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 stage 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.

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
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 hierarchic structure. 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], Doloji 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 Skitmore [19], and the hierarchic structure is shown in Fig. 2.

### TABLE I: STANDING LIST OF PREQUALIFICATION CRITERIA (EL-SAWALHI ET AL. [11])

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

### TABLE II: MAIN CRITERIA AND SUBCITERA FOR CONTRACTOR PREQUALIFICATION (HATCH & SKITMORE [19])

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

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].

**Table III: The Fundamental Scale (SAATY [10])**

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

where \( n \) is the number of criteria, and \( \lambda_{\text{max}} \) 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 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 due to 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

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Local weight</th>
<th>Subcriterion</th>
<th>Local weight</th>
<th>Global weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical ability (TA)</td>
<td>0.243</td>
<td>Experience</td>
<td>0.491</td>
<td>0.119313³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plant and equipment</td>
<td>0.140</td>
<td>0.034020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Personnel</td>
<td>0.148</td>
<td>0.035964</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ability</td>
<td>0.221</td>
<td>0.053703</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past performance and quality</td>
<td>0.293</td>
<td>0.070027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Project management organization</td>
<td>0.254</td>
<td>0.060706</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experience of technical personnel</td>
<td>0.257</td>
<td>0.061423</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Management knowledge</td>
<td>0.196</td>
<td>0.046844</td>
</tr>
<tr>
<td>Management capability (MC)</td>
<td>0.239</td>
<td>Financial stability</td>
<td>0.354</td>
<td>0.077526</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Credit rating</td>
<td>0.300</td>
<td>0.065700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Banking arrangements and bonding</td>
<td>0.153</td>
<td>0.033507</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Financial status</td>
<td>0.193</td>
<td>0.042267</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past failures</td>
<td>0.429</td>
<td>0.072072</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of time in business</td>
<td>0.137</td>
<td>0.023016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past client/contractor relationship</td>
<td>0.255</td>
<td>0.042840</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other relationships</td>
<td>0.179</td>
<td>0.030072</td>
</tr>
<tr>
<td>Financial soundness (FS)</td>
<td>0.219</td>
<td>Safety</td>
<td>0.417</td>
<td>0.054627</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experience modification rating (EMR)</td>
<td>0.146</td>
<td>0.019126</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occupational Safety and Health Administration (OSHA) incidence rate</td>
<td>0.194</td>
<td>0.025414</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Management safety accountability</td>
<td>0.243</td>
<td>0.031833</td>
</tr>
<tr>
<td>Reputation (R)</td>
<td>0.168</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health and safety (HS)</td>
<td>0.131</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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:

$$V = \sum_{i=1}^{K} W_i F_i$$  \hspace{1cm} (2)

where $V$ is the prequalification score, $K$ is the number of subcriteria, $W_i$ is the global weight of the $i$-th subcriterion, and $F_i$ 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.

### References


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