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FINAL CONTRACTOR SELECTION USING THE AHP – A CASE STUDY

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ABSTRACT

Some contractor selection methods currently in existence are criticized as incomplete and biased, and lacking consideration in terms of the contractor's ability to achieve simultaneously, time, cost, quality and safety standards. This research examines an alternative contractor selection model called the analytical hierarchy process (AHP), which will help construction clients to identify contractors with the best potential to deliver satisfactory outcomes in a final contractor selection process which is not based simply on the lowest bid. The AHP comprises three parts: hierarchic structure, prioritization procedure, and calculation of results. This model is tested by a hypothetical scenario where three contractor candidates are evaluated. The criteria used for contractor selection in the model have been identified, and the significance of each criterion has been arrived at by conducting a questionnaire survey in public organizations in Hong Kong. Comparisons are made by ranking the aggregate scores of each candidate with regard to their performance against each of the criteria, and the candidate associated with the highest scores is the best contractor on this occasion.

Keywords: Analytical hierarchy process, contractor selection, prequalification, final selection, tender price

INTRODUCTION

Selecting a capable construction contractor is one of the most important tasks faced by a construction client who wishes to achieve successful project outcomes. Often this task is challenging, because the construction industry is volatile and competitive. (Kangori & Bakheet, 1994) agrees that the probability of construction failure is quite high for individual contractors, and it is important for project owners to confront and manage these risks if they wish to achieve good project results.

The selection process should identify a contractor to whom the client can confidently entrust the responsibility to execute the project satisfactorily, but unfortunately this is not always possible. The majority of current selection methods over-emphasize acceptance of the lowest bid, and the lowest tender price is usually described as being the key to winning a contract. (Works, 1966) Table 1 shows sample attitudes cited by researchers since 1967 concerning the influence of the tender price on the final selection of a contractor. According to these, the key may not be as important as it is usually believed to be. (Choi & Fong, 2000)

Two points summarize the view of the various researchers. (i) Apart from the acceptance of the lowest tender price, there should be a trade-off between cost, time and quality in the final selection of contractor. (ii) However, in public projects, the tender price still dominates over other factors in tender assessment (contractor selection). Because the funding for government projects comes from the taxpayer and prior assessments of contractors are made before inviting tenders, offering projects on the basis of the lowest tender can dispel suspicions of corruption. On the other hand, there is evidence from news reports in Hong Kong that the lowest bidders have failed to complete projects due to financial difficulties or other common grounds. If there is an objective approach that can prove to the general public that projects are awarded based on the best possible combination of a variety of criteria, they will be more receptive to this approach. Logically, the failure of a contractor to complete a project will cost the taxpayers more money in the long run.

Table 1 A sample of attitudes cited by researchers concerning price

Author (year)	Comments
(McCanils, 1967)	'Although the client will normally seek a low price this must be done with discretion as a price that is too low may inhibit the attainment of the client's other objectives of quality and speed'
(Flanagan & Norman, 1982)	'This price is based upon the successful tender who in most cases is the lowest tender received. This tender, however, will not necessarily reflect the "true cost" of the project'
(Pearson, 1985)	'Upon receipt of tenders, it will immediately be obvious that the contractor submitting the lowest fixed fee is not necessarily the one representing the best value for money to the client'
(Merna & Smith, 1990)	'Indeed, the majority of current selection methods exhibit constraint and over-reliance on principle of acceptance of the lowest bid'
(Brook, 1993)	'The aims of selection are to find a contractor who can supply a product for the lowest possible price, and can demonstrate the following: 1. A reputation for good quality workmanship and efficient organization 2. The ability to complete on time 3. A strong financial standing with a good business record 4. The expertise suited to the size and type of project'
(Hartman, 1993)	'While two fundamental factors exist in selection (price and suitability), price often dominates – at times to exclusion of suitability'
(Latham, 1994)	'Choice of consultant or contractor should be made on a value for money basis, with proper weighting of criteria for skill, experience and previous performance, rather than automatically accepting the lowest in all cases'
(Smith, 1995)	'As owners become more sophisticated, the traditional process will be seen for what it really is: usually high risk for all unacceptable levels of service. It is therefore necessary to examine how the 'best buy' can be chosen where more than one variable is involved'
(Kumaraswamy, 1996)	'Public Sector clients are most often constrained to select the lowest (evaluated) bidder, other than in exceptional circumstances, which makes short-listing all the more important. However, it is increasingly recognized that the lowest bid is not necessarily the most economical solution in the long term'

'Selection of contractors involves more than merely opting for the lowest evaluated bid'. (Hatush & Skitmore, 1997) believe that the acceptance of the lowest price in bid evaluation is the prime reason for project delivery problems, as contractors desperately quote low prices by reducing their quality of work, and hope to be compensated by submitting 'claims'. They further comment that 'reliance on bid prices alone as a discriminating factor between bidders is, however, somewhat risky and shortsighted'. They also say that in many countries, such as Denmark, Italy, Portugal, Peru, South Korea, Saudi Arabia, Canada, the USA and France, certain procedures have been adopted that will do away with the dominance of the lowest tender price in contractor selection.

