



IDENTIFICATION OF SELECTION CRITERIA FOR OPERATIONAL VARIATIONS OF THE DESIGN-BUILD SYSTEM: A DELPHI STUDY IN CHINA

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Abstract. The design-build (DB) system has been demonstrated as an effective delivery method and has gained popularity worldwide. However it is observed that a number of operational variations of DB system have emerged since the last decade to cater for different client's requirements. After the client decides to procure his project through the DB system, he still has to choose an appropriate configuration to deliver their projects optimally. However, there is little research on the selection of DB operational variations. One of the main reasons for this is the lack of evaluation criteria for determining the appropriateness of each operational variation. To obtain such criteria, a three-round Delphi survey has been conducted with 20 construction experts in the People's Republic of China (PRC). Seven top selection criteria were identified. These are: (1) availability of competent design-builders; (2) client's capabilities; (3) project complexity; (4) client's control of project; (5) early commencement & short duration; (6) reduced responsibility or involvement; and (7) clearly defined end user's requirements. These selection criteria were found to have a statistically significant agreement. These findings may furnish various stakeholders, DB clients in particular, with better insight to understand and compare the different operational variations of the DB system.

Keywords: design-build, operational variations, selection criteria, Delphi method, China.

1. Introduction

Design-build (DB) is a delivery method where one entity or consortium is contractually responsible for both design and construction (Songer, Molenaar 1997). It has been demonstrated to be an effective delivery method and gained its popularity worldwide in recent years (Konchar, Sanvido 1998; Haque *et al.* 2001; Hale *et al.* 2009; Park *et al.* 2009; Rosner *et al.* 2009). In order to meet different sets of construction circumstances, certain modifications to the basic design-build system have emerged (CIOB 1988). Within the overall concept of design-build, a number of operational variations of the DB system have been developed, including, for example, *develop-and-construction*, *bridging*, *novation DB*, *package deals*, *direct DB* and *turnkey* method (Janssens 1991; Akintoye 1994; Beard *et al.* 2001; Masterman 2002; Gransberg *et al.* 2006; Xia, Chan 2008).

The essential difference between the DB operational variations lies in the proportion of design work undertaken by DB clients (Janssens 1991; Beard *et al.* 2001; Gransberg *et al.* 2006). For instance, in the *develop-and-construction*, the client will engage a design consultant to complete a substantial part of design (more than 50% design) before engaging a design-builder. This may preclude innovation on the part of the design-builder, since

basic solutions and concepts have already been determined (The American Institute of Architects *et al.* 2003), however, it can give the client greater control of projects. In the *turnkey* method, by contrast, the client simply provides requirements for the final product, and then requires the contractor to complete the design and construction. In this contract arrangement, the client can leave most of the design responsibilities to the design-builder, but he may lose control of the project and does not obtain the project as required (Huse 2002). Every DB operational variation has its own strengths and weaknesses. When selecting DB operational variations, clients should, therefore, balance trade-offs and take multiple variables into consideration.

To an inexperienced client, selecting an appropriate operational variation is more difficult than other issues (Janssens 1991). This is because the client should neither provide too much design solution, as it may limit the design-builder's innovation to the design process; nor provide too little because it may impose unnecessary expenses to the potential design-builders and prevent the client from obtaining the satisfactory design solutions. A suitable DB operational variation may lie between these parameters, wherein the design work has been developed adequately for project tendering (Harris III, McCaffer 1995). In the construction field, although there has been a

large amount of research on design-build, few, if any, systematic studies focus on the selection process of DB operational variations. The current paper attempts to fill this research gap.

In the construction industry of the People's Republic of China (PRC), selecting an appropriate DB operational variation poses challenges to many clients. The DB market in the PRC is still immature, and most of clients and DB contractors remain unfamiliar with the delivery process of different DB operational variations (Cao, Yao 2009; Liu 2010; Meng 2010). It is believed that the selection of DB operational variations constitutes obstacles to the application of DB system in China (Xia, Chan 2008). The primary purpose of this paper attempts to identify the selection criteria for DB operational variations in the PRC. With the identified criteria, clients can evaluate the suitability of each DB variation accordingly. A selection model can be ultimately developed in the future based on the findings of the current study.

2. Literature review

When a client decides to deliver his project by DB method, an important step forward is to determine which operational variation of DB is the most appropriate for meeting his needs (Beard *et al.* 2001). Even though the client can leave most of responsibilities/tasks to a successful design-builder in a single DB contract, he should still prepare the DB enquiry and decide how much design work should undertake before engaging a design-builder (Janssens 1991).

