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Contractor management performance evaluation model at prequalification stage

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ABSTRACT

The client's choice of contractor at the project prequalification stage is critical as the selected contractor is responsible for the overall coordination of a project. Although a wide variety of criteria have been employed to develop models for contractor selection, one critical component of their capability – management performance – has historically been among the least addressed but, we argue, most critical elements in a useful selection model. Even in the cases when management performance is considered, it has typically focused only on objective outcome criteria of limited predictive power, such as contractor time and cost performance. This paper reports on the results of a study to develop a comprehensive contractor evaluation model that directly addresses the contractor management capabilities and practices as a critical additional element at the prequalification stage. Using a multi-step research process, including extensive literature review, analysis and synthesis of critical contractor management performance factors, development of an analytic network project (ANP) model, and subsequent case study and field validation, we identified a robust model that enhances the decision support tools for the client organization by creating databases for comparing multiple contractors with respect to management practices. In addition, the evaluation of this prequalification criterion permits the contractors to focus on their efforts to address the critical management practices to improve their project performance.

1. Introduction

One of the most important tasks encountered by a client who hopes for successful project outcomes is selecting a capable construction contractor (Plebankiewicz, 2010). In many countries, the prequalification criteria are commonly tailored to select competent contractors. Once a proper selection process has been completed, the client can then entrust the contractor to carry out the project. The literature identifies several prequalification criteria that can be used in the selection process; the most common of which are: management capability, technical ability, financial capacity, and occupational health and safety (Hatush & Skitmore, 1997; Huang, Tserng, Jaselskis, & Lee, 2014; Plebankiewicz, 2009). Different evaluations are typically conducted for each prequalification criterion; however, the evaluations employed for some prequalification processes are ambiguous or highly subjective (Hosny, Nassar, & Esmail, 2013). Prequalification criteria, such as financial capacity, technical ability, occupational health, and safety are assessed by the evidence provided by the contractors. For example, for the issue of financial capacity, contractors routinely provide evidence of their credit rating, banking arrangements, bonding and financial status; for technical ability, information on equipment availability, resources and tools is commonly provided; for the health and safety performance of the contractor, it is common to show occupation health and safety incident rates. However, while the "hard" evidence supporting these critical criteria are well-understood, evidence to demonstrate competence in the equally-critical prequalification category of management capability is often harder to gather, evaluate, and use to compare competitive bids; in effect, the evaluations employed for management capability are still ambiguous or highly subjective (Plebankiewicz, 2009).

Management capability is an important criterion in the critical prequalification process of contractor selection. The management capability construct, as it compares to other prequalification criteria, embodies an array of different characteristics, behaviors, and traits necessary for effective job performance (Abraham, Karns, Shaw, & Mena, 2001). Management capability has both

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subjective and objective variables embedded in its meaning. Objective criteria that might be assessed include evidence from the contractor's previous performance to certify and confirm the quality of work done, the nature of the project, and years of experience in similar projects (Aje, Odusami, & Ogunsemi, 2009; Huang, 2011). On the other hand, subjective variables typically include monitoring and controlling ability, problem solving skills, stakeholder management, team development skill, general project management knowledge, and resource management. The evaluation of subjective variables used in the prequalification models are therefore ambiguous and subject to multiple and even competing, interpretations.

Various prequalification models for contractor selection have been identified; however, there are two important inadequacies of these models regarding the evaluation of subjective management capability variables. First, the models are not comprehensive since they do not include a sufficient set of the subjective variables relating to the management capability. For example, studies on prequalification evaluation by Fong and Choi (2000), Cheng and Li (2004), Turskis, Tamošaitienė, and Zavadskas (2008) included only the variable of interaction between client and contractor. Second, the models used to date have focused almost exclusively on time and cost performance as project outcome variables, which are typically not sufficiently comprehensive when evaluating the management capability of contractors. For example, studies by Wong (2004), Plebankiewicz (2009) related the assessment of past performance for management capability only to the time and cost performance of the previous projects. Other critical project outcomes, including stakeholder satisfaction or project quality, were not evaluated. Project evaluation is here further complicated by confusion regarding cause and effect in outcomes. For example, although Aje et al. (2009) confirmed that management capability has the highest impact on a project's time and cost performance, it does not necessarily mean conversely that overruns in time and cost are indicative of bad management performance of the contractors. For example, in Assaf and Al-Hejji's (2006) study, 76% of the contractors and 56% of the consultants indicated that the average schedule overrun was between 10% and 30% of the original duration (Al-Momani, 2000; Chan and Kumaraswamy, 1997; Mansfield, Ugwu, & Doran, 1994; Ogunlana, Promkuntong, & Jearkjirm, 1996). Assaf and Al-Hejji (2006) mentioned that the most common cause of delay identified by all the three parties (contractor, client, and consultant) is "change orders," which is most often initiated by the client. Similarly, the causes of rework, a significant factor contributing to poor project performance, are not well understood and remain an innate problem in construction (Love & Edwards, 2004). Therefore, measuring the management capability of contractors only through time and cost performance is inappropriate.

As a result, a genuine concern arises in linking this cause (management capability) to inadequate or only partial effects – schedule and cost. Better evaluation methods have to be developed to assess the management capability prequalification criterion for two reasons. First, it has a major impact on time and cost performance (in addition to other important outcome variables). Second, it can support the identification, evaluation and screening of other, important prequalification criteria approved by the client. To illustrate: an important management capability involves the firm being equipped with the resources and tools/means to ensure the prequalification of contractors with strong technical abilities and subsequently, monitor contractors' on the job performance. Thus, at a minimum, it is crucial to exercise due care in evaluating construction contractors' management capability in order to reach the desired performance in terms of time, cost, and quality.

The purpose of this paper is to develop a model that evaluates the management capability of contractors based on their management practices. Specifically, our model addresses the shortcomings of previous work in contractor management capability evaluation by creating a decision-support method that integrates management variables, practices, and factors influencing contractor performance is developed. There are five phases in this model: (1) determining the importance of the management capability variable with respect to factors influencing a contractor's performance; (2) determining the importance of management practices with respect to their relative management capability variables; (3) allowing the site supervisor or other key stakeholders who monitor the contractor's performance to evaluate these relevant management practices; (4) determining the performance index for each management variable; and (5) combining the performance indices on management practices to evaluate the contractor's overall management capability. The analytic network process (ANP) was employed in this model to evaluate the multidirectional relationships among decision elements.

2. Contractor evaluation and selection models

There are a number of existing tools and methods formulated to evaluate and select contractors, including the analytic network process (ANP), analytic hierarchy process (AHP), Artificial Neural Network (ANN), fuzzy logic, and the multi-utility theory. Researchers like Minchin and Smith (2005) have introduced innovative quality-based performance rating systems that generate an index for all contractors to indicate their quality for a specific frame. On the other hand, Albino and Garavelli (1998) formulated a neural network process to evaluate subcontractors. Senthil, Srirangacharyulu, and Ramesh (2014) addressed the problem of contractor selection by using AHP and fuzzy techniques. The fuzzy number theory has also been used by Yawei, Ziangtian, and Shouyu (2007) to develop a framework for the contractor prequalification process. Zavadskas, Kazimieras, and Tamosaitieme (2008) used the multi-attribute method to assess and select contractors by specifically developing a model that takes into account all factors affecting construction efficiency. The evaluation system developed for highway engineers by Hancher and Lambert (2002) has been used to gauge contractor's performance during year end. The ANP-Monte Carlo simulated model proposed by El-Abbasy, Zayed, Ahmed, Alzraiee, and Abouhamad (2013) is a novel approach where multi-criteria are considered to select the best contractor for highway projects. Although these selection models have been used with varying degrees of success, it is critical to note that the majority of selection models have yet to address interdependencies and uncertainties simultaneously. The decision-making process is influenced by a number of factors or attributes that should be considered when characterizing any competitive contractor. In fact, the cause and effect loop relationships among factors are critical to the entire selection, which means interdependency exists between the factors. In addition, all factors' weighting has a certain degree of inborn uncertainties because different respondents answer differently (between-subject variation can be high). Thus, the integration of an interdependency system and uncertainties is important for each decision making model.

