A risk-oriented tender evaluation system for construction projects in Malaysia

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Abstract:	

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Abstract

Purpose – This paper presents results of an empirical investigation involving private construction clients in Malaysia, which seeks to establish appropriate tender evaluation criteria and weightings for a risk-oriented tender evaluation system.

Design/methodology/ approach – At the initial stage of this study, a list of significant risks is identified and gathered through literature review. These risks are then mapped onto tender evaluation criteria. Following this, the identified risks and their mappings are validated through a questionnaire survey to determine appropriate criteria for tender evaluation. Weightings for the selected evaluation criteria are established through an analytic hierarchy process (AHP) group decision-making (GDM) method.

Findings – In practice, different lists of criteria, covering tender's technical capability and financial performance, are often used by different client organisations. However, there is a paucity of research behind the selection of these criteria and the weighting being attributed to different criteria.

Originality/value – This study provides an important and a valuable insight into the actual criteria used during tender evaluation practice based on an analysis of documentary evidence. Both current practice and existing tender evaluation studies failed to address the risk element adequately. There is a lack of an explicit link between evaluation criteria and project risks. This study fills this knowledge gap by identifying tender evaluation criteria through reviewing criteria used in practice and examining their links to risk factors. The outcome is a tender evaluation system, including appropriate criteria and proper weights, which will help to reduce project risks from a client perspective.

Keywords – Tender evaluation criteria; Construction; Analytic hierarchy process; Group decision-making; risk management

Paper type – Research paper

1.0 Introduction

Tender evaluation is one of the most critical tasks undertaken by clients to identify qualified contractors and select the most competitive offer from prospective tenderers. Effective evaluation ensures that the selected contractor is capable of delivering successful construction projects (Alhazmi and McCaffer, 2000; Huang, 2011; Love et al., 1998), fulfilling client goals, and keeping to project cost, time and quality (Hossain et al., 2013).

Using competitive tendering and awarding contracts to the lowest tenderer have been the common practice in the construction industry worldwide. This approach forces contractors to lower their costs and quote unrealistically low prices to win bids (Hatush and Skitmore, 1997a; Ioannou and Leu, 1993). Most researchers agreed that this approach is one of the significant causes of project failure (Banaitiene and Banaitis, 2006; Hatush and Skitmore, 1998; Holt et al., 1994; Ioannou and Leu, 1993). In past decades, there has been a significant shift in the realm of research in tender evaluation. Most recent studies have focused on multi-criteria methods to evaluate tenders (Enshassi et al., 2013; Jaskowski et al., 2010; Kuo and Lu, 2013; San Cristóbal, 2012; Watt et al., 2010), and several researchers have identified and incorporated different criteria (Hatush and Skitmore, 1998; Herbsman and Ellis, 1992; Holt et al., 1993; Mahdi et al., 2002; Pongpeng and Liston, 2003). However, most of these criteria were based on attitudinal surveys in which subjective lists were prepared through literature review and presented to the respondents to ask their opinions on the importance of those criteria (Watt et al., 2010). Few studies investigated the actual criteria used by the practitioners in practice. In addition, Książek and Ciechowicz (2016) and Palaneeswaran and Kumaraswamy (2001) pointed out that tender evaluation, if conducted diligently, can help the clients minimise risks and avoid many problems which may occur during the execution stage. To achieve this requires evaluation criteria and tender evaluation methods to be explicitly linked to common risks. Unfortunately, this is not the case in current practice and this aspect has not received sufficient attention of researchers either. Such an observation underlies the main rationale of this study.

2.0 Literature review

2.1 Construction project risks

A project is unlikely to be successful when risks are poorly managed. Sources of risk can be related to management of internal resources and external environment (Tah et al., 1993). Internal risks arise from several factors of a project itself, such as team size, history and project similarity, staff expertise and experience, complexity management stability, time compression and resource availability (Kliem and Ludin, 1997). External risks are related to the political, economic, social and natural environment (Alaghbari et al., 2007). They are outside the control of project management team and apply equally to all tenderers (Barber, 2005). They cannot be used to distinguish different bidders. Therefore, external risks are not covered in this study.

Identification of significant risk factors is the most important step of effective managing risks. Once a risk is identified, it is then possible to design appropriate risk response (Chapman, 1990). Risk identification is a process that reveals and determines the possible risks as well as conditions that may cause these risks (Tchankova, 2002). Many existing studies had identified the significant risks in construction projects (Abd Karim et al., 2012; Barlish et al., 2013; El-Sayegh, 2008; Hlaing et al., 2008; Kangari, 1995; Kartam and Kartam, 2001; Mahendra et al., 2013; Wiguna and Scott, 2006; Zou et al., 2006). From an exploratory search, there were 296 risk factors that have been documented in total. After eliminating repetitive factors, an initial list of 135 risk factors was obtained and 45 risks identified as external risks and were removed due to irrelevance to this study. The remaining 90 internal risks were further analysed; similar risks were merge. This results in a final list of 80 risk factors, which were structured into a hierarchy to facilitate the mapping process. A risk breakdown structure was developed as shown in Figure 1. The first level shows the type of risk, the second level divides the risks into different categories, and the third level presents the major risks and the lowest level comprises of 65 risk factors.

{…insert Figure 1 here…}

Since the risks are identified through literature review, they need to be evaluated according to the context of Malaysian construction industry. This is done through a questionnaire survey. Ideally, respondents should be asked to evaluate the criticality of all 65 risk factors listed in Level 4 (Figure 1). However, this would the survey excessively time consuming. Therefore, it was decided that the major risk groups at Level 3 in RBS should be used for the survey with a short definition of each risk (Table 1).

{…*insert Table 1 here*…}

2.2 Tender evaluation criteria and weights

In practice, clients use many criteria such as financial capacity, technical ability, management capability and reputation when evaluating tenders. However, these criteria are usually used only to produce a shortlist of tenders. The final tender selection is often based on tender price alone. In the past decades, more and more researchers have acknowledged that tender evaluation is a multi-criteria problem. Contractor selection should be based on more attributes other than just bid price or cost alone (Liu et al., 2000). The successful contractor should be the one that has the highest combined score of the multiple attributes. Criteria and its relative importance for selecting contractor are among the topics that had received main attention in the literature (Alzober and Yaakub, 2014; Darvish et al., 2009; Hatush and Skitmore, 1997b; Holt et al., 1994; Hosseini Nasab and Mirghani Ghamsarian, 2015; Ogunsemi and Aje, 2006; Singh and Tiong, 2006; Topcu, 2004; Watt et al., 2010).