A number of studies have been undertaken on the DB system (Molenaar, Songer 1998; Alhazmi, McCaffer 2000; Chan *et al.* 2000; Kumaraswamy, Dissanayaka 2001; Chang, Ive 2002; Luu *et al.* 2005; Migliaccio, Shrestha 2009; Asmar *et al.* 2010). However, there are limited studies focusing on the selection of DB operational variations. Janssens (1991) was one of the first researchers to look into this topic. He categorized the variables, which influence the choice of DB operational variations, into those relating to design, cost, time and other particular circumstances. The variation that suits all circumstantial variables will be selected as the most appropriate method for each proposed project. This method has its shortcoming because in real-life projects, it is rather unlikely that all the prescribed requirements can be met.

Beard *et al.* (2001) listed three basic operational variations of design-build (direct design-build, design criteria design-build, and preliminary design-build) and gave detailed explanations of how the choice of these variations may affect a client's project. They asserted that selection of suitable operational variations mainly depends on client's decisions on (1) whether to define his needs by resources within its organization or outside its organization and (2) when the needs or problem-to-be-solved are sufficient to hand over to a contracted entity. Although Beard *et al.* (2001) gave detailed introduction of each variation; no practical methods or tools were provided for the selection of different operational variations.

The U. S. Federal Highway Administration (2006) advocated that after choosing design-build contracting to deliver a particular project, contracting agencies must decide appropriate level of preliminary design to initiate the design-build contract. This decision is influenced by the nature and complexity of the project, the needs of prospective teams to understand the requirements of the clients, the potential risks of the proposed project, and the comfort level for design-builder to develop the scope of the project. Although the importance of selecting DB operational variations was emphasized, the Federal Highway Administration (2006) did not provide practical methods to determine the appropriate level of preliminary design in DB request for proposals.

In order to provide a clearer direction for the selection of DB operational variations, more research work is required. According to Luu *et al.* (2005), the selection process can be divided into two consecutive stages, namely, selection criteria formulation and procurement selection. The formulation of selection criteria is of great importance to the selection process because an appropriate procurement selection model depends largely on prudent identification of selection criteria to reflect clients' and project objectives (Masterman, Gameson 1994). In addition, considering the unique conditions of the PRC DB market, in which most of clients remain unfamiliar with the DB system, a set of selection criteria could provide clients with better insights to understand and compare different DB operational variations.

In order to facilitate the selection of DB operational variations in the PRC, a specific set of selection criteria is urgently required. This paper focuses on identifying the most important selection criteria for different DB operational variations in the PRC. Findings of the current study will provide a solid base for future research to establish a decision model for selecting the best DB operational variation under a given set of circumstances.

3. Research methodology – the Delphi technique

The Delphi method is designed to obtain the most reliable consensus of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback, and with results of each round being fed into the next round (Linstone, Turoff 1975; Chan *et al.* 2001a). It has proven to be a popular and reliable technique for decision making (Okoli, Pawlowski 2004; Landeta 2006). It is best suited in fields where there are no adequate historical data for research purpose (Skulmoski *et al.* 2007). Considering the immaturity of DB market in China, the Delphi technique will serve as an appropriate consensus-reaching method for the research topic in this paper.

The Delphi method typically involves the selection of suitable experts, development of appropriate questions, and analysis of their answers (Cabaniss 2002). The original Delphi procedures have three features: (1) anonymous response; (2) iteration and controlled feedback; (3) statistical group responses (Adnan, Morledge 2003). The number of rounds, in general, varies between two and seven, and the majority of the studies have used three rounds (Schmidt 1997; Rowe, Wright 1999; Adnan, Mor-

ledge 2003). According to Ludwig (1997), the majority of Delphi studies have used between 15–20 respondents. Moreover, with a homogeneous group of experts, good results can be obtained even with a panel as small as 10–15 individuals (Adler, Ziglio 1996).

The Delphi method used in this research was composed of three rounds with 20 experts. All the experts have sufficient DB experience and knowledge (most of them take senior management positions in the relevant organizations). It is believed that with the careful selection of these Delphi experts, the opinions solicited from them in the Delphi questionnaire survey will provide reliable results for the research purpose. In Round 1, experts were asked to list at least five criteria for the selection of DB operational variations. All the experts completed Round 1 questionnaire survey. In Round 2, experts were provided with the consolidated results from round 1 and were required to rate all the criteria based on a 5-point Likert scale to evaluate the importance of each criterion. Seventeen experts completed the Round 2 questionnaire survey. In Round 3, experts were asked to reconsider their ratings of each criterion in the light of consolidated results of round 2. Finally, 17 experts completed the round 3 of the Delphi questionnaire survey.