Although this study only considers the interdependency system and simulation for the evaluation of contractors for a residential building project, the methodology can be readily generalized to a much broader array of project settings, both in construction and in other arenas where vendor/contractor qualification and selection is critical. An evaluation model that has integrated well-known management capability variables, practices, and factors influencing contractor performance is introduced in this paper. This model uses an analytic network process (ANP) to gauge the multidirectional relationships among elements. Using our model (simulation), the weights of the factors are selected based on the weight with the highest possibility from the respondents' probability distribution. The variables' relative importance, as well as their respective management practices' weight was employed to assess contractor performance.

3. Management capability variables for contractors

"Management" encompasses the organizing, planning, controlling, and leading processes executed to achieve the project objectives (Abiola, 2000). It also involves other aspects such as the recruitment and allocation of resources and funds to produce an outcome (Aje et al., 2009). As such, a contractor should equip their company with qualified and skilled staff with project management skills. Nevertheless, perhaps because of the very ambiguity of the term "management," it is nearly impossible to find agreement of the nature of management capability. For example, according to Aje et al. (2009), for example, the variables of management capability, based on the analysis of respondents' ratings, are: contractors' experience; quality control program; management knowledge; past performance and quality achieved; and number (size) of the workforce in the company. Wong, Nicholas, and Holt (2003) identified control and monitoring procedures, the ability to manage risks, and adequacy of information technology knowledge as key managerial factors. According to Hatush and Skitmore (1997), past performance and quality, the nature of the project management organization, experience of technical personnel, and management knowledge are the critical sub-factors of contractor management capability. On the other hand, McCaffer (1979) concluded that the effective use of plant and equipment can significantly impact the contractor's time performance and if it is managed well, successful projects can be delivered. Table 1 depicts the management capability variables listed in various studies. The six most repeated management capability variables are: monitoring and controlling; problem-solving ability; team development skill; management knowledge; organizational management, and resource management. Other than the factor "organizational management," which had obtained the lowest rate of importance, the rest were emphasized as almost equally important, further complicating efforts to arrive at synthesis. Definitionally, these lists are also suspect, in that terms such as "team development" or "management knowledge" are ambiguous and prone to multiple (and sometimes competing) interpretations. Thus, as a first step, it is critical that we fully define the nature of these management capability constructs.

4. Management practices

Once identifying the critical variables in management capability from the literature reviewed above, we sought to further isolate and identify the relevant sub-processes that contribute to each of these capabilities. From the literature, the most common factors relating to the management capability variables are:

Monitoring and controlling: As the project is carried out, the desired results are compared against the project's progress. If the construction project is complex, it becomes difficult to evaluate the results from limited measurements; thus, management capability as it relates to monitoring typically assumes sophisticated and accurate metrics are available for assessing project status (performance measurement) and controlling development (Al-Jibouri, 2003). Four of the most commonly used monitoring criteria in project performance are: cost, time, quality and safety (Cheng & Chen, 2002; Russell, 1991).

Problem solving skills: Research conducted on contractor performance has established that although problem solving skills are highly value, most contractors continue to struggle with these activities (Ahern, Leavy, & Byrne, 2014; Lim & Mohamed, 2000). Problem solving remains a challenge because standard models often identify problems as being either "simple" or "complex" in nature (c.f., Daniel, 1990). Simple problems are often characterized as fully identifiable, governed by well-defined laws of behavior, embody passive subsystems, and based on closed (low interface) environments. Complex problems, on the other hand, arise when not all parts of the system are observable, contain probabilistic elements, evolve over time, and involve constant interaction with the environment. Further, it has been well documented through the CoPS (Complex Project Systems) literature that project management challenges are greater due to the movement toward increasingly complex problems (e.g., Williams, 1999). From the literature, we initially identified 10 factors relating to problem solving skills. As a result of our subsequent expert survey (Table 2), we focused on the critical problem solving practices of communication, understanding on the project and its goal, training, and leadership.

Team development skills: The creation and organized development of project teams has long been understood to positively affect project performance (Müller & Turner, 2007). At the same time, there are a number of alternative models of project team development, all offering insight into the process by which teams move toward optimal collaborative performance. One of the earliest models, employing the "forming, storming, norming, and performing" meme, was developed by Tuckman (1965) as a heuristic to show the necessity of passing through and fully embracing each stage in the development process. An alternative model that shows empirical validation is the "punctuated equilibrium" model of Gersick (1988), who found evidence that teams quickly adopt sub-optimal norms for task

Table 1
Management capability variables for contractor.

Authors	Monitoring and controlling	Problem solving	Team development skill	Management knowledge	Resource management	Organizational management
McCaffer (1979)	✓	✓		✓	✓	
Lam, Ng, Tiesong, Skitmore, and Cheung (2000)				✓		
Abiola (2000)	✓	✓			✓	✓
Fong and Choi (2000)		✓				
Wong et al. (2003)	✓	✓	✓	✓		
Wong (2004)	✓	✓	✓	✓		✓
Turskis et al. (2008)		✓				
Plebankiewicz (2009)				✓		
Aje et al. (2009)	✓	✓	✓	✓	✓	✓
Huang (2011)	✓		✓	✓	✓	
Total citation	6	7	4	7	4	3

Table 2
Problem solving skill for the management capability of contractor.

Authors	1	2	3	4	5	6	7	8	9	10
Tjosvold, Yu, and Hui (2004)		✓	✓	✓	✓	✓				
Strobel and Pan (2010)							✓			
Pinto et al. (2009)	✓		✓		✓			✓		
Briscoe, Dainty, and Millett (2001)		✓			✓	✓	✓	✓	✓	
Gray (2001)				✓	✓	✓			✓	✓
Pant and Baroudi (2008)	✓	✓			✓	✓			✓	
Edum-Fotwe and McCaffer (2000)		✓			✓	✓			✓	✓
Baykasoglu, Dereli, and Das (2007)		✓		✓	✓				✓	✓
Odusami (2002)		✓	✓		✓	✓			✓	✓
Turner and Müller (2005)	✓	✓			✓	✓	✓			
Koskinen (2000)			✓		✓	✓				
Kayworth and Leidner (2000)	✓			✓	✓	✓			✓	✓
Total	4	7	4	4	11	9	3	2	7	5

1 – Trust, 2 – leadership, 3 – cooperative relationship among team member, 4 – open discussion, 5 – communication, 6 – understanding the project and it is goal, 7 – troubleshooting, 8 – partnering, 9 – training, 10 – making decision.

accomplishment and member interaction. As a result of increased tensions and performance dissatisfaction, a reassessment (similar to Tuckman's "storming" phase) occurs that prompts a reappraisal of roles and team goals. Successful project team leaders are able to recognize the means by which teams can quickly gravitate toward positive interpersonal and task-oriented behavior in support of project goals while recognizing the need to guide their progress through team development phases.

