AHP) helps to establish decision models through a process that contains both qualitative and quantitative components. Qualitatively, it helps to decompose a decision problem from the top overall goal to a set of manageable clusters, sub-clusters, and so on down to the final level that usually contains scenarios or alternatives. The clusters or sub-clusters can be forces, attributes, criteria, activities, objectives, etc. Quantitatively, it uses pair-wise comparison to assign weights to the elements at the cluster and sub-cluster levels and finally calculates 'global' weights for assessment taking place at the final level. Each pair-wise comparison measures the relative importance or strength of the elements within a cluster by using a ratio scale. One of the main functions of AHP is to calculate the consistency ratio to ascertain that the matrices are appropriate for analysis. Conceptually, AHP is only applicable to a hierarchy that assumes a unidirectional relation between decision levels. The top level of the hierarchy is the overall goal for the decision model, which decomposes to a more specific level of elements until a level of manageable decision criteria, is met .In this research, the AHP was used in evaluating ten contractors and then a contractor with the highest priority was selected. Further studies can be carried out using the same data set on other multicriteria decision analysis tool so that the efficiency of AHP can be established.*

Keywords: *AHP, Contractor, MCDA, Evaluation, Selection.*

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I. Introduction

Contractor selection is a major project success factor. Clients, assisted by streamlined guidelines, will be able to clearly identify their requirements and select the contractor that is best qualified to complete the project satisfactorily. This is an issue of extreme importance because a qualified contractor can ensure delivery on time, within budget and meeting the clients' expectations.

The Analytical Hierarchy Process (AHP) is a multi-objective decision-making approach that includes hierarchically arranging different objectives and sub-objectives, assessing their relative significance, making pair-wise comparisons, undertaking a structured analysis of available alternatives and thereby enabling more systematic decision making (Saaty, 2000).

This study undertakes the use of the AHP model on data of contractors on a particular contract awarded by the Akwa Ibom state government in Nigeria.

The evaluation of a contractor involves multiple criteria as stipulated in the Due Process Act in Nigeria. Multicriteria Decision Aid (MCDA) is a 7-tuple model depicted as M = {A, C, E, P, S, T,U} (Obot O.U. et al., 2019) where;

A = a set of alternatives
C = a set of criteria
E= a set of evaluation attributes
P = a list of preferences
S = a set of scales associated with the attributes
T = type of evaluation
U = a set of corresponding measures

Table 1: Saaty's 9 point scale (Saaty, 1994)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderately more importance	First element is moderately more important than second one
5	Strongly more important	First element is strongly more importance than second one
7	Very strongly more important	First element is very strongly more important than second one.
9	Extreme more important	First element is extremely more important than second one

2,4,6,8 are intermediate value. Based on this Table

AHP deals with linear relationship according to Baykasoglu and Durmusoglu (2014). On the strength of this, the study undertakes the use of AHP model using data of contractors on a particular contract awarded by the Akwa Ibom state government in Nigeria and suggested that further study can be carried out to ascertain the efficiency of AHP.

II. LITERATURE REVIEW

Kuo *et al*., (2015) used a four step algorithm for locating and selecting the Convenience Store (CVS). They extensively used AHP as it certainly has advantage over the conventional methods. The conventional methods provide a set of systematic steps for problem solving without involving the relationships among the decision factors. The authors proposed a new system decision support theory using fuzzy steps and AHP. The new theory consists of four steps. The first step consists of at least three levels. The first level represents the overall objective or focus of the problem. The second level includes the criteria for evaluating the alternatives, while the third level lists sub-criteria. In the case study that used this theory, 34 stores from across two districts were chosen and evaluated based on data obtained by the actual investigation. The second step consists of the weight determination. Here a questionnaire was prepared to compare the criteria pair wise. For ease in answering the questionnaire, a five point scale based on fuzzy logic was used although Saaty's nine-point scale is recommended. The third and final steps considered data collection and the decision- making. The CVS, which had the highest value, was selected to be the desired.