The questionnaires in each round are as follows:

- Questionnaire 1: Please list at least five selection criteria for DB operational variations;
- Questionnaire 2: Please give ratings to the selection criteria according to their importance;
- Questionnaire 3: Please re-rate the selection criteria in the light of the results from round 2.

4. Identification of selection criteria for DB variations

4.1. Selection of expert panel

One of the most important considerations when carrying out a Delphi study is the identification and selection of potential members to constitute the panel of experts (Ludwig 1997; Stone, Busby 1996). The selection of members or panelists is important because the validity of the study is directly related to this selection process. In each Delphi study, the knowledge and expertise of each panelist must be relevant to questions posed by researchers (Dawson, Brucker 2001). In this Delphi survey, the researcher attempts to identify all the panelists who are knowledgeable or have the practical engagement in the DB field. The selection criteria for Delphi experts were devised based on previous Delphi studies on the similar research fields (Chan *et al.* 2001a; Manoliadis *et al.* 2006; Yeung *et al.* 2007). The following three selection criteria were adopted in order to identify eligible participants for this study:

- (1) Having extensive working experience in the DB projects in the PRC,
- (2) Having direct involvement in the management of DB projects, and
- (3) Having sound knowledge of the DB operational variations.

Invitation letters were e-mailed to 31 potential panelists as to explore their availability to participate in this

study. These experts were identified from the address available from government offices, industry associations, universities, and through personal contacts. In order to obtain the most valuable opinions, the practitioners should have more than 5 years hands-on working experience in the DB field, and the academics should have publications related to design-build. Finally, 20 experts who meet all the selection criteria agreed to attend the Delphi survey after the first contact. A list of the panel members and their types of occupations are shown in Table 1 (experts names and their organizations are not reported to respect their anonymity).

The selected experts represent a wide spectrum of construction professionals in the PRC and provide a balanced view for the Delphi study. Most of the experts have sufficient experience and expertise in DB projects. Table 2 shows the respondent classifications by years working in the construction industry and the DB field.

All the experts have the management experience of DB projects. Furthermore, most of the experts hold senior positions in their organizations. The respondents' job positions/titles are provided in Table 3.

Table 1. List of the experts for the Delphi study

| Type of firm / department | Number |
|----------------------------|--------|
| Real estate developer | 1 |
| Government department | 3 |
| Design consultant company | 3 |
| Project management company | 3 |
| University | 4 |
| Construction company | 6 |
| Total | 20 |

Table 2. Respondent classifications by years in the construction industry and DB field

| Years | In construction industry | In DB field |
|-----------------|--------------------------|-------------|
| 0–5 | 5% | 15% |
| 6–10 | 30% | 50% |
| 11–20 | 30% | 30% |
| 20+ | 35% | 5% |
| Average (Years) | 15 | 9 |

Table 3. The job positions of the experts

| Job position | Number |
|-------------------------------------|--------|
| Chief engineer | 1 |
| Deputy chief engineer | 2 |
| Deputy general manager | 2 |
| Project manager | 3 |
| General director | 1 |
| Project management director | 1 |
| Academic | 2 |
| Engineer | 2 |
| Project management consultant | 2 |
| Director of research institute | 2 |
| Deputy division chief in government | 2 |
| Total | 20 |

The experts' sufficient working experience and sound knowledge of DB project management increase the validity of this Delphi research.

4.2. Three rounds of Delphi questionnaires survey: results and analysis

Round 1: Listing the selection criterion for DB operational variations

The first round of the Delphi questionnaire survey is conducted as the exploration process and is of crucial importance. After the completion of first round survey, the criteria suggested by the 20 experts were carefully analyzed and a list of criteria was formed. Those criteria, which conveyed similar meanings, were combined and rephrased. Considering the fact that the first round stage is served as the exploration process and the research topic is relatively new to the experts, all the 15 criteria obtained in this stage remain for the next round survey. Table 4 shows all the criteria proposed by experts in the round one survey.

Round 2: Ratings obtained from experts

The purpose of the second round Delphi survey is to begin the process of building the consensus among the panelists regarding the importance of each selection criterion. A list of 15 criteria with their explanations and experts-frequency was provided to experts for their reference. Finally 17 experts returned the questionnaires.

