KEY FACTORS IN BID REASONING MODEL

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ABSTRACT: The bidding decision is a complex problem affected by numerous factors. The current study collected a list of determining factors from the results of past research and opinions of six experienced practitioners in competitive bidding. Based on these factors, a bid reasoning model was established to go deeply into the bid decision process. Differing from other earlier work, this model-oriented study focuses on the effects of the determining factors on four reasoning subgoals: competition, risk, company's position in bidding, and need for work. Their different contributions to each reasoning subgoal were reviewed under three main construction procurement methods, namely, unit rate contract, lump sum contract, and design/build contract. The Analytic Hierarchy Process technique was applied in this study. A survey questionnaire was developed with four hierarchies being formulated respectively for the four reasoning subgoals. The survey was conducted in two steps, the pilot survey among the six experienced practitioners and the subsequent one among 153 top contractors in Singapore. From this survey, a set of top key factors and their relative importance weights were identified. This result together with the bid reasoning model can serve as the framework for the further development of the bid decision support system.

INTRODUCTION

The bidding decision is a complex decision-making process that is affected by numerous factors. To study how bid decisions are made, it is important to identify the underlying key determining factors. Surveys by Ahmad and Minkarah (1988), Shash and Abdul-hadi (1992), and Shash (1993) have identified some of the important factors in the bid/no bid and markup decision making. However, in these studies, no deep reasoning has been made about the bid decision process itself. In actuality, a contractor arrives at a bid decision only after a complex reasoning process. In view of this, the present study looks at the factors from the perspective of the reasoning goals that contribute to the overall decision.

Through interviews with six persons experienced in competitive bidding, four key considerations in bidding were identified. These include the potential level of competition, the possible risk margin, the essential company's position in bidding, and the company's keenness in getting the job. These concerns constitute the subgoals in reaching their bid decisions. In the decision process, contractors access these subgoals from a multitude of factors relating to the job, social and economic environment, and the company. In this study, a bid reasoning model from this point of view is presented. Oriented by this model, the key determining factors were then identified.

Moreover, the effect of different contract types has also been considered, unlike previous studies. Depending on the type of contract, the exposure to risk and contractual obligations will differ. Consequently, the contractors will evaluate the bid decision differently. Accordingly, the various determining factors will contribute differently to the subgoals in the decision process. Altogether, three contract types are examined, namely, unit rate, lump sum, and design/build, being the prevailing forms of contract in the industry.

The technique of the Analytic Hierarchy Process (AHP) is adopted to establish the key determining factors. Unlike the usual ranking surveys, this approach not only ranks the factors but also determines their relative importance toward the subgoals through pairwise comparison between the factors. Furthermore, a consistency measure can be assessed from the comparison matrix obtained from the survey so that the inconsistency in the evaluations can be minimized to an acceptable level.

With this technique, the factors were classified into several subset groups and systematically organized into various levels of hierarchies. In this case, four hierarchies were constructed focusing respectively on the four reasoning subgoals. A set of questionnaires was designed based on these hierarchies. The six persons, with an average of over 20 years of experience and holding senior positions in leading contracting companies, were invited to participate in the preliminary survey. Based on the results, the questionnaire was modified and subsequently distributed to 153 top contractors in Singapore construction market. The findings of the survey are presented. The key determining factors are identified, and the effect of different types of contracts is elucidated.

BID REASONING MODEL

Conventional statistical bidding models, based on the work of Friedman (1956) and Gates (1967), differ from each other in the way of calculating the joint probability of winning a bid over the other competitors. Invariably, they then attempt to determine a markup that will maximize the expected profits by taking into account the joint probability of winning. This is an oversimplification of the bid decision process so that these models have rarely been adopted by contractors to form their business strategies. Recently, bidding models based on the underlying determining factors attracted increasing attention. Ahmad (1990) adopted a utility value approach in his bid/no bid decision model. An overall utility of the bid is determined based on qualitative assessments of the key determining factors. Moselhi et al. (1993) used almost the same set of key factors in a neural network model to determine the appropriate markup level after having trained the network using a set of bid cases. Dozzi et al. (1996) recently developed a multicriteria utility model for bid markup by following an approach similar to that of Ahmad (1990) to get the overall utility value of the project and then using a utility function to arrive at the markup value. Because a large variety of determining factors was considered in these models, they fit the real-world situation more closely.

Even with these models, the reasoning within the decision process has not been adequately modeled. To go deeply into the ''heart'' of the bidding problem, a bid reasoning model is developed in this study as presented in Fig. 1. The model

