A MULTI-ATTRIBUTE TENDER EVALUATION MODEL

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SUMMARY

Traditionally, in a construction bidding environment, the tender price is the only concern by the client. However, due to the increasing in awareness of quality and the use of alternative procurement technique which the tender price may not be known through the of the bidding process (e.g. management contracting, cost-plus contract, etc.), it is therefore necessary for the client to consider other decisions non-price decision variables. This leads to a quest for tools using logical and scientific approach in measuring the pros and cons of each tender submission. A number of evaluation model had been developed by using different kind of mathematical models. This papers serves to introduce an alternative approach to model the tender evaluation process through the technique of Analytic Hierarchy Process (AHP) where subjective evaluation on the relative importance among decision variables can be a discussed in a rational and logical manner. Also, the possibility of using a three-point estimate instead of a single point estimate are proposed.

KEYWORDS : Tendering; Multi-attribute Analysis; Analytic Hierarchy Process

INTRODUCTION

The prime objective of tendering for construction projects is to select a construction contractor which is capable carrying out and accomplish the anticipated work within prescribed (or suggested) time and at a competitive cost. However in actual practice, since technical competency and the expected performance on time cannot be observed and measured at objectively in the tender evaluation process, therefore they are tended to be avoided or received less attention then the more physical figure about the proposed tender price of the project which has immediate impact to the client. Also, for project - sector project, in order to be accountable to the public on the money spent, in most countries, the "the lowest bid wins" policy is widely adopted, where as other factors as mentioned are generally ignored.

However, with the gradual increase in the awareness of the quality of the construction stating from 80's, the "lowest bid wins" policy are questioned on preserving the client's interest on the quality of the construction process and as well as the finished products. In addition, as the concept of life cycle cost is gaining popularity also bring the "lowest bid" policy into doubt.

Apart from this, with the increasing use of "package" approach in which design and construction tasks are grouped into a single contract instead of a number for different design and construction components has been favoured by more clients who prefer simple contractual relationship, traditional tender evaluation approach based on comparing the cost renders inappropriate. This is because non-price factors, such as the quality and cost efficiency of the design proposal are of more or less equal importance as the cost must also be taken into due consideration. This trend is also observed in public sector as design and build approach are employed by quasi-government bodies in Hong Kong. Also, the use of Build-Operate-Transfer approach for large infra-structure project leads to the demand for more comprehensive tender evaluation models as more aspects have to be evaluated.

It is easy to observed that to decide which tender is the most satisfactory to the client's requirement, most of the variable are qualitative in nature, that is, such variables can not be ascertained in an absolute and precise manner. Instead, in most case those variables can only be represented by subjective judgment in linguistic format. Such linguistic variables, though imprecise in value, do represent human belief satisfactorily in most circumstances.

A number of mathematical decision making model has been suggested for the construction industry (1), (5), (6), etc.. Such models are all based on traditional mathematical technique which precise value are required. It is believed that such models in fact over-simplify the complex yet heuristic human intuition process. Therefore it is suggested that alternative mathematical model which human reasoning process can be assessed without our-simplification is essential.
This paper serves to briefly review the tender evaluation process. A multi-attribute tender evaluation model based on the concept of Analytic Hierarchy Process (AHP) which is able to assess the relative importance of various decision variables among each other systematically are introduced.

**BRIEF REVIEW TO BID EVALUATION PROCESS**

Competitive bidding is basically the most commonly used method in selecting a contractor in capitalist economy to carry out the prescribed construction work. Regarding the term "competition" it covers a wide range of areas and requirements specific to the projects, which may include time, cost, quality, safety, risks, etc. In the simplest words, the aim of bidding on tendering is to allow the client to select the most appropriate contractor who can provide the best value of money, to build as quickly as require whilst with minimal risk exposure. However, the chance of existence of a perfect bidder who can satisfy all the client's requirements completely are extremely rare, therefore, the search of an optimal rather than a perfectly matched winner bid can be considered as the actual aim of the tendering process.

The common system adopted for competitive tender are open tendering and selective tendering. As indicated by the name, there is no restriction of the entry of bidders to the bidding exercise under the open tendering system. However, as the cost of preparing tender documents for construction projects is high (which may amount to about 1% of the contract sum) and also time consuming, therefore, open tendering is rarely adopt in Hong Kong in both public and private sectors. For selective tendering, the number of contractors entering into the tendering exercise are limited. The eligibility of contractor from entry to be included into the approved list are based on a number of criteria, such as, previous performance, relationship, within the clients, the result of pre-qualification exercise, etc. In Hong Kong, the usual number of contractors invited a tender ranges from 6 to 10, which is in line with previous researches which states that with such number of contractors, the competition will be keen enough to achieve an optimal bid.