At this stage, a 5-point Likert rating scale was used, which ranges from 1 – not important, 2 – somewhat important, 3 – important, 4 – very important, and 5 – extremely important or essential. The 1–5 ordinal scale is frequently used in Delphi research. Respondents specify their level of agreement to a statement when responding to a questionnaire item (Dukes 2005). The mean rating for each criterion was computed to indicate the degree of its importance. In this research, mean score of 3.0 was adopted as a cut-off point. Only the criteria regarded as IMPORTANT will remain for the re-evaluation in round 3. Table 5 shows the results of round 2 of the Delphi questionnaire survey.

The Pearson correlation matrix for the data set is given in Table 6. Inspection of the correlation matrix reveals that the top eight selection criteria are not highly correlated with each other at 5% significance level (even most of them are insignificantly correlated with each other). This provides an adequate basis for proceeding to the next round of Delphi survey on these selection criteria.

To measure the degree of agreement between the panel experts on the ordered list by mean rankings, the Kendall's Coefficient of Concordance (W) was calculated with the aid of the SPSS software. The Kendall's Coefficient of Concordance indicates the degree of agreement between the panel members on the ordered list by mean ranks by taking into account the variations between the rankings. Table 5 also shows that the Kendall's Coefficient of Concordance (W) for the rankings of top eight criteria was 0.197, which was statistically significant at 1%. The null hypothesis that the respondent's ratings within the group are unrelated to each other would have

Table 4. Criteria provided by the panel of experts in round one Delphi survey

| Selection criteria for DB operational variations | Experts frequency |
|--|-------------------|
| 1. <i>Availability of competent design-builders</i> Are there many competent design-builders in the construction market? | 90% |
| 2. <i>Owner's design-build capabilities</i> Does the owner have sufficient DB capabilities, such as rich DB experience and adequate staff? | 80% |
| 3. <i>Project complexity</i> Does the project have very high requirements for construction method, project management, etc? | 75% |
| 4. <i>Owner's control of project</i> Does it enable the owner to have more control of the project? | 70% |
| 5. <i>Reduced responsibility or involvement</i> Does it reduce the owner's project responsibility and involvement as much as possible? | 55% |
| 6. <i>Early commencement & short duration</i> Does it enable the owner to start projects as soon as possible? Is the short duration first priority? | 55% |
| 7. <i>Early cost-establish</i> Does it enable the owner to establish the project cost as soon as possible? | 40% |
| 8. <i>Bid competition</i> Does it increase the bidding competition? Is the price-oriented or quality-based method preferred? | 35% |
| 9. <i>Law & trade's tradition</i> Is it allowed or preferred by the construction laws and local tradition? | 30% |
| 10. <i>Reduced or controlled project variation</i> Does it reduce the project variation? Does it allow the owner have much project variation? | 30% |
| 11. <i>Reduced risk</i> Does it reduce owner's risk as much as possible? Is the risk-aversion emphasized by the owner? | 15% |
| 12. <i>Clear end user's requirements</i> Does the owner have clear project definition or project requirement? | 5% |
| 13. <i>Peer relationship with contractor</i> Does it promote better communication between owner and design-builder? | 5% |
| 14. <i>The quality requirement of project</i> Does it improve the project quality as much as possible? Is the quality more emphasized? | 5% |
| 15. <i>Buildability of the construction</i> Does it improve the buildability of project as much as possible? | 5% |

Table 5. The results of round 2 of the Delphi survey

| Criteria for DB variations selection | Mean rating | Rank |
|---|-------------|------|
| Availability of competent design-builders | 4.44 | 1 |
| Client's DB capabilities | 3.87 | 2 |
| Project complexity | 3.81 | 3 |
| Client's control of the project | 3.41 | 4 |
| Reduced responsibility or involvement | 3.25 | 5 |
| Early commencement & short duration | 3.15 | 6 |
| Early cost establishment | 3.07 | 7 |
| Clear end user's requirements | 3.03 | 8 |

Notes: Number (n) = 17. Kendall's Coefficient of Concordance (W) = 0.197. Level of significance = 0.000

Table 6. The Pearson Correlations matrix among the top eight selection criteria

| | Contractor competence | Design competence | Project complexity | Project control | Reduced responsibility | Short duration | Early cost establishment | Clear requirements |
|-------------------------------|-----------------------|-------------------|--------------------|-----------------|------------------------|----------------|--------------------------|--------------------|
| Contractor competence | 1 | -.088 | .302 | -.217 | -.174 | -.009 | .091 | -.318 |
| Client's DB competence | | 1 | .372 | .426 | -.380 | .112 | .008 | -.311 |
| Project scale & complexity | | | 1 | .314 | -.307 | .010 | .109 | -.546* |
| Client's project control | | | | 1 | -.425 | -.294 | -.050 | -.082 |
| Reduced responsibility | | | | | 1 | .306 | .386 | .499* |
| Short duration | | | | | | 1 | .172 | .241 |
| Early cost establishment | | | | | | | 1 | .436 |
| Clear end user's requirements | | | | | | | | 1 |

Notes: *Correlation is significant at the 0.05 level (2-tailed).

to be rejected. Therefore, it can be concluded that a significant amount of agreement among the respondents of panel experts has been found.