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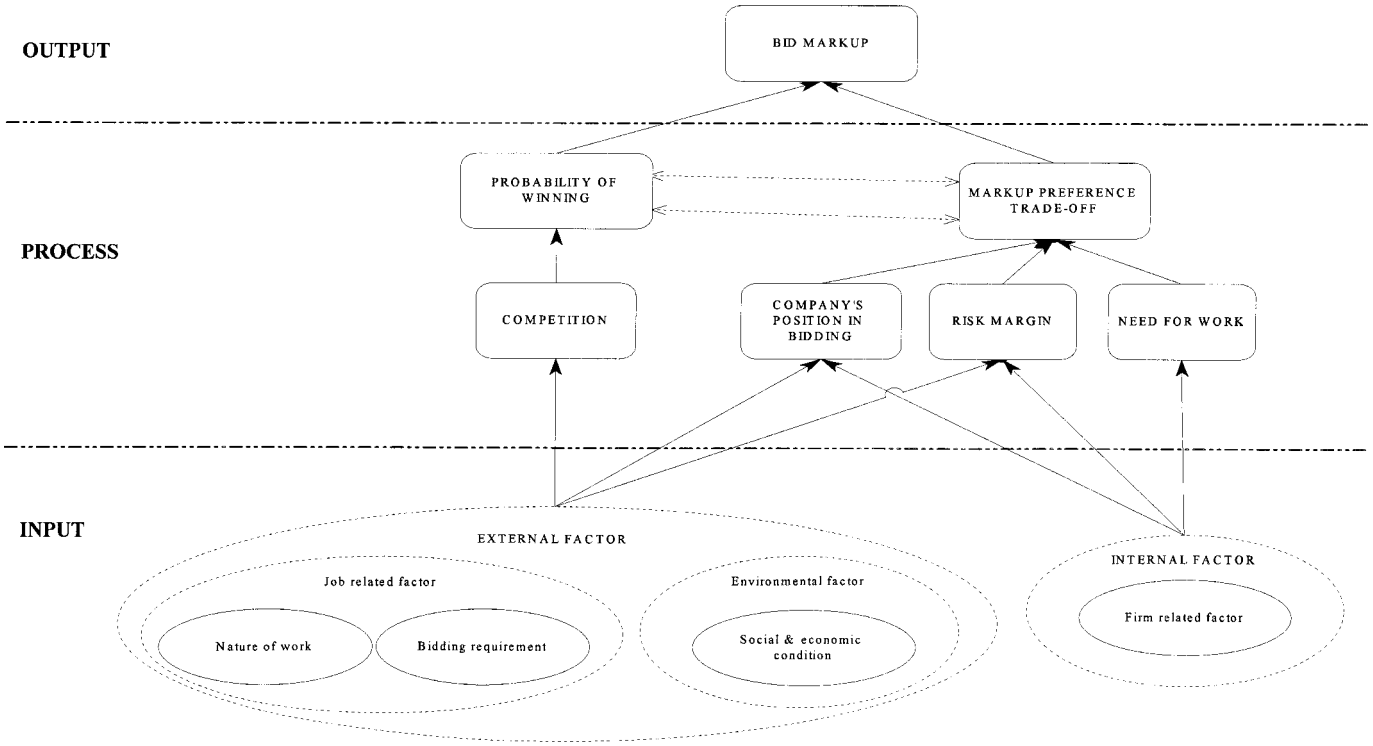

FIG. 1. Multiattribute Bid Reasoning Model

incorporates four key considerations (or reasoning subgoals) of the contractors in the bid decision process, namely, competition, risk, need for work, and company's position in bidding. The potential key determining factors comprising internal and external factors support the bid decision through the four reasoning subgoals.

Competition

The assignment of an appropriate level of markup to the base estimate is the critical part of a contractor's business strategy. To bid with a higher markup increases the profit if the bid can be won, but decreases the probability of winning. The probability of winning a bid is closely associated with the potential level of competition, which is commonly reflected by the number and competitiveness of the competitors. For a given project and level of risk, the keener the competition, the lower is the markup of the winning bid. The level of competition can be assessed from external factors pertaining to the nature of the project, bidding requirement, and the social-economic environment.

Risk

The estimated cost forms the base for markup evaluation to arrive at the final bid. However, due to uncontrollable risk elements, the actual construction cost will never be exactly equal to the estimated construction costs. A contingency provision is usually included in the estimate for these elements. However, if it is inadequate, the cost overruns will cut into the markup and, in some cases, result in a pure loss at the end of the project for the contractor. In addition to external factors, the internal factors, which reflect the capabilities and resources of the company in relation to the project and environment, also determine the risk exposure.

Need for Work

For a given markup, the expected profit can be determined based on the level of competition and risk assessment. An optimal markup can then be ascertained to maximize expected profit. However, this assumes a linear preference to the value of money. Willenbrock (1973) introduced utility theory into his bid markup model to incorporate the contractor's nonlinear preference to the value of money. Neufville and King (1991), in their survey, determined that contractors take different attitudes under different situations. In the case of high need for work and low-risk project, they are generally risk positive and are prepared to accept a markup less than the expected monetary value. Otherwise, they will consider adding a premium to their bids to account for the risk of the project and their lack of enthusiasm for the job. This need for work forms the third reasoning subgoal for the present bid model.

Company's Position in Bidding

Another reasoning subgoal is the company's position in bidding. Depending on the situation at the time of bidding, certain projects might appear to be very suitable to the company's specialty and resources. In this case, the company will have an advantageous leverage in the competition over its competitors. A strong position in competition will make the company take a more risk-positive attitude.

DETERMINING FACTORS AND BID MODEL

Earlier work has identified some key factors relating to the bid decision. A survey on top U.S. contractors conducted by Ahmad and Minkarah (1988) revealed 31 factors that were thought to influence the two steps of bidding decision process: bid/no bid decision and the percentage of markup decision. Shash and Abdul-hadi (1992) and Shash (1993) in their study on some Saudi Arabian and U.K. contractors listed 35 and 55 factors, respectively. Although these factors were quite extensive, they were only dealt with in general, and no attempt was made to distinguish them according to the different reasoning subgoals that go into the bidding process. Nevertheless, Smith (1995) listed some factors pertaining to risk and uncertainty in estimating and tendering, which contributes to ''risk,'' one of the reasoning subgoals. Neufville and King (1991) pre-

J. Constr. Eng. Manage., 2000, 126(5): 349-357

sented some factors related to ''need for work,'' another reasoning subgoal.

In the present study, a set of factors gathered from the literature is identified, which excludes those that are insignificant and includes other factors that may be important from the perspective of some reasoning subgoals. These factors are classified into two main categories: the internal factors and external factors, as depicted in Table 1.

The internal factors are those inherently related to the company, including its expertise, experience, financial ability, resource possession, current workload, etc. These factors reflect the company's ability and present status. They evolve with time, but independent of job. The contractor can exert his control over most of these factors.

External factors are those that are job-related or uncontrollable by the contractor. These include factors related to the nature of the work, bidding requirement, and the social and economic environment. Factors pertaining to the nature of work, such as size of project, degree of technological difficulty, resource requirements, public exposure and prestige of the project, etc., reflect the pertinent features of the project. Factors related to bidding requirement, such as prequalification requirement, bidding method, time allowed for bid preparation, etc., are the client's prerequisites for bidders' compliance in bidding. Environmental factors reflect the status of the surrounding world, mainly relating to the social and economic conditions, including the current bidding market, resource market, government regulations, etc. Factors pertaining to the nature of work depend on the specific project, whereas those related to bidding requirement depend on the project and the client. However, the environmental factors evolve with time and are independent of the job. All external factors are independent of any specific contractor.