Management knowledge: Knowledge can be defined as information that is relevant, actionable, and based at least partially on experience (Leonard & Sensiper, 1998). Professional capability in project management is achieved through the blend of knowledge acquired via training (tacit knowledge) and skills developed through experience (explicit knowledge). These skills are then applied to practice. The knowledge required to manage a construction project is critical. According to Edum-Fotwe and McCaffer (2000) the general management knowledge areas for contractors are economics, the relevant legal framework, social trends, political development, IT advancement, statistics and probability theory, and risk. From the expert survey, it was observed that the economics, legal framework, political development, and IT advancement had been highlighted more frequently than other criteria and were subsequently used in our study.

Resource management: Resource management is one of the most important ingredients for competitiveness and profitability in today's construction industry (Abbasianjahromi & Rajaie, 2012; Dolan, Saba, Jackson, & Schuler, 2002). In order to control costs, equipment and labor must be utilized in the most efficient way possible. Resource management is an important management capability variable that has been extensively covered in literature. Its related factors are 'plant and equipment' and 'labor management' (Fong & Choi, 2000; Topcu, 2004; Wong, 2004).

5. Factors affecting contractor's performance

According to Assaf, Al-Hammad, and Ubaid (1996), there are many factors which can influence contractors' performance. Project type, duration, size of contract budget, size and number of change orders, unanticipated rework, past experience, sufficiency of labor and materials, knowledge of the contract, contractor/client relationship, designer's participation, interest rates, sufficiency of profits, consumer spending are factors that have been frequently repeated in the literature. Because the number of factors that affect contractor performance are quite high, we categorized them into four categories, which are "Project Properties," "Technical Characteristics," "Contractor Characteristics," and "Economic Factors" (refer to Table 3).

Project Properties: Each project's properties represent contextual conditions of a project that will affect its performance. A project's properties specify how a project is built and debugged. According to Chen and Lee (2007) the criteria related to project properties are project type (commercial, residential, industrial, infrastructural), duration, and the size of the contract.

Technical Characteristics: This criterion is related to the technical capabilities of the contractor's key management personnel and company, as well as project procedures (e.g., project control procedures). Plebankiewicz (2009), Huang (2011) categorized technical characteristics of contractors into different

Table 3
Factors affecting the performance of contractor.

Authors	Project properties	Technical characteristic	Contractor characteristic	Economic factors
Vlatas (1986)	✓		✓	✓
Russell and Jaselskis (1992)	✓	✓	✓	✓
Russell and Zhai (1996)	✓			✓
Alarcón and Mourgues (2002)		✓	✓	✓
Wang and Yuan (2011)	✓	✓	✓	✓
Memon, Abdul Rahman, Abdullah, and Abdu Azis (2011)	✓	✓	✓	
Chan (2012)			✓	✓
Love, Davis, Ellis, and Cheung (2010)	✓	✓	✓	
Wasi and Skitmore (2001)	✓	✓	✓	✓
Alwi, Hampson, and Mohamed (2002)	✓	✓	✓	
Assaf et al. (1996)	✓	✓	✓	
Xiao and Proverbs (2003)	✓		✓	✓
Total	10	8	11	8

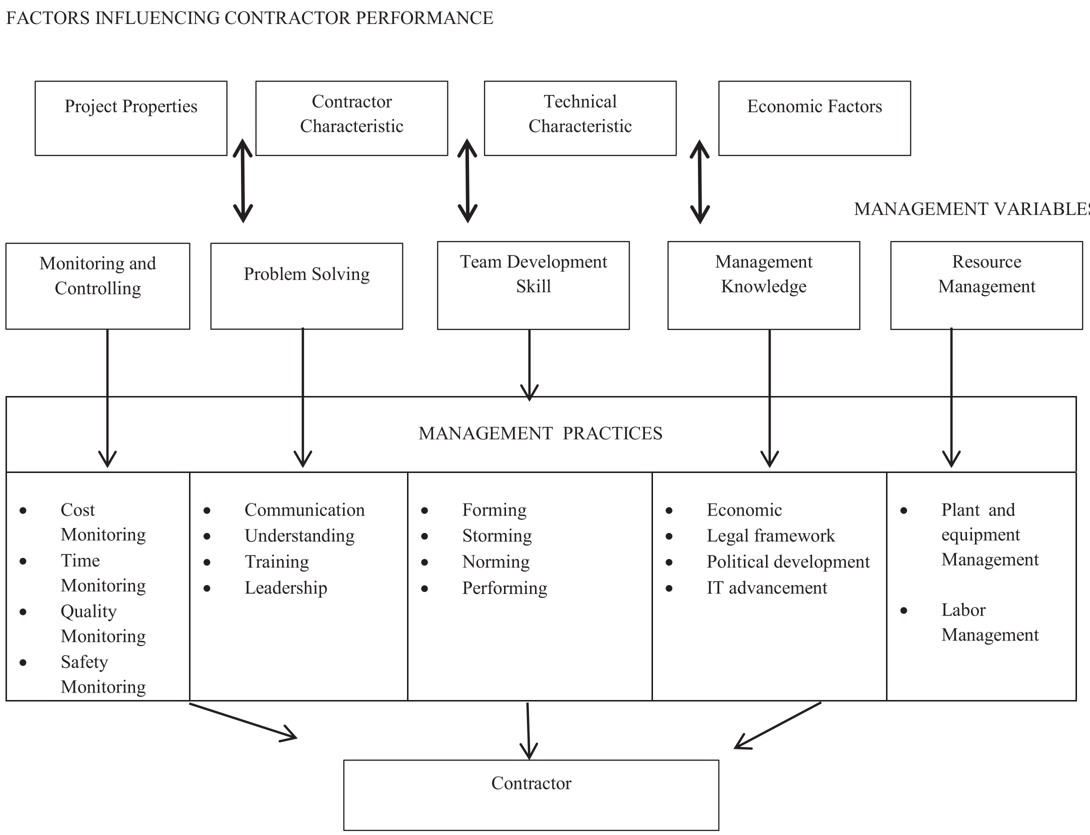

Fig. 1. Network structure model of the contractor performance.

sub-components, which are experience, plant and equipment, personnel, and ability.

Contractor Characteristics: This category identifies the owner-contractor characteristics that can affect project performance (Alarcón & Mourgues, 2002). The most important characteristic, in the eyes of a majority of owners, is the contractor's knowledge of the contract and the contractor relationship with the owner. Trust, for example, has been shown to be a critical element in developing and maintaining a productive owner/contractor relationship (Gil, Pinto, & Smyth, 2012; Pinto, Slevin, & English, 2009). In addition, the manner in which the contractor handles their relationship with the owner during a technical inspection reflects the health of the relationship.

Economic Factors: Failure to manage the risks related to relevant economic factors leads to the strong chance that contractors will suffer economic losses (Wang & Yuan, 2011). Dun and Bradstreet (D&B) Corporation, for example, estimated that more than 60% of contractor failures are due to economic factors (Russell, 1991). According to the literature, insufficient profits, market loss, high interest rates, low consumer spending, and an uncertain future are the factors that contribute to failure. Moreover, there is a direct correlation between the availability of construction projects and general economic conditions; a lack of projects will affect the financial profile of contractors.

Fig. 1 shows the network structure of the evaluation model of the contractor performance that considers the interdependence of management variables and influencing factors. In Fig. 1, the interrelationships are highlighted by the bold arrows and all management practices are assumed to have a unidirectional correlation with the management variables.