Round 3: Re-assessing the selection criteria

In Round 3, the questionnaire survey was concerned with the re-examination of the importance of each criterion in the light of the overall panel response in Round 2. Therefore it moves the experts towards a consensus of opinion. Finally, 17 experts returned their completed questionnaire.

Most experts reconsidered their evaluation and made adjustments to their ratings. The results of the statistical summary are provided in Table 7. In this final round, seven criteria pass the cut-off point.

Tables 6 and 7 show that there is no change in the order of the top four criteria, which are availability competent design-builders, client's DB capabilities, project complexity and client's control of the project. 'Early commencement & short duration' changed from sixth rank to the fifth rank; 'Early cost establishment' failed to pass the importance evaluation and it was excluded from the final list of selection criteria. The Kendall's Coefficient of Concordance (W) was also calculated with the aid of the SPSS software to measure the degree of agreement among the panel members. It reveals that the consistency of the experts' rankings for the top seven selection

criteria was improved by 52.8%, which was also statistically significant at 1% level.

The Pearson correlation matrix as indicated in Table 8 manifests that the top seven selection criteria are not highly correlated with each other at 5% significance level (even most of them are insignificantly correlated with each other). It indicates that these competences are independent with each other, and they are not likely to have any multiplier effect between them. Finally, these seven criteria are adopted as the key criteria for the selection of DB operational variations.

Table 7. The results of round 3 of the Delphi survey

| Criteria for DB variations selection | Mean rating | Rank |
|---|-------------|------|
| Availability of competent design-builders | 4.53 | 1 |
| Client's DB capability | 3.97 | 2 |
| Project complexity | 3.75 | 3 |
| Client's control of the project | 3.50 | 4 |
| Early commencement & short duration | 3.37 | 5 |
| Reduced responsibility or involvement | 3.25 | 6 |
| Clear end user's requirements | 3.12 | 7 |
| Early cost establishment | 2.93 | 8 |

Notes: Number (n) = 17. Kendall's Coefficient of Concordance (W) = 0.301. Level of significance = 0.000

Table 8. Correlations matrix among the top eight selection criteria

| | Contractor competence | Design competence | Project complexity | Project control | Short duration | Reduced responsibility | Clear requirements |
|-------------------------------|-----------------------|-------------------|--------------------|-----------------|----------------|------------------------|--------------------|
| Contractor's competence | 1 | -.142 | .316 | -.275 | -.149 | -.026 | -.516* |
| Client's DB capability | | 1 | .384 | .468 | .143 | -.445 | -.335 |
| Project scale & complexity | | | 1 | .227 | -.057 | .202 | -.505* |
| Client's project control | | | | 1 | -.182 | -.428 | -.074 |
| Short duration | | | | | 1 | -.027 | .093 |
| Reduced responsibility | | | | | | 1 | .197 |
| Clear end user's requirements | | | | | | | 1 |

Notes: * Correlation is significant at the 0.05 level (2-tailed).

5. Discussion

5.1. Operational variations of design-build in China

In the construction market of the PRC, the main DB operational variations include develop-and-construction, novation DB, enhanced DB, traditional DB and Turnkey method (Xia, Chan 2008). For most clients, selecting the appropriate operational variations of the DB system is never an easy task.

Develop-and-construction is shorthand for “develop the detail from the employer’s design and construct the works” (Janssens 1991). Since the client or his consultants undertake most of the design work, it will limit the design-builder’s innovation input and the selection of design-builders tends to be price-oriented (The American Institute of Architects *et al.* 2003). Although the develop-and-construction is not favored by design-builders (Akin-toye 1994), many owners take it a hybrid system to take advantages of design-build and the traditional design-bid-build method. It is widely used in the PRC DB market.