Most of the internal (firm-related) factors are not accessible to others, and they vary from one company to another. Although they may affect the bid markup decisions, there is no way to apply them to reason about the competition level. The factors that can be employed to reason about the level of competition are the external factors. On the other hand, the contractor's own internal factors would dictate directly his keenness to bid (i.e., need for work). For example, contractors with a current heavy workload will have no great interest for getting more new jobs. The interactions between the internal and external factors decide the level of risk and the company's position in bidding.

TABLE 1. List of Factors for Proposed Bidding Model

Category (1)	Reasoning subgoals and factors (2)
External factors	
Job related	Nature of work
	1. Type of project
	2. Size of project
	3. Degree of technological difficulty
	4. Cash flow requirement
	5. Type and number of supervisory required
	6. Type and number of labor required
	7. Type and number of equipment required
	8. Site accessibility
	9. Project public exposure and prestige
	10. Project timescale and penalty for noncompletion
	11. Degree of subcontracting
	12. Identity of owner/consultant
	13. Safety hazards
	14. Site space constraints
	15. Consultants' interpretation of the specification
	16. Delay or shortage on payment
	Bidding requirement
	17. Required bond capacity
	18. Prequalification requirement
	19. Bidding method (open/close)
	20. Time allowed for bid preparation
	21. Completeness of drawing and specification
Environmental	Social and economic condition
	22. Availability of other projects
	23. Availability of qualified labor
	24. Availability of qualified staffs
	25. Availability of equipment
	26. Availability of qualified subcontractor
	27. Government regulation
	28. Degree of difficulty in obtaining bank loan
	29. Resource price fluctuation
Internal factors	Firm-related factors
	30. Expertise in management and coordination
	31. Similar experience
	32. Familiarity with site condition
	33. Reliability of subcontractors
	34. Current workload in bid preparation
	35. Competence of estimators
	36. Adequacy of resource market price information
	37. Current workload of projects
	38. Promotion of company reputation
	39. Required rate of return in investment
	40. General office's overhead recovery
	41. Need for continuity in employment of key personnel and work force
	42. Relationship with owner
	43. Share of market
	44. Financial ability
	45. Strength of business partner/subsidiaries
	46. Possession of qualified staffs
	47. Possession of qualified labor
	48. Possession of qualified subcontractor
	49. Possession of required equipment
	50. Company's ability in design involvement and innovation
	51. Company's ability in required construction technique

AHP

The AHP is a framework of logic and problem resolving achieved by organizing perceptions, feelings, judgments, and memories into a hierarchy of forces that influences decision results (Saaty 1994). It was developed by Saaty in the 1970s. With this technique, complex decision problems can be decomposed into some smaller constituent subparts, according to the reasoning subgoals focused by the decision maker. In this way, it provides a structured approach to understanding the problem, and it also helps the expert participants focus on each criterion one at a time (Saaty 1980). The most distinctive features of AHP are the systematic hierarchical structure, pairwise comparison, and inconsistency assessments.

In a hierarchical structure, the reasoning goal appears at the top of the structure. The determining factors are appropriately categorized into groups and subgroups. Each group, subgroup, or determining factor is referred to as a force element in the hierarchical structure. Force elements under one common parent node in the hierarchy are referred to as one set of force elements. If any set of subelements contained by the common parent force element becomes too large, the problem can be further broken down through the hierarchical structure. In this way, the force elements can be systematically arranged into the hierarchy with sufficient levels. The groups or subgroups representing more general concepts will always appear in the higher levels than those representing less general concepts. The most specific elements (the determining factors) should be arranged at the lowest level.

Each force element is compared in pairs with other force elements in the same set according to their contributions to their common parent node in the level immediately above. Unlike the traditional methods adopted by most surveys that require the participants to consider the entire range of elements at the same time, with the AHP technique, only one pair of

J. Constr. Eng. Manage., 2000, 126(5): 349-357

elements is focused on each time, and the number of elements in one set are restricted to only a few. In this way, the inconsistency in judgment is minimized to a great extent. Experiences and preferences are best merged into this procedure as the intuitive assessments of their significance are assigned.

In the pairwise comparisons, a nine-point qualitative scale was used to depict the intensity of relative importance. Despite its discrete nature, it has been demonstrated that the nine-point scale is reasonable and able to reflect the degree to which we can discriminate the intensity of relationships among the force elements (*Expert* 1996). For each set of force elements a matrix A of pairwise comparisons can be derived

$$\mathbf{A} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_j & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_j & \cdots & w_2/w_n \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ w_i/w_1 & w_i/w_2 & \cdots & w_i/w_j & \cdots & w_i/w_n \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_j & \cdots & w_n/w_n \end{bmatrix} \quad (1)$$

where w_i/w_j = relative importance of factor i compared to factor j; and n = number of factors in the set. The relative importance of the n factors can be obtained by resolving the following equation:

$$\mathbf{A} \cdot \mathbf{W} = \lambda_{max} \cdot \mathbf{W} \quad (2)$$

where $\mathbf{W} = (w_1, w_2, w_3, \ldots, w_n)^T$ = vector of relative weights; and λ_{max} = largest eigenvalue of matrix $\mathbf{A}$. If there is no judgment inconsistency, λ_{max} should equal to n. The AHP does not require decision makers to be perfectly consistent but, rather, provides a measure of inconsistency (Harker 1989). As a result, a consistency ratio (CR) can be computed from the above equation. The value of CR should preferably be <0.1. If it is found to be >0.1, the results of pairwise comparisons need to be reevaluated.

By multiplying the relative weights of the force elements (obtained from the pairwise comparisons) to those of the corresponding force elements on the next higher level and repeating the process up to the reasoning goal (at the top of the hierarchy), the set of global importance weights with respect to the reasoning goal can be derived. Through the above synthesis and aggregation process, the AHP thus leads from simple pairwise comparison judgments to the priorities in the hierarchy.