In an early research, Nguyen (1985) considered cost, experience and performance as the three most important evaluation criteria. These criteria were recommended to be used to evaluate the variation of tender prices before a tender was selected. The increase in project complexity and client’s needs now require a wider range of criteria to evaluate tenders. Russell and Skibniewski (1990) suggested additional criteria to measure resources, safety and financial. Two different sets of criteria were established for public and private owners respectively. These were categorised into three groups: (1) preliminary screening criteria such as references/reputation/past performance; (2) contractor resources criteria, consisting of financial stability, the status of current work, technical expertise; and (3) project specific criteria. During a study in the UK, Holt et al. (1993) proposed three similar groupings: (1) prequalification elements that include organisation, financial, management resources, past experience and past performance; (2) project-specific factors that include similar project experience, key personnel, plant resources and current workload; and (3) cost. Subsequent researchers had introduced new sub-criteria into the prequalification lists, such as litigation tendency and qualification of personnel; and prior relationship into the project-specific list. Hatush and Skitmore (1997b) explored universal criteria for both prequalification and bid evaluation. They found that most criteria considered by earlier researchers can be categorised into five groups: financial soundness, technical ability, management capability, health and safety and reputation.

Ng and Skitmore (1999) pointed out that the selection of criteria was influenced by decision makers' discipline and misinterpretation of the client's or project's requirements by the consultants working for the clients' organisation. Their survey found that there is a difference in perception of criteria among public clients, private clients and consultants in the UK. Of the ten criteria that were ranked most important, only four were common for both clients and consultants. They were: financial stability, performance, fraudulent activity and stability of firm. In another study in the UK, Wong et al. (2000) identified 14 similar criteria adopted by the public and private sectors. These criteria were also closely related to those reported by Holt et al. (1993). Pongpeng and Liston (2003) conducted a questionnaire survey within the Thai construction industry and developed a common set of criteria for the public and private sectors. The results revealed that both sectors considered project planning, project monitoring and project management experience as the most important criteria. In addition, they found that the public sector considered time-related criteria as important, while criteria related to project cost were considered more important by the private sector. However, the majority of evaluation criteria were shared by both the public and private sectors; only five out of 23 criteria were identified as statistically different in mean importance. Singh and Tiong (2006), through interviews with four professionals identified relevant contractor selection criteria (CSC) in the context of construction industry in Singapore. These included company's attributes, past performance, financial, performance potential and project specifics. In addition to identification of suitable criteria, it is also important to establish appropriate weights for different criteria. Weight for a criterion represents the relative importance of that criterion in a set of criteria. Conventionally, decision makers arrange the list of criteria in the order of importance and assign weight to each criterion based on corporate requirements and individual judgements. However, intuitive and subjective judgements to determine weights can lead to biases and mistakes when deciding the most qualified tenderer. Latham (1994) pointed out the importance of proper weighting of criteria when choosing contractor on a value for money basis. The use of arbitrary weights in the multi-attribute analysis, combined with the lack of a standard methodology, increases the chance for misuse and arbitrary decisions. To address this, researchers have proposed various methods to establish weighting indices. For instance, Russell and Skibniewski (1990) used statistical weighting to derive criteria weights by normalising the mean impact obtained from questionnaire analysis. Holt et al. (1994) consolidated the importance response (IR) and problem frequency response (PR) values to derive weighting index. The IR value was measured by aggregating responses using relative formula, i.e. total variable score divided by a total score of sample size. The PR value was represented by the mean value of a variable's problem frequency in relation to the number of contracts awarded for each respondent. The final weighting index is calculated using the formula of 0.5*(IR + PR).

Recently, group decision-making methods have been widely adopted by researchers in establishing weights for multiple criteria. The most common one is the Analytic Hierarchy Process (AHP) method, which decomposes a problem into a hierarchy, uses pairwise comparison matrix for collecting expert judgments and synthesises the results using a mathematical formula for establishing weights of criteria. Its ability to derive accurate ratio scale measurements has led the method to be widely used in decision making where multiple criteria weights can be determined simultaneously. Al-Harbi (2001) and Topcu (2004) utilised Expert Choice software based on AHP to establish criteria weights. One advantage of using this software is that it automates the computation of consistency check of judgments, which is an essential step of the AHP method (Ishizaka and Labib, 2009). Fong and Choi (2000) applied this method on eight main criteria and 11 sub-criteria during their study, using questionnaire to obtain expert judgements about the relative importance of criteria. However, a voting technique was used to synthesise 13 expert judgments to obtain a collective decision. One major drawback in voting is it may not achieve a commonly agreed decision. Other members may not necessarily agree with the decision but have to follow with the 'highest number of votes is the winner' rule.

Cheng and Li (2004) used the results of pairwise comparisons from the study by Fong and Choi (2000) to derive the relative weights of criteria using the Analytic Network Process (ANP). ANP is a more general form of AHP, which structures a problem into a network instead of a hierarchy. Since their model assumed the eight main criteria to be interdependent, therefore, ANP requires additional eight pairwise comparison matrices concerning each main criterion to be performed. The results obtained from the comparisons were used to form a super-matrix for obtaining final weights. The advantage of ANP over AHP is that it considers interdependent relationships between criteria when establishing final weights. However, the complexities of mathematical calculations to derive the weighted super-matrix as well as to raise the matrix to sufficiently large power until convergence occurs make ANP difficult to use. In fact, the study by Cheng and Li (2004) only considered a small number of criteria and it is unclear how the matrix was raised to derive final weights.

Singh and Tiong (2005) and Plebankiewicz (2009) used Fuzzy Set Theory (FST) to determine criteria weights. In this approach, important weights assigned in the form of linguistic variables by experts were translated into fuzzy numbers, which were then aggregated and averaged across all experts to obtain average fuzzy score matrix. Following this, the de-fuzzification operation was carried out to produce the crisp value and normalised weight for each sub-criterion was obtained by dividing the total crisp values. A clear advantage of this method is that it allows the experts to make judgements in linguistic terms. Nevertheless, fuzzy operations involve many calculations make it difficult to understand. Moreover, averaging the judgments during the de-fuzzification operation has a significant influence on the weights, if one of the decision makers provides a judgment far from those of the group.

The literature review has identified several shortcomings of the tender evaluation existing studies. Firstly, most of the evaluation criteria and their weights are identified through questionnaire surveys and interviews with professionals. As they relied on the subjective judgment of individuals, their validity is likely limited to the context where the studies were conducted. Secondly, most researchers compiled lists of criteria based on the literature review. There is a lack of attempt to investigate the actual criteria used by clients in practice. Finally, there is a shortage of research on the linkage between evaluation criteria and project risks. This study seeks to address these problems and develop a risk-oriented tender evaluation system in the context of Malaysian construction industry.