6. The ANP Approach for constructing the performance evaluation

Saaty (1996) developed a general analytic network process (ANP) based on the analytic hierarchy process (AHP) to capture dependence and feedback problems (Yang, Chuang, & Huang, 2009). The ANP enables the systematic handling of different kinds of dependence and feedback in the decision system (Abdollahi et al., 2015). ANP has been applied to variety of fields, including strategic planning and operational research decisions (Lin, Chiu, & Tsai, 2008; Wu & Lee, 2007a, 2007b). As aforementioned, management variables and factors affecting contractor performance are interrelated. ANP studies a problem through a control hierarchy network and the decision is structured in clusters – elements as well as links. A cluster gathers the correspondent elements into a network or sub-network. Activities within a cluster (its interactions and feedback loops) refer to the "inter dependencies" while those among clusters are termed "outer dependencies" (Saaty, 1999). These dependencies are important for making comprehensive decisions as well as depicting the interrelations among clusters or elements. Further, in ANP, the network can be expressed easily in mathematical form, whereas this is the shortcoming of the ANN multi criteria decision method (Agatonovic-Kustrin & Beresford, 2000). ANP captures interdependence by calculating the composite weights to formulate a "super matrix;" a unifying framework used to rank the priority of elements as either a hierarchy or a system with feedback (Saaty, 1980). Through the super matrix, the stable weight values of the elements with consideration of different interrelated elements were identified. To capture the weight of elements, systematic pairwise comparisons are made for all possible combinations of element and cluster. The ANP's basis for comparison is the same as AHP where a scale of 1–9 is used to let the decision-maker input their knowledge and experience accordingly (Harker & Vargas, 1990) as well as determine the number of times that an element is dominated by another in a given criterion. To understand various elements' preferences, comparisons are made with reference to the "control" element at a different layer. The scale consists of absolute numbers and each pair can have the preferred element defined as: (1) equally important, (2) moderately more important, (3) strongly more important, (4) very strongly more important, and (5) absolutely more important. These are representative of the number 1, 3, 5, 7, and 9 respectively while 2, 4, 6, and 8 are the in-between values when comparisons are made between two consecutive judgments (Saaty, 1996).

7. Methods

The research methodology of this study consists of six steps: (1) conducting an expert survey, (2) designing the main questionnaire, (3) administering the questionnaire, (4) determining the factors' weight (5) developing the model and (6) validating the model.

7.1. Expert survey

An expert survey was conducted to limit the number of criteria that we had obtained from the initial literature review. According to Saaty (1980), as the number of criteria increases, the brain's ability to make comparisons deteriorates and comparison will become more complex and less trustworthy. Therefore in this study, the highest cited criteria in the literature were selected and from the expert survey, we assessed their importance rank. The Relative Importance Index (RII) method was used in this study to rank the importance of each criterion. The RII was calculated to identify the most critical management variables and management practices. The expert survey was conducted with 15 directors of top construction consulting firms in Malaysia. The directors were the key member of their respective firms routinely involved in the selection of eligible contractors for contract award.

Through our expert survey questionnaire, the experts were asked to rate the importance of each criterion, ranging from 1 to 5 where (5) is "absolutely important" and (1) is "the least important". A sample of the questionnaire scaling is shown in Table 4.

The importance index of the individual criteria was calculated using Eq. (1) (Kometa & Olomolaiye, 1997). Using this equation, the Relative Importance Index (RII) values can be calculated, with range from 0 to 1. The critical criteria/factors have the highest RII value, suggesting they are the most influential or the most important in the subset.

$$\mathrm{RII} = \frac{\sum_{i=1}^{n} W_i}{A * N} \tag{1}$$

where RII is Relative Importance Index, W_i is weight of the criteria (i) given by respondents ranged between 1 and 5, A is the maximum weight given by respondents, and N is the number of respondents.

In addition, using data from the expert survey, we tested the interrelationships among factors affecting contractor performance and management variables. It is clear that there is a different degree of importance among management variables when different influencing factors were considered as a control. We conducted a test to see if there was a different degree of importance among the factors affecting contractor performance with respect to each management variable. We used a pairwise comparison survey of the factors affecting contractor performance with each management variable taken as the control factor in turn. A scale of 1–9 was used to compare the two options (Saaty, 1996). Using SPSS, we conducted a one-way analysis of variance (ANOVA) at a 5% level of significance (P-value) to determine whether there was any statistically significant difference among the means obtained for each management variable as a control factor (Montgomery, Runger, & Hubele, 2004). The results of the ANOVA tests presented in Table 5 reveals a significant difference exists ($P < 0.05$) between factors affecting contractor performance with respect to each management variable, suggesting that the factors affecting contractor performance and the management variables were interrelated.

7.2. Main questionnaire design

We developed our questionnaire using ANP based on both our theory (shown in Fig. 1) and the demonstrated evidence that there is an interrelationship between the management variables and factors affecting contractor performance. We conducted pairwise comparisons using separate questionnaires after setting up the network model with the alternative interrelationships. Similar to AHP, when employing ANP, the pairwise comparisons of the elements at each layer are conducted with respect to the control element. Initially, the experts evaluated the contractor's performance by comparing the management variables with each influencing factor serving as a control variable. Next, the pairwise comparison was conducted between factors affecting contractor performance with respect to each management variable. With this information, it was possible to simultaneously determine both the relative importance of management variables and relative intensity of factors that affect them. Finally, we conducted comparisons between management practices with respect to their relative

Table 4
Sample of questionnaire.

Criteria	Absolutely important (5)	Very important (4)	Important (3)	Not so important (2)	Least important (1)
A					
B					

Table 5
ANOVA analysis for factors affecting contractor performance with respect to each management variable.

Controlling factors	Source of variation	Sum of squares	Degree of freedom	Mean square	F value	Significance level (P) *
Monitoring and controlling	Between group	65.867	5	13.173	6.340	0.000
	Within group	174.533	84	2.078		
Problem solving	Between group	43.975	5	8.795	12.765	0.000
	Within group	57.906	84	0.689		
Team development skill	Between group	119.156	5	23.831	7.719	0.000
	Within group	259.333	84	3.087		
Management knowledge	Between group	24.325	5	4.865	3.422	0.007
	Within group	119.429	84	1.422		
Resource management	Between group	11.538	5	2.308	5.318	0.000
	Within group	36.429	84	0.434		

* The mean difference is significant at the 0.05 level.

Table 6
Sample of pairwise comparison.

With respect to a control factor										
Degree of importance										
Criteria A	(9) Absolute	(7) Very strong	(5) Strong	(3) Moderate	(1) Equal	(3) Moderate	(5) Strong	(7) Very strong	(9) Absolute	Criteria B

management variables. As before, for pairwise comparison between the factors, a scale of 1–9 was used to compare two options (Saaty, 1996). A sample from our pairwise questionnaire is shown in Table 6. Saaty (1996) recommended that the number of comparisons of N elements should be $N\ (N-1)/2$. Thus, in our study 10 questions were needed to compare the five management variables ($N = 5$) with respect to each of the influencing factors, resulting in a 5 * 5 matrix for each respondent. Hence, 40 questions were needed for the four influencing factors as control elements. Similarly, 30 questions were asked for the pairwise comparisons between the four influencing factors with respect to the management variables.

7.3. Questionnaire survey administration

The consulting firms under the Association of Consulting Engineers Malaysia (ACEM) were selected for this study. Most of the well-established and experienced consultancy firms in Malaysia are accredited members of ACEM with the SIRIM certification. All ACEM members are professional engineers registered with the Board of Engineering Malaysia (BEM). The total number of consulting firms under ACEM that specialize in civil work and building are 102. Forty-five of these firms specialize in project management for residential buildings. In the questionnaire distribution phase, to avoid any ambiguity or interpretation difficulty that could affect the respondents' understanding, we visited and conducted on-site surveys. A total of 25 firms were visited with 15 directors participating in the survey, leading to a response rate of 60%.