As a systematic approach in decision making, the AHP has been successfully applied in the area of construction management by several researchers. Dozzi et al. (1996) used this approach to weight bidding criteria in a bid markup decision model. Similarly, Seydel and Olson (1990) introduced this method to assist the decision makers in making their preference trade-off among several decision criteria. Chua et al. (1999) employed this technique to derive the relative importance of the critical project success factors based on expert judgments. The present study adopts a similar methodology for the bid reasoning model.

FORMULATION OF HIERARCHIES

Based on their potential contributions to the four reasoning subgoals, the factors in Table 1 are regrouped and organized into corresponding hierarchies for the AHP.

Hierarchy of Competition

The level of competition is reflected by the number of competitors and the keenness of these competitors. As aforementioned, only external factors have been considered for this subgoal. As shown in Fig. 2, these factors are organized under three main categories. The first relates to the nature of work. These factors include the type and size of the project, its tech-

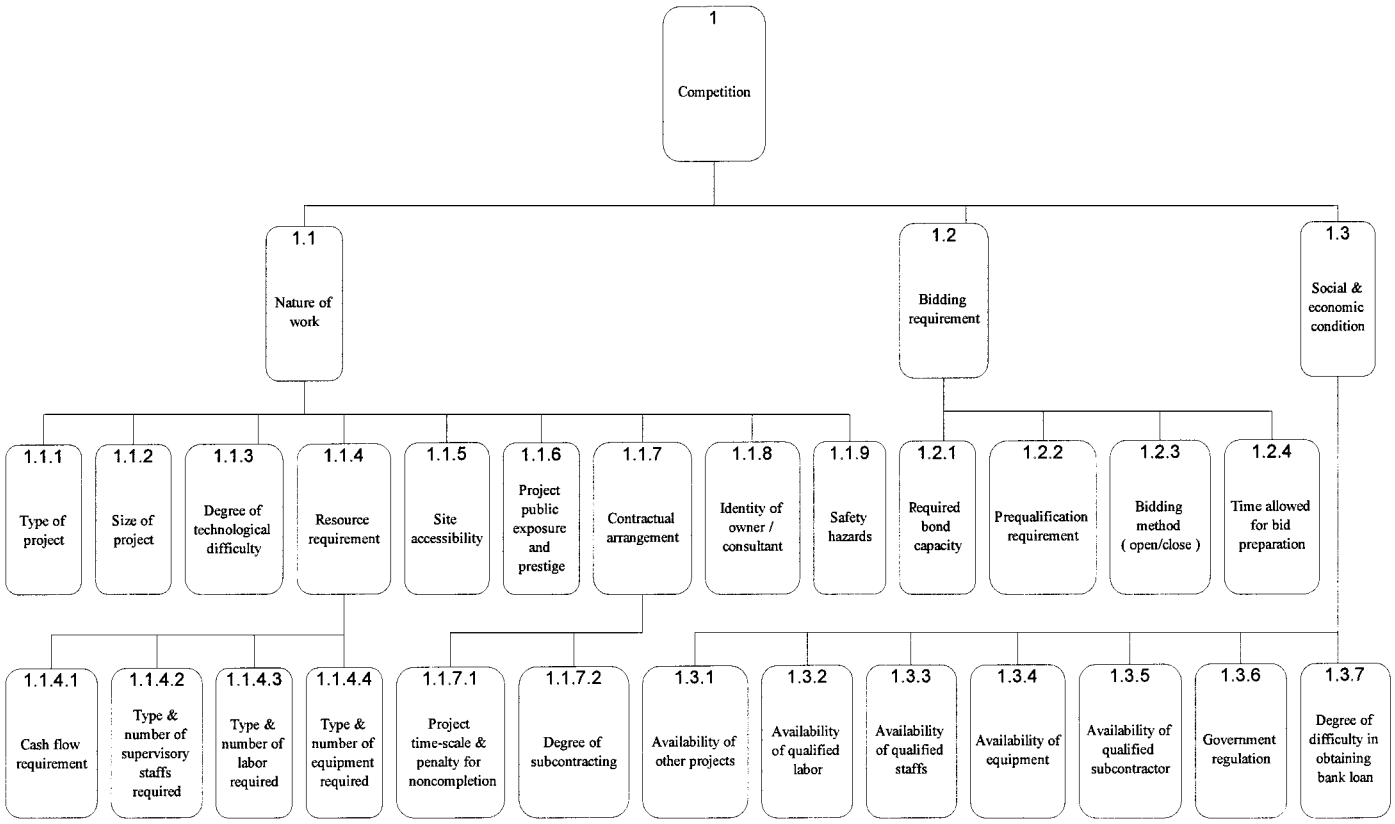

FIG. 2. Hierarchy of Competition

J. Constr. Eng. Manage., 2000, 126(5): 349-357

nical difficulty, resource requirements and site accessibility. Public exposure and prestige of the project, contractual arrangement, the owner and consultant, and safety considerations are the other factors. The second category of factors pertain to the requirements of the bid. They include bond and prequalification requirements, bidding method, and time allowed for bid preparation. These factors can add constraints on some contractors thereby reducing the number of potential competitors for the bid. The last category concerns the social and economic conditions at the time of bidding. The factors relate to market conditions, availability of key resources in the industry, and government regulatory and financing considerations.

Hierarchy of Risk

In the hierarchy of risk, external and internal factors are classified under two broad categories, namely, risk exposure during bid preparation and risk exposure during project execution, as shown in Fig. 3. During bid preparation, uncertainty generally arises from two sources: accuracy in estimating, and adequacy and clarity of required information. Current workload in estimation, time allowed for bid preparation, and the competence and biases of the estimators are factors closely related to the estimating team. With respect to information, ambiguities and completeness in the bidding documents can affect the accuracy of cost estimation and result in potential for changes in scope during the construction stage (Akinci and Fischer 1998). Another factor pertains to the resource market price information, which affects price assumptions in the estimate.