In novation DB, a successful design-builder is required to employ the employer’s consultants to complete the design work in the post-contract stage. The design-builder accepts the innovated consultants in order to maintain the consistency of the design work. But the more design work the design-builder takes, the more likely he or she will decline such arrangement because it restricts design-builder’s innovation input. In ‘enhanced design-build’, the design-builder is contractually responsible for design development, working details and construction work. It is an emerging delivery system, which has attracted much enthusiasm in Hong Kong (Chan 2000). The enhanced DB gives the owner greater control, while preserving the time saving advantages of the DB system.

In traditional design-build, the design-builder takes full responsibility for all the design and construction. In the turnkey method, the contractor provides everything including commission and handover after the construction. The term ‘turnkey’ and its concept have been widely accepted in the industry. As one of the basic DB operational variations, the turnkey method is traditionally applied to major industrial projects (Janssens 1991).

To select an appropriate operational variation of DB, clients should not simply leave all the design and construction work to the design-builder because they may lose control of the projects and may not get the projects as required. At the same time, it is also not wise to provide overly detailed design and specification, leaving little room for the design-builder’s innovative design. The selection criteria identified in this study provide clients with perspectives to understand and examine different operational variations.

5.2. The selection criteria of DB operational variations

The final outcome of this paper is the identification of seven selection criteria for DB operational variations in the construction market of the PRC. In order to ensure the success of DB projects, clients and their consultants should closely examine these criteria to select the appro-

priate operational variation. It should be added that the Delphi method, by its inherent nature, serves as a self-validating mechanism because panel experts are given chances to re-assess their scores with reference to the consolidated mean scores assessed by other experts. By using the Delphi method, the maximum amount of unbiased and objective information can be obtained from the experts.

Availability of competent design-builders

The competence of design-builders is critical to the success of DB projects (Chan *et al.* 2001b; Ling *et al.* 2004). When selecting the DB operational variations, owners have to investigate the availability of competent design-builders, and the DB projects should be under the control of experienced design-builders that possess all the necessary ability to combine both design and construction functions and coordinates various building professionals for the project (Molenaar, Songer 1998; Mo, Ng 1997; Pearson, Skues 1999; Leung 1999). In addition, the more work left to the design-builder (such as in the turnkey method), the higher requirements for design-builder’s capabilities. Therefore, when there are a large number of competent design-builders in the construction market, owners can possibly consider turnkey or traditional DB as applicable options.

The DB capabilities of clients

The client plays an important role in contributing to the success of construction projects (Alinaitwe 2008). In DB projects, although the client may leave most of the project responsibilities to design-builders (such as in the turnkey method), he should still possess DB competences to deliver the DB project smoothly. In particular, owners should have the capability to decide on the optimal level of design completion, to review the design solutions proposed by design-builders, and to install effective monitoring and approval mechanisms for design changes (Deakin 1999; Pearson, Skues 1999; Ling, Liu 2004). In addition to the design capabilities, owners should clearly define project scope and objectives; have sufficient staff or consultant teams, and have similar DB experience to ensure the success of DB projects (Songer, Molenaar 1997; Ling, Liu 2004; Lam *et al.* 2008). In general, the requirements for clients’ DB capabilities increase when DB operational variations move from develop-and-construction to turnkey method. In the selection of DB operational variations, clients should therefore, evaluate their DB competences objectively in order to have a firm control the DB projects.

Project complexity

Project complexity is regarded as the most important project characteristics that affect the selection of DB operational variations. It is generally accepted that the operational variations, in which the design-builder undertakes most of the project definition and design work, are malleable for projects of high to medium complexity (Beard *et al.* 2001). Although the concept of complexity is not entirely clear (Williams 1999), the importance of

the complexity to the project management process is widely acknowledged (Baccarini 1996). Many empirical studies in the construction field have found that project complexity affects project outcomes in various ways (Akintoye 2000; Doyle, Hughes 2000; Tatikonda, Rosenthal 2000; Austin *et al.* 2002; Chan *et al.* 2004). In large or complex projects, it is applicable to reach out immediately to a total facility provider to develop a facility program, because such projects usually call for multiple contracts, sub-contractors, suppliers, outside agencies, and complex coordination systems.

Owner's requirements

The following three selection criteria, namely, owner's control of the project, early commencement & short duration, and reduced responsibility, clearly reflect the owner's expectations toward the DB delivery system. As the traditional design-bid-build delivery method is inadequate to meet the demands and challenges of the changing world, more and more clients resort to the DB operational variations due to their evident advantages, such as single-point responsibility, shortening time, pushing contractors to upgrade technology (Ndekugri, Turner 1994; Songer, Molenaar 1997; Konchar, Sanvido 1998). However, when selecting DB operational variations, it should be kept in mind that every DB operational variation has its own strengths and weaknesses, and the owner has to face trade-offs when choosing the appropriate one. For example, in the turnkey method, the client can greatly reduce his project responsibility or involvement, but at the same time, he will have less control of the project.