7.4. Determination of factor weighting

In this study we used the row geometric mean method (RGMM) to test the relative weight of each criteria against others, similar to an approach previously taken by Crawford and Williams (1985) in determining the weight of factors or priority ranking of criteria. RGMM is used to derive a priority vector to order the collective judgment matrix. Multiplying the n elements in each row in the matrix, taking the nth root, and preparing a new column for the resulting numbers are the first steps, which then requires the observer to normalize the new column (i.e., divide each number by the sum of the numbers). Eq. (2) is shown below:

$$W_i = \frac{\sqrt[1/n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n}\left(\sqrt[1/n]{\prod_{j=1}^{n} a_{ij}}\right)} \tag{2}$$

Since there were 15 experts who had participated in the survey, 15 matrices were built for each cluster's pairwise comparison. The appropriate way to combine the different sets of judgment is using geometric means (Aczél & Saaty, 1983). However, two different tests (consistency and compatibility) for the viability of each matrix must be conducted before the geometric mean can be accepted.

7.4.1. Consistency

One of the most important issues in an ANP study is to check the consistency of each respondent's criteria weighting against others in the sample. The ANP model is based on consistent judgement; however, since this judgement is derived from human subjects it is possible that consistency will suffer as the number of criteria increases. Thus, the Consistency Ratio (CR) should be considered to evaluate the degree of inconsistency. If the CR is less than 0.10, the judgments are reasonably consistent and therefore, acceptable. If the CR is greater than 0.10, then the judgments should be revised. The calculation of consistency test was described in detail in Öztayşi, Kaya, and Kahraman (2011). In this study, we found CR values to be below 0.10, so all respondent matrices were considered consistent.

7.4.2. Compatibility

Following Saaty (2005), the compatibility of the model was evaluated to assess the closeness of an individual's judgment against composite outcomes. The geometric mean of the individuals must first be obtained and then each of the individual judgments is compared with the outcome to determine the closeness of an individual judgment. If the compatibility ratio of the matrix is 1.1 or less, the matrix is considered compatible. After assessing the compatibility of the matrices, those with the most incompatibility were eliminated. A new geometric matrix was calculated based on the remainder of the matrices and the compatibility test was once more conducted. This process continued until the matrices and the geometric means of the resulting matrices were compatible. In this study, the average number of incompatible (eliminated) matrices in each of the 15 comparisons was two matrices.

7.5. Model development

The developed model for contractor management practice performance evaluation and selection was implemented using the formula shown as Eq. (3). From this model, we obtained the contractor's performance score, which can be used to enhance the probability of selecting a competent contractor based on the highest score. Three steps were defined for this program model. The first step was to locate the input data. In order to assess the contractor performance, we identified the weight of the 18 management practices. These practices were categorized into five clusters known as the five management capability variables. As noted above, we employed the ANP methodology (Saaty & Takizawa, 1986) because of the interrelation between the management variables and factors affecting contractor performance. By using ANP, we obtained the compound weight of the factors and used them in making the super matrix. From the analysis, the weights of management variables and management practices were obtained and used as an input for the model. The second step covered the actual contractor performance on site. During the implementation stage, site supervisors or senior site supervisors who were involved in supervising contractor performance were asked to score each contractor's management practices based on the scale that ranged from bad contractor performance to superior contractor performance. The range of contractor scores is from 1–10 for each practice, where values of 1 or 2 indicated bad performance ($1 \leqslant$ bad performance < 3); 3–5 indicated average performance ($3 \leqslant$ average performance < 6); 6–8 indicated good performance ($6 \leqslant$ good performance $\leqslant 8$); and 9 or 10 indicated superior performance ($8 <$ superior performance $\leqslant 10$). This scale was built based on the experts' opinion. The third step involved calculating input data with the score which was applied to the contractor performance (Eq. (3)). From this step, the output data will indicate the contractor management capability score. The mathematical formula is as follows:

$$\mathrm{CI}_j = \sum_{i=1}^{m}\left[\left(\sum_{p=1}^{n}\mathrm{CS}_{ip} * W_{ip}\right) * W_i\right] \tag{3}$$

where CI_j = contractor index (CI) for contractor j; CS_{ip} = score for contractor management practice ip; W_{ip} = weight of management practice p with respect to its management variable i; W_i = weight of management variable i; n = number of practices in each management variable category; m = number of management variable.

The model was implemented using Matlab. Fig. 2 shows the function of the model by IDEF (0) diagram.

7.6. Validation of the model

According to Memon, Majid, and Mustaffar (2007), any newly developed model should take into account its technical aspects and feasibility. The technical aspects of the programming code were tested to verify the validity of the model. We used sensitivity analysis to evaluate the model under different scenarios in order to test the stability of outcomes as a result of changes in criteria importance weighting. Sensitivity analysis allows for a process of testing "what-if" scenarios to determine the model stability (Islam & Saaty, 2010) and to identify the changes that may adversely affect the final result (Fu & Hag-Elsafi, 1997). Feasibility of the model can be achieved by conducting interviews with experts to ask their opinion regarding the whole process and the result.

Validating the model's suitability through use of real data for prequalification contractor selection is impractical as it is impossible to know in advance which contracting companies will register for any projects until the advertisement has been distributed from the client firm (Porwal & Hewage, 2013). Therefore, we could not evaluate their management performance a priori to formal application. On the other hand, it would be onerous and costly to attempt to apply our model to the entire country (Malaysia) for all on-going projects in order to develop a comprehensive database on the management performance of all construction firms for future prequalification selection. In this study, we sought a more limited initial goal of validating the feasibility of the model in a single setting. Therefore, we tested the model in one contracting company that had already been awarded a project. After analyzing our findings, we returned to the main consulting company that awarded this project to the respective contractor company. We subsequently asked the directors of the consulting company if the new information for the evaluation of management performance would help them in their final selection. These results will be reported in Section 11.

8. Data analysis and model implementation

To determine the importance weights of each selection criteria from the data collected through questionnaires, we conducted the following steps for each ANP process:

8.1. Step 1: pairwise comparison of the management variables

We first conducted pairwise comparison of management variables with respect to each control elements of factors affecting contractor performance. In this manner, the relative importance weights (w) of management variables on each of the specific control elements were identified. The weights from the pairwise comparisons of management variables with respect to the four control elements were summarized in Table 7.

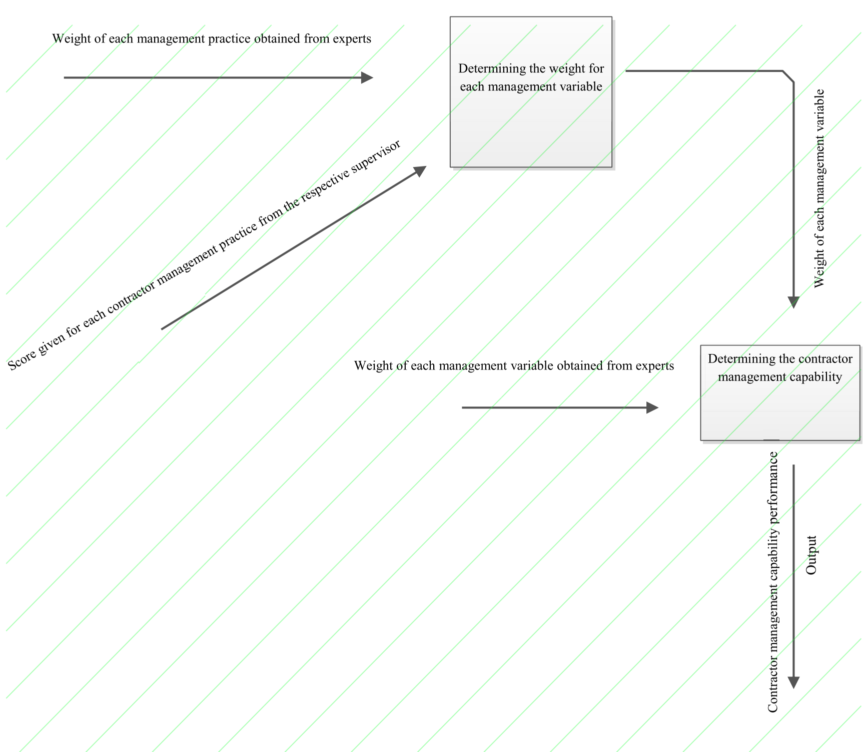

Fig. 2. Matlab development function using IDEF (0).