Korpela and Touminan (2010) presented an integrated approach to warehouse site selection process, where both quantitative and qualitative aspects were considered. The main objective of the warehouse site selection was to optimize the inventory policies, enable smooth and efficient transportation facilities, and decide on various aspects such as location and size of stocking points etc., as related to logistics systems design. The algorithm constitutes of four phases. The first and the second phase defined the problem to set goals for the decision making and identifies the sites and gather sufficient information to evaluate them respectively. The third phase consists of analysis where in AHP is used for qualitative analysis and to compare the alternatives based on intangible criteria. Cost analysis is also done in this phase to evaluate the impact of each alternatives on the total logistics cost. Fourth phase combines the outcome of both analyses to calculate and choose the site based on benefit and cost ratio. The authors described a case where a warehouse is selected.

Tam *et al*., (2014) used AHP in vendor selection of a telecommunication system, which is a complex, multi-person, multicriteria decision problem. They found AHP to be very useful in involving several decision makers with different conflicting objectives to arrive at a consensus decision. The decision process as a result is systematic and reduces time to select the vendor.

Jung *et al*., (2011) presented optimization models for selecting best software product among the alternatives of each module in the development of modular software product among the alternatives of each module in the development of modular system. A weight is given to the module using AHP based on access frequency of the module.

Ozden (2006) used the Analytical Network Process (ANP) in selecting knowledge management strategies. The study had the ability to incorporate feedback and interdependent relationships among criteria and alternatives. It gave valuable information and guidelines which hopefully will help the KM managers to evaluate KM strategies through their organization in an effective way. Six steps were used for the study which are: (a) Organizational optimization of knowledge resources such as human power, capital and managerial efforts. (b) Building an information technology (IT) infrastructure. (c) Structuring a learning organization. (d) Fostering a knowledge-oriented culture. (e) Establishing knowledge-based systems. (f) Executing KM projects and programs. The Weakness of the research was the inability of ANP to give a simple explanation of concepts and process to management there by making it challenging.

George *et al*., (2016) presented a model for evaluation of due process tenders in public procurement with the specific objective of developing a computational model for the evaluation of due process tenders in public procurement. The study combined the independent probability distributions of the technical and financial evaluation results of each bidder which then serve as decision support variable for determining the best responsive bidder. The study sampled data and necessary information gathered to aid in the formulation of the model. The model was validated; i.e. comparing outcome with what is obtainable in real life events. Scores were graded and data collected was simulated using MATLAB. Results of the simulation show that only ten bidders were evaluated into the "Excellent" grade. The weakness of the research was the lack of pair wise comparison.

Al Harbi (2003) presented a contractor selection using analytical hierarchy process. It has the objective of selecting the best contractor. The study comprises of four steps. The first step consists of the formation of a hierarchical structure that consists of at least three levels. The first level represents the overall objectives and focus of the problem. The second level includes the criteria for evaluating the alternatives, while the third level list sub-criteria. A questionnaire was prepared to compare the criteria pair-wise. The contractor with the highest priority or Eigen vector was selected. The study revealed that AHP can settle just direct models.

2.1The Design

The design comprises the database, the AHP module and the user interface. Each of the components is discussed in the following sections.

2.2 The Database

The database consists of the following:

a. Contractor Table comprises the contractor Identity, name of contractor, address, phone number, email address.

b. Experience Table comprises the experience of technical staff, professional status of contractors, innovations, management capability, and length of time in business.

c. Finance Table comprises the financial capability, credit worthiness, banking report and bid price

d. Miscellaneous Table consist of equipment adequacy, cooperate social responsibility, community service history, environmental health impact and current work load.

e. Quality Table consists of evidence of successful completion of project, quality control measure and safety measure.

2.3 The AHP module.

The AHP breaks down the contractor selection into hierarchy that comprises the Goal, Criteria, and the Alternatives, where pair wise comparison is done between Criteria on every data set with one another. This is depicted in Figure 1. The pair wise comparison is carried out by AHP using Criteria namely: Experience, Finance, Quality and Miscellaneous. The alternatives are A_1, A_2, A_3,…, A_n where n is the number of contractors bidding for the contract.

$A_1 \ldots A_n$ = $\text{Alternative}_1 \ldots \text{Alternative}_n$

The graphical representation of the model is shown in Figure1.

