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Application of the AHP in project management

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Abstract

This paper presents the Analytical Hierarchy Process (AHP) as a potential decision making method for use in project management. The contractor prequalification problem is used as an example. A hierarchical structure is constructed for the prequalification criteria and the contractors wishing to prequalify for a project. By applying the AHP, the prequalification criteria can be prioritized and 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. The paper presents group decision-making using the AHP. The AHP implementation steps will be simplified by using the 'Expert Choice' professional software that is available commercially and designed for implementing AHP. It is hoped that this will encourage the application of the AHP by project management professionals. © 2000 Elsevier Science Ltd and IPMA. All rights reserved.

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1. Introduction

The Analytical Hierarchy Process (AHP) is a decision-aiding method developed by Saaty [24–27]. 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 [24]. 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 [29]. 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 paper will briefly review the concepts and applications of the multiple criteria decision analysis, the AHP's implementation steps, and demonstrate AHP application on the contractor prequalification problem. It is hoped that this will encourage its application in the whole area of project management.

2. Multiple criteria decision analysis (MCDA)

Project managers are faced with decision environments and problems in projects that are complex. The elements of the problems are numerous, and the interrelationships 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 judgement systems are integral elements of project problems [15]. Therefore, the ability to make sound decisions is very important to the success of a project. In fact, Schuyler [28] 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.

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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 [5]. 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 [5,12,20,32,34,35]. In other words, MCDA is useful in circumstances which necessitate the consideration of different courses of action, which can not be evaluated by the measurement of a simple, single dimension [5].

Hwang and Yoon [14] 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 [5].

3. The analytical hierarchy process (AHP)

Belton [4] 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 [33] 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 [6] and Dyer [9] 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 [7] and Dyer and Wendel [10] attacked the AHP on the grounds that it lacks a firm theoretical basis. Harker and Vargas [13] and Perez [19] discussed these major criticisms and proved with a theoretical work and examples that they are not valid. 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.

Saaty [24–27] 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 subsequent 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 eigenvalue, λ_{max}, to calculate the consistency index, CI as follows: $\mathrm{CI} = (\lambda_{max} - n)/(n-1)$, 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 [24–27]

Numerical rating	Verbal judgments 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

Fortunately, there is no need to implement the steps manually. Professional commercial software, Expert Choice, developed by Expert Choice, Inc. [11], is available on the market which simplifies the implementation of the AHP's steps and automates many of its computations.

4. 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 [11].

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 'groupthink' 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 groupthink 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.

Table 2
Average random consistency (RI) [24–27]

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

5. Application of the AHP in project management

In this paper, contractor prequalification (an evaluation problem) will be used as an example of the possibility of using AHP in project management. Prequalification is defined by Moore [17] and Stephen [30] as the screening of construction contractors by project owners or their representatives according to a predetermined set of criteria deemed necessary for successful project performance, in order to determine the contractors' competence or ability to participate in the project bid. Another formal definition by Clough [8] is that prequalification means that 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.

A number of studies have focused on contractor prequalification. Lower [16] reviewed the guidelines of the prequalification process in different States in the US. He also discussed how prequalification can provide the owner with appropriate facilities representing an effective and efficient expenditure of money.

Nguyen [18] argued that the prequalification process remains largely an art where subjective judgment, based on individual experience, becomes an essential part of the process.

Russel and Skibniewski [22] mentioned that the actual process of contractor prequalification had received little attention in the past. Russel and Skibniewski [23] tried to describe the contractor prequalification process along with the decision-making strategies and the factors that influence the process. They reported five methods that they found in use for contractor prequalification: dimensional weighting, two-step prequalification, dimension-wide strategy, prequalification formula, and subjective judgment.

In the *dimensional weighting method* [22], the choice selection criteria and their weights are dependent on the owner. All contractors are ranked on the basis of the criteria. A contractor's total score is calculated by summing their ranks multiplied by the weight of the respective criteria. Then, contractors are ranked on the basis of their total scores, and this rank order of the contractors is used for prequalification. The problem with this method is deciding the weight of the respective criteria, something for which the AHP does provide a methodology.

The *two-step prequalification method* [22] is a modification of the dimensional weighting method. In the first step, screening of contractors is done on preliminary factors. They must get through this step to be eligible for the second phase of prequalification. In the second step, the dimensional weighting technique is used for more specialized factors. This method is useful for quick removal of ineligible candidates. This is consistent with the 'elimination by aspect' method suggested by Tversky [31].

