CONTRACTOR SELECTION FOR DESIGN/BUILD PROJECTS

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ABSTRACT: As traditional construction procurement approaches are found to be inadequate in meeting the demands and challenges of recent times, alternative procurement routes such as through management contracting or build-operate-transfer are increasingly being adopted. Although design/build is one of the more popular alternative procurement methods that also has a long history, it does not appear to have well-established contractor selection procedures. This paper focuses on developing a model for contractor prequalification and bid evaluation in design/build projects. For this purpose, it presents a comparative overview of some international practices in the design/build contractor selection process. The overall objective is to identify the core aspects of selecting a suitable bidder in order to achieve the best ''value for money.'' The strengths and weaknesses of current practices of contractor selection are highlighted while identifying some of the best practices followed in design/build projects by various clients.

BACKGROUND

Contracts are fundamental to any project, and selection of the main construction contractor is a critical and vital task. The success level of any construction project may be argued to depend largely on the basic philosophy of ''the right person for the right job.'' The significant role played by contractors thus underscores the criticality of identifying the ''best person'' for the construction contract. Several researchers [such as Russell and Skibniewski (1988); Jaselskis and Russell (1992); Russell et al. (1992); Holt et al. (1994, 1996); Crowley and Hancher (1995); Russell (1996); Kumaraswamy (1996); Hatush and Skitmore (1997a,b), and Alsugair (1999)] have identified commonly used criteria for prequalification and bid evaluation and have proposed improved methodologies for contractor selection.

A great deal of research and a considerable number of applications have thus emerged in the realm of general contractor prequalification and selection. In addition, various researchers and organizations such as the Design-Build Institute of America (DBIA) have undertaken studies on many aspects of design/build practice (DBIA 1999). However, only a very few studies have focused on the contractor selection aspects of the increasingly popular design/build procurement route. Under the design/build procurement system, the client contracts directly with a single entity (i.e., the design/build contractor who normally has complete responsibility for developing a design that meets the client's expectations and for constructing that design). The increased responsibilities of the contractor and the reduced ''checks and balances'' (in this system) thus suggest that even greater care is needed in the task of identifying the ''right'' bidder for undertaking a design/build contract.

SCOPE OF RESEARCH STUDY

The main initial thrust of the research was to study the current practices of contractor selection for design/build projects in Hong Kong, to compare them with some international practices, and to identify their strengths and weaknesses. Furthermore, the study aimed at identifying common selection criteria when choosing design/build contractors and indicators that would assist in evaluating the chosen criteria. The overall exercise aims at developing and proposing a structured methodology for contractor selection for design/build projects and also envisages a subsequent study of the possibilities of developing an ''intelligent decision support system'' for that application.

This research exercise was launched with a ''knowledge mining'' phase, which included collecting existing documented and experience-based knowledge from the literature and interviewing and surveying experts. The experts were contacted for detailed information, either using direct telephone interviews and postal correspondence, or e-mail and other Internet-based communications, which greatly enhanced the power and speed of the knowledge acquisition. Knowledge was initially elicited in relation to general contractor prequalification and bid evaluation procedures used by public clients in Hong Kong, the United States, Australia, Singapore, and Sri Lanka. This was followed by a focus on design/build contractor selection procedures used by public clients in the United States, Hong Kong, and Canada. One hundred ninety-six experts/experienced practitioners were contacted, following which 110 were interviewed or corresponded with (of whom 24 are Hong Kong–based). Thirty construction contractor prequalification procedures and eight design/build contractor selection procedures were studied. Also, an Internet-based questionnaire survey to identify the universal criteria for prequalification and bid evaluation was launched. The URL address for the survey is ⟨http://hello.to/design-build⟩.

DESIGN/BUILD AS PROJECT DELIVERY SYSTEM

In the traditional construction procurement process, the client hires a consultancy team made up of experts, such as architects, designers, project managers, quantity surveyors/cost engineers, and supervisory personnel, while contracting the construction to the selected contractor. The present day multiple needs and complexities of the construction industry often make the use of such a traditional procurement system somewhat inefficient in terms of cost and time. Furthermore, the adversarial roles often assumed by the various parties in a traditional system may discourage teamwork while leading to avoidable disputes. In such situations, the design/build route offers an alternative with its many evident advantages such as single-point responsibility, fast-track project delivery, enhanced financial certainty, improved buildability, reduced disputes, and increased productivity.

The design/build concept has deep historical roots. In ancient times the ''master builder'' had full responsibility for all phases of a project, including engineering, aesthetic design, plan preparation, drafting, and construction, for example in the construction of ancient pyramids, churches, or temples. But the design/build approach in the present day context would involve a multidisciplinary team, rather than an omniscient and omnipresent master builder. Design/build now implies a proj-

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TABLE 1. Benefits and Concerns in Using Design/Build

Client (1)	Architect/engineer (2)	Contractor (3)	Designer (4)
(a) Benefits			
Fosters innovative solutions Reduces total project delivery time Lowers number of formal change orders Lowers total project costs	Single source of responsibility Offers clarity of liability Lowers number of formal change orders Reduces response time to change requests	Rewards innovation Increases designer/contract or interaction Lowers project risk Increases project control Improves business performance	More control over in-place project quality Improves designer business performance Reduces claims Improves interdisciplinary design decisions Rewards innovation
(b) Concerns			
Loss of independent professional consultant Lack of flexibility to respond to changing client needs Issues of durability, flexibility of systems, future expansion, etc. Substituted materials Inspection services	Limitation of design/build as a project delivery method Need for determination of project requirements Reluctance, resistance, initial early difficulty in joining a (joint venture) construction team Impact of changes Liability	Inability to shift responsibility for errors and omissions Increased obligation to owner Complexity of design/build may make organizing and assigning roles within design/build entity difficult Extended warranties Costly bid preparations that involve several alternatives that may not mature into contract	Responding to design/build request for proposals is costly Perceived difficulty in obtaining design liability insurance and/or performance and payment bonds Diminution of design issues in project delivery

ect delivery system whereby both the design and the implementation of that design are performed by the same entity. This single entity, the ''design/build contractor,'' agrees to deliver the design and to construct the project, either directly, using his own resources, or with subcontractors and consultants.