The final selection of a contractor involves criteria for which data are qualitative, subjective and imprecise. Whatever the selection method is, the significance of three criteria, namely time, cost and quality, should be considered. In this research, we propose a new alter- native selection tool for a more comprehensive evaluation of a contractor's all-round performance potential. Reviewing a representative sample of the existing literature, 11 models of prequalification and 4 models for final contractor selection were found. These are listed in Tables 2 and 3. Two special considerations are taken into account in this research. 1. The definition of a successful project depends on many entities throughout the whole building process. This research was concerned only with the client's view. 2. It was not our intention to identify the best or most popular contractor selection method. Evaluation of the performance of existing methods should be studied thoroughly, and the uniqueness of a country's construction industry should also be taken into account.

ANALYTICAL HIERARCHY PROCESS (AHP)

The analytical hierarchy process (AHP), first introduced by Thomas L. Saaty, is described by (Patrovi, 1994) as 'a decision-aiding tool for dealing with complex, unstructured and multi-attribute decision'. Nydick and Hill (1992) describe the AHP as 'a methodology to rank alternative courses of action based on the decision maker's judgment concerning the importance of the criteria and the extent to which they are met by each alternative'.

(Muralidhar, Santhnam, & Wilson, 1990) support the belief that the AHP caters specifically for decision making with multi- criteria. Apart from this, the high precision of relative priorities in the calculations enhances the effectiveness of this technique. In our work, the relative priority of each criterion was counted to three decimal places.

Table 2 Prequalification Models

Models	Authors (year)
Dimensional Weighting	(Jaselskis, 1988)
Dimensional Wide Modeling	(Jaselskis & Russell, 1991)
Two-step Modeling	(Jaselskis & Russell, 1991)
Prequalification Formula	(Russel & Skibniewski, 1990b) (Jaselskis & Russell, 1991)
Knowledge Intensive Model	(Russel & Skibinewski, 1990a)
Financial Model	(Russel, 1992)
Linear Model	(Russel, 1992)
Multi Attribute Utility Model	(Diekmann, 1981)

Fuzzy sets Model	(Nguyen, 1985)
Statistic Model	(Jaselskis, 1988)
Hybrid Model	(Russel, 1992)

Table 3 Final contractor selection models

Models	Authors (year)
Performance Assessment Scoring System	(Authority, 1994)
Multi-attribute analysis	(Holt, Olomolaiye, & Harris, 1995)
Simplified quality assessment	(RICS, 1997)
Logistic regression technique	(Jaselskis & Russell, 1991)

There are three basic steps in using the AHP: hierarchic structure, prioritization procedure, ad calculation of results.

HIERARCHIC STRUCTURE

A complex decision problem is expressed as a hierarchy. The overall objective of the decision lies at the top of the hierarchy, the criteria (elements affecting the decisions), sub-criteria and decision alter- natives are on each descending level of the hierarchy. (Saaty, 1994) emphasizes the fact that the hierarchic structure is beneficial to a decision-maker. It provides 'an overall view of the complex relationships inherent in the situation and in the judgment process and it also allows the decision-maker to assess whether he or she is comparing issues of the same order of magnitude'.

PRIORITIZATION PROCEDURE

The next step is to define the priority (or weight) of each criterion. Elements in each level are compared pairwise with respect to their importance to an element at a higher level, starting at the top of the hierarchy and working down. With reference to (Latham, 1994), the advantage of using a pairwise method is that it allows the decision-maker to focus on a comparison of two objects, and the observation can be made free from extraneous influences. For pairwise comparisons, a matrix is the preferred form. (Russell & Skibniewski, 1988)

CALCULATION OF RESULTS

The relative weights of the elements of each level with regard to an element on the next level are computed as the components of the normalized eigenvector associated with the largest Eigen value of their comparison matrix. The composite weights of the decision alternatives are then determined by aggregating the weights throughout the hierarchy.

One of the advantages of the AHP is that it provides consistency checking on judgments. According to (Satty, 1995), consistency is defined as when 'the intensities of relations among ideas or objects based on a particular criterion justify each other in some logical way'.

PROBLEM STATEMENT

Not much research or published data about final selection exist. Four final selection models and eleven prequalification models were found in our literature review. Existing selection practices exhibit an inherent weakness, and this may result in an incomprehensive evaluation of contractor's performance. The development of a better selection tool is essential for successful projects. The proposed contractor selection technique using the analytical hierarchy process should be able to overcome the tradeoffs in tender price, time and quality, and both quantitative and qualitative criteria can be considered. Our research concentrated on reviewing the different contractor selection methods available, examining the dominance of tender price in selection, and applying the AHP to contractor selection. We concentrated on the final stage of selecting a contractor, the forming of prequalification lists being beyond the scope of the study.