Clear definition of projects

The clear end user's requirement means that the owner should have a clear conception of the building functions at the early stage. Many studies propose that the client should develop a clear project definition, owner's requirements, and client's brief in DB projects (Mo, Ng 1997; Molenaar, Songer 1998; Leung 1999; Pearson, Skues 1999; Chan *et al.* 2001b). If the owner is very clear about the project's goals, scope, and expected outcome, then the DB system will work to the owner's benefit; otherwise, it can be very costly if the information provided by the owner to the contractor at the outset of the design build process is incorrect (Mogaibel 1999).

5.3. Validation of the selection criteria

The identification of selection criteria is of great importance to the selection of DB operational variations. In order to set up a comprehensive, objective, reliable and practical framework for the selection of DB operational variations in the future research study, the seven identified selection criteria should be validated to ascertain that they are appropriate to measure the performance of every DB operational variation.

Five structured interviews were conducted with five DB project participants who had hands-on experience in running DB projects in the construction industry of China to collect their views on the identified criteria. All

interviewees are at Directorate grade and each has more than 15 years of experience in the construction industry. Each of them also has experience in running three or more DB projects in China; the profiles of the interviewees are provided in Table 9.

The seven criteria were presented to the interviewees. The processes of the three round Delphi questionnaire survey were also explained. The interviewees were requested to examine the appropriateness of the seven identified selection criteria together with their individual rankings. In addition, they were encouraged to propose other variables that should be taken into consideration when making the similar decisions.

Table 9. Interviewees' details for validating selection criteria for DB operational variations

| No. | Position | Organization | Role | Working years in construction | Working years in DB field |
|-----|-----------------------------|----------------------------------|------------------|-------------------------------|---------------------------|
| 1 | Senior project manager | Construction group company | Consultant | 35 | 22 |
| 2 | General manager | Construction engineering company | Main contractor | 16 | 9 |
| 3 | General director | Project management company | Owner consultant | 24 | 17 |
| 4 | Construction division chief | University | Owner | 22 | 15 |
| 5 | Project manager | Real estate developer | Owner | 15 | 7 |

In general, although minor variation exists on the ranking of selection criteria, most of the interviewees agreed that the seven selection criteria are appropriate to measure the performance of DB operational variations in China. Expert 3 proposed that the factor of relationship between owners and DB contractors should be also considered because when there is a lack of mutual trust between owners and DB contractors; owners tend to undertake more pre-construction work themselves before leaving the projects to design-builders. This factor was once proposed by the Delphi experts in the first round of the Delphi survey. However, it did not pass the importance evaluation in the second round (with the mean score lower than 3.0). Finally, the seven selection criteria were consolidated and adopted for the future research study.

5.4. Application of the section criteria

The selection of DB operational variations is a multi-criteria decision making process that poses challenge to many clients. The current research study recommends seven most important selection criteria and their rankings. The research findings will facilitate DB clients to evaluate different DB projects and select the appropriate DB operational variation. This is illustrated by the following two cases.

The Jin Mao Tower is a typical DB project of develop-and-construction. It is an 88-story landmark skyscraper in Lujiazui area of the Pudong district of Shanghai, the People's Republic of China. Similar to most of the DB owners in China, the China Shanghai Foreign Trade Center Co., Ltd was inexperienced with DB system but wanted to have firm control of this project. Additionally, the owner did not have clear definition of the final project at the early stage. At the same time, there were not enough competent design-builders in the PRC back then. Given the characteristics of this project, the owner was therefore recommended to complete the majority of the design work before leaving the project to the successful design-builder. In the real practice, the owner employed Skidmore, Owings & Merrill (SOM) as the design consultant based on its concept design through international open bidding. SOM then developed the design work to design development stage. After the tendering stage, the successful DB contractor, Shanghai Construction Group, was contractually responsible for the remaining working drawing and all the construction work. This contract arrangement gave the owner greater control of the project while still preserving the time saving advantages of design-build system.