In *dimension-wide strategy method* [22], a list of the most important prequalification criteria is developed in descending order depending on how important the criteria is. Contractors are then evaluated on these factors. If a candidate fails to meet any of the criteria, the candidate is removed from the prequalification process. The method continues until contractors are measured on all criteria [18].

The *prequalification formula method* [22] prequalifies contractors on the basis of a formula that calculates the maximum capability of a contractor. The maximum capability is defined as the maximum amount of uncompleted work in progress that the contractor can have at any one time. In this method, the contractor's prequalification is dependent on the contractors maximum capability, current uncompleted work and the size of the project under consideration. If the difference between the contractor's capability and current uncompleted work is less than the project works, then the contractor is removed from the bidding process.

The previous methods were devised with a common goal to introduce an efficient and systematic procedure for contractor prequalification. In some instances, owners may base their contractor selection decision on *subjective judgment* and not on a structured approach. The judgment may be influenced by owner biases, such as previous experience with the contractor or how well the contractor's field staff operates.

Aitah [1] studied the bid awarding system used in Saudi Arabia. He evaluated public building construction projects, and concluded that the projects awarded to the lowest bidder have lower performance quality and schedule delays as compared to the projects which were awarded based on specific prequalification criteria.

Al-Alawi [2] conducted a study on contractor prequalification for public projects in Bahrain. He surveyed the market and determined the most important criteria in the prequalification process, and developed a computerized tool for implementing it.

Russel [21] analyzed contractor failure in the US and recommended that an owner should have two means of avoiding or minimize the impact of contractor failure: (1) analyzing the contractor qualification prior to contract award; and (2) monitoring the contractor's performance after contract award.

Al-Ghobali [3] surveyed the Saudi construction market and listed a number of factors against which contractors should be considered for prequalification. This included experience, financial stability, past performance, current workload, management staff, manpower resources availability, contractor organization, familiarity with the project's geographic location, project management capabilities, quality assurance and control, previous failure to complete a contract, equipment resources, purchase expertise and material handling, safety consciousness, claim attitude, planning/scheduling and cost control, and equipment repairing and maintenance yard facilities.

6. Example

A simplified project example of contractor prequalification 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 3 presents a project example for which contractors A, B, C, D and E wish to prequalify. An argument could be presented that contractor E is not meeting the minimum criteria. Descriptions presented in Table 3 under 'Contractor E', such as 'bad organization' and 'unethical techniques', qualifies him for immediate elimination from the list by the project owner. This is quite consistent with the method 'elimination by aspect' suggested by Tversky [31]. Nevertheless, it is the choice of the decision-maker to eliminate contractor E immediately since he/she does not meet the minimum criteria. Contractor E could be left on the list (the choice in this paper for demonstration purposes) so that he appears at the end of the list of 'best contractors in descending order', as will be shown at the end of the example. The matter is safeguarded by checking the consistency of the pairwise comparison which is a part of the AHP procedure.

By following the AHP procedure described in the Section 5, the hierarchy of the problem can be developed as shown in Fig. 1. 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 as shown in Table 4.

Table 3
Example

	Contractor A	Contractor B	Contractor C	Contractor D	Contractor E
Experience	5 years experience	7 years experience	8 years experience	10 years experience	15 years experience
	Two similar projects	One similar project	No similar project	Two similar projects	No similar project
		Special procurement experience	1 international project		
Financial stability	$7 M assets	$10 M assets	$14 M assets	$11 M assets	$6 M assets
	High growth rate	$5.5 M liabilities	$6 M liabilities	$4 M liabilities	$1.5 M liabilities
	No liability	Part of a group of companies		Good relation with banks	
Quality performance	Good organization	Average organization	Good organization	Good organization	Bad organization
	C.M. personnel	C.M. personnel	C.M. team	Good reputation	Unethical techniques
	Good reputation	Two delayed projects	Government award	Many certificates	One project terminated
	Many certificates	Safety program	Good reputation	Cost raised in some projects	Average quality
	Safety program		QA/QC program		
Manpower resources	150 labourers	100 labourers	120 labourers	90 labourers	40 labourers
	10 special skilled labourers	200 by subcontract	Good skilled labors	130 by subcontract	260 by subcontract
		Availability in peaks	25 special skilled labourers		
Equipment resources	4 mixer machines	6 mixer machines	1 batching plant	4 mixer machines	2 mixer machines
	1 excavator	1 excavator	2 concrete transferring trucks	1 excavator	10 others
	15 others	1 bulldozer	2 mixer machines	9 others	2000 sf steel formwork
		20 others	1 excavator		6000 sf wooden formwork
		15,000 sf steel formwork	1 bulldozer		
			16 others		
			17,000 sf steel formwork		
Current works load	1 big project ending	2 projects ending (1 big + 1 medium)	1 medium project started	2 big projects ending	2 small projects started
	2 projects in mid (1 medium +1 small)		2 projects ending (1 big + 1 medium)	1 medium project in mid	3 projects ending (2 small + 1 medium)

