Construction Contractor Selection in Taiwan Using AHP

Fu-Yuan Chiang, Vincent F. Yu, and Pin Luarn

***Abstract*—In Taiwan, construction-project owners sometimes divide contractor selection into two phases: prequalification and final selection. The first phase entails evaluating the contractors' prequalifications and is a multi-criteria decision-making (MCDM) process, with contractors evaluated based on the weighted sum of their criteria scores. However, the criteria weights are usually determined according to the opinions of the project owners or professionals and may have some shortcomings. This study applies the analytic hierarchy process (AHP) to determine criteria weights and overcome these shortcomings. First, this study determines the appropriate evaluation criteria and constructs the hierarchical structure of the criteria. Second, experts' opinions are analyzed to calculate the following criteria weights: technical ability (0.243), management capability (0.239), financial soundness (0.219), reputation (0.168) and health and safety (0.131). The model proposed in this study for evaluating contractors' prequalifications can serve as a good reference for project owners in the process of selecting contractors.**

***Index Terms*—Contractor selection, prequalification, analytic hierarchy process.**

I. Introduction

For construction project management, it is critical to select a qualified contractor who can meet the construction project owners' time, cost, and quality expectations. However, a construction contractor might fail to fulfill the contract requirements associated with a facility. Thus, screening qualified contractors during the selection process is very important for project owners.

In Taiwan, construction-project owners sometimes use a two-stage process to select contractors. The first stage entails evaluating contractors' prequalifications to screen for qualified contractors. The second entails comparing the bidding price of all of the qualified contractors. The contractor with the lowest total bid price will win the project. The first stage of this process—i.e., evaluating the prequalifications of the contractors—is a multicriteria decision-making (MCDM) process, with contractors evaluated based on the weighted sum of their criteria scores. The criteria weights are usually determined based on the opinions of the project owners or professionals and may have some shortcomings. Some research on prequalifications can overcome these shortcomings. More specifically, this study applies the Analytic Hierarchy Process (AHP) to determine the criteria weights.

II. Contractor Prequalification

Contractor prequalification is a process (see Fig. 1) that uses a set of criteria either given by the project owners or based on experts' opinions to screen and determine whether a contractor can sufficiently perform a contract [1]. Contractors who wish to bid on a project need to be qualified before they can be issued bidding documents. Contractor prequalification models in the literature include the dimensional weighting aggregation model, expert systems, multiattribute analysis, fuzzy sets, logistic regression, the support vector machine (SVM), a cash-flow-based model and AHP.

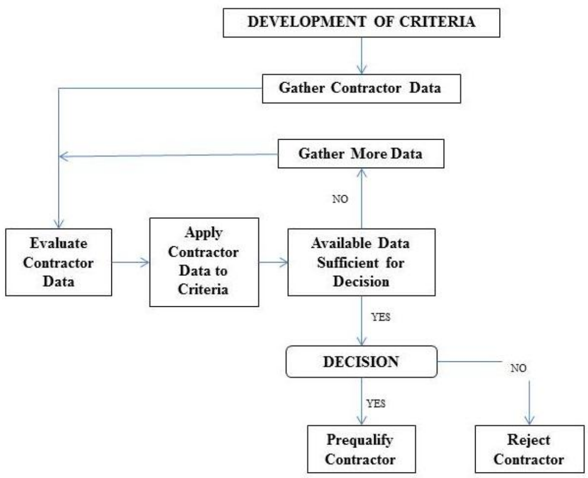

Fig. 1. Flow diagram of contractor prequalification process (Russell & Skibniewski [1]).

Russell and Skibniewski [2] created the computer program Qualifier-1 to draw up a model with a linear combination of decision criteria. Once the rating for each decision factor is entered into the program, the aggregated weighted rating of each contractor candidate can be measured to facilitate prequalification decision making. Qualifier-2, a more advanced program than Qualifier-1 with a knowledge-based expert system, was developed by Russell *et al*. [3] to add decision rules into the program design and enhance the decision-making process.

Although some models strongly considered quantitative factors, they actually enhanced those factors' inherent deficiencies. This problem led to the development of a quantitative model to employ multiple variables for the analysis. The prequalification criteria entered into the model are identified and weighted to reflect the importance in the determined and selected process [4].