Table 7
Relative weights of management variables with respect to each factors affecting contractor performance.

Evaluation Factors	Affecting factors			
	Project properties	Contractor characteristic	Technical characteristic	Economic factors
Monitoring and controlling	0.509	0.048	0.071	0.526
Problem solving	0.208	0.253	0.429	0.229
Team development skill	0.167	0.506	0.329	0.058
Management knowledge	0.049	0.124	0.041	0.054
Resource management	0.067	0.069	0.13	0.133

8.2. Step 2: pairwise comparisons of the factors affecting contractor performance

Similarly, we then conducted the pairwise comparisons of the factors affecting contractor performance with respect to each management variable as a control factor. The weights from these pairwise comparisons are summarized in Table 8.

8.3. Step 3: formulating the super matrix

In a hierarchy and feedback system, the super matrix is a well-known and unifying framework to prioritize the criteria (Saaty, 1980). A super matrix can be seen as a matrix that describes the relation of the elements and clusters of a system. In the super matrix, the impact of all elements in each cluster is expressed using the priority weight. A value of zero means that there is no direct relationship between the elements. From the super matrix, it was expected that the priorities were in steady state. Using the stochastic process, the matrix multiplies itself repeatedly until it reaches stable values. It should be noted that the multiplication of the super matrix cannot provide stable values unless each column's sum becomes 1.0. After weighting the two layers of elements (i.e., management variables and the factors affecting contractor performance), these were put in the super matrix to derive the stable weight values. Table 9 indicates the combination of values from Tables 7 and 8 to form the initial super matrix. The relationship of elements in the same layer was assumed to be insignificant, and so these were assigned the value zero. Using the stochastic process, the matrix was multiplied 13 times to reach the stable values necessary to generate Table 10. The steady weights of the management variables were thus ordered: problem solving skill (0.298), team development skill (0.290), monitoring and controlling (0.243), resource management (0.102), and management knowledge (0.067). The relative weights of the influencing factors that affect the performance of the contractors were ordered: technical characteristics (0.336), contractor characteristics (0.266), project properties (0.202), and economic factors (0.196). The data reveal that the evaluator considers problem solving and skill in team development as a contractor's most important management capabilities. At the same time, technical characteristics and contractor characteristic are considered as the most important factors affecting contractor performance.

8.4. Step 4: pairwise comparisons of management practices

The weights of the management practices in each management variable were determined in order to evaluate contractor performance through pairwise comparisons. Table 11 shows the weight of the management variables and the related weight for the corresponding management practices. The numerals in parentheses are the product of the relative weight of the management practice.

9. Illustrative example

To further validate our model, we conducted an illustrative example (real data) to demonstrate how the model evaluates contractor performance. A police quarter building project at Johor Bahru (Malaysia) budgeted to the amount Ringgit Malaysia (RM) 100 million was awarded to a contractor company. The project was subsequently divided into substructure and superstructure performance. In this paper, we only examine the evaluation for substructure performance, although the same calculation could easily be applied for superstructure performance. We selected the site supervisor or senior site supervisor as respondents because they were the stakeholders involved in supervising the contractor's performance. Site supervisors or senior site supervisors were asked to evaluate and score each contractor's management practices. The score for each management practice was multiplied with the relative weights of the management practices (see Table 12). The sum from this multiplication for each group of management practices shows how the contractor performed for each management variable (based on the scale defined). The weight of each variable was then multiplied with the sum of each group obtained from the previous calculation. Finally, each result was added to show the contractor's effectiveness in each part of the project performance (substructure and superstructure). In addition, the mean derived from the sum for each part of a project performance score indicates the contractor management capability performance in the project.

Table 12 shows the result of the contractor management practice performance for the substructure. Recall that in developing our model using ANP, we had identified score ranges for rating performance quality. As shown in Table 12, the total score for the monitoring and controlling variable is 6.368, and according to our scale, suggests a "good performance" rating. Team development

Table 8
Relative weights of factors affecting contractor performance with respect to each management variable.

Affecting factors	Evaluating factors				
	Monitoring and controlling	Problem solving	Team development skill	Management knowledge	Resource management
Project properties	0.528	0.076	0.108	0.137	0.107
Contractor characteristic	0.055	0.213	0.486	0.592	0.078
Technical characteristic	0.109	0.540	0.359	0.061	0.396
Economic factors	0.308	0.171	0.047	0.210	0.419

Table 9
Initial super matrix for ANP approach.

	Monitoring and controlling	Problem solving	Team development skill	Management knowledge	Resource management	Project properties	Contractor characteristic	Technical characteristic	Economic factors
Monitoring and controlling	0	0	0	0	0	0.509	0.048	0.071	0.526
Problem solving	0	0	0	0	0	0.208	0.253	0.429	0.229
Team development skill	0	0	0	0	0	0.167	0.506	0.329	0.058
Management knowledge	0	0	0	0	0	0.049	0.124	0.041	0.054
Resource management	0	0	0	0	0	0.067	0.069	0.13	0.133
Project properties	0.528	0.076	0.108	0.137	0.107	0	0	0	0
Contractor characteristic	0.055	0.213	0.486	0.592	0.078	0	0	0	0
Technical characteristic	0.109	0.54	0.359	0.061	0.396	0	0	0	0
Economic factors	0.308	0.171	0.047	0.21	0.419	0	0	0	0

Table 10
Long term super matrix for ANP approach.

	Monitoring and controlling	Problem solving	Team development skill	Management knowledge	Resource management	Project properties	Contractor characteristic	Technical characteristic	Economic factors
Monitoring and controlling	0	0	0	0	0	0.243	0.243	0.243	0.243
Problem solving	0	0	0	0	0	0.298	0.298	0.298	0.298
Team development skill	0	0	0	0	0	0.290	0.290	0.290	0.290
Management knowledge	0	0	0	0	0	0.067	0.067	0.067	0.067
Resource management	0	0	0	0	0	0.102	0.102	0.102	0.102
Project properties	0.202	0.202	0.202	0.202	0.202	0	0	0	0
Contractor characteristic	0.266	0.266	0.266	0.266	0.266	0	0	0	0
Technical characteristic	0.336	0.336	0.336	0.336	0.336	0	0	0	0
Economic factors	0.196	0.196	0.196	0.196	0.196	0	0	0	0

Table 11
Relative importance of management variables and their associated management practice.

Monitoring and controlling $W_i = 0.243$	Problem solving $W_i = 0.298$	Team development skill $W_i = 0.290$	Management knowledge $W_i = 0.067$	Resource management $W_i = 0.102$
Cost monitoring (0.088)	Communication (0.319)	Forming (0.564)	Economic (0.174)	Plant and equipment management (0.791)
Time monitoring (0.077)	Understanding (0.058)	Storming (0.224)	Legal framework (0.584)	
Quality monitoring (0.39)	Training (0.129)	Norming (0.054)	Political development (0.178)	Labor management (0.209)
Safety monitoring (0.445)	Leadership (0.494)	Performing (0.158)	IT advancement (0.064)	

skill and management knowledge are rated average, with total scores of 4.316 and 4.69, respectively. The contractor likewise exhibited average performance for problem solving skill and resource management skill with scores of 5.058 and 4.209, respectively. The total management capability performance score for this contractor in our substructure construction case was 5.044 and according to the scale, the contractor had exhibited average performance. Interestingly, though outside the specific setting of our case study, the contractor also subsequently received a rating of 4.05 for superstructure performance, again suggesting average performance. Therefore, the mean obtained from two parts of the project showed average overall management capability performance with a combined score of 4.54.