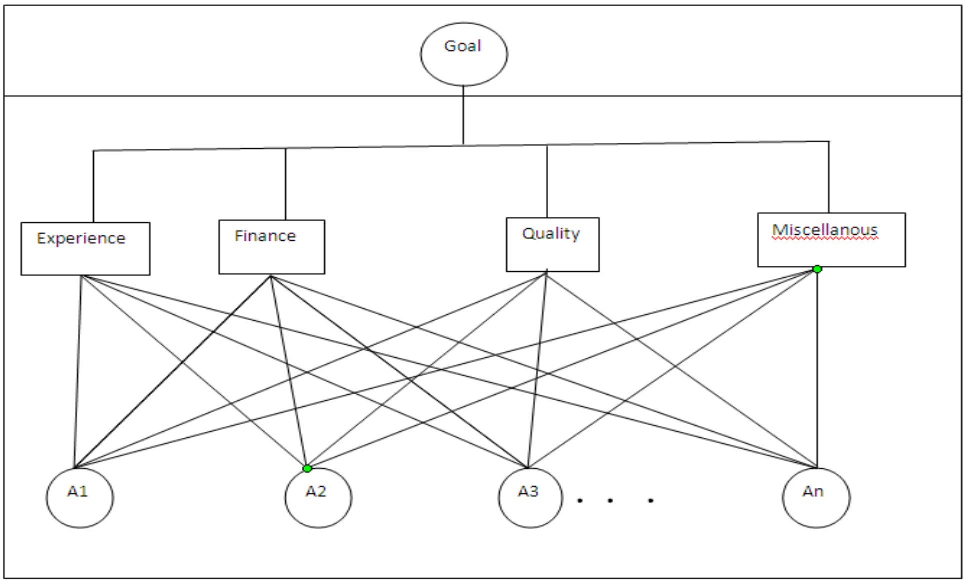

Figure 1: Model of the AHP for contractor selection.

2.4. Evaluation of the Criteria

The local priorities or weights of the criteria as assigned by an expert (Director of works Civil Engineering Directorate in the ministry of works) are as follows: Experience = 40%; Finance = 10%; Quality = 45%; Miscellaneous = 5%; Total = 100%.

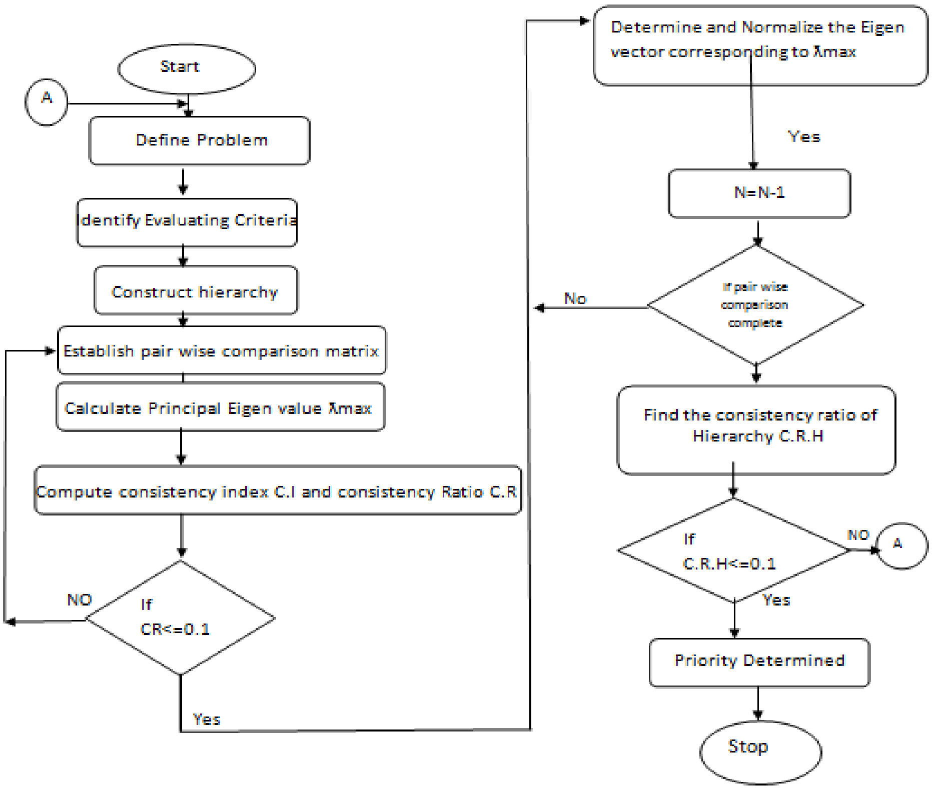

Figure 3: Flow diagram of AHP: Source: Uzoka et al (2011)