SUITABILITY OF DESIGN/BUILD AS PREFERRED PROCUREMENT ROUTE IN CERTAIN SITUATIONS

Various researchers have studied ways of improving the selection of a suitable procurement route for specific conditions and the consequent impacts on the outcomes. Skitmore and Marsden (1988) suggested a model to aid in the selection of the most appropriate procurement arrangements for a building project. Chan (1995) reported a research study carried out in Australia on procurement route selection and proposed the development of an expert system for providing advice during the choice of procurement paths. Kumaraswamy and Dissanayaka (1998) listed 38 potential criteria/priorities against which a construction client may target and measure project performance. From those, Kumaraswamy et al. (1999) selected 11 performance criteria (e.g., lower capital costs, lower life-cycle costs, cost certainty, shorter construction duration, and dispute minimization). These criteria would be considered more critically when comparing the effects of different procurement systems. This was intended to lead to more rationalized choices of performance-oriented procurement systems. The success criteria for design/build and the increased use of this procurement route are discussed in Songer et al. (1996). Furthermore, Songer and Molenaar (1997) and Molenaar and Songer (1998) mentioned various project characteristics for successfully using design/build in the public sector.

In the specific domain of design/build contracting, an Internet-based predictive and advisory system, Design-Build Selector (DBS) has been developed by the Georgia Institute of Technology, Atlanta, and the University of Colorado, Boulder, Colo., with data from over 100 completed public-sector design/build projects. The DBS is a tool intended to aid public-sector owners in choosing projects that are appropriate for design/build contracting. The DBS will produce an overall rating for the appropriateness of projects for design/build. The Internet URL address for accessing DBS is ⟨http://www.colorado.edu/engineering/civil/design-build/dbs⟩. The DBIA, with a stated goal of becoming one of the global centers of expertise on design/build practice, conducts studies, organizes seminars and training programs, and publishes study materials to create and disseminate educational information and to furnish advice and support to facility owners and design/build users. The Internet URL address for accessing DBIA is ⟨http://www.dbia.org⟩. In another approach, the benefits and concerns of using design/build as a procurement option—from the perspective of clients, contractors, designers, architects, and engineers, as discussed in Public Works and General Services, Canada (PWGSC) (1998a,b)—have been consolidated and are compared in Table 1.

GENERAL PRACTICES IN CONTRACTOR SELECTION FOR DESIGN/BUILD PROJECTS

As in most traditional procurement systems, contractor selection for design/build projects also follows prequalification, short-listing, and bid evaluation procedures. But, as it is more complex and critical to select the most appropriate ''proposer'' (who also may be commonly known as the bidder) to cater to the extra risks involved in design/build, the core requirements of contractor selection have to be rigorously revisited and fresh approaches have to be formulated. Normally, public clients are constrained to select the lowest bidder for contracting, except in exceptional cases. This approach may be valid in simple and straightforward situations, where a clear idea of costs and conditions have been established due to the repetitive nature of works and similarity in working environments. However, it may be invalid in most situations, because the award of a contract to a bidder based on lowest price alone may result in a ''false economy.''

The ''best value'' procurement is one that is structured to consider price and other relevant factors in making the bid selection to provide the greatest ''value for money'' to the client. The best methods are the ones that allow the entire team to be selected based upon capabilities, experience, and qualifications, not merely on low price. Determining the successful bidder for a contract requires a detailed assessment of available information. PWGSC practices a single-stage contractor selection process for simple design/build projects. The single-stage evaluation process, which is primarily a low bid selection, is recommended for projects where requirements can easily be defined. This single-stage evaluation procedure involves short listing of ''eligible'' bidders based on evaluation of the proposals against the following principal criteria: (1) Understanding of the project, weight factor = 20±; (2) design and construction approach, weight factor = 20±; (3) delivery of

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the work, weight factor = 10±; (4) management of the services, weight factor = 10±; (5) qualifications and experience of the design/build teams (consultants/designers and constructor/builder), weight factor = 20±; and (6) costs of the project, weight factor = 50±.

The weight factors shown for each criterion in the above are merely examples. The weights assigned to each criterion are chosen to reflect its importance relative to a specific project need and therefore vary significantly from project to project. The information relating to criteria 1–5 and costs of the projects are to be submitted in separate envelopes. The cost envelopes will be opened only after completion of evaluation of criteria 1–5, and the cost envelopes of those bidders who do not score a predetermined total for items 1–5 will not be opened (PWGSC 1998b).

But, in general, a two-stage selection process that includes both a prequalification/short-listing stage, as well as a bid-evaluation stage, is recommended for projects that are highly complex in nature or those subject to other demanding circumstances. Molenaar et al. (1999) discussed the advantages and disadvantages of single-stage, two-stage, and qualifications-based contractor selection approaches. Also, it was mentioned that the two-phase design/build method outlined in the 1996 Federal Acquisition Reform Act delivers the best overall budget and schedule performance. The following section of this paper describes a two-stage contractor selection process for design/build projects, highlighting some general aspects of prequalification and bid evaluation.

Prequalification

Prequalification for design/build projects is normally project specific, and the focus is to identify competent contractors who are interested in submitting bids. The prequalification exercise is to evaluate the capabilities of tenderers in terms of criteria such as financial capabilities, management capabilities, track record, equipment resources, and human resources. Potter and Sanvido (1994) introduced a structured design/build prequalification system. Potter and Sanvido (1995) discussed various aspects of implementing the design/build prequalification system.