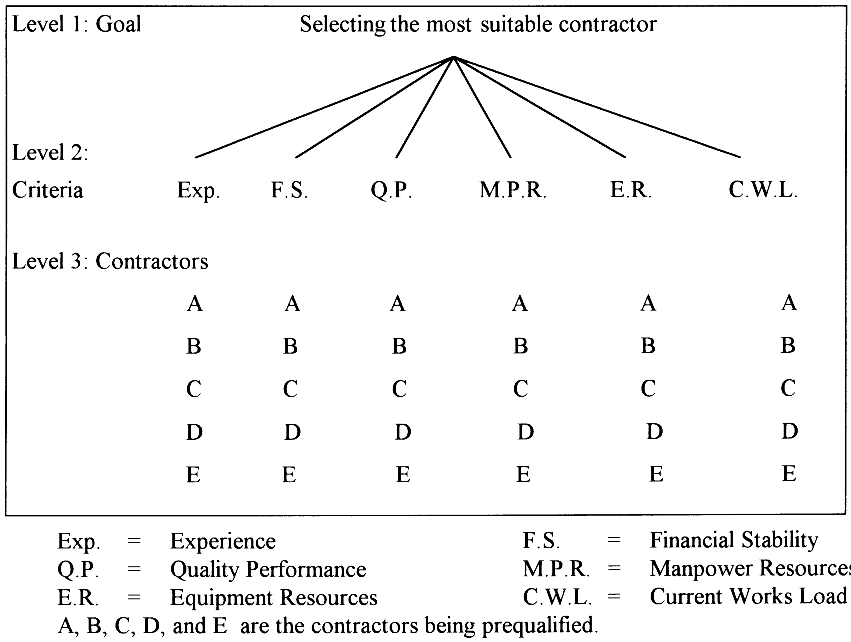

Fig. 1. Hierarchy of the project example..

Then, the following can be done manually or automatically by the AHP software, Expert Choice:

1. synthesizing the pair-wise comparison matrix (example: Table 5);
2. calculating the priority vector for a criterion such as experience (example: Table 5);
3. calculating the consistency ratio;
4. calculating λ_{max};
5. calculating the consistency index, CI;
6. selecting appropriate value of the random consistency ratio from Table 2; and
7. checking the consistency of the pair-wise comparison matrix to check whether the decision-maker's comparisons were consistent or not.

The calculations for these items will be explained next for illustration purposes. Synthesizing the pair-wise comparison matrix is performed by dividing each element of the matrix by its column total. For example, the value 0.08 in Table 5 is obtained by dividing 1 (from Table 4) by 12.5, the sum of the column items in Table 4 $(1+3+2+6+1/2)$.

The priority vector in Table 5 can be obtained by finding the row averages. For example, the priority of contractor A with respect to the criterion 'experience' in Table 5 is calculated by dividing the sum of the rows $(0.08+0.082+0.073+0.078+0.118)$ by the number of contractors (columns), i.e., 5, in order to obtain the value 0.086. The priority vector for experience, indicated in Table 5, is given below.

$$\begin{bmatrix} 0.086 \\ 0.249 \\ 0.152 \\ 0.457 \\ 0.055 \end{bmatrix} \tag{1}$$

Now, estimating the consistency ratio is as follows:

Table 4
Pair-wise comparison matrix for experience

Exp.	A	B	C	D	E
A	1	1/3	1/2	1/6	2
B	3	1	2	1/2	4
C	2	1/2	1	1/3	3
D	6	2	3	1	7
E	1/2	1/4	1/3	1/7	1

Table 5
Synthesized matrix for experience[a]