3.0 Research method

This study comprises three components: (1) identifying significant risk factors; (2) specifying tender evaluation criteria; and (3) establishing criteria weights. A literature review was used to identify an initial list of risk factors by only focusing on internal risks. An empirical investigation is carried out with five prominent private developers in Malaysia to collect information on actual criteria used in tender evaluation practice. An analysis of the evaluation criteria and identified risks helped to establish linkages between two lists. Then, a questionnaire survey is carried out to evaluate the criticality of significant risk factors and the effectiveness of the evaluation criteria to mitigate those risks. The survey results help to define a list of criteria to be included in the intended tender evaluation system. Finally, AHP method is used to establish criteria weights with the participation of 22 practitioners in three stages. At first, an AHP questionnaire was designed to ask practitioners to provide the relative importance of criteria based on their experiences. The target subjects were a group of developers and the selection of this group was due to their primary involvement in the tender evaluation process. The feedback from the practitioners was logged into an AHP spreadsheets template. Secondly, consistency checking process was carried out; some practitioners were asked to reconsider their judgments when inconsistency was found. Suggested values were automatically generated based on tools developed by Goepel (2013). Thirdly, a consensus process was carried out to measures the agreement between multiple practitioners on the criteria weights. Once an acceptable level of consensus was achieved, the criteria weights were calculated. Details of the AHP-GDM application are discussed in the following sections.

4.0 Discussion, analysis and results

4.1 Identifying significant risk factors

The main objective of the questionnaire survey is to validate the identified risks and their mapping to tender evaluation criteria. The questionnaire was distributed to 419 practitioners, 125 had responded and the response rate was 29.8%. This is considered relatively good as the range of 20% - 30% is considered normal for most questionnaire surveys in the construction industry (Akintoye and Fitzgerald, 2000; Root and Blismas, 2003). In the questionnaire survey, the respondents were asked to assess the criticality of the identified risks using a five-point Likert scale (1=not at all critical to 5=extremely critical). The analysis result using the Statistical Package for Social Science (SPSS) showed that practitioners identified risk factors were significant (mean > 3.50) in the construction projects in Malaysia. Table 2 shows the risk factors ranking according to Relative Importance Index (RII), which is calculated using a formula proposed by Ramanathan et al. (2012).

{…*insert Table 2 here*…}

4.2 Specifying tender evaluation criteria

The task of identifying existing tender evaluation criteria was achieved through an interview and a review of tender evaluation standard operating procedures (SOP) documents of five prominent developers in Malaysia. It was found that the private clients generally carried out tender evaluation in two stages: a technical evaluation stage and a commercial evaluation stage. Technical evaluation assesses three major components: (a) mandatory requirement – evaluates the general and contractual obligation of the contractor to start work; (b) technical capability – evaluates information pertaining to the capability and capacity to undertake the project; and (c) financial capability – evaluates financial soundness of the contractor. The commercial evaluation assesses the tender price. Initially, 107 criteria were recorded and after a consolidation process, 54 common criteria were identified. In addition, tender evaluation criteria suggested by literature were also reviewed; some 90 criteria in several common categories were identified, including financial, managerial, technical, health and safety, quality and past performance. The two sets of criteria from practice and from literature, were recorded on separate master lists as proposed by Watt et al. (2009). Following a comparison analysis, they were consolidated into one list, as shown in Table 3. The Table also shows the results of mapping of tender evaluation criteria with project risk factors. A risk mapping technique was developed from the concept map proposed by Novak (1998) and Hills (2010) to ensure the criteria cover elements of risk.

The questionnaire asked respondents to rate the effectiveness of evaluation criteria in addressing the mapped project risks. A five-point Likert scale (1=not at all effective to 5=extremely effective) is used for this purpose. To simplify the analysis, the results of the statistical mean score are defined into two categories: (1) mean score of below 3.0 is considered not effective, and (2) mean score of more than 3.0 is considered effective. As shown in Table 3, all the criteria are considered effective by respondents, and the lowest mean score is 3.384 for 'organisation registration'. Therefore, these criteria are appropriate to be used in the tender evaluation. In practice, the assessment of mandatory requirements is based on a pass or fail test. This is to ensure potential tenders meet the minimum requirements for undertaking a construction project. The assessment of commercial evaluation merely checks an arithmetical error and ranking tenders in ascending order of prices. Whereas, a technical evaluation is used to assess the capability and capacity of tenders to deliver a project. Due to multiple criteria are involved, there is a need of assigning a weighting to each criterion when evaluating different tenders. In this study, the weighting is established through the AHP-GDM method and discussed in the subsequent section.

{…*insert Table 3 here*…}

4.3 Establishing weights for criteria

AHP-GDM method is used to establish weights for different criteria based on the collective judgments of a group of construction practitioners. The process consists of 5 steps, each of which is explained in the following sections:

1) Selecting an appropriate group of experts: identify and select experts who have experience and have been involved in tender evaluation practice.

2) Pairwise comparison matrix (PCM): selected experts were asked to complete a series of pairwise comparison matrices by eliciting their judgments into an input table.

3) Individual judgments consistency analysis: an AHP spreadsheets template is used for checking individual responses for inconsistency in their judgments and request for modification to improve the consistency.

4) Consensus analysis: the spreadsheets tool measures the level of agreement among experts on the relative importance of criteria.

5) Synthesis priorities: the tool finally computes weights for all criteria using the geometric mean method.

Step 1: Selecting an appropriate group of experts

The decision-making process is complicated and very difficult to achieve by only a single person due to time pressure, lack of expertise and experience. Thus, the collective decision can reduce the risk of mistakes and improve the decision outcomes (Wu and Kou, 2016). Yang et al. (2015) described an expert as one who has a high level of knowledge on a particular subject and represents an authorised person who is involved in the decision-making process. The 22 participants of this study were selected from 8 prominent private developers in Malaysia. Their background information is presented in Table 4.

{*…insert Table 4 here…*}

Step 2: Pairwise comparison matrices

In the first round of AHP survey, a questionnaire containing the input table for pairwise comparisons were sent to all participants for their input judgments. 13 matrices were provided: one matrix for the main category and twelve matrices for all sub-criteria (Table 5).

{*…insert Table 5 here…*}

The participants were asked to compare the relative importance of the criteria in pair by specifying the intensity based on a scale 1-9 (Saaty, 1977). Once all the participants have provided their judgments, two analyses are carried out: (1) consistency checking to assess the reasonableness of the entries, which is one of the most important steps in AHP for verifying the logical judgment. If the judgment provided by a participant is inconsistent, then at least one comparison provided by that participant is defective (more explanation in step3 below); and (2) consensus analysis is carried out to evaluate the degree of agreement between different participants (step 4). An acceptable level of consensus ensures that the final results are based on collective opinions of the group of experts (Yang et al., 2015). These processes are explained in the following sections.