RESEARCH METHODOLOGY

Sixty-eight criteria involved in contractor selection were collected from the literature review and grouped into major underlying factors. A questionnaire survey was conducted with frequent public sector construction procurers in Hong Kong. The survey was used as an instrument: (a) to find out the attitudes of public sector construction clients towards the significance of tender price in final contractor selection; (b) to find the level of client satisfaction with existing selection methods and contractor performance; and (c) to prioritize the criteria responsible for the overall significance in the final selection of contractor within those organizations. These priorities are incorporated also into the application of the AHP in contractor selection. 13 replies were received from 40 questionnaires sent out to clients of public works in January 1998, a response rate of 33%. The relative importance of each criterion used in the AHP was collected through the questionnaire survey. The format of the questionnaire was synthesized with reference to (Holt, Olomolaiye, & Harris, 1995). Our review of the literature suggests different ways of working out the collective decision, arithmetic mean, and geometric mean. (Nydick & Hill, 1992) points out that one method are to 'see what alternative has the most votes, followed by the one with next highest vote, and so on'. For the sake of simplicity and reliability, (Saaty, 1996b)'s suggestion was adopted in this study. Whenever two priorities got the same number of votes, the arithmetic mean was taken.

ANALYSIS OF SURVEY RESPONSE

All of the respondents to the questionnaire have been involved in the decision making process of contractor selection. Sufficient practical experience was guaranteed from this survey. Respondents were asked to identify the criteria necessary for contractor selection. The superior significance of tender price was challenged (Figure 1). As expected, less than 100% (91%) of respondents accepted tender price as one of the criteria in final selection of contractor. Financial capability, past performance and past experience were ranked as the top selection criteria. 82% of the respondents agreed that their contractor selection processes were systematic, so clearly 18% disagreed. 36% of those who disagreed thought a more satisfactory decision would be achieved through a more systematic practice, 18% of the sample did not support the suggestion, while 46% gave no comment.

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HYPOTHETICAL CASE APPLICATION

In this section a detailed hypothetical example of how the AHP can be used in contractor selection is provided.

HIERARCHIC STRUCTURE

Overall objective, criteria and sub criteria must be identified. In this section, the overall objective is 'selecting the most capable contractor', the main aim of our research. 68 criteria of contractor selection raised in 10 publications (Ministry of Public Building and Works, 1966; (McCanils, 1967); (NJCC, 1974); (Baker & Orsaah, 1985); (Russel & Skibinewski, Qualifier 1: A Computerized Decision Model for Contractor Prequalification, 1990a); (Griffith, 1992); (Brook, 1993); (Holt, Olomolaiye, & Harris, 1993); (Smith, 1995) and (Hatush & Skitmore, 1997) were collected and analyzed. Among these criteria, which criterion will become an element in the hierarchy is a problem. The definitions and rationales of the criteria are discussed. The reasons for choosing the criteria are explained in Table 4. The selection of the most capable contractor is broken up into a hierarchy. The criteria and the sub criteria are as follows.