10. Discussion

Prequalifying contractors is a critical element in project planning because it can have a huge impact on the final outcomes of the project. While screening potential contractors' management performance is an important feature of prequalifying, current evaluations of management capabilities in contractor prequalification are often inadequate since they are only related to the time and cost performance of the contractor. We noted earlier in this paper that although time and cost performance are important elements in identifying competent contractors, solely relying on these metrics may give an incomplete picture of their performance capability, particularly when time or cost overruns occur for reasons outside of the contracts' control. Thus, our primary goal of this research was to address a topic that, while critical to construction success, has received far less attention and empirical analysis than other elements in contractor evaluation. It is noteworthy that research continues to identify systematic failures in construction projects, as measured in terms of time and cost overruns, suggesting that although our knowledge of project management is expanding, there continue to be practical gaps in applying this knowledge to improve project delivery. Could it be, in fact, that one flaw in our models to date is simply that we are measuring the wrong things? It is with this question in mind that we sought a critical reassessment of the criticality of management performance in contractor evaluation.

The selection of a contractor should not only relate to their capacity for producing profit, but also depend on whether they can perform the management practices effectively. Thus, in the present study, a performance evaluation model containing management variables and practices was developed and tested. We found that the relative importance of these management variables are dependent on the major performance influencing factors, and their interdependency can be captured by an analytic network process that is based on stochastic transiting. This model first captures the relative importance of management variables before the influencing factors' relative intensity is determined. This study has defined

Table 12
Contractor management performance evaluation for substructure.

Management variables	Management practices	Management practices score	Performance index
Monitoring and controlling	Cost monitoring	0.088 * (6) = 0.528	6.368 * 0.243 = 1.55
	Time monitoring	0.077 * (5) = 0.385	
	Quality monitoring	0.39 * (6) = 2.34	
	Safety monitoring	0.445 * (7) = 3.115	
	Total sum: 6.368 $6 \leqslant 6.368 \leqslant 8$ (good performance)		
Problem Solving	Communication	0.319 * (5) = 1.595	5.058 * 0.298 = 1.5
	Understanding	0.058 * (6) = 0.348	
	Training	0.129 * (5) = 0.645	
	Leadership	0.494 * (5) = 2.47	
	Total sum: 5.058 $3 \leqslant 5.058 < 6$ (average performance)		
Team development skill	Forming	0.564 * (4) = 2.256	4.316 * 0.290 = 1.25
	Storming	0.224 * (4) = 0.896	
	Norming	0.054 * (4) = 0.216	
	Performing	0.158 * (6) = 0.948	
	Total sum: 4.316 $3 \leqslant 4.316 < 6$ (average performance)		
Management knowledge	Economic	0.174 * (6) = 1.044	4.69 * 0.067 = 0.314
	Legal framework	0.584 * (5) = 2.92	
	Political development	0.178 * (3) = 0.534	
	IT advancement	0.064 * (3) = 0.192	
	Total sum: 4.69 $3 \leqslant 4.69 < 6$ (average performance)		
Resource management	Plant and equipment management	0.791 * (4) = 3.164	4.209 * 0.102 = 0.43
	Labor management	0.209 * (5) = 1.045	
	Total sum: 4.209 $3 \leqslant 4.209 < 6$ (average performance)		1.55 + 1.5 + 1.25 + 0.314 + 0.43 = 5.044 $3 \leqslant 5.044 < 6$ (Average performance)

not only the relevant criteria that experts consider to be most important for management capability, but also, the relative ranking/weighting of these criteria from the consultants' point of view. The data demonstrates that evaluators regarded problem-solving ability and team development skill as the most important management variables to a contractor. Therefore, once they are awarded with a project, they are expected to handle such issues effectively. At the same time, the technical and contractor characteristics are regarded as the two significant factors that will influence the contractor's performance as they perform the management practices. Further, their monitoring and controlling skills are most directly determined based on their safety and quality standards. Their problem solving skills are affected most strongly by their leadership and communication skills, and their team development skills are dependent on their ability to form and storm their human resources. Knowledge of the legal framework and political development are critical for assessing management knowledge. Finally, plant and equipment management were regarded as more important than labor management for the resource management skills. These findings are critical because they offer a critical, empirical perspective on some of the controversies regarding what is important for management competency as a construct.

Our research contributes to the literature in the field of contractor prequalification evaluation in a number of ways. First, we noted that the elements in the category of "management performance" have long been subject to multiple interpretations and imprecise construct explication. Through an extensive literature review (identified in Tables 1–3) we sought to develop conceptual synthesis through identifying commonalties across these lists of management performance criteria. Our subsequent list offers a cohesive yet robust set of the critical management performance criteria, viewed as a critical element in contractor assessment evaluation. Second, we employed ANP and other affiliated techniques to identify the relative weighting of these factors and subsequent model development and validation. Finally, as a further check on the validity of the evaluation model, we sought to test both the technical aspects and feasibility of the model in a construction project field setting. Our findings suggest that the model offers a viable means for conducting contractor evaluations across multiple project settings and under multiple conditions. Therefore, our model increases the ability of clients to evaluate contractor performance in site, the further ability to compile a database of contractors' management capabilities, based on multiple assessments across projects over an extended time period. Contractors, as well, can benefit from this research through gaining a better understanding of the management capability factors that identified in this study as the most important to clients. This knowledge will allow contractors to take a hard look at their perceived strengths and weaknesses, make critical adjustments to operating procedures, and improve necessary skills sets and expertise.

11. Model validation

We tested the technical aspect of the model using a predefined scenario to determine the model's stability towards different conditions. The subsequent case study (highlighted in Table 12) was used to examine the robustness of the performance index result when different scenarios were applied for each management practice score. The first scenario encompassed a small change in the scoring for each management practice. With this, the robustness of the outcome was tested against minor changes and also the critical management practices that had highest impact on the outcome of the model were identified. Once the critical practices were identified, the second scenario, which involves applying the wide range of changes on scoring for the critical practice, examined the stability of the outcome.

For the first scenario, the site supervisor's scores on a specific management practice were reduced by one score while others were maintained. This was repeated for all management practices. A morphological box test was used to distinguish the similarities and differences between the results obtained from changes on each management practice and the result obtained from the case study. As can be seen in Fig. 3, the results obtained from the changes on each management practice are between 4.88 and 5.04, which are still in the range of $3 \leqslant$ average performance < 6. Therefore, the contractor's performance was still average. This result was encouraging, as it confirmed that the model was not sensitive to minor changes. Interestingly, among the 18 management practices, the group development stage (practice) "forming" was the dominating influencing factor.