Contractor prequalification models bring many factors (for

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DOI: 10.7763/IJET.2017.V9.972

example, experience and financial standing) into the decision-making process. Although the factors provided by construction owners should be valid, some of these factors are difficult to quantify in a mathematical model. To resolve this situation, a model based on fuzzy set theory was introduced by Edyta Plebankiewicz [5].

A logistic regression (LR) model for forecasting contractor performance was developed by Wong [6] based on 31 tender-evaluation criteria. Forty-eight real projects were included in the model design. Later, this model was employed to validate 20 independent cases, proving to be 75% statistically correct in forecasting contractor performance.

Lam *et al*. [7] argue that contractor prequalification is nonlinear and that both quantitative and qualitative factors should be included in the model. Furthermore, they develop a new contractor prequalification model that employs a support vector machine.

Huang *et al*. [8] propose the adoption of a cash flow-based credit model for the prequalification of contractors' financial health because cash flows impact the ability of contractors to meet financial obligations in the construction industry.

A hybrid prequalification and selection model was developed by Abudayyeh *et al*. [9] to employ AHP, specifically when multiple criteria are considered. This hybrid model was leveraged by public owners to ensure that contractors can complete projects successfully.

III. Methodology

AHP, which was developed by Saaty [10], is a decision-aiding method that determines the relative importance weights of decision criteria. It uses a structured technique for analyzing MCDM problems based on pairwise comparisons. The strength of this approach is that AHP not only organizes quantifiable and non-quantifiable factors in a scaled systematic way but also provides a structured, relatively simple solution to decision-making problems.

The AHP process can be summarized in 4 basic steps [9]:

1) Define the problem and structure of the hierarchy using the criteria and possible solutions;
2) Construct a pairwise comparison matrix of alternatives for each criterion or subcriterion;
3) Calculate priorities;
4) Determine consistencies.

A. Criteria and Hierarchic Structure

The first contractor prequalification decision problem is to collect a set of criteria and express them as a hierarchy. The major problem solution of the decision lies at the top of the hierarchy. The criteria and sub-criteria are found on each descending level of the hierarchy. Based on the available literature review, only El-Sawalhi *et al*. [11] summarizes criteria from works published by several researchers (see Table I); however, an additional number of criteria for contractor prequalification have been raised (Abudayyeh *et al*. [9], Ng and Skitmore [12], Arslan *et al*. [13], Li *et al*. [14], Nieto-Morote and Ruz-Vila [15], Alzahrani and Emsley [16], Ng and Tang [17], Doloi *et al*. [18], Hatush and Skitmore, [19]). During the last couple of years, determining which of these criteria will become an element in the hierarchy has been a problem. Definitions for these criteria (see Table II) have been suggested by Hatch and Skitmor [19], and the hierarchic structure is shown in Fig. 2.

TABLE I: Standing List of Prequalification Criteria (El-Sawalhi *et al.* [11])

Group	Attribute
Financial stability	Credit rating
	Turnover
	Bank arrangement
	Debit ratio
	Liquidity
	Profitability
Management and technical ability	Experience of staff
	Management capability
	Qualification of staff
	Past performance
	Quality performance
	Company organization
	Innovate method
Experience	Type of project
	Size of project
	Number of projects
	Experience in the region
	Length of time in business
Historical non-performance	Company image
	Skilled manpower
	Client satisfaction
	Record of failure
	Claims and litigation
Resources	Equipment
	Number of staff
Quality	Quality control
	Quality policy
	Quality assurance
Health and safety	Safety performance
	Accountability
	Injury and illness

TABLE II: Main Criteria and Subcriteria for Contractor Prequalification (Hatch & Skitmore [19])

Main criteria	Subcriteria
Financial soundness (FS)	1. Financial stability 2. Credit rating 3. Banking arrangements and bonding 4. Financial status
Technical ability (TA)	1. Experience 2. Plant and equipment 3. Personnel 4. Ability
Management capability (MC)	1. Past performance and quality 2. Project management organization 3. Experience of technical personnel 4. Management knowledge
Health and safety (HS)	1. Safety 2. Experience modification rating (EMR) 3. Occupational Safety and Health Administration (OSHA) incidence rate 4. Management safety accountability
Reputation (R)	1. Past failures 2. Length of time in business 3. Past client/contractor relationship 4. Other relationships

B. Pairwise Comparison

The next step is to define the relative priority of each criterion and the method Pairwise comparison is used, and only two criteria are involved in the comparison at one time.