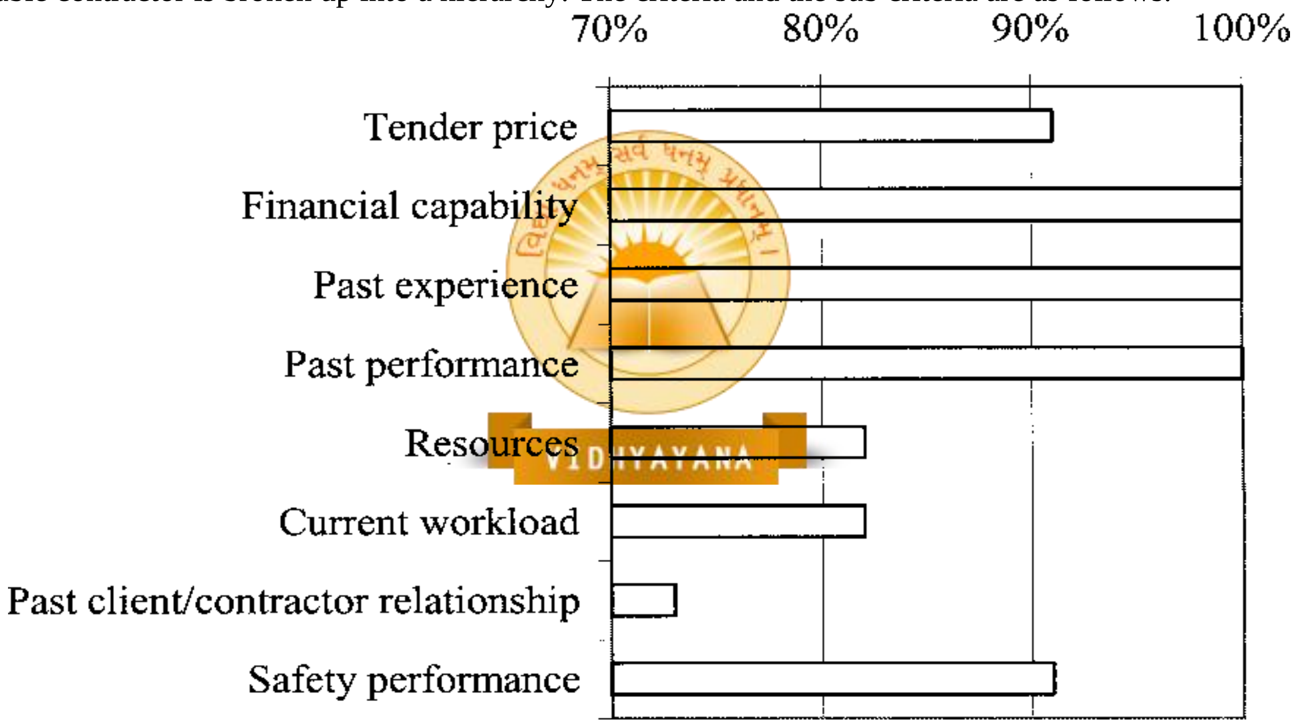

Figure 1 Factors considered by clients in contractor selection

In Figure 2 the overall objective 'selecting the most capable contractor' lies at the top of the hierarchy, and the 8 criteria include tender price, financial capability, past performance, past experience, resources, current workload, past client–contractor relationship and safety performance. Some of the criteria are broken down into sub criteria, giving a total of 15 'criteria'.

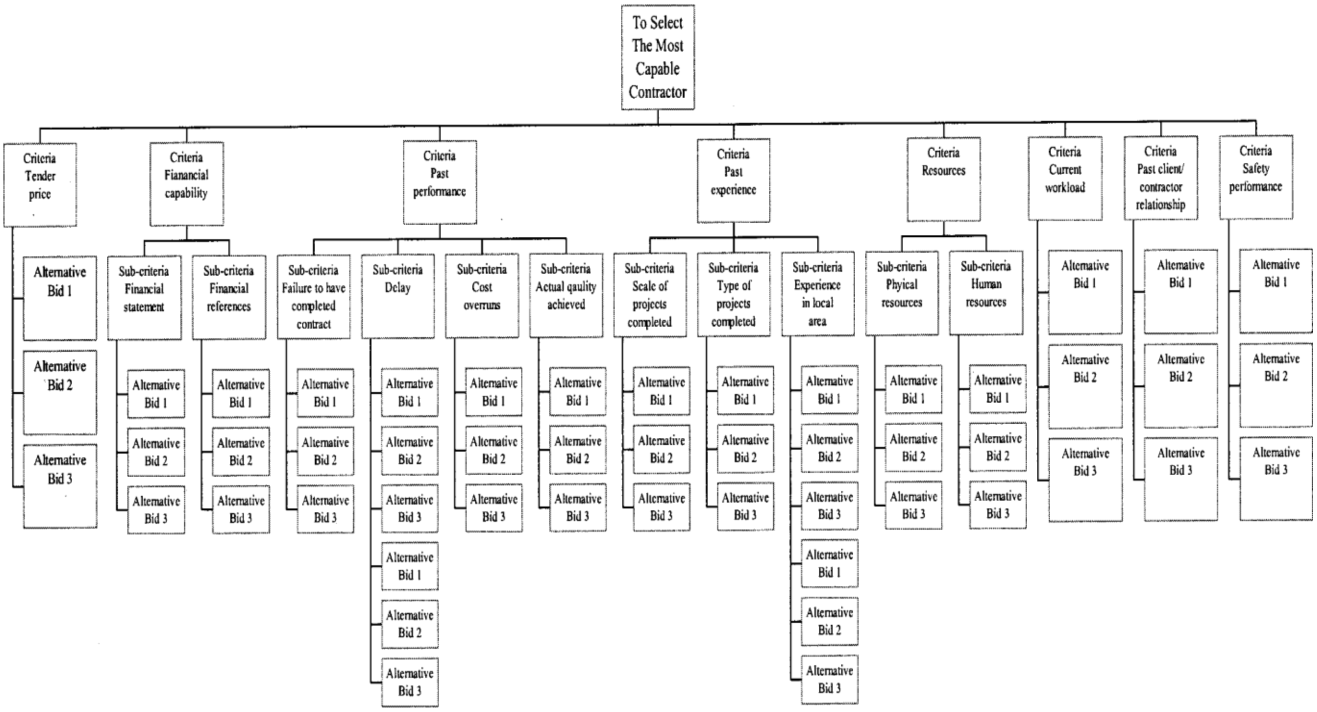

Figure 2 Hierarchy of selecting the most capable contractor**Table 4** Rationale for the choice of criteria for questionnaire survey – contractor selection

Choice of Criteria for Questionnaire Survey	
A. Price	The lowest tender price tends to attract a client's interest as superior to other criteria
B. Financial Capability	It focuses on the financial stability and backing of contractors. Insufficient financial standing of a successfully selected contractor can lead to late completion and unsatisfactory quality of work
➢ **Financial Statement**	Ratio analysis accounts and turnover history are tools of ratio analysis aimed at assessing the financial standing of a contractor Apart from these, financial ratios such as liquidity ratio deserve to be analyzed Other relevant financial ratios from various financial statements should be included
➢ **Financial References**	Financial references, including credit reference and credit rating, are all evidence to show the degree of a contractor's financial stability for loan
C. Past Performance	Past performance is a guide to likely future performance, and illustrates a contractor's ability to execute a contract
➢ **Failure to have Contract Completed**	The reasons for failure to complete a contract are complicated, but this is an apparent warning of the reliability of a contractor
➢ **Delay**	Late completion induces rental loss and additional interest
➢ **Additional Cost**	Client may not be able to afford overruns in cost