Step 3: Individual judgments consistency analysis

Once individual judgments are aggregated into group judgments, one of the challenges is to ensure the consistency of the group PCM (Dong and Saaty, 2014). The reliability of results of an AHP method is directly dependent on consistency of individual judgments. Xu (2000) proved that the group judgment matrix derived by using geometric mean is of acceptable consistency if all individual PCMs are of acceptable consistency. This is supported by Groselj and Zadnik Stirn (2012) who claimed that if the comparison matrices of all individuals are of acceptable consistency, the weighted geometric mean judgment matrix is also of acceptable consistency. For consistency checking analysis, two procedures need to be carried out: (a) consistency checking; and (b) consistency improvement (Franek and Kresta, 2014; Saaty, 2003).

a) Consistency checking

The acceptable value of Consistency Ratio (CR) should be no higher than 0.1 (Saaty, 1980). During this study, Row Geometric Mean Method (RGMM) is used to derive weights, and CR is calculated based on a formula provided by Saaty (2003). Of the 22 respondents who completed the AHP questionnaire, only three respondents provided consistent judgments for all matrices. Nine respondents were not consistent in all matrices and the overall results of consistency were poor.

The initial results are presented in Table 6. This preliminary finding (first round) was expected as practitioners are not familiar with AHP and a large number of pairwise comparisons need to be completed. Another reason for the inconsistency is the limitation of AHP judgement scale. For example, if *A* is 6 times preferred to *B* and *B* is 3 times preferred to *C*, then the consistent value for comparing *A* to *C* should be 18, which is not allowed in AHP because the scale is limited to 9. The process of improving consistency is discussed in the following section.

{…*insert Table 6 here*…}

b) Individual consistency improving method

When CR > 0.1, the respondents are required to improve the consistency by reconsidering their judgments. One of the methods for improving consistency is to identify the most inconsistent pairwise comparison. The simplest way is by comparing the input of PCM (αij) with a ratio derived from the calculated weights ω_i / ω_j. Those values of αij that show the most difference from ω_i / ω_j are the pairwise comparison which need to be changed in the direction of ω_i / ω_j to improve consistency (Coulter et al., 2006). Another method proposed by Saaty (2003) and Cao et al. (2008) is using perturbation matrix which uses the relationship $n\lambda_{\max} - n = \sum_{i,j=1}^{n} (\varepsilon_{ij} + \varepsilon_{ij}^{-1})$, where $\varepsilon_{ij} = \alpha_{ij} \cdot \omega_i / \omega_j$ for revising input judgment. This method identifies the ε_{ij} that is farthest from one and a change of the corrrespondng α_{ij} would result in a new PCM with a smaller eigenvalue. This method suggests modifying input judgment where ε_{ij} is the largest to a smaller value, and such a change will result in an improved consistency. One limitation of this method is that no explicit advised value is suggested to improve consistency. Thus, the consistency checking has to be repeated when a new input value is entered until the matrix reaches an acceptable level of consistency. Nevertheless, an iterative process of consistency checking was impractical for this study due to time constraints. In particular, respondents may lose interest if their revised input judgments are rejected repeatedly. The iterative process of revising or updating judgments may make respondents uncomfortable (Dong and Saaty, 2014). For this reason, a tool that provides an integrative approach for identifying inconsistent pairwise, suggesting advice value and checking consistency is desirable for this study.

In the second round of AHP survey, the AHP excel template developed by Goepel (2013) is used. The input judgments collected in the first round were logged into the tool and meetings were held with respondents to consider judgment revisions. The advantage of this tool is that it can identify inconsistent judgments, provide advised values to improve consistency, and calculate the consistency ratio instantaneously. Table 7 shows the results of the consistency improvement process.

{…*insert Table 7 here*…}

Step 4: Consensus analysis

Group decision making deals with aggregating all the individuals' preference rankings into a consensus ranking. The aim is to find a satisfactory group solution which is most acceptable to the group as a whole. A group PCM can be represented by aggregating of individual judgment (AIJ) or aggregating of individual priorities (AIP) (Forman and Peniwati, 1998). The aggregation is carried out using the arithmetic mean method (AMM) and geometric mean method (GMM) (Ossadnik et al., 2016, Wu et al., 2008, Forman and Peniwati, 1998). The AIJ combines individual judgments to produce a group matrix and then calculates group priority vectors. The GMM must be used to preserve the reciprocity property and satisfy axiomatic conditions (Aczel and Saaty, 1983, Saaty and Peniwati, 2008). On the other hand, the AIP computes individual priority vectors and then aggregates them into group preference using AMM or GMM. Forman and Peniwati (1998) recommended using GMM as it is more consistent with the meaning of both judgments and priorities in AHP.

Xu (2000) suggested using geometric mean method (GMM) for aggregating individual judgments and eigenvector method (EVM) for computing priority vectors. The reason is that if individual judgments have an acceptable consistency, then so have the group combined judgments. Hence, consistency check needs to be carried out for individual judgments only. The aggregation of individual judgments is carried out with the GMM formula, $a_{ij}^{G} = \prod_{k=1}^{m} \left(a_{ij}^{k}\right)^{\beta_k}$; β_k being the weight of the k^{th} individual, $k=1,2,\ldots,m$ in the group and $\sum_{k=1}^{m} \beta_k = 1$. In this study, equal weight is applied to all individuals, then $\beta_k = \frac{1}{m}$ for all k.

An interesting aspect of using the AHP spreadsheets template is that it minimises the difficulty pf calculating consensus, as it automatically measures consensus level. This is calculated based on the row geometric mean method (RGMM) results of individual priorities using Shannon entropy (Goepel 2013). Goepel furthered categorised the consensus level into five groups as shown in Figure 2. The values below 65% indicates no consensus within the group and a high diversity of judgments. Values above 75% indicates a high level of agreement between group members.

{…insert Figure 2 here…}

Table 8 shows the result of consensus level analysis. Only M10 has very high-level consensus. The small matrix size of 3x3 may explain the good consensus among all respondents. Ten matrices have high consensus level and two matrices are in the moderate consensus level group.