Subcriteria in a level of the hierarchy are pairwise and are compared to derive priorities with respect to their importance to the criteria at a higher level, starting at the top of the hierarchy and working down. The scale used for making the pairwise comparison judgments is provided in Table III [10].

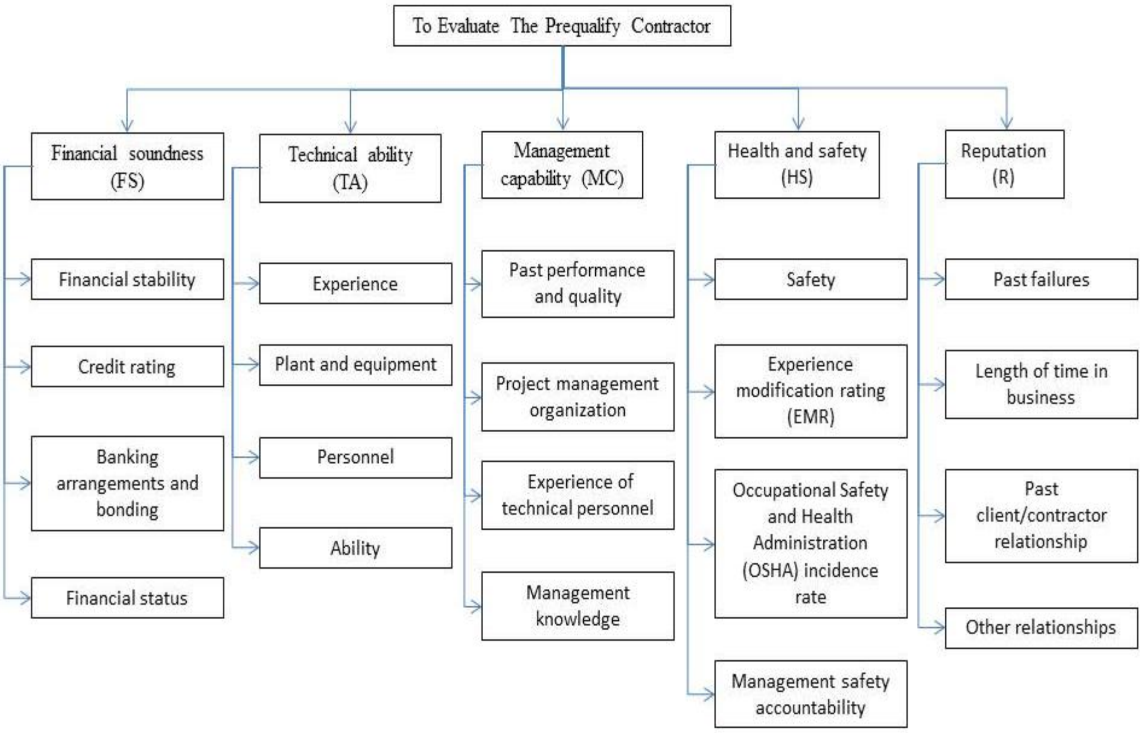

Fig. 2. Hierarchy for evaluating the prequalifications of contractors.

TABLE III: THE FUNDAMENTAL SCALE (SAATY [10])

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

C. Samples and Consistency Requirements

During the pairwise comparison process, consider the limitation of a 9-value scale and the inconsistency in human judgment when weights are assessed. The aggregation weight vector may be invalid. The consistency index (CI) is used to measure inconsistency. The *CI* is defined as (1):

$$CI = \frac{\lambda max - n}{n-1} \tag{1}$$

where n is the number of criteria, and λmax is the maximum eigenvalue. If the consistency of the pairwise comparison results is to be accepted, the ratio (called the consistency ratio, CR) of the *CI* to that from random matrices must be significantly small (specified as approximately 10% or less). Otherwise, the pairwise comparison results must be rejected [10].