➢ **Actual Quality Achieved**	Good quality outcome is a result of comprehensive quality control (QC) programmed and QC policy
D. Past Experience	Accumulated experience in tackling difficulties is an asset of an entity, since unanticipated problems will be encountered during construction
➢ **Scale of Projects Completed**	Technical skill, size, image and reputation are reflected by the scale and type of projects carried out or completed
➢ **Types of Project Completed**	
➢ **Experience in local area**	Length of time in business shows a contractor's experience, but experience in foreign projects may not be advantageous to a local project
E. Resource	Adequate and suitable physical and human resources help to foresee whether
➢ **Physical Resource**	contractor is likely to satisfactorily carry out the contract
➢ **Human Resource**	
F. Current Workload	Whether the resources will be available for a particular project depends on the workload during construction duration
G. Past Client/Contractor Relationship	Serious past disagreements and disputes cause deteriorations in mutual trust. Transfer of information and willingness to compromise are weakened
H. Safety Performance	Poor safety awareness, safety precautions, and policy are huge costs, and may result in delays

PRIORITIZATION PROCEDURE

The definition of the priority of each criterion is obtained by conducting a questionnaire survey. The elements on the second level (tender price, financial capability . . .) are arranged into a matrix, and the decision-makers make judgments about the relative importance of the element with respect to the overall goal of selecting the most capable contractor. Does tender price dominate over financial capability or does financial capability take first place? All of the questions concerning the weighting are collected from the questionnaire survey. The judgments are entered using the fundamental scale for pairwise comparisons (see Table 5). First, the verbal judgment is indicated on the scale, and then translated into corresponding numbers. The vector of priority is the principal Eigen- vector of the matrix.

Pairwise comparison is used, because only two elements are involved in the comparison at same time. (hatush & Skitmore, 1998) (Satty, Multicriteria Decision Making, 1996a) describes pairwise comparison as 'the element that appears in the left-hand column is always compared with the element appearing in the top row, and the value is given to the element in the column as it is compared with the element in the row. If it is regarded less favorably, the judgment is a fraction. The reciprocal value is entered in the position where the second element, when it appears in the column, is compared with the first element when it appears in the row'.

An element is equally important when compared with itself, so where the row A and column A meet in position (A, A) insert 1. The main diagonal of a matrix must consist of 1's. If an individual, using the recommended scale, enters the number 4 in the (B, C) position, he thinks A is between more 'weakly' and 'strongly' important than C. The reciprocal value 1/4 is automatically entered in the (C, B). The normalized eigenvector shown in Table 6 represents the relative importance of the criterion. Based on the above calculation, the relative priorities of criteria in the final selection of contractor are shown on Table 7.

Table 5 The comparison scale as used by Saaty (1995)

Preferences Expressed in Numeric Variables	Preferences Expressed in Linguistic Variables
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Values between Adjacent Scale Values

SUMMARY OF PRIORITY OF EACH CRITERION

(Satty, Multicriteria Decision Making, 1996a) points out that 'if there are more than two levels, the various priority vectors can be combined into priority matrices, which yield one final priority vector for the bottom level'. Local priority is the priority relative to its parent. Table 8 shows the priority of each criterion in the final selection of a contractor. Global priority, also called final priority, is the priority relative to the goal.

Table 6 Normalized matrix

Criterion	Tender price	Financial capability	Past performance	Past experience	Resources	Current workload	Past client/ contractor relationship	Safety performance	Priority vector/ Eigenvector Normalized
Tender price	210/449[a]	1890/2483	75/209	140/419	63/293	49/204	28/153	7/39	0.342[b]
Financial capability	35/449	315/2483	105/209	140/419	441/1465	21/68	28/153	5/39	0.245
Past performance	42/449	45/2483	15/209	100/419	63/293	35/204	8/51	6/39	0.140
Past experience	30/449	45/2483	3/209	20/419	252/1465	35/204	4/51	6/39	0.090
Resources	42/449	45/2483	3/209	5/419	63/1465	7/204	28/153	9/39	0.079
Current workload	30/449	35/2483	3/209	4/419	63/1465	7/204	28/153	1/39	0.049
Past client/contractor Relationship	30/449	45/2483	5/418	20/1257	9/1465	1/204	4/153	4/39	0.032
Safety performance	30/449	63/2483	5/418	10/1257	7/1465	7/204	1/153	1/39	0.023

[a] This entry is obtained by dividing the tender price entry result in the criteria comparison matrix by the tender price column total.

[b] This entry is obtained as follows: {210/449 + 1890/2483 + 75/209 + 140/419 + 63/293 + 49/204 + 28/153 + 7/39}1/8 = 0.342.