III. The Experiment and Results

The experiment was carried out with Super Decision software as the computation and analysis tool. Figure 4 depict the data capturing environment in a GUI of super decision.

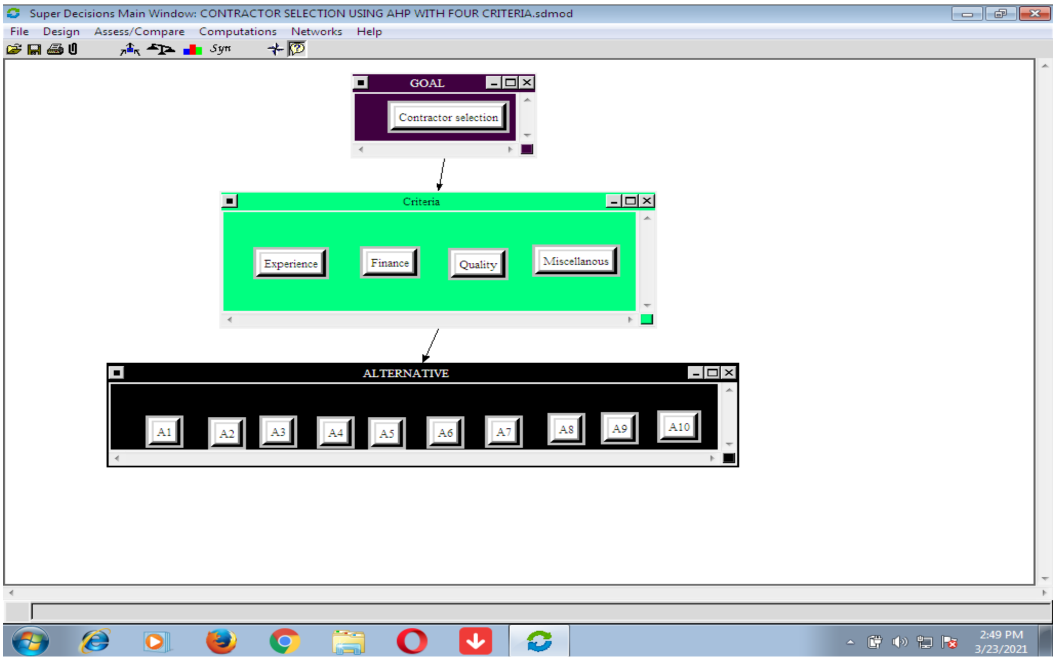

Figure 4: Super Decision GUI for AHP

Table 2 Pair wise comparison for Criteria

Contractor selection	Experience	Finance	Quality	Miscellaneous
Experience	1.00	**4**	1/3	8
Finance	¼	1.00	1/7	2
Quality	3	7	1.00	9
Miscellaneous	1/8	1/2	1/9	1.00
Sum	**4.375**	**12.5**	**1.5873**	**20**

Table 3: Normalized or Synthesized matrix for the criteria

Contractor selection	Experience	Finance	Quality	Miscellaneous	Eigen vector/ priority
Experience	0.2286	0.3200	0.2100	0.4000	0.2897
Finance	0.0571	0.0800	0.0900	0.1000	0.0818
Quality	0.6857	0.5600	0.6300	0.4500	0.5814
Miscellaneous	0.0286	0.0400	0.0700	0.0500	0.0471
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Table 4: Priorities as factors

Contractor selection	Experience	Finance	Quality	Miscellaneous
Criteria weights	0.2897	0.0818	0.5814	0.0471
Experience	1.00	4	1/3	8
Finance	¼	1.00	1/7	2
Quality	3	7	1.00	9
Miscellaneous	1/8	½	1/9	1.00

Table 5 shows the calculated weighted column and weighted sum. The weighted column is obtained by replacing the value of a comparison of a criterion with itself with the criteria's weight while the weighted sum is the sum of each row in the table. Table 6 shows the calculation of λmax. To obtain λmax, the weighted sum is divided by priority and the total is divided by the number of criteria n.

