



APPLICATION OF THE ANALYTICAL HIERARCHY PROCESS (AHP) IN THE SELECTION OF CONTRACTORS/CONSULTANTS

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Abstract

Present paper review about all the aspects of selection of contractor with the Analytical Hierarchy Process (AHP) as a potential decision making method for use in project management. Given that contractor plays a critical role in any construction project, contractor selection constitutes key decision. It is a very important part of project it must be well experienced. A hierarchical structure is constructed for the prequalification criteria. By applying the AHP, the prequalification criteria can be prioritized and a descending order list of contractor can be made in order to select the best contractor to perform the project. A sensitivity analysis can be performed to check the sensitivity of the final decisions to minor changes in judgments. This review presents group decision-making using the AHP. The AHP implementation steps can be simplified by using the computer programming. It is hoped that this will encourage the application of the AHP by project management professionals.

Keywords: Analytical Hierarchy Process (AHP), multiple criteria, contractor/consultant.

Introduction

The prequalification procedure, i.e. the elimination of incompetent contractors from the selection process according to a predetermined set of criteria, is one of the currently utilized procedures worldwide for contractor selection Palaneeswaran and Kumaraswamy[14], Topcu

[22]. Since "it is increasingly recognized that the lowest bid is not necessarily the most economical solution in the long term" Kumaraswamy[11], both the selected criteria and a sound evaluation methodology are essential factors in any contractor selection procedure, including prequalification, in order to assure the ability of selected contractor to achieve simultaneously time, cost, and quality specifications.

The Analytical Hierarchy Process (AHP) is a decision aiding method developed by Saaty [15, 16, 17, 18, 19, and 20]. It aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision-maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process [15]. Since a decision-maker bases judgments on knowledge and experience, then makes decisions accordingly, the AHP approach agrees well with the behavior of a decision-maker. The strength of this approach is that it organizes tangible and intangible factors in a systematic way, and provides a structured yet relatively simple solution to the decision-making problems [19]. In addition, by breaking a problem down in a logical fashion from the large, descending in gradual steps, to the smaller and smaller, one is able to connect, through simple paired comparison judgments, the small to the large.

The objective of this paper is to introduce the application of the AHP in project management. The review the concepts and applications of the multiple criteria decision analysis, the AHP's implementation steps, and demonstrate AHP application on the contractor prequalification. It

is hoped that this will encourage its application in the whole area of project management.

Literature Survey

Project managers are faced with decision environments and problems in projects that are complex. The elements of the problems are numerous, and the inter-relationships among the elements are extremely complicated. Relationships between elements of a problem may be highly nonlinear; changes in the elements may not be related by simple proportionality. Furthermore, human value and judgment systems are integral elements of project problems. Therefore, the ability to make sound decisions is very important to the success of a project. In fact, Schuyler [21] makes it a skill that is certainly near the top of the list of project management skills, and notices that few of us have had formal training in decision making.

Multiple criteria decision-making (MCDM) approaches are major parts of decision theory and analysis. They seek to take explicit account of more than one criterion in supporting the decision process [3]. The aim of MCDM methods is to help decision-makers learn about the problems they face, to learn about their own and other parties' personal value systems, to learn about organizational values and objectives, and through exploring these in the context of the problem to guide them in identifying a preferred course of action [3]. In other words, MCDA is useful in circumstances which necessitate the consideration of different courses of action, which cannot be evaluated by the measurement of a simple, single dimension [3].

Hwang and Yoon [9] published a comprehensive survey of multiple attribute decision making methods and applications. Two types of the problems that are common in the project management that best fit MCDA models are evaluation problems and design problems. The evaluation problem is concerned with the evaluation of, and possible choice between, discretely defined alternatives. The design problem is concerned with the identification of a preferred alternative from a potentially infinite set of alternatives implicitly defined by a set of constraints [3].

Belton [2] compared AHP and a simple multi-attribute value (MAV), as two of the multiple criteria approaches. She noticed that both approaches have been widely used in practice

which can be considered as a measure of success. She also commented that the greatest weakness of the MAV approach is its failure to incorporate systematic checks on the consistency of judgments. She noticed that for large evaluations, the number of judgments required by the AHP can be somewhat of a burden.

A number of criticisms have been launched at AHP over the years. Watson and Freeling [24] said that in order to elicit the weights of the criteria by means of a ratio scale, the method asks decision-makers meaningless questions, for example: 'Which of these two criteria is more important for the goal? By how much?' Belton and Gear [4] and Dyer [5] pointed out that this method can suffer from rank reversal (an alternative chosen as the best over a set of X, is not chosen when some alternative, perhaps an unimportant one, is excluded from X). Belton and Gear [4] attacked the AHP on the grounds that it lacks a firm theoretical basis. They commented that the AHP is based upon a firm theoretical foundation and, as examples in the literature and the day-to-day operations of various governmental agencies, corporations and consulting firms illustrate, the AHP is a viable, usable decision-making tool.