As the efforts and costs involved in bid preparation and bid evaluation are enormous, the number of prequalified, short-listed bidders for design/build projects is limited and the preferred range is between 3 and 5. Unlike normal projects, the number of prospective bidders is quite limited; hence, a comprehensive and detailed analysis of contractor information is essential for prequalification and short listing to avoid any subsequent contractor failures and other risks. Some clients, such as PWGSC, the Utah Department of Transportation (UDOT), Salt Lake City, Utah, and the Florida Department of Transportation (FDOT), Tallahassee, Fla., encourage quality and innovations in bid submissions by sharing bid preparation expenses between the client and bidders (FDOT 1996, UDOT 1997). In addition, some clients may, at times, complete a significant portion of a design before letting the work for design/build contracting, for various reasons (for example, to save duplicated efforts by different bidders in pursuit of the same contract).

Bid Evaluation

In the case of simple projects, evaluation based on price alone is recommended. For example, FDOT uses a low bid approach of bid evaluation, called low bid design/build, which means the contract award is based on the lowest responsive bid (FDOT 1996). The low bid approach is used on projects where the scope is very tight, clearly defined, and innovations or alternatives are not being sought. The FDOT developed a procedure to include, optionally, a bid adjustment for the value of time. This value-of-time factor (VTF) adjustment is based on the proposed number of days to complete the project multiplied by a value per day established by FDOT. Palaneeswaran et al. (1999) discussed the VTF adjustments in some design/build contractor selection practices.

Normally, prequalified and short-listed bidders are asked to submit two separate proposals, namely, a technical proposal and a price proposal, which are then evaluated separately. Members of the designated technical evaluation team evaluate the technical proposals on the basis of approved evaluation criteria. Normally, there may be certain elements unique to a particular proposal—elements of higher quality or better solutions. Although those quality elements should not elicit correspondingly high quality expectations in other bids as well, the technical evaluation team members may be influenced by those attractive elements in their evaluation of other proposals, instead of being guided by the client's original requirements alone. The UDOT describes this tendency as ''technical leveling'' (i.e., taking a quality element from one proposal and attempting to raise the level of the other proposals to that new, higher level) (UDOT 1997). It is suggested that, as far as the bids meeting the minimum requirements of the request for proposals for a particular evaluation element, the evaluators should not subsequently propose a better solution and technical leveling should be avoided.

Similarly, the financial evaluation team evaluates the price proposals and allocates scores for the price bids. The technical and price proposal scores are combined on the basis of approved proportions or by using an approved contractor selection formula to decide on the best bid considering the best value for money. Such formulas or equations to combine the technical and price proposals are formulated based on the experience of the client or client advisory teams and after ob-

TABLE 2. Formulas/Equations for Combining Technical and Price Proposal Scores—as Derived and Developed from Some Existing Approaches

Formula/equation (1)	Clients (2)	Remarks (3)
$S = (1/100)(pT_s + (100 - p)P_s)$, where S = combined score, T_s = technical score, P_s = price score, and p = percentage weighting for technical score	Clients such as Works Bureau, Hong Kong	Award based on highest combined score S. The percentage p normally varies from 20–50%
$S = (1/100)(p_1Q_s + pT_s + (100 - p - p_1)P_s)$, for example, $S = 0.3(Q_s + T_s) + 0.4P_s$, in which S = combined score, T_s = technical score, P_s = price score, Q_s = PS, p = percentage weighting for technical score, and p_1 = percentage weighting for PS	Clients such as Division of Design and Construction, Mo.	Award based on highest combined score S.
$S_{ad} = P/T_s$, where S_{ad} = adjusted score, T_s = technical score, and P = bid amount	Clients such as FDOT and PWGSC in their ASDB projects	Award based on lowest S_{ad}
$S_{at} = P_t/T_s$, in which $P_t = (V_t + P)$, where S_{at} = adjusted score with time value, T_s = technical score, P_t = time-adjusted price, P = bid amount, and V_t = time value per day	Clients such as FDOT and PWGSC in their ASDB projects where VTF is considered	Award based on lowest S_{at}, value of time V_t is determined by procuring department

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taining approval from relevant apex bodies (such as the Central Tender Board in Hong Kong). For example, FDOT uses a similar approach, termed adjusted score design/build (ASDB), for selecting a "successful" bidder (FDOT 1996). The ASDB approach means the contract award is based on the lowest adjusted score, which is determined by dividing the price proposal by the technical proposal score.

Table 2 shows some examples of formulas/equations that were developed to summarize different approaches to combining technical and price proposal scores, as presently followed by various clients. These formulas/equations were formulated to express the described approaches in a concise and comparable format. As discussed by Molenaar et al. (1999), the scoring systems differ from client to client. Standardizing formalized and repeatable methods thus may reduce costs (that would otherwise be incurred in formulating fresh procedures). Furthermore, it may be argued that preset formulas and equations to combine the technical proposals and price proposals could restrict flexibility and do not allow for reasoned analysis or determination. In the I-15 corridor reconstruction project, UDOT did not use a formula or equation to combine the technical and price proposals (UDOT 1997). This allowed maximum flexibility to analyze, justify, and determine the proposal that was most advantageous to the state.