During the project execution stage, the risk elements are classified under four groups: nature of the work, firm inherent risk, client and consultant posed risk, and social and economic conditions. The first group, nature of work, comprises factors related to project characteristics similar to those in the competition hierarchy. Degree of subcontracting, and project duration and penalty for noncompletion of project pose some degree of risk to the project and have also been included. The second group, firm inherent risk, relates to the expertise and experience of the company and the reliability of its subcontractors. The main considerations in client's/consultant's posed

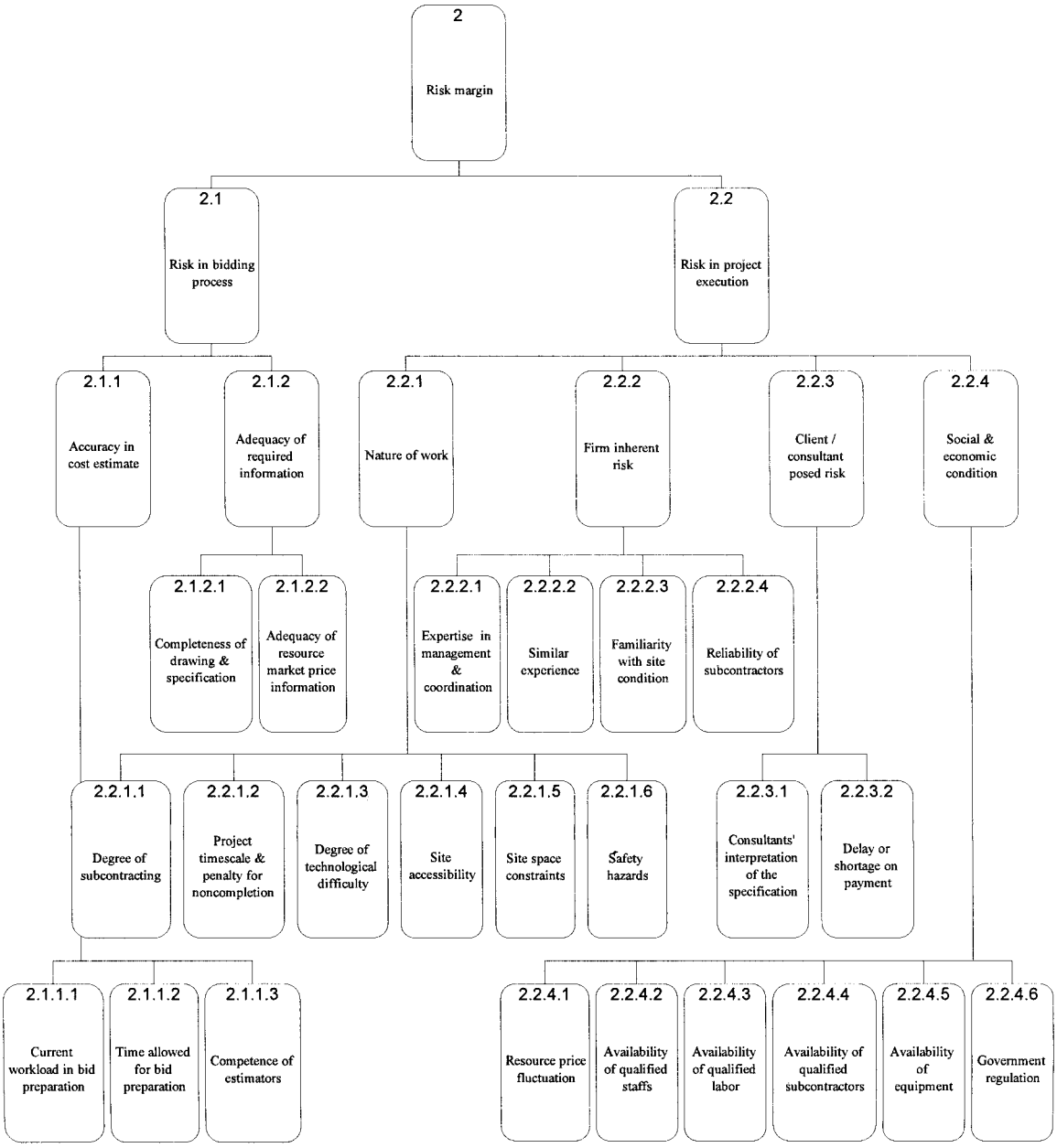

FIG. 3. Hierarchy of Risk

J. Constr. Eng. Manage., 2000, 126(5): 349-357

risk include the consultant's interpretation of the contract specifications and the owner's progress payments. These factors can hinder the performance of the contract. The factors related to the social and economic conditions are similar to those in the competition hierarchy. Resource price fluctuation is another factor that has been included for consideration.

Hierarchy of Need for Work

Some of the factors contributing to the subgoal of need for work have been identified by Neufville and King (1991). Those adopted in this study are shown in Fig. 4. One group of factors reflects the company's current situation. These factors pertain to the company's current workload in bid preparation and project execution. A heavy current workload would inevitably make the contractor less enthusiastic to acquire new jobs.

A second group of factors reflects the business strategy of the company. Rate of return on investment and overhead recovery are factors relating to financial objectives. There are other long-term nonfinancial considerations as well such as company's reputation, market share, and maintaining good relationship with owner. In some situations, there may be a need to secure sufficient jobs to keep key personnel and workforce. Because there are not too many factors altogether, they have been placed in the same level under the goal node.

Hierarchy of Company's Position in Bidding

The hierarchy for contractor's position in bidding is shown in Fig. 5. It can be assessed from the company's financial and technological leverage, its relationship with the owner, and the strength of his partners and subsidiaries. The company's pool of key resources, its expertise in management and coordination, and its technical specialty and similar experience reflect the company's technical leverage. These factors increase the company's competitiveness in bidding; for example, a strong financial leverage reduces the company's exposure to cash flow difficulties, whereas a strong technical leverage reduces its risk exposures during execution.