Exp.	A	B	C	D	E	Priority vector
A	0.08	0.082	0.073	0.078	0.118	0.086
B	0.24	0.245	0.293	0.233	0.235	0.249
C	0.16	0.122	0.146	0.155	0.176	0.152
D	0.48	0.489	0.439	0.466	0.412	0.457
E	0.04	0.061	0.049	0.066	0.059	0.055
						$\sum = 0.999$

[a] $\lambda_{max} = 5.037$, CI = 0.00925, RI = 1.12, CR = 0.0082 < 0.1 OK.

$$0.086\begin{bmatrix}1\\3\\2\\6\\1/2\end{bmatrix}+0.249\begin{bmatrix}1/3\\1\\1/2\\2\\1/4\end{bmatrix}+0.152\begin{bmatrix}1/2\\2\\1\\3\\1/3\end{bmatrix}+0.457\begin{bmatrix}1/6\\1/2\\1/3\\1\\1/7\end{bmatrix}+0.055\begin{bmatrix}2\\4\\3\\7\\1\end{bmatrix}=\underset{\text{(weighted sum matrix)}}{\begin{bmatrix}0.431\\1.259\\0.766\\2.312\\0.276\end{bmatrix}} \quad (2)$$

Dividing all the elements of the weighted sum matrices by their respective priority vector element, we obtain:

$$\frac{0.431}{0.086}=5.012,\quad \frac{1.259}{0.249}=5.056,\quad \frac{0.766}{0.152}=5.039,\quad \frac{2.312}{0.457}=5.059,\quad \frac{0.276}{0.055}=5.018 \quad (3)$$

We then compute the average of these values to obtain λ_{max}

$$\lambda_{max}=\frac{(5.012+5.056+5.039+5.059+5.018)}{5}=5.037 \quad (4)$$

Now, we find the consistency index, CI, as follows:

$$CI=\frac{\lambda_{max}-n}{n-1}=\frac{5.037-5}{5-1}=0.00925 \quad (5)$$

Selecting appropriate value of random consistency ratio, RI, for a matrix size of five using Table 2, we find RI = 1.12. We then calculate the consistency ratio, CR, as follows:

$$CR=\frac{CI}{RI}=\frac{0.00925}{1.12}=0.0082 \quad (6)$$

Table 7
Pair-wise comparison matrix for quality performance (QP)[a]

QP	A	B	C	D	E	Priority vector
A	1	7	1/3	2	8	0.269
B	1/7	1	1/5	1/4	4	0.074
C	3	5	1	4	9	0.461
D	1/2	4	1/4	1	6	0.163
E	1/8	1/4	1/9	1/6	1	0.031
						$\sum = 0.998$

[a] $\lambda_{max} = 5.38$, CI = 0.095, RI = 1.12, CR = 0.085 < 0.1 OK.

As the value of CR is less than 0.1, the judgments are acceptable. Similarly, the pair-wise comparison matrices and priority vectors for the remaining criteria can be found as shown in Tables 6–10, respectively.

In addition to the pair-wise comparison for the decision alternatives, we also use the same pair-wise comparison procedure to set priorities for all six criteria in terms of importance of each in contributing to the overall goal. Table 11 shows the pair-wise comparison matrix and priority vector for the six criteria.

Now, the Expert Choice software can do the rest automatically, or we manually combine the criterion priorities and the priorities of each decision alternative relative to each criterion in order to develop an overall priority ranking of the decision alternative which is termed as the priority matrix (Table 12). The calculations for finding the overall priority of contractors are given below for illustration purposes:

Overall priority of contractor A

$$=0.372(0.086)+0.293(0.425)+0.156(0.269)+(0.151)+0.039(0.084)+0.087(0.144)=0.222 \quad (7)$$

Table 6
Pair-wise comparison matrix for financial stability (FS)[a]

FS	A	B	C	D	E	Priority vector
A	1	6	3	2	7	0.425
B	1/6	1	1/4	1/2	3	0.088
C	1/3	4	1	1/3	5	0.178
D	1/2	2	3	1	7	0.268
E	1/7	1/3	1/5	1/7	1	0.039
						$\sum = 0.998$

[a] $\lambda_{max} = 5.32$, CI = 0.08, RI = 1.12, CR = 0.071 < 0.1 OK.