The Analytic Hierarchy Process (AHP)

Developed by T.L. Saaty, the Analytic Hierarchy Process (AHP) is a multi criteria decision aiding method based on a solid axiomatic foundation. AHP is a systematic procedure for dealing with complex decision making problems in which many competing alternatives (projects, actions, scenarios) exist. Forman and Selly [8], Saaty and Vargas [19], Saaty [17], Saaty [20], Vargas [25]. The alternatives are ranked using several quantitative and/or qualitative criteria, depending on how they contribute in achieving an overall goal

Table : Pairwise comparison matrix A of alternatives P_i with respect to criterion K

K	P1	P2	...	Pn
P1	1	a ₁₂	...	a _{1n}
P2	1/a ₁₂	1	...	a _{2n}
.
.
.
Pn	1/a _{1n}	1/a _{2n}	...	1

AHP is based on a hierarchical structuring of the elements that are involved in a decision problem. The hierarchy incorporates the knowledge, the experience and the intuition of the decision-maker for the specific problem. The simplest hierarchy consists of three levels. On the top of the hierarchy lies the decision's goal. On the second level lie the criteria by which the alternatives (third level) will be evaluated. In more complex situations, the main goal can be broken down into sub-goals or/and a criterion (or property) can be broken down into sub-criteria. People who are involved in the problem, their goals and their policies can also be used as additional levels.

The hierarchy evaluation is based on pairwise comparisons. The decision maker compares two alternatives A_i and A_j with respect to a criterion and assigns a numerical value to their relative weight. The result of the comparison is expressed in a fundamental scale of values ranging from 1 (A_i, A_j contribute equally to the objective) to 9 (the evidence favoring A_i over A_j is of the highest possible order of affirmation). Given that the n elements of a level are evaluated in pairs using an element of the immediately higher level, an $n \times n$ comparison matrix is obtained (Table). If the immediate higher level includes m criteria, m matrixes will be formed. In every comparison matrix all the main diagonal elements are equal to one ($a_{ij} = 1$) and two symmetrical elements are reciprocals of each other ($a_{ij} \times a_{ji} = 1$).

Since $n(n-1)/2$ pairwise comparisons are required to complete a comparison matrix, $mn(n-1)/2$ judgments must be made to complete the evaluation of the n elements of a level using as criterion the m elements of the immediately higher level. For large evaluations, the number of comparisons required by the AHP can be somewhat of a burden. For example, if 5 bids are to be evaluated, in a model containing 20 criteria, at least $10 \times 20 = 200$ judgments must be made.

The decision-maker's judgments may not be consistent with one another. A comparison matrix is consistent if and only if $a_{ij} \times a_{jk} = a_{ik}$ for all i, j, k . AHP measures the in-consistency of judgments by calculating the consistency index CI of the matrix

$$\lambda_{max} - n$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad \text{-----eq. 1}$$

where λ_{max} is the principal Eigen value of the matrix.

The consistency index CI is in term divided by the *average random consistency index* RI to obtain the *consistency ratio* CR .

$$CR = \frac{CI}{RI} \quad \text{-----eq. 2}$$

The RI index is a constant value for an $n \times n$ matrix, which has resulted from a computer simulation of $n \times n$ matrices with random values from the 1-9 scale and for which $a_{ij} = 1/a_{ji}$. If CR is less than 5% for a 3×3 matrix, 9% for a 4×4 matrix, and 10% for larger matrices, then the matrix is consistent.

Once its values are defined, a comparison matrix is normalized and the local priority (the relative dominance) of the matrix elements with respect to the higher level criterion is calculated. The overall priority of the current level elements is calculated by adding the products of their local priorities by the priority of the corresponding criterion of the immediately higher level. Next, the overall priority of a current level element is used to calculate the local priorities of the immediately lower level which is use it as a criterion, and so on, till the lowest level of the hierarchy is reached. The priorities of the lowest level elements (alternatives) provide the relative contribution of the elements in achieving the overall goal.

Note that the AHP also allows group decision making. Each member of the group provides separately his own judgments according to his experience, values and knowledge. If the group has achieved consensus on some judgment, only that judgment is registered. If during the process it is impossible to arrive at a consensus on a judgment, the group may use some voting technique, or may choose to take the "average" of the judgments, that is the geometric mean of the judgments. The group may decide to give all group members equal weight, or the group members could give them different weights that reflect their position in the project.

Saaty [15-20] 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-maker's viewpoint) through the intermediate levels (criteria on which sub-sequent levels depend) to the lowest level which usually contains the list of alternatives.
 3. Construct a set of pair-wise comparison matrices (size $n \times n$) 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 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, λ_{max} , to calculate the consistency index, CI as follows: $CI = (\lambda_{max} - n) / (n - 1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.
 7. Steps 3-6 are performed for all levels in the hierarchy.

Table 1

Pair-wise comparison scale for AHP preferences [15 - 20]

Numerical rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
	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 2

Average random consistency (RI) [15 - 20]

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

Group decision making

The AHP allows group decision making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve it by the AHP steps. Brainstorming and sharing ideas and insights

(inherent in the use of Expert Choice in a group setting) often leads to a more complete representation and understanding of the issues. The following suggestions and recommendations are suggested in the Expert Choice software manual.