QUESTIONNAIRE SURVEY

A questionnaire survey was conducted to obtain the relative importance of the various factors in the bid reasoning model using the AHP technique. The survey forms were divided into three sections. The first presents the bidding model and a description of the factors to give the participants the overall approach and objective. The second section solicits some general information about the background of the respondents and their firms, and the general strategies adopted by them. The last section is the questionnaire for the paired comparisons of the force elements according to the AHP approach. The compar-

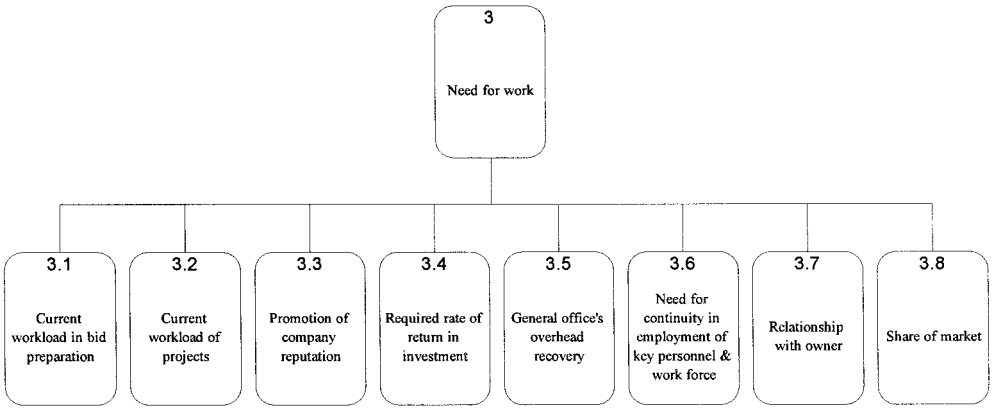

FIG. 4. Hierarchy of Need for Work

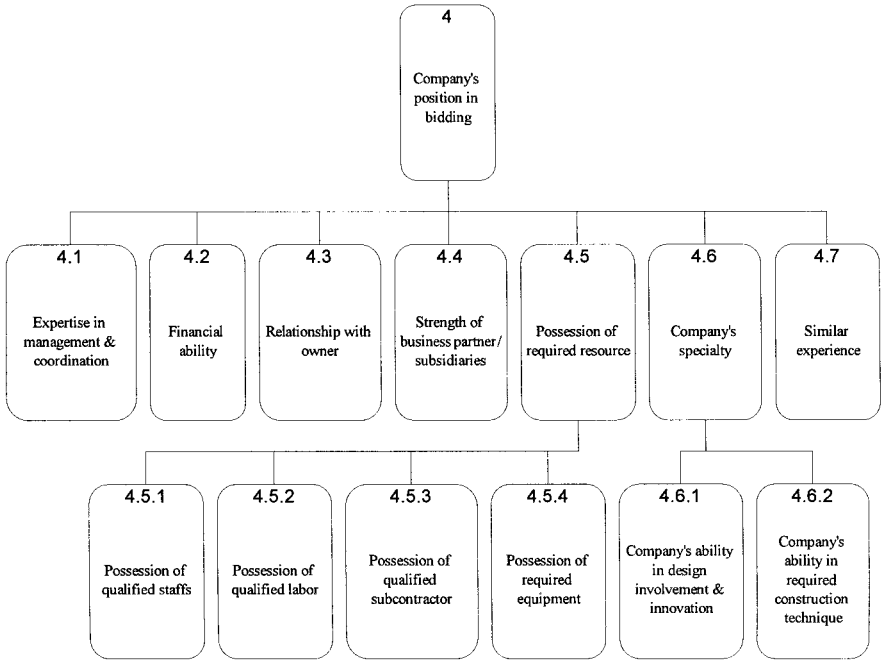

FIG. 5. Hierarchy of Company's Position in Bidding

J. Constr. Eng. Manage., 2000, 126(5): 349-357

isons were conducted for the four reasoning subgoals following the hierarchies developed earlier. They were made with respect to three different contract types: unit rate, lump sum, and design/build, except for the subgoal contractor's need for work, as this is deemed to be independent of the type of contract.

The survey was conducted in two steps. First, six persons experienced in competitive bidding were invited to participate in a preliminary survey. They are all holding senior positions in reputable organizations. One of them is from a leading local construction firm. Another four are from overseas subsidiaries of notable foreign contractors. The sixth is from a professional project management consultant company. Before distributing the questionnaire, a personal interview was arranged to brief each of them on the bidding model, the AHP procedure, and the meaning of the factors investigated. To avoid any bias derived from experience over a particular job, they were specifically reminded to make their judgments based on their general experience and knowledge.

Through the preliminary survey, the relative importance of the determining factors was reviewed. The least important factors as evaluated by them were ignored. The questionnaire was modified accordingly and subsequently distributed to several top contractors in the Singapore construction market.

RESULTS AND DISCUSSION

The questionnaire was distributed to all of the 153 G7 and G8 contractors (G7 and G8 contractors have a paid-up capital and net capital worth of S$2,500,000 and S$5,000,000, respectively, and can tender for projects up to S$50,000,000 and exceeding S$50,000,000, respectively). Nineteen sets were returned, and all were from G8 contractors. Thus, there are a total of 25 responses including 6 from the preliminary study. Some general findings can be noted from the survey as follows:

- Over 70% of the respondents have experienced circumstances in which the company urgently needs to win a bid of the contract type and situation.
- Nearly 90% of the respondents attributed the main cause of their bidding failures to overestimation of the cost to do the work.
- The percentages of work obtained through competitive bidding ranged from 10 to 90%.
- Almost 80% of the respondents have never used any statistical/mathematical model to assist their bidding decisions.

The main part of returned survey forms (i.e., the pairwise comparisons of the determining factors) were analyzed with the AHP software Expert Choice (*Expert* 1996). Starting from the bottom level, the relative importance weights and CR were calculated for each subgroup of factors. Weights were synthesized level by level. For each level, the consistency was reviewed. In this process, three sets of the survey results were found to be highly inconsistent and therefore were discarded. The CRs of the other 22 sets were within an acceptable level. The global importance weights for the factors were finally derived. The factors can also be ranked according to their global importance weights.