Table 8
Pair-wise comparison matrix for manpower resources (MPR)[a]

MPR	A	B	C	D	E	Priority vector
A	1	1/2	1/4	2	5	0.151
B	2	1	1/3	5	7	0.273
C	4	3	1	4	6	0.449
D	1/2	1/5	1/4	1	2	0.081
E	1/5	1/7	1/6	1/2	1	0.045
						$\sum = 0.999$

[a] $\lambda_{max} = 5.24$, CI = 0.059, RI = 1.12, CR = 0.053 < 0.1 OK.

Overall priority of contractor B

$$= 3.372(0.249) + 0.293(0.088) + 0.156(0.074) + 0.053(0.273) + 0.039(0.264) + 0.087(0.537) = 0.201 \quad (8)$$

Table 9
Pair-wise comparison matrix for equipment resources (ER)[a]

ER	A	B	C	D	E	Priority vector
A	1	1/6	1/8	2	3	0.084
B	6	1	1/4	5	7	0.264
C	8	4	1	9	9	0.556
D	1/2	1/5	1/9	1	2	0.057
E	1/3	1/7	1/9	1/2	1	0.038
						$\sum = 0.999$

[a] $\lambda_{max} = 5.28$, CI = 0.071, RI = 1.12, CR = 0.063 < 0.1 OK.

Table 10
Pair-wise comparison matrix for current work load (CWL)[a]

CWL	A	B	C	D	E	Priority vector
A	1	1/5	1/3	3	3	0.144
B	5	1	5	6	6	0.537
C	3	1/5	1	2	2	0.173
D	1/3	1/6	1/2	1	2	0.084
E	1/3	1/6	1/2	1/2	1	0.062
						$\sum = 0.999$

[a] $\lambda_{max} = 5.40$, CI = 0.10, RI = 1.12, CR = 0.089 < 0.1 OK.

Table 11
Pair-wise comparison matrix for the six criteria[a]

	Exp.	FS	QP	MPR	ER	CWL	Priority vector
Exp.	1	2	3	6	6	5	0.372
FS	1/2	1	3	6	6	5	0.293
QP	1/3	1/3	1	4	4	3	0.156
MPR	1/6	1/6	1/4	1	2	1/2	0.053
ER	1/6	1/6	1/4	1/2	1	1/4	0.039
CWL	1/5	1/5	1/3	2	4	1	0.087
							$\sum = 1.00$

[a] $\lambda_{max} = 6.31$, CI = 0.062, RI = 1.24, CR = 0.05 < 0.1 OK.

Overall priority of contractor C

$$= 0.372(0.152) + 0.293(0.178) + 0.156(0.461) + 0.053(0.449) + 0.039(0556) + 0.087(0.173) = 0.241 \quad (9)$$

Overall priority of contractor D

$$= 0.372(0.457) + 0.293(0.268) + 0.156(0.163) + 0.053(0.081) + 0.039(0.057) + 0.087(0.084) = 0.288 \quad (10)$$

Overall priority of contractor E

$$= 0.372(0.055) + 0.293(0.039) + 0.156(0.031) + 0.053(0.045) + 0.039(0.038) + 0.087(0.062) = 0.046 \quad (11)$$

For prequalification purposes, the contractors are now ranked according to their overall priorities, as follows: D, C, A, B, and E, indicating that D is the best qualified contractor to perform the project.

Expert Choice does provide facilities for performing sensitivity analysis, where the decision-maker can check the sensitivity of his judgements on the overall priorities of contractors by trying different values for his comparison judgements.

7. Summary

Project management involves complex decision making situations that require discerning abilities and methods to make sound decisions. The paper has presented the AHP as a decision-making method that allows the consideration of multiple criteria. An example of contractor prequalification was created to demonstrate AHP application in project management.

Table 12
Priority matrix for contractor prequalification

	Exp. (0.372)	FS (02.93)	QP (0.156)	MPR (0.053)	ER (0.039)	CWL (0.087)	Overall priority vector
A	0.086	0.425	0.269	0.151	0.084	0.144	0.222
B	0.249	0.088	0.074	0.273	0.264	0.537	0.201
C	0.152	0.178	0.461	0.449	0.556	0.173	0.241
D	0.457	0.268	0.163	0.081	0.057	0.084	0.288
E	0.055	0.039	0.031	0.045	0.038	0.062	0.046

Contractor prequalification involves criteria and priorities that are determined by owner requirements and preferences as well as the characteristics of the individual contractors. AHP allows group decision-making. The method can also be implemented on computer.

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