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Table 7 Relative Priorities of Criteria

Criterion	Relative Priority
Tender price	0.342
Financial capability	0.245
Past performance	0.140
Past experience	0.090
Resources	0.079
Current workload	0.049
Past client/contractor relationship	0.032
Safety performance	0.023

Table 8 The priority of each criterion in final selection of contractor

Criterion	Local Priority[a]	Global Priority[b]	Sub Criterion	Local Priority[a]	Global Priority[b]
Tender Price	0.342	0.342	–	–	–
Financial Capability	0.245	0.245	Financial Statement	0.900	0.211c
			Financial References	0.100	0.024
Past Performance	0.140	0.140	Failure To Have Contract Completed	0.649	0.091
			Cost Overruns	0.161	0.023
			Delay	0.145	0.020
			Actual Quality Achieved	0.045	0.006
Past Experience	0.090	0.090	Scale Of Projects Completed	0.480	0.043
			Type Of Projects Completed	0.405	0.037
			Experience In Local Area	0.115	0.010
Resources	0.079	0.079	Physical Resources	0.500	0.0395
			Human Resources	0.500	0.0395
Current Workload	0.049	0.049	–	–	–
Past Client/ Contractor Relationship	0.032	0.032	–	–	–

Safety					
Performance	0.023	0.023	–	–	–

[a] Local priority is derived from judgment with respect to a single criterion.

[b] Global priority is derived from multiplication by the priority of the criterion.

[c] This entry is obtained as follows: 0.245 3 0.900 =0.221. The global priority of the sub criterion is obtained by multiplying the local priority of the sub criterion by the priority of the criterion.

CALCULATING THE RESULTS

Three contractors (bids 1, 2 and 3) are supposed to be interested in bidding for a construction project. These three contractors must be compared pairwise for each criterion. This process is almost identical to the procedures that are used to develop the normalized eigenvector of criteria. Bids 1, 2 and 3, three alternatives, are compared with respect to each criterion. This is repeated for the rest of the criteria. There are fifteen criteria in total in the hierarchy. The weightings of each criterion are determined using the steps previously described. These weightings are hypothetical, and are shown in Figure 3. Table 9 provides the relative priority of the selection by criterion type, and the scores of the three alternatives. For instance, the normalized eigenvector of the tender price criterion is calculated and shown in the tender price column. Larger values of the eigenvector reveal greater importance of selection with respect to the criterion. Bid 3 best addresses the tender price criterion, followed by bids 1 and 2.

At present, the list of criteria has been defined, their relative importance has been determined, and the scores of the three contractors according to the criteria have been assigned. The next step is to determine the priority of bids 1, 2 and 3. Table 10 illustrates the final overall prioritization of the three alternatives. The order of prioritization is bid 2, 1 and 3 (from best to worst). Bid 2 has the highest scores of (0.375) and is considered the best for these illustrations.

Tender price	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	1/7	1/5	0.072
Bid 2	7	1	3	0.650
Bid 3	5	1/3	1	0.278

λ max = 3.065 C.I. = 0.032 C.R. = 0.056

Financial statement	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	1/2	1/2	0.200
Bid 2	2	1	1	0.400
Bid 3	2	1	1	0.400

λ max = 3.000 C.I. = 0.000 C.R. = 0.000

Financial references	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	8	6	0.747
Bid 2	1/8	1	1/5	0.060
Bid 3	1/8	5	1	0.193

λ max = 3.197 C.I. = 0.099 C.R. = 0.170

Failure to have contract completed	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	1/4	1	0.674
Bid 2	4	1	2	0.101
Bid 3	1	1/2	1	0.226

λ max = 3.053 C.I. = 0.027 C.R. = 0.151

Cost overruns	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	8	8	0.796
Bid 2	1/8	1	2	0.125
Bid 3	1/8	1/2	1	0.079

λ max = 3.053 C.I. = 0.027 C.R. = 0.051

Delay	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	4	6	0.691
Bid 2	1/4	1	3	0.218
Bid 3	1/6	1/3	1	0.091

λ max = 3.053 C.I. = 0.027 C.R. = 0.051

Actual quality achieved	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	9	6	0.770
Bid 2	1/9	1	1/3	0.068
Bid 3	1/6	3	1	0.162

λ max = 3.053 C.I. = 0.027 C.R. = 0.051

Scale of projects completed	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	7	5	0.731
Bid 2	1/7	1	1/3	0.081
Bid 3	1/5	3	1	0.188

λ max = 3.064 C.I. = 0.032 C.R. = 0.062

Types of projects completed	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	2	1	0.400
Bid 2	1/2	1	1/2	0.200
Bid 3	1	2	1	0.400

λ max = 3.000 C.I. = 0.000 C.R. = 0.000

Experience in local area	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	1/3	1/4	0.126
Bid 2	3	1	1	0.416
Bid 3	4	1	1	0.458

λ max = 3.009 C.I. = 0.005 C.R. = 0.009

Physical resources	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	6	8	0.754
Bid 2	1/6	1	4	0.181
Bid 3	1/8	1/4	1	0.065

λ max = 3.136 C.I. = 0.068 C.R. = 0.117

Human resources	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	6	4	0.691
Bid 2	1/6	1	1/3	0.091
Bid 3	1/4	3	1	0.218

λ max = 3.053 C.I. = 0.027 C.R. = 0.051

Current workload	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	6	1	0.472
Bid 2	1/6	1	5	0.084
Bid 3	1	5	1	0.444