Ranking Consensus

With more than two sets of rankings, Kendall's coefficient of concordance F is an appropriate nonparametric test for determining the overall consensus of the ranking of the factors by the respondents (Yeomans 1968). The test of significance for F is based upon the sampling distribution of the sum of squared deviation of the $\Sigma_{j=1}^{e} R_{ij}$ around $\overline{\Sigma_{j=1}^{e} R_{ij}}$, where R_{ij} denotes the ranking of the ith factor by the jth respondent, and e is the total number of respondents; and $\overline{\Sigma_{j=1}^{e} R_{ij}}$ is the averaged value of $\Sigma_{j=1}^{e} R_{ij}$ for each of the s number of factors. When the total number of factors $s > 7$, the sampling distribution is approximated by the X^2 distribution with $s - 1$ degrees of freedom. In this case, F can be represented by $X^2_{(\text{calc})}$, in which

$$X^2_{(\text{calc})} = \frac{12 \sum_{i=1}^{s} \left(\sum_{j=1}^{h} R_{ij} - \frac{\sum_{i=1}^{s} \sum_{j=1}^{h} R_{ij}}{s} \right)^2}{hs(s+1)} \quad (3)$$

Table 2 shows the $X^2_{(\text{calc})}$ values calculated for each subgoal under a different type of contract. It was found that the participants' ranking of the factors appears to be in consensus at a 95% confidence level in all cases with only one exception —factors related to risk subgoal for unit rate contract (which is in consensus at a 90% confidence level). Although the sample size is not very large, the accumulated experience of the respondents averaged over 15 years in construction bidding and project management. Furthermore, considering the consensus of the importance ranking of the factors obtained, the results of the survey should be reasonably reflective of the consensus of the construction industry.

TABLE 2. $X^2_{(\text{calc})}$ Values for Each Bidding Parameter under Different Types of Contracts

Type of contract (1)	Bid Reasoning Goal: Competition (DOF = 13) (2)	Risk (DOF = 15) (3)	Need for work (DOF = 7) (4)	Company's position in bidding (DOF = 9) (5)
Unit price contract	28.98	20.93	40.76	66.53
Lump sum contract	44.86	29.47	40.76	76.16
Design/build contract	45.15	39.55	40.76	80.62
$X_{0.05}$	22.36	25.00	14.07	16.92

Note: DOF means degree of freedom. DOF = $s - 1$ (s is the total number of factors); $X^2_{0.05}$ is the one-tailed test at 95% confidence level for F.

Effect of Type of Contract

Fig. 6 shows the average global importance weights of the factors under different types of contracts for the respective subgoals. One evident trend is that the impact of the type of contract is more significant in the risk subgoal than the other two subgoals (need for work being independent of contract type). This is perceivable as risk exposure and its allocation are very different for each of these types of contracts.

For the subgoal competition, most of the factors except for a few are independent of the contract type. The most notable difference is in the factor of ''time allowed for bid preparation'' (No. 20) which shows that its significance is much more emphasized in design/build and lump sum contracts than in the unit rate contract. Due to the different scope of work, more time is needed in a design/build contract followed by a lump sum contract in order to prepare the bid comparing to unit rate contract. The lump sum contract covers cost estimation and quantity takeoff, whereas design/build contract involves not only these works but also design and construction planning. From the design/build contract to the lump sum contract to the unit rate contract, the scope of work is decreasing. This

J. Constr. Eng. Manage., 2000, 126(5): 349-357

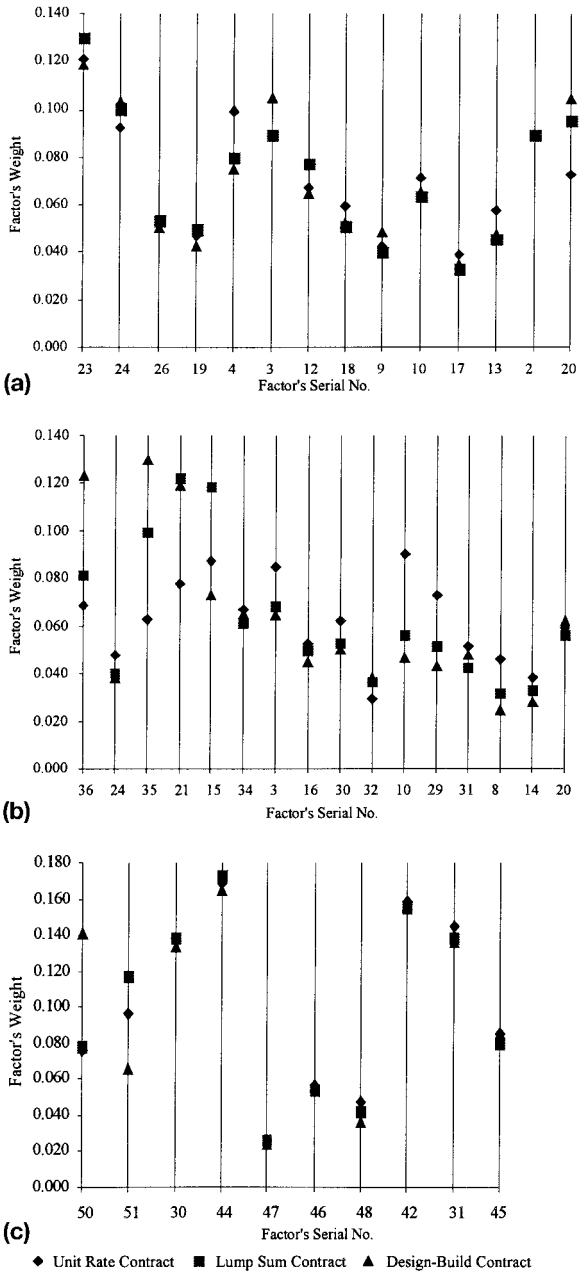

FIG. 6. Importance Weights for Individual Reasoning Subgoals under Different Contract Types: (a) Competition; (b) Risk; (c) Company's Position in Bidding

difference is reflected in the time required to prepare the bid packages. For all three contract types, ''availability of projects'' (No. 23) is ranked the most important factor, whereas ''required bond capacity'' is ranked the least important factor, although their weights differ.