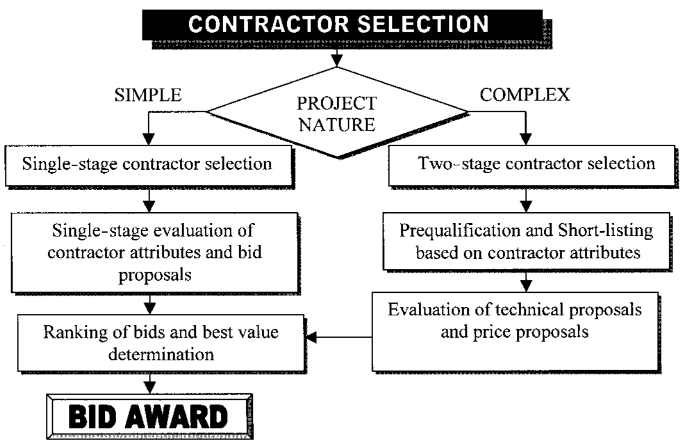

FIG. 1. Proposed Contractor Selection Model

Best Value Determination

The changing paradigm of contractor selection questions the wisdom of considering the lowest price alone and substitutes fresh procurement approaches incorporating "value for money." To achieve the best value for money, the tender evaluation should consider not only price competitiveness, but also compliance with users' requirements, reliability of performance, qualitative superiority, and whole-life costs. Corcoran and McLean (1998) conducted a study to determine the meaning of the procurement principle "value for money" for public-sector decision makers. They described "value for money" as the principle concerned with balancing conflicting elements (product with cost and, in some instances, risk) for the purpose of obtaining the "best deal" for the procuring department. To achieve "best value," both qualitative and quantitative analysis of bid proposals have to be performed. Quantitative approaches may range from discounted cash flow/net present value analysis and life-cycle cost analysis, for example, to value engineering proposals. Qualitative approaches are mostly governed by client requirements of time, cost, and quality, with various client preferred combinations such as the relative importance of "cost versus time" and "time versus quality." The clients may consider questions such as How much more should be paid to achieve benefits from added value/best value? and Does the added value justify the additional price?

Generally, public clients tend to avoid negotiations because (1) it appears to contravene the philosophy of open competition in tendering; (2) it is very difficult to maintain confidentiality during negotiations; and (3) they are answerable to the public and other governing bodies in justifying the tactics finally used. However, some clients use innovative approaches to overcome such constraints and obtain the best value for money when choosing the best offer. For example, a best and final offer (BAFO) approach was used in the I-15 corridor reconstruction project by UDOT (UDOT 1997).

PROPOSED MODEL OF CONTRACTOR SELECTION FOR DESIGN/BUILD PROJECTS

This section describes a new model recommended for selecting the "best" design/build bidder. The model has been

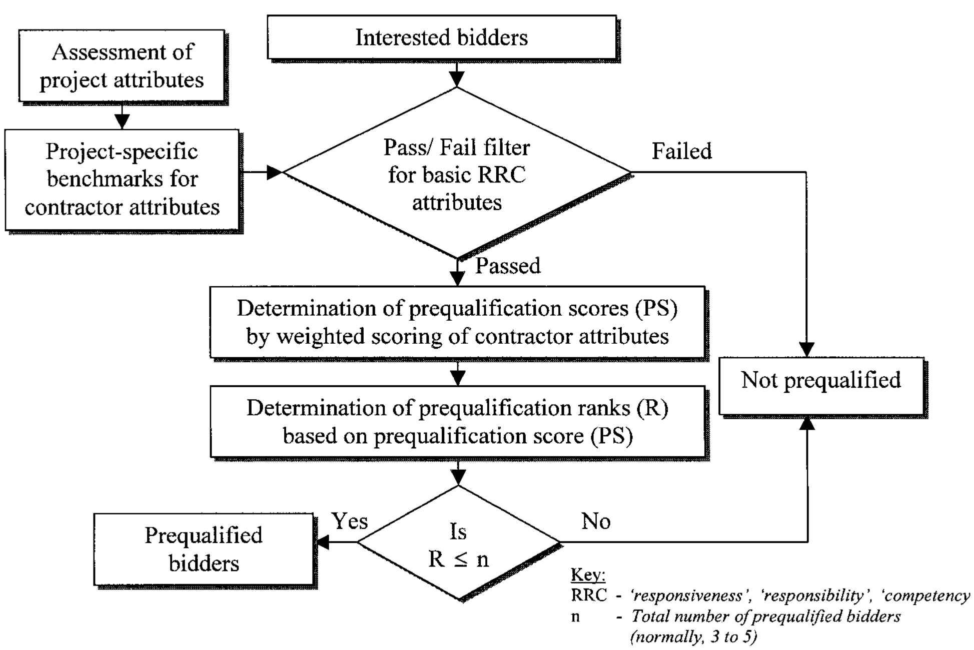

FIG. 2. Model for Two-Stage Prequalification and Short Listing of Bidders

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developed on the basis of the ongoing research project in Hong Kong that was mentioned earlier. This research initially examined general contractor selection practices of various public clients in different countries and later focused specifically on the issues of contractor selection for design/build projects. In the proposed model, design/build projects will first be broadly categorized into either ''simple'' or ''complex'' projects, based on the assessment of project attributes as illustrated in Appendix I. Depending on this classification of the project (i.e., whether simple or complex) either a single-stage or two-stage contractor selection procedure can be selected, as illustrated in Fig. 1. For simple projects the single-stage selection process is proposed. In cases of projects of complex nature, the proposed contractor selection procedure is in two distinct phases, namely, prequalification/short listing and bid evaluation. Fig. 2 shows the proposed flow chart of a two-stage selection model for prequalification and short listing of design/build bidders for further bid evaluation.

The model envisages that interested bidders would be required to submit detailed information regarding their financial, technical, organizational, managerial, and other capabilities. Project-specific basic benchmarks for contractor attributes are determined on the basis of an assessment of relevant project attributes. Initially, all the submissions are checked for attributes, which together are known as RRC attributes: responsiveness (promptness, realism, and completeness), responsibility (such as conformance with rules, legal and other regulations, quality certifications, insurance, health and safety, and environmental requirements), and competency (such as resources, experience, management, and organization). This pass/fail filter stage checks for compliance with the established basic benchmark requirements (for RRC attributes) and removes those who do not meet the mandatory requirements. Next, steps are taken, using the formulas developed and described in Appendix II, to determine the prequalification score (PS) for all the ''passed'' contractors. The contractors are next