{…insert Table 8 here…}

The two matrices that have moderate consensus level were analysed further. Goepel (2003) proposed to rearrange the calculated AHP consensus indicator into clusters in the form of a matrix. As a result, one input judgment (R12) for M01 and four input judgments (R06, R08, R11, R20) for M06 were identified that are far off from a group based on Shanon entropy diversity index. Subsequently, respondents were contacted to revise their judgments in order to improve the consensus level for these matrices. Unfortunately, they did not return their revised judgments and it is assumed that the respondents decided to keep their original judgments. When consensus cannot be reached, the deterministic approach may be used in which individual judgment matrices are synthesises using geometric mean; the eigenvalue method (EVM) is then used to find consensus priority weights (Basak and Saaty, 1993). Since the consensus level for these matrices is reasonably high (more than 65%), it was decided to accept their judgments. Alternatively, their judgments may be omitted from the group to improve the results of group priority vectors.

Step 5: Synthesis priorities

After all individual matrices have been aggregated into group matrices, the last step is to synthesis the local priority vectors (local weights) for all categories and criteria. The priority weights are calculated using EVM. The normalised eigenvector corresponding to the principal eigenvalue of the judgmental matrix provides the weights of the corresponding criteria. Two types of priority weights exist in AHP: (a) the local weights (LW) represent the relative importance of the criteria within a given categories, and the sum of the local weights is equal to 1; and (b) the global weights (GW) represent the relative importance of each criterion as compared to all the others. The GW is obtained by multiplying the local weights of criteria with the categorical weight (CW) (Hummel et al., 2014), and the results are shown in Table 9. Subsequently, the score of tenders can be calculated using formula, $T1 = \sum_{i=1}^{n} gwi \; x \; Sri$, whereby gwi is the global weight of criterion i (i $=1,2,3,\ldots n$) and Sri is rating score given to the criterion i.

{…*insert Table 9 here*…}

The categorical weights show the importance of the category relative to others. The *cash flow* category has been highlighted as the most important (25.20%) by all the respondents, followed by the *capacity to deliver project* and *project team and key personnel* categories which were weighted quite similarly (10.76% and 10.08%). On the other hand, *site safety and environmental protection* and *quality control* categories were the least important, based on these results (2.51% and 3.53%). This result reinforces the finding by Pongpeng and Liston (2003), which identified cost-related criteria as most important to the private clients.

In order to get some insights into practitioners' perception of the importance of criteria, the results of questionnaire survey and AHP were compared. Interestingly, the study found an inconsistent ranking on the level of importance of categories between general and private perceptions. One significant difference is the category of 'lack of project management expertise', which was ranked 4th in a questionnaire survey but was ranked 9th in AHP. Nevertheless, the practitioners have consensus on four most important categories, which are 'cash flow difficulties', 'improper project planning', 'incompetent project team and key personnel' and 'incapacity to deliver project' (Table 10).

{…*insert Table 10 here*…}

Findings of the study highlighted that the identified risk factors are significant from the viewpoints of all the respondents surveyed. The statistical analysis results showed that those risks related to management and financial are significantly relevant to project success. These include cash flow, project planning and scheduling, project management expertise, and project team and key personnel. Even though resources are essential for carrying out project activities, risk factors of 'construction materials' and 'plant and equipment' are considered least critical on project completion by the respondents. In addition, both analyses showed that 'site safety and environmental protection' is least critical to project success and is considered least important when assessing tenders. Also, this is consistent with the finding from a study in Singapore by Singh and Tiong (2006).

5.0 Conclusions

Effective tender evaluation can have a significant impact on project outcome. If it is conducted properly using an appropriate method, the client can minimise project risks and get a best outcome. Many existing project failures are linked to risks not being considered effectively during the tender evaluation stage due to the lack of suitable methods. This study sought to integrate two main knowledge areas which are risks and tender evaluation. Studying the relationship between risks and evaluation criteria provide a new dimension of knowledge and understanding on the main objective of tender evaluation that is to reduce project risks and maximise overall value. This study makes three significant contributions in this regard:

a) This study provides an important and valuable insight into the actual criteria used in tender evaluation practice, based on an analysis of documentary evidence. Many research studies identified evaluation criteria only through attitudinal surveys and few studies investigated the actual criteria used by practitioners in practice. This study provides an important reference for future research particularly in private sector.
b) Most existing tender evaluation studies failed to address the risk element as there is a lack of an explicit link between evaluation criteria and project risks. This study fills this knowledge gap by identifying tender evaluation criteria through reviewing criteria used in practice and examining their links to risk factors. The linkage has been validated by a survey with practitioners in the Malaysian construction industry.
c) The weights of criteria were established based on the input of 22 practitioners from various private organisations and this can be used as a guidance for evaluating the technical capability of tenderers and provide vital input to tender selection decisions.

This study was focused on Malaysia. Although the final list of evaluation criteria are similar criteria to criteria identified by other studies in various countries, the selection and the effectiveness of each criterion needs to be evaluated in the context of a specific country. In addition, this study concentrated on the practice of private construction clients, and criteria and weights may need to be modified when used for the public sector. Future studies may consider to define evaluation criteria and weights specifically for different type of procurement routes. Besides, this study applied equal weight for all individual judgments. Thus, another perspective of future study could explore the outcomes when different weights were assigned to the judgments of different individuals.