As mentioned, approved tender list may be from the result of pre-qualification. Pre-qualification, as defined by Russell and Skibniewski, is "a process of determining a candidates (contractors) competence or ability to meet specific requirements for a task involving a wide range of criteria for which information is often qualitative or subjective". A list of general criteria are also provided in the paper. From the list, it confirm the definition that most of the decision variables for pre-qualification cannot be assessed in objective manner, that is, in precise numerical values.

For the tender evaluation process, in most cases, only the cost will be considered. This is based on the argument that if pre-qualification has been carried out in formulating the approved contract list, approved contractors are presumably competent in various aspects which are already evaluated in the pre-qualification exercise. However, with the increasing lease of alternative procurement system, where contractor can suggest alternative construction techniques and management systems. (design and build), these way affect the time required for carrying out the project. In such situation, it is insufficient to compare the contract sum in determining which contractor the best value of money. In order to select the "most appropriate" contractor, scientific and objective evaluation of all decision variables should be taken into serious consideration. A number of models has been developed for pre-qualification process, but the tender evaluation has received relatively less attention. Only a handful number of researches as been observed. In this paper, a multi-attribute ordering model based on the concept of Analytic Hierarchy Process (AHP) is suggested to tackle the task of interpreting subjective judgment during the tender evaluation process in a logical and systematic manner.

**THE MODEL FOR TENDER EVALUATION**

The Analytic Hierarchy Process (AHP) developed by Saaty provides a hierarchical framework for decision maker to analyze the decision variables in a systematic manner. Apart from this, it also provides a means to evaluate the relative importance among decision variables. Under AHP, a decision is to be divided into a number of hierarchies. Under each hierarchical level is a set of decision variables or situations to be analyzed. The relatively importance of each variable with others are compared by a pair-wise comparison process, and the result of the comparison will be subjected to further analysis for finding out the relative ranking of variables. A sample AHP model is illustrated in Figure 1:
For tender evaluation, a simple decision model based on AHP as below is proposed:

The tender evaluation is structured in a three-level AHP model. The first level constitutes the overall decisions, that is, the task of finding the most appropriate contractor. The second level consists of the decision variables for selecting the "appropriate contractors". For the sake of illustration, a seven-variable model are adopted. Those variable are listed as below. In actual application, decision makers can create as many decision variables as necessary. However, it must be remembered the more the number of decision variables, the more data are to be handled. (For $n$ number of variables, the corresponding number of pair-wise comparison is $(n^2-n)/2$)

List of variables for the proposed AHP model for tender evaluation:

- Time \((T)\)
- Cost \((C)\)
- Quality \((Q)\)
- Technical Competence \((Tc)\)
- Financial Competence \((F)\)
- Relationship \((R)\)
For the third and lowest level of the model, it comprises the contractors entering into the tendering exercise (bidder) and are to be evaluated. A n-bidder situation is adopted for illustration. The completed model is illustrated in figure 3.

![Figure 3 - Proposed 3-level AHP for tender evaluation in a n-bidder situation](image)

To commence the evaluation process, the relative importance of the decision variables of the second level variables are evaluated first. Each variables will be compared with other variables in a pair-wise manner. The results obtained can be represented by a $7 \times 7$ matrix ($A$) as below (Figure 4). The matrix has the properties that the value of the diagonal are equal to one. This is very obvious as when comparing the variables among itself, the relative importance should always equal to each other. Also, when comparing two variables, say $X$ and $Y$, when the value of relative importance for $X$ to $Y$ is $k$, then the relative importance for $Y$ to $X$ should be equal to $1/k$. In short, such characteristics can be represented as:

$$A = \begin{pmatrix}
    a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\
    a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \\
    a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} & a_{37} \\
    a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} & a_{47} \\
    a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} & a_{57} \\
    a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} & a_{67} \\
    a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & a_{77}
\end{pmatrix}$$