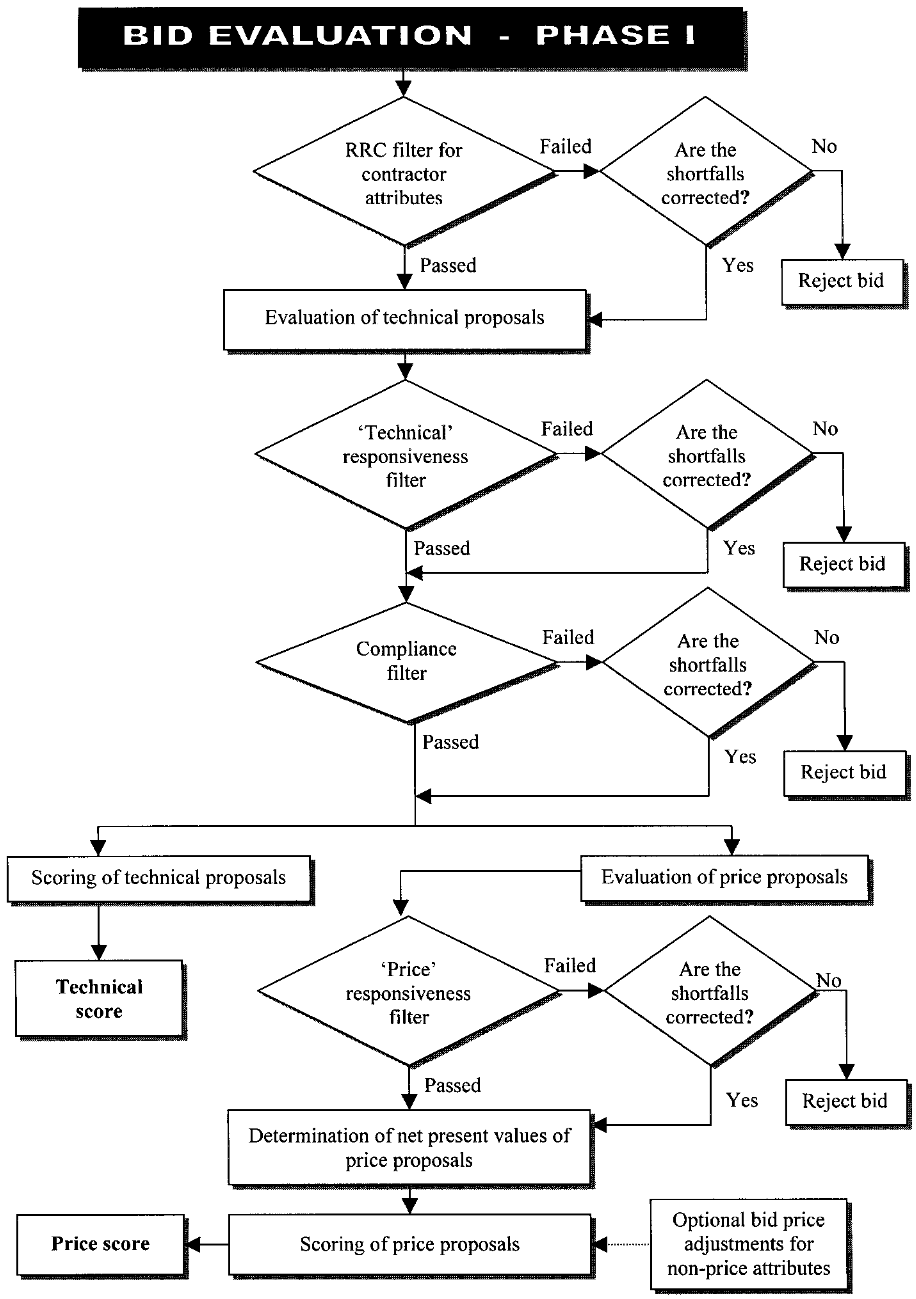

FIG. 3. Design/Build Bid Evaluation—Phase I

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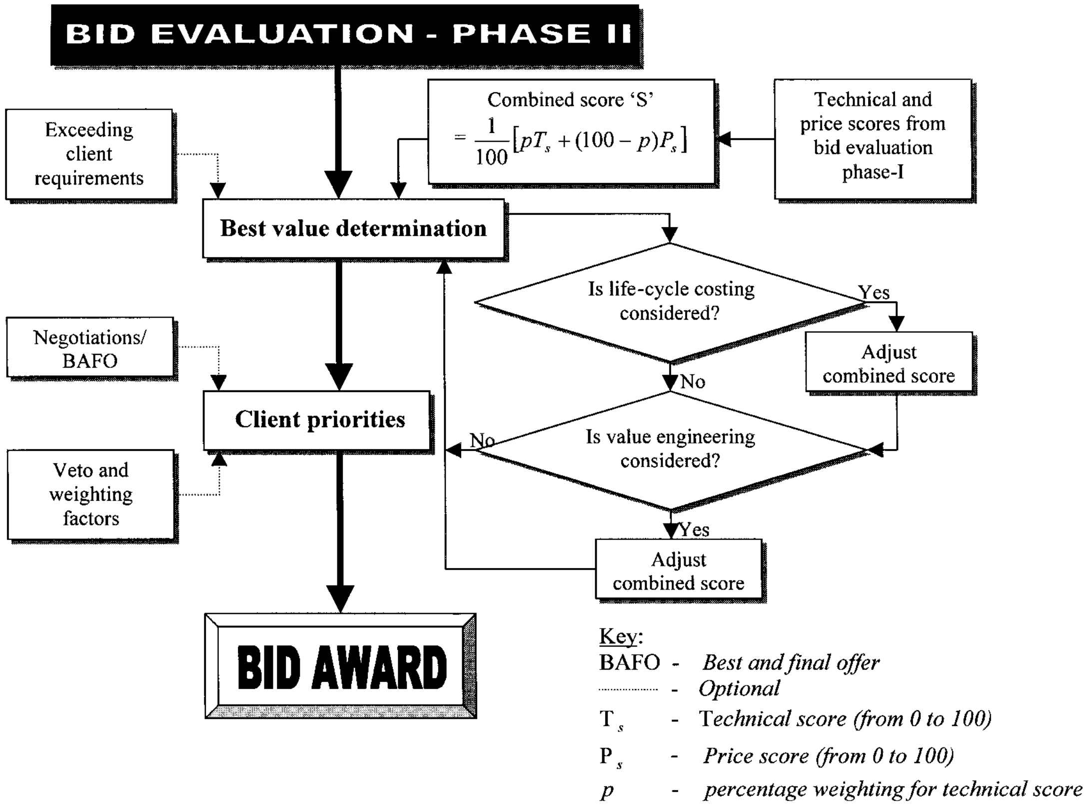

FIG. 4. Design/Build Bid Evaluation—Phase II

ranked on the basis of their PS. Top-ranked bidders (preferably, about three to five in number) are then short listed for bid submission.