Table 5: calculated weighted columns and weighted sum.

	Experience	Finance	Quality	Miscellaneous	Weighted sum
Experience	0.2897	0.3200	0.2100	0.4000	1.2197
Finance	0.0571	0.0818	0.0900	0.1000	0.1000
Quality	0.6857	0.5600	0.5814	0.4500	0.4500
Miscellaneous	0.0286	0.0400	0.0700	0.0471	0.0471

Table 6: Calculation of λmax.

Weighted sum	Priority	Derived priority
1.2197	0.2897	4.2102
0.3289	0.0818	4.0208
2.2771	0.5814	3.9166
0.1857	0.0471	3.9427
	Total	**16.0903**

$$\lambda max = total\ derived\ priority/n$$
$$= 16.0903/4$$
$$= 4.0226.$$

$$C.I = (\lambda max - n)/\ (n - 1)$$

Where n is the number of compared elements (in this case n=4).

Therefore $C.I = (4.0226 - 4)\ /(\ 4 - 1) = 0.0226/3$

$$= 0.0075$$
$$C.R = C.I/\ RI = 0.0075/0.9$$
$$= 0.0083$$

Since CR<0.1, we can assume that our judgment matrix is reasonably consistent. So we can continue with the process of decision making using AHP. Table 7 shows the comparison of alternatives based on the four criteria and Pair wise comparison matrix for criterion "Experience" is shown on table 8.

Table 7: The comparison of "Alternatives" for the four criteria.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Experience	Excellent	Average	Below average	Above average	Above average	Average	Excellent	Below average	Average	Average
Finance	100m	20m	25m	40m	50m	60m	15m	10m	30m	5m
Quality	Above average	Average	Excellent	Below average	Below average	Average	Excellent	Above average	Average	Below average
Miscellaneous	Above average	Above average	Below average	Average	Excellent	Above average	Below average	Average	Excellent	Average

The datasets were obtained from the Akwa Ibom State ministry of works on a contract that have already been executed by a contractor for the Akwa Ibom State Government.

Table 8: Pair wise comparison matrix for criterion "Experience".

Experience	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	5	9	3	3	5	1	9	5	5
A2	1/5	1	3	1/3	1/3	3	1/5	1/3	1	1
A3	1/9	1/3	1	1/5	1/5	1/3	1/9	1	1/3	1/3
A4	1/3	3	5	1	1	3	1/3	5	3	3
A5	1/3	3	5	1	1	3	1/3	5	3	3
A6	1/5	1/3	1/3	1/3	1/3	1	1/5	3	1	1
A7	1	5	9	3	3	5	1	9	5	5
A8	1/9	3	1	1/5	1/5	1/3	1/9	1	1/3	1/3
A9	1/5	1	3	1/3	1/3	1	1/5	3	1	1
A10	1/5	1	3	1/3	1/3	1	1/5	3	1	1
Sum	3.68	22.67	39.33	9.72	9.72	22.66	3.68	39.33	20.66	20.66

Table 9: Normalized matrix for criterion "Experience"

Experience	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Eigen vector (Priority)
A1	0.27	0.22	0.23	0.31	0.31	0.22	0.27	0.23	0.24	0.24	0.254
A2	0.05	0.04	0.08	0.3	0.03	0.13	0.05	0.008	0.05	0.05	0.0788
A3	0.03	0.01	0.03	0.02	0.02	0.01	0.03	0.03	0.02	0.02	0.022
A4	0.09	0.13	0.13	0.01	0.01	0.13	0.09	0.13	0.15	0.15	0.102
A5	0.09	0.13	0.13	0.10	0.10	0.13	0.09	0.13	0.15	0.15	0.12
A6	0.05	0.01	0.008	0.03	0.03	0.04	0.05	0.08	0.05	0.05	0.0398
A7	0.27	0.22	0.23	0.31	0.31	0.22	0.27	0.23	0.24	0.24	0.254
A8	0.03	0.13	0.03	0.02	0.02	0.01	0.030	0.03	0.02	0.02	0.034
A9	0.05	0.04	0.08	0.03	0.03	0.04	0.05	0.08	0.05	0.05	0.05
A10	0.05	0.04	0.08	0.03	0.03	0.04	0.05	0.08	0.05	0.05	0.05