Figure 4 - Priority matrix $A$ for 2nd level variables

where $a_{ij} = 1/a_{ji}$ and $a_{ii} = 1$ for $i,j = \{1,2,3,4,5,6,7\}$

Then, The priority vector of the matrix ($A_p$) is obtained by calculating the eigenvalue of the matrix $A$

$$A_p = (a_1, a_2, a_3, a_4, a_5, a_6, a_7) \text{ where } \sum_{k=1}^{7} a_k = 1$$
Then the process will move to the third level. In this level, bidders will be compared each other for each variables in the second level. In other words, seven priorities matrix is to be produced. (An example of this is Figure 5:

\[
X_T =
\begin{pmatrix}
  t_{11} & t_{12} & \cdots & t_{1m} & t_{1n} \\
  t_{21} & t_{22} & \cdots & t_{2m} & t_{2n} \\
  \vdots & \vdots & \ddots & \vdots & \vdots \\
  t_{m1} & t_{m2} & \cdots & t_{mm} & t_{mn} \\
  t_{n1} & t_{n2} & \cdots & t_{nm} & t_{nn}
\end{pmatrix}
\]

Bidder 1
Bidder 2
Bidder m
Bidder n

Figure 5 - 3rd level priority matrix among bidders for 2nd-level variable (cost)

where \( t_{ij} = 1 / \lambda_{ij} \) and \( \lambda_{ii} = 1 \) for \( i, j = \{1, \ldots, m, \ldots, n\} \)

Again, the priority vector (eigenvalue) of each matrix are obtained. By combining all priority matrix together, a matrix \( X \) is found (Figure 6).

\[
X =
\begin{pmatrix}
  X_{11} & X_{12} & X_{13} & X_{14} & X_{15} & X_{16} & X_{17} \\
  X_{21} & X_{22} & X_{23} & X_{24} & X_{25} & X_{26} & X_{27} \\
  \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
  X_{m1} & X_{m2} & X_{m3} & X_{m4} & X_{m5} & X_{m6} & X_{m7} \\
  \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
  \end{pmatrix}
\]

Bidder 1
Bidder 2
Bidder m
Bidder n

Figure 6 - Combined matrix \( X \) of eigenvalue for priority matrix for respective decision variables at 2nd level

\[
\sum_{i=1}^{n} x_{ij} = 1 \quad \text{and} \quad j = \{1, 2, 3, 4, 5, 6, 7\}
\]

When matrixes for the second and third level are computed, they will undergo simple matrix multiplication to find out the relative priority of the bidders.

\[
Z = X \, \boxtimes \, A_p
\]
where

\[
Z = \begin{pmatrix}
  z_{11} & x_{12} & x_{13} & x_{14} & x_{15} & x_{16} & x_{17} \\
  \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
  x_{m1} & \vdots & \vdots & \vdots & \vdots & \vdots & x_{m7} \\
  \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
  x_{n1} & x_{n2} & x_{n3} & x_{n4} & x_{n5} & x_{n6} & x_{n7}
\end{pmatrix}
\]

The result can be interpreted as such: the higher the value of \( z_k \), the more preferable the bidder is.

It is observed that while carrying out the pair-wise comparison between variables, a single point value estimate is required. As discussed, as humans are not always comfortable with giving precise point value in expressing judgment. Therefore, the use of single value point estimate for expressing subjective judgment in AHP analysis still cannot fully model the human decision process. To tackle the issue, it is suggested that instead of using a single point estimate for expressing belief, the concept of PERT (Project Evaluation and Review Technique) can be borrowed. Under this situation, instead of providing a single point estimate, a three-point estimate, which comprises the lower (\( a \)) and upper bound (\( b \)) and the most probable estimate (\( m \)) are to be provided by the decision maker when carrying out the pair-wise comparison. This three-point estimate constitutes a triangular distribution, and the mean of the distribution, denoted \( Em \) and calculated by the following formula, can be regarded as a better point estimate for corresponding analysis.

\[
Em = \frac{a + 4m + b}{6}
\]

where \( Em \) is the mean of the three-point value estimate

\( m \), \( a \), and \( b \) are the most probable(vertex), lower bound, and upper bound of the distribution

CONCLUSION

In this study, a multi-criteria decision model utilizing the concept of Analytic Hierarchy Process (AHP) is suggested to handle the increasing complex tender evaluation problem. The AHP technique offers a systematic approach to compare the relative importance of each variables through well-structured hierarchical model. Also, by incorporating the concept of PERT technique into the pair-wise comparison process in the AHP technique, a more realistic process of estimation where human imprecise intuition can be taken into due consideration systematically. In fact, it is observed that there is high possibility that the concept of fuzzy sets (8) can replace the PERT technique in providing a more cogent analysis on evaluating the relationship among various decisions variables where subjective judgment can be represented more satisfactorily.

REFERENCES