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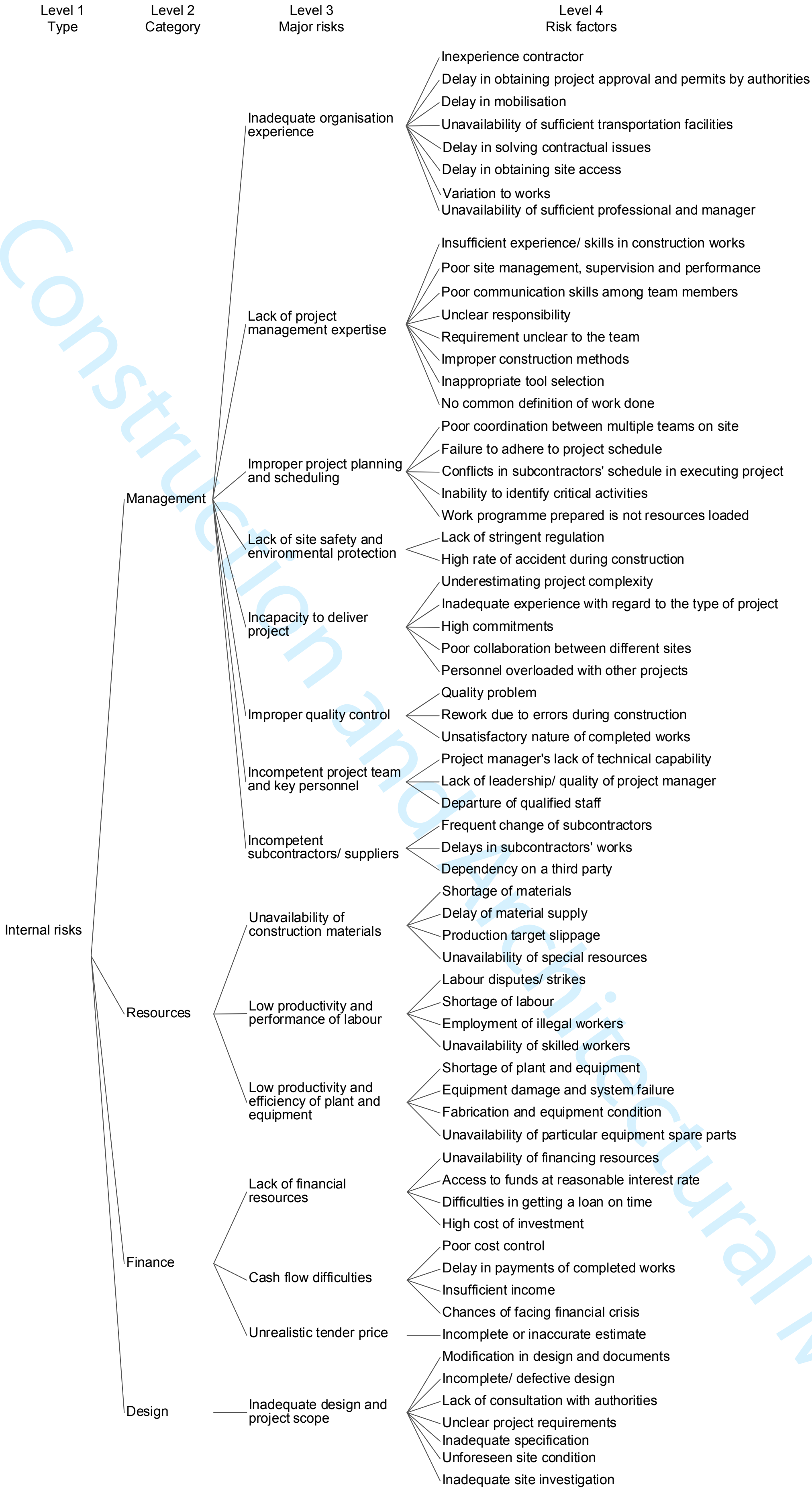

Figure 1: Risk breakdown structure (RBS) of risk identified from literature

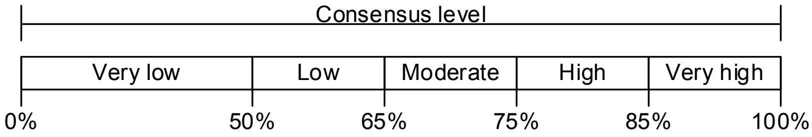

Figure 1: Consensus level indicator

Table 1: Significant risks of construction projects

Major risks	Definition
Inadequate organisation experience (OE)	Inadequate experience in construction project and familiarity with market regulations
Lack of project management expertise (PM)	Poor site management and supervision, inadequate project coordination and communication on site and lack of project records and documentation
Improper project planning and scheduling (PS)	Incomplete work programme, work programme is not resources-loaded and inability to identify critical activities
Lack of site safety & environmental protection (SE)	High rate of accidents during construction, lack of stringent regulation that will have an impact on construction and company's poor attention to environmental issues
Incapacity to deliver project (CD)	Inability to deliver project due to project complexity and current commitment
Improper quality control (QC)	Tolerance of defects and inferior quality of completed works and rework due to errors during construction
Incompetent project team and key personnel (PT)	Inadequate experience and qualification of project manager and personnel
Incompetent subcontractors and suppliers (SS)	Inability of subcontractors/suppliers to contribute to construction activities and poor collaboration on work schedule
Low productivity and performance of labour (PL)	Facing difficulties in hiring and maintaining an adequate number of workers
Unavailability of construction materials (CM)	Shortages of materials and unfeasible delivery time
Low productivity and efficiency of plant & equipment (PE)	Inadequate number of machinery on site and equipment damage and failure
Lack of financial resources (FR)	Difficulties in getting a loan on time and access to funds at reasonable rate and chances of a financial crisis
Cash flow difficulties (CF)	Insufficient cash due to poor cost control, delay in payment and cost overrun
Unrealistic tender price (TP)	Incomplete or inaccurate cost estimate
Inadequate design and project scope (DS)	Inappropriate design information, inadequate site investigation and lack of documentation

Table 2: Ranking of risks based on relative importance index (RII)

Project risk factors		Mean	RII	Rank
CF	Cash flow difficulties	4.224	84.48	1
FR	Lack of financial resources	4.224	84.48	1
PS	Improper project planning and scheduling	4.144	82.88	3
PT	Incompetent project team and key personnel	4.056	81.12	4
PM	Lack of project management expertise	4.056	81.12	4
CD	Incapacity to deliver project	4.000	80.00	6
OE	Inadequate organisation experience	4.000	80.00	6
SS	Incompetent subcontractors and suppliers	3.976	79.52	8
PL	Low productivity and performance of labour	3.912	78.24	9
TP	Unrealistic tender price	3.912	78.24	9
QC	Improper quality control	3.880	77.60	11
DS	Inadequate design and project scope	3.880	77.60	12
CM	Unavailability of construction materials	3.872	77.44	13
SE	Lack of site safety & environmental protection	3.744	74.88	14
PE	Low productivity and efficiency of plant & equipment	3.712	74.24	15