Table 10: Pair wise comparison matrix for criterion "Finance"

Finance	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	5	4	3	2	2	5	9	3	9
A2	1/5	1	2	½	1/3	1/3	2	2	2	4
A3	¼	1/2	1	½	½	½	2	3	2	5
A4	1/3	2	2	1	½	½	3	4	2	8
A5	½	3	2	2	1	½	3	5	2	9
A6	½	3	2	2	2	1	4	6	2	9
A7	1/5	½	½	1/3	1/3	¼	1	2	½	3
A8	1/9	½	1/3	¼	1/5	1/6	½	1	1/3	2
A9	1/3	1/2	2	½	½	1/3	2	3	1	6
A10	1/9	1/4	1/5	1/8	1/9	1/9	1/3	1/2	1/6	1
Sum	3.54	16.25	16.03	10.21	7.48	5.69	22.83	35.50	14.50	56

Table 11: Normalized matrix for criterion "Finance"

Finance	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Eigen vector (Priority)
A1	0.28	0.31	0.25	0.29	0.27	0.35	0.22	0.25	0.21	0.16	0.259
A2	0.06	0.06	0.12	0.05	0.04	0.06	0.09	0.06	0.14	0.07	0.075
A3	0.07	0.03	0.06	0.05	0.07	0.09	0.09	0.08	0.03	0.09	0.066
A4	0.09	0.12	0.12	0.10	0.07	0.09	0.13	0.11	0.14	0.14	0.111
A5	0.14	0.18	0.12	0.20	0.13	0.09	0.13	0.14	0.14	0.16	0.143
A6	0.14	0.18	0.12	0.20	0.27	0.18	0.18	0.17	0.21	0.16	0.185
A7	0.06	0.03	0.03	0.03	0.04	0.04	0.04	0.06	0.03	0.05	0.041
A8	0.04	0.03	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.04	0.028
A9	0.09	0.03	0.12	0.05	0.07	0.06	0.09	0.08	0.07	0.11	0.077

A10	0.03	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.015

Table 12: Pair wise comparison matrix for criterion "Quality"

Quality	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	1/3	1/3	5	5	3	5	1	3	5
A2	1/3	1	1/5	3	3	1	1/5	1/3	1	3
A3	3	5	1	7	7	5	1	3	5	7
A4	5	1/3	1/7	1	1	1/3	1/7	1/5	1/3	1
A5	1/5	1/3	1/7	1	1	1/3	1/7	1/5	1/3	1
A6	1/3	1	1/5	3	3	1	1/5	1/3	1	3
A7	1/5	5	1	7	7	5	1	3	5	7
A8	1	3	1/3	5	5	3	1/3	1	3	5
A9	1/3	1	1/5	3	3	1	1/5	1/3	1	3
A10	5	1/3	1/7	1	1	1/3	1/7	1/5	1/3	1
Sum	16.40	17.33	3.70	36	36	20	8.35	9.59	19.99	31.2

Table 13: Nrmalized matrix for criterion "Quality"

Quality	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Eigen vector (Priority)
A1	0.06	0.17	0.09	0.14	0.14	0.15	0.60	0.10	0.15	0.0.006	0.1606
A2	0.02	0.06	0.05	0.08	0.08	0.05	0.02	0.03	0.05	0.10	0.054
A3	0.18	0.29	0.27	0.19	0.19	0.25	0.12	0.31	0.25	0.22	0.2274
A4	0.18	0.02	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.041
A5	0.18	0.02	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.041
A6	0.02	0.06	0.05	0.08	0.08	0.05	0.02	0.03	0.05	0.01	0.054
A7	0.01	0.29	0.27	0.19	0.19	0.25	0.12	0.31	0.25	0.22	0.21
A8	0.06	0.17	0.09	0.14	0.14	0.15	0.04	0.10	0.15	0.16	0.134
A9	0.02	0.06	0.05	0.08	0.08	0.05	0.02	0.03	0.050	0.10	0.054
A10	0.18	0.02	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.041