For subgoal risk ''competence of estimators'' (No. 35) is the factor with the greatest spread in importance weights for the three contract types. This may be attributed to the difference in scope of work of the estimators and the risk exposure to estimating error. In lump sum contracts the estimators have to be accurate on the quantities and the prices unlike the unit rate contract. The competence of the estimators is more significant in the preparation of a design/build bid. The estimators must work closely with in-house architects and engineers to understand the project as well. A good estimate will require that the estimator, especially the chief estimator, has some knowledge of the methods and technology that will be applied in the project. The bid price varies largely with the competence and bias of the estimators. Another few factors with significant spreads are ''adequacy of resource market price information,'' ''completeness of drawing and specification,'' ''consultants' interpretation of specification,'' and ''project timescale and penalty for noncompletion'' (Nos. 36, 21, 15, and 10, respectively).

For subgoal company's position in bidding, the effect of contract type is relatively insignificant for all of the factors except for the factors ''company's ability in design involvement and innovation'' and ''company's ability in required construction technique'' (Nos. 50 and 51).

Key Determining Factors

The top-half factors with higher averaged importance weights are selected as key determining factors. On average, the weights carried by them make up about 61–73% of the total weights in each subgoal. These weights in each subgoal are renormalized so that the summation of them is equal to 1. The renormalized weights are shown in Table 3 for the respective subgoals. The classification is derived from the original grouping in Table 1.

As for the reasoning goal of competition, the contributions of factors pertaining to the nature of work amount to over 50% of total key weights in all three contract types. The factors related to social and economic conditions carry about 35% of total key weights, and among them, ''availability of projects'' has been regarded as the most important factors in all three contract types. ''Time allowed for bid preparation,'' which is one of bid requirements, contributes about another 11, 14, and 16% of the total key weights, respectively, in unit rate, lump sum, and design/build contract.

The key determining factors for risk assessment pertain to nature of work and the contractor's capabilities and workload. The factors related to the nature of work contribute 55% of total key weights in unit rate and lump sum contracts and 37% in the design/build contract. On the other hand, the contributions of firm-related factors are about 21, 24, and 36% of total key weights, respectively, in unit rate, lump sum, and design/build contracts. The contributions from classes of factors (nature of work and firm-related) form between 70 and 80% of the total key weights for all contract types.

With respect to the subgoal need for work, ''need for continuity in employment of key personnel and workforce'' and ''current workload of projects'' were cited as the two top key determining factors. The two most important key determining factors for a company's leverage in competition are ''financial ability'' and ''relationship with owner,'' accounting for about 45% of the total key weights regardless of contract type.

CONCLUSIONS

The current study is oriented by a bid reasoning model that goes deeper into the heart of the bid decision. In this way, the significance of the factors with respect to each reasoning subgoal of the bid decision can be ascertained. These reasoning subgoals include competition, risk, need for work, and company's position in bidding. The AHP method has been adopted to identify the key determining factors for the bid decision. The hierarchical structure of the approach allows the participants to focus on each criterion one at a time. The respondents participating in the study weighted the importance of all factors considered in the study by comparing their importance in pairs. Despite some spreads in opinions that are linked to their organizational philosophy or background, the respondents exhibit a reasonable level of consensus in the ranking of these factors.

The effect of the type of contract has been addressed. The impact of contract type is the most significant in risk assessment. The risk exposure and its allocation are very different

J. Constr. Eng. Manage., 2000, 126(5): 349-357

TABLE 3. Normalized Importance Weights for Factors Contributing to Subgoals

Reasoning goal (1)	Factors (2)	Weights: Unit rate contract (3)	Weights: Lump sum contract (4)	Weights: Design/build contract (5)	Classification (6)
Competition	Availability of other projects	0.190	0.196	0.179	Social and economic condition
	Availability of qualified staffs	0.146	0.151	0.156	Social and economic condition
	Cash flow requirement	0.156	0.121	0.114	Nature of work
	Degree of technological difficulty	0.140	0.135	0.159	Nature of work
	Identity of owner/consultant	—	0.117	—	Nature of work
	Project timescale and penalty for noncompletion	0.113	—	0.100	Nature of work
	Size of project	0.141	0.135	0.136	Nature of work
	Time allowed for bid preparation	0.114	0.144	0.158	Bid requirement
Risk	Adequacy of resource market price information	0.113	0.123	0.180	Social and economic condition
	Competence of estimators	0.103	0.150	0.189	Firm related factor
	Completeness of drawing and specification	0.127	0.184	0.173	Nature of work
	Consultants' interpretation of the specification	0.143	0.179	0.106	Nature of work
	Current workload in bid preparation	0.109	0.092	0.095	Firm related factor
	Degree of technological difficulty	0.139	0.103	0.094	Nature of work
	Expertise in management and coordination	—	—	0.073	Firm related factor
	Project timescale and penalty for noncompletion	0.148	0.085	—	Nature of work
	Resource price fluctuation	0.119	—	—	Social and economic condition
	Time allowed for bid preparation	—	0.085	0.090	Bid requirement
Need for work	Current workload of projects	0.255	0.255	0.255	Firm related factor
	Need for continuity in employment of key personnel and workforce	0.306	0.306	0.306	Firm related factor
	Relationship with owner	0.249	0.249	0.249	Firm related factor
	Required rate of return in investment	0.190	0.190	0.190	Firm related factor
Company's position in bidding	Company's ability in design involvement and execution	—	—	0.192	Firm related factor
	Company's ability in required construction technique	0.137	0.162	—	Firm related factor
	Expertise in management and coordination	0.196	0.192	0.183	Firm related factor
	Financial ability	0.239	0.240	0.226	Firm related factor
	Relationship with owner	0.224	0.214	0.212	Firm related factor
	Similar experience	0.205	0.192	0.187	Firm related factor

for each of these contract types. On the other hand, the effect of contract type on company's position in bidding is relatively insignificant.

This study does not only identify the key determining factors, but also the corresponding sets of importance weights. Together they could serve as the knowledge domain of an intelligent decision support system with the current proposed model as the framework for reasoning the bid decision.

APPENDIX. REFERENCES

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