The essential components of design/build bids are the technical proposal and the price proposal. For very simple projects where requirements are straightforward and can be easily defined, bid evaluation based on price alone is possible. However, because the design/build approach is mostly adopted in complex situations, a more detailed evaluation methodology is usually needed. Some clients also may prefer to adjust bids for nonprice attributes such as time, to obtain best value for money.

Furthermore, negotiations for both price and nonprice attributes are practiced by some clients before awarding the contract. As there are many practical difficulties and ethical considerations in negotiation, alternative approaches such as BAFO is practiced to obtain value for money. Last, there may be some overriding client preferences such as political and economic factors that may have a significant impact on the ultimate decisions. Such overriding considerations may lead to discarding or discounting of otherwise attractive bids. Although clients usually reserve their rights to make (and do not need to justify) their own decisions on the awards, the procurements covered under the World Trade Organization General Procurement Agreement should usually be guided by generic procurement principles such as ''open and fair competition,'' ''transparency,'' value for money, and ''public accountability.''

The proposed structured bid evaluation process consists of two phases, as illustrated in Figs. 3 and 4. In the first phase, contractor attributes are initially checked in the RRC filter (for rechecking contractor attributes against requirements) and any shortfalls in the requirements require rectification by the bidder/proposer. The evaluation of technical proposals is next carried out in three stages, through the responsiveness filter, compliance filter, and scoring to determine the technical scores for bids. The responsiveness filter checks for promptness, realism, and completeness. The compliance filter makes pass/fail binary checks for (1) client requirements; (2) absence of qualifications/conditions; (3) legal requirements; (4) design codes/standards; (5) environmental concerns; (6) safety and occupational health requirements; and (7) other regulations/requirements. Like technical proposals, price proposals also are checked for responsiveness, after which the net present values of price proposals are calculated. Some clients also may prefer to adjust bids for nonprice attributes such as time to obtain best value for money. Such adjustments are made before scoring the price proposals.

The second phase of bid evaluation consists of best value determination and consideration of client priorities. As discussed previously, private clients usually enjoy more freedom at this stage, whereas public clients are constrained to a greater extent in decision making. Useful assessment tools such as life-cycle costing and value engineering are considered in the best value determination, along with technical and price score inputs from the first phase. In addition, any aspects of bid proposals that exceed basic client requirements should be analyzed using the above tools in conjunction with questions such as Is it useful to exceed the basic client requirement?, Is it necessary?, Does the added value justify the additional price?, Are there any alternatives?, Which is the best alternative?, and What is the cost of the best alternative? At the end, client priorities such as (1) veto and weighting factors (i.e., rejections or allowances to be made for overriding considerations such as trade sanctions, as discussed earlier); and (2) negotiations/BAFO can be considered (as deemed necessary) before award. The BAFO (if considered) approach may be similar to the practice in the I-15 reconstruction project by UDOT (1997).

CONCLUSIONS

Design/build procurement provides opportunities for innovation and excellence while also rewarding both clients and

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contractors who choose that route. The team approach also helps to defuse the historically adversarially ''charged'' construction environment. The aim should be to optimize the project design, schedule, and quality while fostering pleasant and therefore constructive working relationships among client and contractor teams. Such a harmonious and rewarding environment can be targeted by the correct selection of a contractor.

The correct choice of a contractor using more than just a low bid criterion should thus contribute significantly to the overall success of the design/build project, ideally resulting in a ''win-win'' environment for both the client and the design/build team. The low bid approach is usually suitable and thus suggested (to be considered in the first instance) for simple projects in general. Selection on lowest bid price alone in projects other than simple ones may well lead to greater costs in the long term. Furthermore, this approach may lead to overlooking any opportunities of having added benefits and better value for money. In summary, it would be fair to conclude that traditional approaches to contractor selection do not usually directly meet the challenges or needs of design/build projects. The ongoing research study has revealed some of the best practices in this area and facilitated the formulation of a basic contractor selection model that also highlights the usefulness of a structured approach to design/build contractor selection.

Samples of current practices as described in this paper also reconfirmed the usefulness of design/build as a project delivery system and indicated some innovative contractor selection practices. The proposed model will provide an even more structured approach and assist in formulating guidelines for clients in contractor selection for design/build projects. This model may form a basis for repeatable (more consistent and reusable) contractor selection systems. Added benefits include optimized costs (for both clients and contractors) and fewer chances of bids being challenged by unsuccessful bidders. Furthermore, this basic model is expected to form the basis for developing an envisaged knowledge-based decision support system for design/build contractor selection—to be developed in the next phase of this research and to be linked to the proposed knowledge-based client advisory system for optimizing procurement routes in different scenarios (Kumaraswamy et al. 1999).