Table 14: Pair wise comparison matrix for criterion "Miscellaneous"

Miscellaneous	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	1	5	3	1/3	1	5	3	1/3	3
A2	1	1	5	3	1/3	1	5	3	1/3	3
A3	1/5	1/5	1	1/3	1/7	1/5	1	1/3	1/7	1/3
A4	1/3	1/3	3	1	1/5	1/3	3	1	1/5	1
A5	3	3	7	5	1	3	7	5	1	5
A6	1	1	5	3	1/3	1	5	3	1/3	3
A7	1/5	1/5	1	1/3	1/7	1/5	1	1/3	1/7	1/3
A8	1/3	1/3	3	1	1/5	1/3	3	1	1/5	1
A9	3	3	7	5	1	3	7	5	1	5
A10	1/3	1/3	3	1	1/5	1/3	3	1	1/5	1
Sum	10.39	10.39	40	22.66	3.88	10.39	40	22.66	3.88	22.66

Table 15: Normalized matrix for criterion "Miscellaneous"

Miscellaneous	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Eigen vector (Priority)
A1	0.10	0.10	0.13	0.13	0.09	0.10	0.13	0.13	0.09	0.13	0.113
A2	0.10	0.10	0.13	0.13	0.09	0.10	0.13	0.13	0.09	0.13	0.113
A3	0.02	0.02	0.03	0.01	0.04	0.02	0.03	0.01	0.04	0.01	0.023
A4	0.03	0.03	0.08	0.04	0.05	0.03	0.08	0.040	0.05	0.04	0.044
A5	0.29	0.29	0.18	0.22	0.26	0.24	0.18	0.22	0.26	0.22	0.236
A6	0.10	0.10	0.13	0.13	0.09	0.10	0.13	0.13	0.09	0.13	0.113
A7	0.02	0.02	0.03	0.01	0.04	0.02	0.03	0.01	0.04	0.01	0.023
A8	0.03	0.03	0.08	0.04	0.05	0.03	0.08	0.04	0.05	0.04	0.047
A9	0.29	0.29	0.18	0.22	0.26	0.29	0.19	0.22	0.26	0.22	0.241
A10	0.03	0.03	0.08	0.04	0.05	0.03	0.08	0.04	0.05	0.04	0.047

Values in Table 16 are Eigen vectors or priorities of the four criteria of Table 3.

Table 16: Overall priority vectors

Experience	Finance	Quality	Miscellaneous
0.2897	0.0818	0.5814	0.0471

Let overall priority vector for individual criteria be equal to L_i, priority vector for each alternative be equal to P_i. Therefore final priority is equal to $\sum_{i=1}^{n} l_i P_i$. The values for this on a particular Contract is presented in Table 17

Table 17: Priority vector for various alternatives.

	Experience	Finance	Quality	Miscellaneous	Final Priority vector
A1	0.254	0.259	0.1606	0.113	0.1934
A2	0.0788	0.075	0.054	0.113	0.0654
A3	0.022	0.066	0.2274	0.023	0.1451
A4	0.102	0.111	0.041	0.044	0.0645
A5	0.12	0.143	0.024	0.236	0.0715
A6	0.0398	0.185	0.054	0.113	0.0624
A7	0.254	0.041	0.21	0.023	0.2001
A8	0.034	0.028	0.134	0.047	0.0923
A9	0.05	0.077	0.054	0.241	0.0635
A10	0.05	0.015	0.041	0.047	0.0418

Based on Table 17, the best contractor is alternative 7 (A7) with priority vector of 0.2001, the highest of the 10 alternatives.

IV. Conclusion And Recommendation For Future Work

The paper presents the procedure used in selecting a contractor from a list of contractors applying for a contract using AHP.

Further studies should be embarked upon by comparing the AHP with other multicriteria decision analysis tools to ascertain the efficiency of AHP.

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