Table 3: Overall result of risks and tender evaluation criteria

Main risks	Evaluation criteria		
Technical evaluation			Mean
OE (4.000)	OE01	Organisational maturity / strength	3.872
	OE02	Qualification and experience of key management staff	4.104
	OE03	Experience with the contractor in past construction projects	3.800
	OE04	Organisational registration with relevant construction bodies	3.384
	OE05*	Familiarity with local regulating authority	3.824
PM (4.056)	PM01	Experience, i.e. value of projects completed	3.968
	PM02	Project organisation chart including key task and responsibility	3.848
	PM03	Construction method statement and technology	4.032
	PM04	Availability of proper Standard Operating Procedure (SOP)	3.888
PS (4.144)	PS01	Clear work programme in relation to project milestone	4.192
	PS02	Sufficient planning sheet including sequence of works	4.016
	PS03	Use of project management software	3.552
	PS04*	Flexibility in the critical path	3.784
	PS05*	Detailed plan, i.e. resources plan for the construction activities	4.088
SE (3.744)	SE01	Safety programme and environmental requirement	3.912
	SE02	Hire competent safety and environment personnel	3.848
	SE03	Safety & Health Assessment System in Construction (SHASSIC)	3.696
	SE04	Proposal for waste disposal during construction	3.616
	SE05	Environmental plan during construction	3.728
CD (4.00)	CD01	Experience in a similar type of projects, i.e. number of projects	4.104
	CD02	Track record or performance history	4.080
	CD03	Number of concurrent projects	3.968
	CD04	Balance of work of concurrent projects to be completed	3.936
QC (3.880)	QC01	Quality assurance and control programme	3.976
	QC02	Quality control plan	3.840
	QC03	Independent QA/QC department	3.808
	QC04	Work quality record or certification	3.768
	QC05	Quality management system	3.864
PT (4.056)	PT01	Qualified and experienced project manager	4.304
	PT02	Depth of experience of project manager on the similar project	4.120
	PT03	Qualified and experienced site supervisory staff	4.016
	PT04	Sufficient number of site personnel	3.872
SS (3.976)	SS01	Adequate list of subcontractors and suppliers	3.856
	SS02*	Reputation of the subcontractors to be employed	3.976
	SS03*	Standard of sub-contractors' work in past projects	3.976
	SS04*	Relationship of contractor with subcontractors/ suppliers	3.904
PL (3.912)	PL01	Manpower histogram (allocation of construction activities)	3.672
	PL02	Proportion of local and foreign labours for the project	3.704
	PL03	Number of skilled worker/ craftsmen	4.056
CM (3.872)	CM01	Details of sources of construction materials	3.784
	CM02	Details of long lead items	3.784
	CM03	Submit storage yard plan (including location and layout plan)	3.552
	CM04*	Procurement plan for materials i.e. material schedule	4.056
PE (3.712)	PE01	Number of plant & equipment proposed for the project	3.848
	PE02	Information on 'own or hire' plant and equipment	3.584
	PE03	Information on maintenance of plant and equipment	3.624
	PE04*	Plant maintenance programs (schedule of inspection or repair)	3.672
	PE05	Spare part stocking (inventory to prevent shortage)	3.432
CF (4.224)	CF01	Audited account for the last three years (fund availability)	4.080
	CF02	Information on financial ratio	3.976
	CF03	Budgeting including cash inflow and outflow	4.064
	CF04*	Cash-out/payment schedule	3.992
Commercial Evaluation			
TP	TP01	Consistency of the cost breakdown against the tender sum	4.064

Table 3: Overall result of risks and tender evaluation criteria

Main risks	Evaluation criteria		
(3.912)	TP02	Comparison of the rate for major items	4.096
	TP03	Competitiveness of tender price against client's estimate	3.976
	TP04	Variance of tenderers' price against the lowest tender price	3.944
	TP05	Comparison based on GFA of existing project	3.840
Mandatory requirements			
FR	FR01	Obtain a letter of support from the bank for credit facilities	4.120
(4.224)	FR02	Provide a letter of undertaking to provide a bank guarantee	4.088
	FR03	Sufficient authorised and paid-up capital	4.088
	FR04*	Credit rating score	3.952
DS	DS01	Statement of compliance with contract requirements	4.040
(3.880)	DS02	Mandatory site visit to familiarise with the project site	4.048
	DS03	Tender clarification and response	4.152

Note: (*) criteria identified from the literature review

Table 4: Background of participants

	< 5 years	5-10 years	11-20Years	> 20 years
Architect		2		
Engineer		2		
Quantity Surveyor	1	8	5	2
Others			2	
N (list)	1	12	7	2

Table 5: Pairwise comparison matrices (PCM) in the AHP

Matrix	Matrix size
M01 – Criticality of significant project risks	12 x 12
M02 – Organisational experience	5 x 5
M03 – Project management expertise	4 x 4
M04 – Project planning and scheduling	5 x 5
M05 – Site safety and environmental protection	5 x 5
M06 – Capacity to deliver projects	4 x 4
M07 – Quality control	5 x 5
M08 – Project team and key personnel	4 x 4
M09 – Subcontractor and suppliers	4 x 4
M10 – Productivity and performance of labour	3 x 3
M11 – Construction materials	4 x 4
M12 – Productivity and efficiency of plant & equipment	5 x 5
M13 – Cash flow	4 x 4

Table 6: Results of consistency analysis of individual judgments

n	Consistency Ratio (CR) value												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
R01	.24	.11	.11	.00	.01	.11	.00	.06	.04	.00	.01	.06	.00
R02	.04	.02	.02	.03	.03	.03	.10	.00	.07	.02	.02	.02	.00
R03	.22	.31	1.45	.21	.11	.26	.50	.69	.30	.00	.11	.10	.16
R04	.04	.04	0.00	.02	.00	.00	.04	.07	.01	.00	.00	.01	.00
R05	.63	1.37	.19	1.27	.58	1.48	1.12	1.65	1.91	.33	.27	.38	.32
R06	.44	.25	.20	.15	.30	.29	.22	.18	.25	.14	.41	.71	.52
R07	.87	.51	.42	.42	.47	.25	.50	.35	.30	.45	.44	.33	.30
R08	.62	.37	.31	.42	.25	1.70	.37	2.13	.25	.59	.49	.45	.38
R09	.24	.27	.39	.14	.20	.25	.20	.17	.14	.45	.17	.30	.33
R10	.16	.00	.00	.00	.01	.00	.02	.00	.02	.02	.02	.02	.00
R11	.39	.20	.49	1.14	1.01	.34	.06	.54	.33	.45	.08	.22	2.39
R12	.29	.32	1.14	.15	.00	.00	.05	.11	.05	.31	.26	.15	.10
R13	.65	.32	.29	.21	.35	.33	.31	.39	.57	.59	.33	.52	.23
R14	.32	.38	.54	.42	.43	.38	.34	2.54	.38	.59	.36	.60	.57
R15	.10	.08	.33	.04	.17	.04	.12	.06	.09	.14	.08	.13	.30
R16	.08	.48	.42	.37	.60	.26	.16	.71	.00	.14	.00	.00	.25
R17	1.54	1.22	.34	.52	.40	.32	.35	.43	.36	.38	.34	.35	.39
R18	.59	.37	.43	.37	.48	.43	.43	.43	.43	.52	.05	.08	.03
R19	.50	.25	.26	.28	.25	.02	.32	.46	.12	.06	.01	.16	.22
R20	.36	1.54	.41	1.07	.37	.27	.34	.31	.21	.45	.22	.26	.49
R21	.05	.04	.01	.08	.08	.00	.00	.05	.06	.04	.06	.04	.00
R22	.32	.05	.11	.42	.15	.02	.40	.15	.12	.06	.01	.16	.13