1. Group decisions involving participants with common interests are typical of many organizational decisions. Even if we assume a group with common interests, individual group members will each have their own motivations and, hence, will be in conflict on certain issues. Nevertheless, since the group members are 'supposed' to be striving for the same goal and have more in common than in conflict, it is usually best to work as a group and attempt to achieve consensus. This mode maximizes communication as well as each group member's stake in the decision.
2. An interesting aspect of using Expert Choice is that it minimizes the difficult problem of 'group-think' or dominance by a strong member of the group. This occurs because attention is focused on a specific aspect of the problem as judgments are being made, eliminating drift from topic to topic as so often happens in group discussions. As a result, a person who may be shy and hesitant to speak up when a group's discussion drifts from topic to topic will feel more comfortable in speaking up when the discussion is organized and attention turns to his area of expertise. Since Expert Choice reduces the influences of group-think and dominance, other decision processes such as the well known Delphi technique may no longer be attractive. The Delphi technique was designed to alleviate groupthink and dominance problems. However, it also inhibits communication between members of the group. If desired, Expert Choice could be used within the Delphi context.
3. When Expert Choice is used in a group session, the group can be shown a hierarchy that has been prepared in advance. They can modify it to suit their understanding of the problem. The group defines the issues to be examined and alters the prepared hierarchy or constructs a new hierarchy to cover all the important issues. A group with widely varying perspectives can feel comfortable with a complex issue, when the issue is broken down into different levels. Each member can present his own concerns and definitions. Then, the group can cooperate

in identifying the overall structure of the issue. In this way, agreement can be reached on the higher-order and lower-order objectives of the problem by including all the concerns that members have expressed.

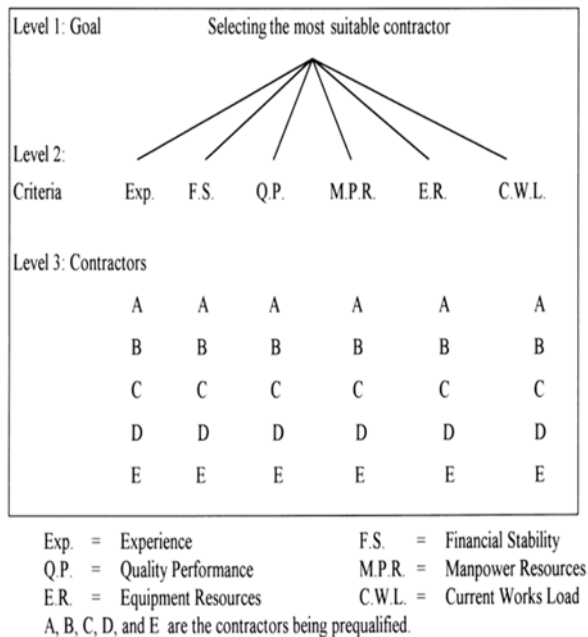
The group would then provide the judgments. If the group has achieved consensus on some judgment, input only that judgment. If during the process it is impossible to arrive at a consensus on a judgment, the group may use some voting technique, or may choose to take the 'average' of the judgments. The group may decide to give all group members equal weight, or the group members could give them different weights that reflect their position in the project. All calculations are done automatically on the computer screen.

4. The Group Meeting: While Expert Choice is an ideal tool for generating group decisions through a cohesive, rigorous process, the software does not replace the components necessary for good group facilitation. There are a number of different approaches to group decision-making, some better than others. Above all, it is important to have a meeting in which everyone is engaged, and there is buy-in and consensus with the result.

A simplified project example of contractor pre-qualification will be demonstrated here for illustration purposes. To simplify calculations, the factors that will be used in the project example for prequalification are experience, financial stability, quality performance, manpower resources, equipment resources, and current workload. Other criteria can be added if necessary, together with a suggestion that a computer be used to simplify calculations.

Table 1 Pair wise comparison scale for AHP preference [11-14] given by saaty for verbal judgment of preferences with some numerical ratings.

By following the AHP procedure, the hierarchy of the problem can be developed as shown in box below. For step 3, the decision-makers have to indicate preferences or priority for each decision alternative in terms of how it contributes to each criterion.



Expected Outcomes

Project management involves complex decision making situations that require discerning abilities and methods to make sound decisions. It has presented the AHP as a decision-making method that allows the consideration of multiple criteria. An example of contractors/ consultants prequalification can be created to demonstrate AHP application in project management. Contractors and or Consultants prequalification involve criteria and priorities that are determined by owner requirements and preferences as well as the characteristics of the individual executing agency. AHP allows group decision-making.

Conclusion

The exercise of prequalification on International bidding of major projects is done. The above process will be very much helpful for taking the decision on multi criterion basis. The method can be implemented on computer for getting fast decision. However the method can be used by financial Agencies to check proposals submitted by borrowing agencies to finalize the contractors and or consultants for prequalification.

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