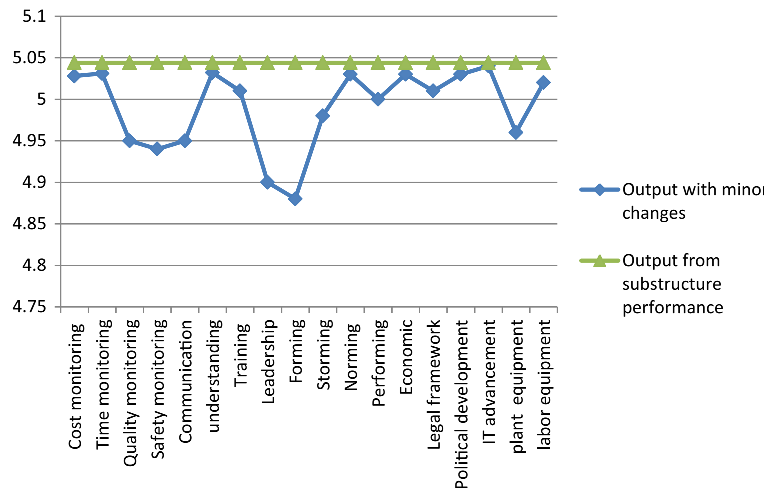

Fig. 3. Output performance indexes obtained from different scores for each management practice.

In the second scenario, we applied all possible values in the scoring range (1–10) to the "forming" factor as the most critical management practice. The result for the practice of "forming" is shown in Fig. 4. The output performance index shows that between the score of 1–9, the performance index result is in the range of 3 $\leqslant$ average performance < 6. However, for a score of 10, the output results show a different range of outcome indicating good performance (i.e., 6 $\leqslant$ good performance $\leqslant$ 8). A solution for this inadequacy is to ask other stakeholders who monitor contractor performance to score for this practice and the mean derived from these scores would be considered as the final score in the calculation.

Finally, feasibility of the model was addressed by conducting interviews with the director of the consulting firm that awarded the contract to the contracting firm (in our case study) for the purpose of verifying or validating the efficiency of the proposed model. The case study was described as illustrative example in Section 9. From the case study, we could identify descriptions of management capability of contractors from poor to superior performance. In order to validate the efficiency of the proposed model, we conducted an interview with the director of the consulting firm that awarded the contract to the contracting firm. During the interview, the director was asked to provide information used in the selection of the proposed contractor, such as the critical prequalification criteria, his assessment of the usefulness of these criteria when selecting a contractor, and the utility of the criteria at prequalification when compared with the final assessed performance of the contractor on the awarded project.

The criteria for contractor selection were financial stability, technical ability, and management capability of contractors. According to the director, the prequalification process was made more complicated by the inability to distinguish among contractors due to high uncertainty (poor discriminatory criteria); that is, while few contracting firms were recognized as eligible to be awarded the contract, among these firms, it is very difficult to formulate a decision model that allowed optimal selection. All viable firms had good financial stability and possessed sufficient equipment and resources (technical ability) to perform the job. On the other hand, the assessment of management capability was not considered seriously since the selected candidates had almost identical schedule and cost overruns from their previous projects, these were the sole outcome criteria considered, and it was difficult to identify if the overruns were their fault or the result of external, uncontrollable causes. As a result, final contractor selection was simply based on lowest tender bid price. From the director's viewpoint, the final assessment for the contractor performance after the project was completed was too limited and not an acceptable means for evaluation. What was needed, in his opinion, was more accurate, "real-time" information that could be used for immediate evaluation.

The result of the case study was presented, showing that the evaluated contractor was rated with an "average" management capability performance for the project. The director was asked to indicate if the developed model was practical for evaluating the management capability of contractor at prequalification stage. The director observed that the weak time and cost performance

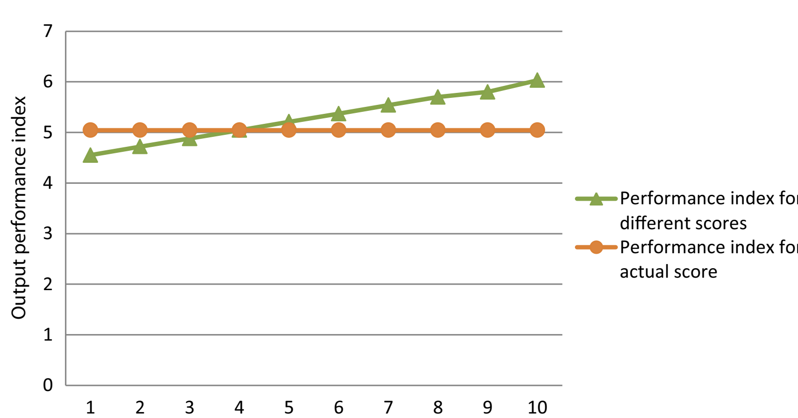

Fig. 4. Output performance indexes obtained from different scores for forming practice.

of contractors and their measured average management capability score were directly related. This view is consistent with the results of a study by Aje et al. (2009), demonstrating that management capability had the highest impact on time and cost performance.

We conducted one additional test to assess our model's feasibility by interviewing seven directors from the consulting firm that was involved during the expert interviews and main questionnaire survey. Illustrating the usefulness of this model for the issue of prequalification selection, the most notable comments from the directors include:

> "Prior to this technique, our firm employed a method for qualification that involved time and cost performance of contractors to evaluate the management capability performance; however, using the new method, the results show that this method actually does a much better job of highlighting and prioritizing the relevant and critical criteria for selection."

> "This marking method can serve as a motivational device for contractors to perform the full range of their duties to the best-possible degree as their performance was monitored carefully. This will lead to reduction of time and cost overrun of a project."

12. Conclusion

Contractor prequalification is a challenging process as it requires project owners to take into consideration a wide range of criteria, including many that do not readily lend themselves to objective evaluation. Assessing management capability, though a critical prequalification by previous research, is one aspect of this challenge as it forces owners to assess a host of both objective and subjective criteria. This paper was developed to assess the degree of which these management capability criteria can be first identified and then applied in prequalification. This model compares to other prequalification selection methods emphasized more on the subjective management variables. Therefore, the evaluation can thus become more comprehensive as it is based on a larger set of relevant variables rather than time and cost only. Another advantage of the proposed model is that the vagueness of experts' opinions is first validated through consistency and compatibility tests before it is used in the evaluation model.

The output of the model is an evaluation score rating the effectiveness of a contractor's management capability. The proposed model can be used as decision support systems to help both consultants and clients. Consultants and other client site representatives are able to monitor the contractor's performance, allowing clients to use this model as a decision support system for prequalification selecting among eligible contractor based on their management practices performance. In addition, by making contractors aware of the critical relevant selection criteria that will be used for future prequalification decisions, contractors will become more motivated in performing their job, while attending to the most critical management performance activities, since their performance is monitored more carefully. Thus, this decision support model offers practical applications for contractors and client organizations in promoting critical prequalification criteria a visibly as possible, serving as a reference point for both contractors and client firms.

Although we believe that this model has the flexibility to accommodate different evaluation environments, it is likely that the priority weight of the criteria would be different depending on different construction environment settings. It was to address this presumed variance that ANP has been applied; i.e., to generate a general methodology with application for special situations. However, depending on differing environments (for example, our study employed Malaysian consulting firms), modifications on the factors and criteria could be performed to formulate a comprehensive model that can suit different environments: not simply national or cultural boundaries but also across multiple project category types. For example, Information Technology (IT) contractor organizations could profit from determining the critical skills (management performance capabilities) that would best apply in software and other IT project settings. This study focused on subjective (and occasionally ambiguous) variables for the evaluation of management capability, however, objective values such as number of safety violations or percentage of annual staff turnover were not considered since the objective variables are assessed with evidence from the contractor's previous performance. Future studies should consider integrating both sets of variables (objective and subjective) to provide a more comprehensive management practices evaluation model. Additionally, this study collected data from a sample of consultants with extensive industry experience; however, future research should seek ways to address contractors and clients' viewpoints directly, by sampling sets of each of these groups in order to identify the manner both in which they concur with critical management capability variables and ways in which their perspectives differ.

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