APPENDIX I. PROPOSED PROJECT CATEGORIZATION MODEL

This model has been developed to categorize design/build projects into either simple or complex projects. This classification is based on an assessment of project attributes. A sample list of project attributes that can be considered for classification purposes are (1) design/build contractor's time management requirements; (2) client's time management requirements; (3) significance and number of milestones; (4) project size; (5) project scope; (6) estimated project cost; (7) cost control/demands/constraints; (8) design aspects (e.g., innovations); (9) construction aspects (e.g., new technologies); (10) site specific constraints; (11) quality aspects; and (12) considerations of exceeding client's expectations (such as early completion). The model envisages that the following steps should be taken in classifying any project into simple or complex:

1. For the project considered, all the project attributes have to be assessed on a scale of 1–4 for determining individual scores S_a for every attribute.
2. Next, the total score T_a of project attribute scores has to be calculated, i.e., $T_a = \sum_{a=1}^{t} S_a$, where T_a = sum of project attribute scores, and t = total number of project attributes considered.
3. Then, the aggregated average score C_s has to be calculated using the formula $C_s = (T_a/t)$.
4. The projects can be classified using the rule if $C_s > C_l$ then P_i = complex, otherwise P_i = simple, where C_l = limiting value for project categorization, and P_i = project categorization index.

The default value considered for C_l is equal to 2, and it can be changed according to the client's requirements. A sample breakdown of scoring guidelines for some of the project attributes are provided below:

1. For design/build contractor's time management requirements
   - Simple bar charts and network diagrams with manual control are sufficient—score 1.
   - Complex network diagrams using simple project management software are needed—score 2.
   - Detailed project planning for time and other resources using advanced project management software is needed—score 3.
   - Elaborate time management plan with advanced project management systems as well as project management expertise are needed—score 4.
2. For estimated project cost
   - Low—score 1
   - Medium—score 2
   - High—score 3
   - Very high—score 4
3. For cost control/constraints
   - Simple and clearly defined scope, no constraints—score 1
   - Somewhat complicated, but well-defined scope—score 2
   - Life-cycle costing is to be considered—score 3
   - Budget constraints and life-cycle costs are significant—score4
4. For project size
   - Small—score 1
   - Medium—score 2
   - Large—score 3
   - Mega—score 4
5. For design aspects
   - Design is very simple and not a major consideration—score 1.
   - Normal designs (which are tried elsewhere) are sufficient—score 2.
   - Somewhat complex designs are involved, with some possible innovations—score 3.
   - Designs could differ significantly, are complex, and necessitate innovative approaches—score 4.
6. For construction aspects
   - Construction is very simple and no complex processes are involved—score 1.
   - Normal construction techniques with proven technologies are sufficient—score 2.
   - Somewhat complex and innovative construction processes/technologies are involved—score 3.
   - Construction procedures could differ significantly, are complex, and necessitate innovative approaches/techniques—score 4.

APPENDIX II. PROPOSED SCORING SYSTEM FOR PREQUALIFICATION

The proposed scoring system for design/build contractor prequalification is summarized in this appendix. In the following example, the prequalification criteria are grouped under headings such as (1) finance; (2) human resources; (3) organization and management; (4) project-specific requirements; (5) past experience; (6) past performance; (7) technology; (8)

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quality system; (9) health and safety system; and (10) equipment. These criteria are in turn divided into subcriteria. For example, the finance criterion is divided into the following subcriteria: annual turnover, net tangible assets, liquidity, solvency, work-in-progress, magnitude of capital base, profitability, credit rating checks, trend analysis, and financing institutions' guarantees.

The model envisages that all relevant information provided by the interested bidders must be assessed against the corresponding (identified) prequalification subcriteria. According to the model, each subcriterion will be scored on a scale of 0–5. The following steps have to be followed to determine the PS:

1. The submissions of every interested bidder have to be checked against the preliminary pass/fail filter for RRC attributes.
2. The submissions of every passed bidder are then evaluated against each prequalification criterion and its subcriteria and the weighted prequalification criterion scores are determined using the following formula: prequalification criterion score $P_c = (1/5)(\sum_{s=1}^{m} W_s \times S_s)$. In this equation m = number of subcriteria for the prequalification criterion, W_s = weight of prequalification subcriterion, and S_s = score of prequalification subcriterion (on a scale of 0–5).
3. Then PS has to be determined for every bidder using the following formula: $\text{PS} = (1/100)(\sum_{c=1}^{n} W_c \times P_c)$. In this equation N = number of prequalification criteria, W_c = weight for the prequalification criterion, and P_c = prequalification criterion score.

An example calculation for determining the prequalification criterion score P_c is provided in Table 3. In this example, the prequalification criterion score for the equipment criterion = $(1/5) \times (385) = 77$. An example calculation of a combined PS has been given in Table 4. In this example, PS = $(1/100) \times (7934) = 79.34$.

TABLE 3. Example Calculations for Equipment Prequalification Criterion

Subcriteria (1)	Weight, W_s (2)	Score, S_s[a] (3)	Weighted score, $W_s \times S_s$ (4)
Ownership of equipment	20	4	80
Condition of equipment	25	3	75
Adequacy	30	5	150
Experience in operating	15	4	60
Operation and maintenance system	10	2	20

Note: $\Sigma W_s = 100$; $\Sigma W_s \times S_s = 385$.
[a]On a scale of 0–5.

TABLE 4. Example Calculations for PS

Prequalification criteria (1)	Weight, W_c (2)	Prequalification criterion score, P_c (3)	Weighted score, $W_c \times P_c$ (4)
Finance	18	82	1,476
Human resources	14	84	1,176
Organization and management	12	78	936
Project-specific requirements	10	74	740
Past experience	8	68	544
Past performance	8	88	704
Technology	8	80	640
Quality system	8	85	680
Health and safety	8	72	576
Equipment	6	77	462

Note: $\Sigma W_c = 100$; $\Sigma W_c \times P_c = 7{,}934$.

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APPENDIX III. REFERENCES

Alsugair, A. M. (1999). ''Framework for evaluating bids of construction contractors.'' *J. Mgmt. in Engrg.*, ASCE, 15(2), 72–78.

Chan, A. (1995). ''Towards an expert system on project procurement.'' *J. Constr. Procurement*, Glamourgan, U.K., 1(2), 111–123.

Corcoran, J., and McLean, F. (1998). ''The selection of management consultants—How are governments dealing with this difficult decision? An exploratory study.'' *Int. J. Public Sector Mgmt.*, Bradford, U.K., 11(1), 37–54.