Another oil storage project, located in Guangdong province, provided a vivid example of Turnkey method. This project is owned by Oiltanking Daya Bay Co., Ltd, an internationally service provider for liquid bulk storage and logistics. It has sufficient experience with DB system and has clear definition it required. At the same time, there is adequate supply of competent design-builders in the Petroleum and Chemistry industries where the DB system has been adopted for more than twenty years. Therefore the owner may leave most of the project design to the successful design-builder at the early stage of the project. In this project, the successful DB contractor, Chengda Engineering Corporation of China – one of the 200 largest international engineering companies was responsible for the preliminary design, detailed design, facility procurement and construction. The owner purchased almost the whole facility from the contractor.

5.5. Limitation of the current study and future research work

The selection of DB operational variation is a multi-criteria decision-making process. The selection criteria identified in this research provide perspectives to evaluate different DB operational variations. However, it is worth noting that some of the identified criteria are still broad, vague concept (such as the project complexity). Different assessors may have their own semantic interpretation on each selection criterion. Thus it is desirable to identify suitable quantitative interpretations/indicators for each criterion and provides objective evaluation results based on quantitative evidence in the future. In addition, it is stressed that the scoring of selection criteria is on relative importance, not on actual importance. A subjective assessment of the scoring results is made to analyze the perceived relative importance of selection criteria. The fact that this subjective assessment does not provide any

absolute value on the importance is recognized. Therefore other methods for determining the rankings of the selection criteria such as AHP, non-parametric Kendall Rank, etc) may be adopted in future research study. It is expected that the final selection model will help owners select the appropriate DB operational variations and promote the application of the DB system in the construction market of China. Given that the selection of DB operational variations is a problem not only in China, further research should be conducted in other countries to seek their similarities and differences for international comparisons.

6. Conclusions

The DB system has been widely used overseas, however it has not gained popularity in the PRC. The selection of DB operational variations is important to the success of DB projects but also poses difficulty to the clients. The focal point of this analysis is to develop the selection criteria for DB operational variations in the construction market of the PRC. Seven selection criteria have been identified in this study. The finding indicates that a client should comprehensively evaluate the availability of design-builders in the market, his DB capabilities and project requirements, and project characteristics in order to choose the appropriate DB operational variation. These findings can furnish stakeholders, not only the clients, with perspectives to understand and compare the different operational variations of DB system. It also deepens the current body of knowledge and serves as an acceleration of the development in this filed.

In identifying and developing a practical set of selection criteria for DB operational variations, the Delphi method serves as a self-validating mechanism and provides a valuable framework for tapping experts' knowledge. This is especially true when there are very few studies available in this field. It yielded both insight and structure to assess different DB variations.

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ATRANKOS KRITERIJŲ PROJEKTAVIMO IR STATYBOS SISTEMOS DARBINIAMS VARIANTAMS NUSTATYMAS: DELPHI TYRIMAS KINIJOJE

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Santrauka

Įrodyta, kad projektavimo ir statybos (P ir S) sistema – veiksmingas vykdymo metodas, tad ji išpopuliarėjo visame pasaulyje. Tačiau pastebėta, kad per pastarąjį dešimtmetį atsirado ne vienas darbinis P ir S sistemos variantas, tenkinantis skirtingus kliento poreikius. Klientui nutarus projekto paslaugas pirkti naudojant P ir S sistemą, jam vis tiek tenka pačiam pasirinkti tinkamą derinį, idant projektas vyktų optimaliai. Tačiau darbinių P ir S variantų pasirinkimas beveik nebuvo tyrinėtas. Viena pagrindinių priežasčių – trūksta vertinimo kriterijų, kurie leistų nustatyti kiekvieno darbinio varianto tinkamumą. Siekiant nustatyti tokius kriterijus, atliekant Delphi apklausą trimis etapais buvo apklausta 20 statybos ekspertų iš Kinijos Liaudies Respublikos (KLR). Nustatyti septyni svarbiausi atrankos kriterijai: 1) kompetentingų projektuotojų statytojų pasiūla; 2) kliento pajėgumai; 3) projekto sudėtingumas; 4) kiek klientas kontroliuoja projektą; 5) ankstyva pradžia ir nedidelė trukmė; 6) mažesnė atsakomybė arba dalyvavimas; 7) aiškiai nusakyti galutinio kliento reikalavimai. Nustatyta, kad susitarimas dėl šių atrankos kriterijų yra statistiškai reikšmingas. Įvairioms suinteresuotoms grupėms, o ypač P ir S klientams, šios išvados gali padėti geriau suprasti įvairius darbinius P ir S sistemos variantus ir juos palyginti.

Reikšminiai žodžiai: projektavimas ir statyba, darbiniai variantai, atrankos kriterijai, Delphi metodas, Kinija.

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