Table 7: Results of judgments' consistency improvement

	Consistency Ratio (CR) value												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
R01	.10	.07	.09	.00	.01	.03	.00	.06	.08	.00	.02	.06	.00
R02	.08	.02	.02	.03	.03	.03	.02	.00	.07	.02	.02	.02	.00
R03	.10	.06	.04	.07	.03	.06	.07	.01	.08	.00	.07	.10	.09
R04	.04	.04	.00	.02	.00	.00	.04	.07	.01	.00	.00	.01	.00
R05	.09	.09	.05	.10	.05	.07	.09	.06	.03	.06	.07	.07	.06
R06	.09	.10	.10	.06	.06	.09	.06	.08	.09	.08	.06	.08	.04
R07	.09	.07	.10	.07	.08	.07	.09	.09	.08	.08	.04	.10	.03
R08	.10	.10	.06	.06	.08	.05	.09	.05	.07	.04	.07	.09	.03
R09	.10	.10	.07	.04	.04	.07	.08	.04	.08	.08	.03	.09	.07
R10	.09	.00	.00	.00	.01	.00	.02	.00	.02	.02	.02	.02	.00
R11	.10	.07	.08	.06	.10	.09	.06	.05	.08	.06	.08	.09	.09
R12	.09	.10	.06	.08	.00	.00	.05	.07	.05	.10	.06	.07	.10
R13	.09	.09	.06	.09	.10	.09	.09	.08	.09	.06	.09	.07	.10
R14	.10	.04	.10	.05	.09	.08	.09	.08	.08	.04	.10	.09	.09
R15	.10	.08	.10	.04	.06	.04	.10	.06	.09	.06	.08	.04	.04
R16	.08	.09	.05	.10	.09	.05	.07	.05	.00	.04	.00	.00	.07
R17	.10	.07	.09	.07	.07	.06	.08	.07	.06	.10	.05	.10	.05
R18	.10	.09	.09	.08	.06	.09	.05	.09	.07	.03	.08	.08	.09
R19	.09	.07	.09	.09	.10	.09	.10	.08	.09	.06	.10	.10	.09
R20	.10	.09	.09	.08	.09	.05	.09	.08	.06	.06	.05	.09	.04
R21	.05	.04	.01	.08	.08	.00	.00	.05	.06	.04	.06	.04	.00
R22	.09	.10	.08	.07	.09	.02	.07	.04	.05	.06	.01	.09	.09

Table 8: Result of consensus level analysis

Matrix	Consensus level
M01 – Criticality of significant project risks	70.3%
M02 – Organisation experience	75.2%
M03 – Project management expertise	75.1%
M04 – Project planning and scheduling	77.3%
M05 – Site safety and environmental protection	78.3%
M06 – Capacity to deliver projects	71.9%
M07 – Quality control	83.7%
M08 – Project team and key personnel	81.2%
M09 – Subcontractor and suppliers	81.3%
M10 – Productivity and performance of labour	88.2%
M11 – Construction materials	82.9%
M12 – Productivity and efficiency of plant & equipment	79.2%
M13 – Cash flow	77.5%

Table 9: Categorical, local and global weights of criteria

Category	(CW)	Criteria	LW (%)	GW (%)
Inadequate organisation experience	4.56%	OE01	13.1%	0.60%
		OE02	27.0%	1.23%
		OE03	22.5%	1.03%
		OE04	6.0%	0.27%
		OE05	31.4%	1.43%
Lack of project management expertise	5.67%	PP01	25.7%	1.46%
		PP02	9.4%	0.53%
		PP03	39.5%	2.24%
		PP04	25.3%	1.43%
Improper project planning and scheduling	8.06%	PS01	17.1%	1.38%
		PS02	14.5%	1.17%
		PS03	9.8%	0.79%
		PS04	22.55	1.82%
		PS05	36.1%	2.91%
Lack of site safety and environmental protection	2.51%	SE01	22.1%	0.55%
		SE02	22.7%	0.57%
		SE03	23.5%	0.59%
		SE04	9.2%	0.23%
		SE05	22.5%	0.56%
Incapacity to deliver project	10.76%	CD01	19.2%	2.07%
		CD02	28.9%	3.11%
		CD03	22.3%	2.40%
		CD04	29.7%	3.20%
Improper quality control	3.53%	QC01	15.4%	0.54%
		QC02	18.1%	0.64%
		QC03	10.7%	0.38%
		QC04	16.9%	0.60%
		QC05	38.9%	1.37%
Incompetent project team and key personnel	10.08%	PT01	20.9%	2.11%
		PT02	34.4%	3.47%
		PT03	26.9%	2.71%
		PT04	17.8%	1.79%
Incompetent subcontractors and suppliers	7.59%	SS01	8.5%	0.65%
		SS02	28.3%	2.15%
		SS03	34.8%	2.64%
		SS04	28.4%	2.16%
Low productivity and performance of labour	9.68%	PL01	28.1%	2.72%
		PL02	12.5%	1.21%
		PL03	59.3%	5.74%
Unavailability of construction materials	6.54%	CM01	16.4%	1.07%
		CM02	20.3%	1.33%
		CM03	12.5%	0.82%
		CM04	50.9%	3.33%
Low efficiency of plant & equipment	5.81%	EP01	27.0%	1.57%
		EP02	9.4%	0.55%
		EP03	18.6%	1.08%
		EP04	23.5%	1.37%
		EP05	21.5%	1.25%
Cash flow difficulties	25.20%	CF01	16.8%	4.23%
		CF02	25.5%	6.43%
		CF03	26.2%	6.60%
		CF04	31.5%	7.94%
Total	100%			100%

Table 10: Comparison ranking of categories based on RII and AHP

Categories		RII	Rank	AHP	Rank
CF	Cash flow difficulties	84.48	1	25.20%	1
PS	Improper project planning and scheduling	82.88	2	8.10%	5
PT	Incompetent project team and key personnel	81.12	3	10.10%	3
PM	Lack of project management expertise	81.12	4	5.70%	9
CD	Incapacity to deliver project	80.00	5	10.80%	2
OE	Inadequate organisation experience	80.00	6	4.60%	10
SS	Incompetent subcontractors and suppliers	79.52	7	7.60%	6
PL	Low productivity & performance of labour	78.24	8	9.70%	4
QC	Improper quality control	77.60	9	3.50%	11
CM	Unavailability of construction materials	77.44	10	6.50%	7
SE	Lack of site safety & environmental protection	74.88	11	2.50%	12
PE	Low efficiency of plant & equipment	74.24	12	5.80%	8