Crowley, L. G., and Hancher, D. E. (1995). ''Evaluation of competitive bids.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 121(2), 238–245.

Design-Build Institute of America (DBIA). (1999). *Design-build manual of practice*, Washington, D.C.

Florida Department of Transportation (FDOT). (1996). *Design-build procurement and administration, Topic No. 625-020-010-a*, Tallahassee, Fla.

Hatush, Z., and Skitmore, M. (1997a). ''Assessment and evaluation of contractor data against client goals using PERT approach.'' *Constr. Mgmt. and Economics*, London, 15, 327–340.

Hatush, Z., and Skitmore, M. (1997b). ''Criteria for contractor selection.'' *Constr. Mgmt. and Economics*, London, 15(1), 19–38.

Holt, G. D., Olomolaiye, P. O., and Harris, F. C. (1994). ''Evaluating performance potential in the selection of construction contractors.'' *Engrg., Constr. and Arch. Mgmt.*, Oxford, U.K., 1(1), 29–50.

Holt, G. D., Olomolaiye, P. O., and Harris, F. C. (1996). ''Tendering procedures, contractual arrangements and Latham: The contractors' view.'' *Engrg., Constr. and Arch. Mgmt.*, Oxford, U.K., 3(1,2), 97–115.

Jaselskis, E. J., and Russell, J. S. (1992). ''Risk analysis approach to selection of contractor evaluation method.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 118(4), 814–821.

Kumaraswamy, M. M. (1996). ''Contractor evaluation and selection—A Hong Kong perspective.'' *Build. and Envir. J.*, Oxford, U.K., 31(3), 273–282.

Kumaraswamy, M. M., and Dissanayaka, S. M. (1998). ''Linking procurement systems to project priorities.'' *J. Build. Res. and Information*, London, 26(4), 223–238.

Kumaraswamy, M. M., Dissanayaka, S. M., and Palaneeswaran, E. (1999). ''Client satisfaction through improved procurement.'' *Build. Technol. and Mgmt. J.*, 25, Kuala Lumpur, Malaysia.

Molenaar, K. R., and Songer, A. D. (1998). ''Model for public sector design/build project selection.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 124(6), 467–479.

Molenaar, K. R., Songer, A. D., and Barash, M. (1999). ''Public-sector design/build evolution and performance.'' *J. Mgmt. in Engrg.*, ASCE, 15(2), 54–62.

Palaneeswaran, E., Kumaraswamy, M. M., and Tam, P. W. M. (1999). ''Comparing approaches to contractor selection for design and build projects.'' *Proc., Joint Triennial Symp. (CIB W55, W65 and W92) on Customer Satisfaction: A Focus for Research and Practice*, P. Bowen and R. Hindle, eds., Vol. 3, 936–945.

Potter, K., and Sanvido, V. (1994). ''Design/build prequalification system.'' *J. Mgmt. in Engrg.*, ASCE, 10(2), 48–56.

Potter, K., and Sanvido, V. (1995). ''Implementing a design/build prequalification system.'' *J. Mgmt. in Engrg.*, ASCE, 11(3), 30–34.

Public Works and General Services, Canada (PWGSC). (1998a). *Design-build general form of contract (prototype).*

Public Works and General Services, Canada (PWGSC). (1998b). *Design-build manual conception—Construction.*

Russell, J. S. (1996). *Constructor prequalification—Choosing the best contractor and avoiding constructor failure*, ASCE, New York.

J. Constr. Eng. Manage., 2000, 126(5): 331-339

Russell, J. S., Hancher, D. E., and Skibniewski, M. J. (1992). ‘‘Contractor prequalification data for construction owners.’’ *Constr. Mgmt. and Economics*, London, 10, 117–135.
Russell, J. S., and Skibniewski, M. J. (1988). ‘‘Decision criteria in contractor prequalification.’’ *J. Mgmt. in Engrg.*, ASCE, 4(2), 148–164.
Skitmore, R. M., and Marsden, D. E. (1988). ‘‘Which procurement system? Towards a universal procurement selection technique.’’ *Constr. Mgmt. and Economics*, London, 6, 71–89.
Songer, A. D., and Molenaar, K. R. (1997). ‘‘Project characteristics for successful public-sector design-build.’’ *J. Constr. Engrg. and Mgmt.*, ASCE, 123(1), 34–40.
Songer, A. D., Molenaar, K. R., and Robinson, G. D. (1996). ‘‘Selection factors and success criteria for design-build in the U.S. and U.K.’’ *J. Constr. Procurement*, Glamourgan, U.K., 2(2), 69–82.
Utah Department of Transportation (UDOT). (1997). ‘‘I-15 corridor reconstruction project.’’ *Design/Build Contracting Initial Rep. Spec. Experimental Proj.*, Salt Lake City, Utah.

APPENDIX IV. NOTATION

The following symbols are used in this paper:

a, c, s = positive integer indices;
C_l = limiting value for project categorization determined by client;
C_s = aggregated average score for project attributes;
m = number of subcriteria for cth prequalification criterion;
N = number of prequalification criteria;
n = maximum number of prequalified/short-listed bidders (preferably from 3 to 5);
P = bid amount;
P_c = PS for cth prequalification criterion;
P_i = project classification index;
P_s = price score;
P_t = time-adjusted price;
p = percentage weighting for technical score;
p_1 = percentage weighting for PS;
Q_s = PS;
R = prequalification rank of contractor;
S = combined score;
S_a = score for ath project assessment attribute (on scale of 1–4);
S_{ad} = adjusted score;
S_{at} = adjusted score with time value;
S_s = score for sth prequalification subcriterion (on scale of 0–5);
T_a = sum of project attribute scores;
T_s = technical score;
t = number of project assessment attributes considered;
V_t = time value per day;
W_c = weight for cth prequalification criterion; and
W_s = weight for sth prequalification subcriterion.

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