λ max = 3.004 C.I. = 0.002 C.R. = 0.004

Past client/ contractor relationship	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	9	8	0.804
Bid 2	1/9	1	1/2	0.074
Bid 3	1/8	2	1	0.122

λ max = 3.036 C.I. = 0.018 C.R. = 0.035

Safety performance	Bid 1	Bid 2	Bid 3	Normalized priorities
Bid 1	1	1/4	1	0.184
Bid 2	4	1	2	0.584
Bid 3	1	1/2	1	0.232

λ max = 3.053 C.I. = 0.027 C.R. = 0.051

λ max = Principal Eigenvalue
C.I. = Consistency Index
C.R. = Consistency Ratio

Figure 3 hypothetical illustrations of the scores of the three contractors

Table 9 Final overall prioritization of the three bids

Tender price		Financial statement	Financial references	Failure to have contract completed	Cost overruns	Delay	Quality	Scale
Bid 1	0.072	0.200	0.747	0.674	0.796	0.691	0.770	0.731
Bid 2	0.650	0.400	0.060	0.101	0.125	0.218	0.068	0.081
Bid 3	0.278	0.400	0.193	0.226	0.079	0.091	0.162	0.188
Relative Criteria priority	0.342	0.221	0.024	0.091	0.023	0.020	0.006	0.043
Type		**Experience**	**Physical resources**	**Human resources**	**Current workload**	**Past client/ contractor relationship**	**Safety performance**	
Bid 1	0.400	0.126	0.754	0.691	0.472	0.804	0.184	
Bid 2	0.200	0.416	0.181	0.091	0.084	0.074	0.584	
Bid 3	0.400	0.458	0.065	0.218	0.444	0.122	0.232	
Criteria Relative priority	0.037	0.010	0.0395	0.0395	0.049	0.032	0.023	

Table 10 Composite prioritization

Bid 1	0.342 (0.072) + 0.221 (0.200) + 0.024 (0.747) + 0.091 (0.674) + 0.023 (0.796) + 0.020 (0.691) + 0.006 (0.770) + 0.043 (0.731) + 0.037 (0.400) + 0.010 (0.126) + 0.0395 (0.754) + 0.0395 (0.691) + 0.049 (0.472) + 0.032 (0.804) + 0.023 (0.184) =	**0.342**
Bid 2	0.342 (0.650) + 0.221 (0.400) + 0.024 (0.060) + 0.091 (0.101) + 0.023 (0.125) + 0.020 (0.218) + 0.006 (0.068) + 0.043 (0.081) + 0.037 (0.200) + 0.010 (0.416) + 0.0395 (0.181) + 0.0395 (0.091) + 0.049 (0.084) + 0.032 (0.074) + 0.023 (0.584) =	**0.375**
Bid 3	0.342 (0.278) + 0.221 (0.400) + 0.024 (0.193) + 0.091 (0.226) + 0.023 (0.079) + 0.020 (0.091) + 0.006 (0.162) + 0.043 (0.188) + 0.037 (0.400) + 0.010 (0.458) + 0.0395 (0.065) + 0.0395 (0.218) + 0.049 (0.444) + 0.032 (0.122) + 0.023 (0.232) =	**0.283**

CONCLUSIONS

Contractor selection has been a much-debated issue over the past few decades. Some construction clients are used to accepting the lowest bids from prequalified contractors, and it is undeniable that the tender sum is a major consideration because of the instability and competitiveness of the construction industry, but should the potential to deliver an acceptable project on schedule with adequate quality standards be sacrificed? Quality, time and cost should not be under- or overweighed, so an effective selection process is crucial for clients wishing to strike a balance for successful project outcomes. The definition of success is both objective and subjective, and varies according to clients, designers and contractors. Contractor selection can be divided into two phases: prequalification and final selection. Our research aimed at the latter stage: selecting a contractor to whom to award a contract.

68 criteria were collected from 10 publications, summarized, and grouped into a smaller number of underlying factors. However, these groupings were still too many for our questionnaire, so they were revised further into 8 categories. Tender price is usually the most significant, or even the only, criterion in contractor selection. As the awarding of contracts now sometimes depends on the ability of contractors to perform satisfactorily, the lowest price as the main criterion is challenged by many authors.

Since each construction project is unique, final contractor selection through the AHP gives clients the flexibility to add or reduce the elements of a problem hierarchy regarding an individual project. In addition, the strengths and weakness of each eligible contractor are exposed. The AHP is therefore valid as a model for contractor selection.