In this study, the survey targets included construction project owners and experts. Fifty questionnaires were recovered and analyzed. After eliminating inconsistent questionnaires (i.e., *CR*>0.1), the weight analysis included 29 valid questionnaires.

IV. RESULTS AND DISCUSSION

The weighting results obtained using the AHP approach is shown in Table IV. Technical ability (TA) and management capability (MC) are the most important criteria for contractor prequalification. Gündüz *et al*. [20] analyzes the performance factors for delayed construction projects. The first three factors were lack of experience, inefficient scheduling and planning, and incompetent site management. Thus, for the owners of construction projects not only to ensure that projects are successful but also to avoid schedule delays, technical ability (TA) and management capability (MC) must be the most important criterion in evaluating the contractor-prequalification process.

Financial soundness (FS) is the third most important criterion for contractor prequalification. Fan *et al*. [21] find that that among 11 industries in 39 countries, the construction industry had the second-highest mean leverage. This means that the construction industry has to rely heavily on loans and assumes higher financial risks than other industries. Li *et al*. [22] find that 70% of Taiwan's construction companies default because of financial failure and bankruptcy. Therefore, project owners have an urgent need to assess contractors' financial soundness during the prequalification stage.

TABLE IV: WEIGHT OF EACH CRITERION

Criterion	Local weight[a]	Subcriterion	Local weight[a]	Global weight[b]
Technical ability (TA)	0.243	Experience	0.491	0.119313[c]
		Plant and equipment	0.140	0.034020
		Personnel	0.148	0.035964
		Ability	0.221	0.053703
Management capability (MC)	0.239	Past performance and quality	0.293	0.070027
		Project management organization	0.254	0.060706
		Experience of technical personnel	0.257	0.061423
		Management knowledge	0.196	0.046844
Financial soundness (FS)	0.219	Financial stability	0.354	0.077526
		Credit rating	0.300	0.065700
		Banking arrangements and bonding	0.153	0.033507
		Financial status	0.193	0.042267
Reputation (R)	0.168	Past failures	0.429	0.072072
		Length of time in business	0.137	0.023016
		Past client/contractor relationship	0.255	0.042840
		Other relationships	0.179	0.030072
Health and safety (HS)	0.131	Safety	0.417	0.054627
		Experience modification rating (EMR)	0.146	0.019126
		Occupational Safety and Health Administration (OSHA) incidence rate	0.194	0.025414
		Management safety accountability	0.243	0.031833

a The local weight is derived from judgment with respect to a single criterion.
b The global weight of the subcriterion is obtained by multiplying the local weight of the subcriterion by the local weight of the criterion.
c This entry is obtained as follows: 0.243* 0.491 =0.119313.

The last two criteria weights for contractor prequalification are reputation (R) and health and safety (HS). This indicates that construction-project owners are either not very concerned about or unlikely to reference contractors' reputation and health and safety.

In this study, the following contractor prequalification model is suggested:

$$V = \sum_{i=1}^{k} W_i F_i \quad (2)$$

where V is the prequalification score, K is the number of subcriteria, Wi is the global weight of the i-th subcriterion, and Fi is the score of the i-th subcriterion that given by the project owner or professionals. The owner can use this model to evaluate the prequalification of contractors and sort by the score (V). The final task is to choose the higher-evaluated contractor for the second phase of bidding in the contractor-selection process.

V. CONCLUSION

Selecting a qualified contractor is an important task for a project owner to ensure that his project is completed within budget, on schedule and with good quality. The method of evaluating prequalifications to screen for qualified contractors and then selecting a qualified contractor with the lowest total bid price is a useful approach for project owners, giving them the opportunity to select an experienced, competitive contractor. This study proposes an approach to the multicriteria contractor selection process. Twenty quantitative and qualitative subcriteria were identified. AHP was used to rank and weight the criteria according to their importance. The contractor's technical ability and management capabilities had the highest impact when selecting contractors, with weights of 24.3% and 23.9%, respectively.

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