REFERENCES

- Authority, H. K. (1994). *PASS Performance Assessment Scoring System.* Housing Department. Hong Kong Housing Authority.
- Baker, M., & Orsaah, S. (1985, May). How do Customers Choose a Contractor? *1*.
- Brook, M. (1993). Estimating and Tendering For Construction Work. *Butterworth Heinenmann* .
- Choi, S. K.-Y., & Fong, P. S.-W. (2000, July). Final contractor selection using the analytical hterarchy process. *Construction Management and Economics* , *18*, pp. 547 - 557.
- Diekmann, J. E. (1981). Cost - Plus Contractor Selection for Construction Work. *Journal of the Technical Council for ASCE* , *107* (1), 13 - 25.
- Flanagan, R., & Norman, G. (1982, March). Making Good Use of Low Bids. *226* (7).
- Griffith, A. (1992). *Small Building Works Management.* London: Macmillan.
- Hartman, F. T. (1993). Construction Dispute Resolution through an Improved Contracting Process in the Canadian Context. Loughborough University.
- hatush, Z., & Skitmore, M. (1998). Contractor Selection using multicriteria utility theprу: An Additive Model Building and environment .
- Hatush, Z., & Skitmore, M. (1997). Evaluating contractor prequalification data: selection crieria and project success factors.
- Holt, G. D., Olomolaiye, P. O., & Harris, F. C. (1995). A Review of Contractor Selection in the UK Construction Industry. *Business & Enviornment* , *4*, pp. 241 - 248.
- Holt, G. D., Olomolaiye, P. O., & Harris, F. C. (1995). Applying Multi Attribute Analysis to Contractor Selection Decisions. *European Journal of Purchasing and Supply Management* , *1* (3), 139 - 148.

- Holt, G., Olomolaiye, P., & Harris, F. C. (1993). factors influencing UK Construction clients' choice of contractor . *Building and Environment* .
- Jaselskis, E. J. (1988). Achieveing Construction Projects through Predictive Discrete Choice Models. Austin: University of Taxas.
- Jaselskis, E. J., & Russell, J. S. (1991). An Efficiently Structured Approach for Selection of Most Promising Construction Contractors. *Project Management Journal* , *12* (4), 31 - 39.
- Kangori, R., & Bakheet, M. (1994). Linguistic Analysis of Risk in Project Planning. *Proceedings of the Computing in Civil Engineering Congress*, (pp. 20 - 22). Washington D. C.
- Kumaraswamy, M. (1996). Contractor Evaluation and Selection : A Hong Kong Perspective. *Building and Environment* , *3*, pp. 272 - 283.
- Latham, M. (1994). *Constructing the Team, HMSO.* London.
- McCanils, E. W. (1967). *Tendering Procedures and Contractual Arrangement.* Research and Information Group of the Quality Surveyors' Committee.
- Merna, A., & Smith, N. J. (1990). Bid Evaluation for UK Public Sector Construction Contracts. *Proceedings of the Institution of Civil Engineers*, *88*, pp. 91 - 105.
- Muralidhar, K., Santhnam, R., & Wilson, R. L. (1990, February). Using the Analytic Hierarchy Process for Information System Project Selection. *Information and Management* , pp. 87 - 95.
- Nguyen, V. U. (1985). Tender Evaluation by Fuzzy Sets. *Journal of Construction Engineering and Management ASCE* , *111*, 231 - 243.
- NJCC. (1974). Tendering Procedure for Industrilized Building Projects. *RIBA* .
- Nydick, R. L., & Hill, R. P. (1992). Using the Analytic Hierarchy Process to Structure the Supplier Selection Procedure. *Journal of Purchasing and Materials Management* , 31 - 36.
- Patrovi, F. Y. (1994). Determining what to benchmark an analysis hierarchy process approach. *Interanational Journal of Operations and Production management* , *14* (6), 25-39.
- Pearson, G. T. (1985). Tender Assessement Chartered Quantity Surveyors. *18* , 194-5.
- RICS. (1997). The Effect of Competitive Tendering on value in Construction. *Royal Institution of Chartered Surveyors, London* .
- Russel, J. S. (1992). Decision models for analysis and evaluation of construction contractors. *Construction Management and Econmoics* , *10*, 185-202.
- Russel, J. S., & Skibinewski, M. J. (1990a). Qualifier 1: A Computerized Decision Model for Contractor Prequalification. *Journal of Computing in Civil engineering ACSE* , *4* (1), 77-90.
- Russel, J. S., & Skibniewski, M. J. (1990b). Qualifier 2: A Knoowlegde based system for contractor

Prequalification. *Journal of Construction Engineering and Management ACSE , 116* (1), 157-71.

- Russell, J. S., & Skibniewski, M. J. (1988). Decision crieteria in Contractor Prequalification. *Jornal of Management in Engineering ASCE , 4* (1), 148-64.
- Saaty, T. L. (1994). Decision Making in Economic, Political, Social, and Technological Environments with the Analytic Hierarchy Process. RWA Publication PA.
- Saaty, T. L. (1996b). Decision Making with Dependence and Feedback. The Analytic Network Process. RWA Publication Pittsburgh PA.
- Satty, T. L. (1995). Decision Making for Leaders: The Analytical Hierarchy Process for Decision in a Complex World. RWA Publication PA.
- Satty, T. L. (1996a). Multicriteria Decision Making. RWA Publication, Pittsburgh PA.
- Smith, A. J. (1995). Estimating, Tendering and Bidding for Construction. Macmillan London.
- Works, M. o. (1966). *Tendering Procedures : Early Selection of Contractors Serial Tendering.* London: Directorate of Building Management, HMSO.