

DESIGN AND BUILD PROJECT SUCCESS FACTORS: MULTIVARIATE ANALYSIS

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ABSTRACT: This study aimed to identify a set of project success factors for design and build (D&B) projects and examine the relative importance of these factors on project outcome. Six project success factors (project team commitment, contractor's competencies, risk and liability assessment, client's competencies, end-users' needs, and constraints imposed by end-users) were extracted from factor analysis of data provided by 53 participants of public-sector D&B projects through a questionnaire survey. Project team commitment, client's competencies, and contractor's competencies were found to be important to bring successful project outcome from the multiple regression findings. Contractor's competencies also contributed to project time performance. Project team members should also recognize that time and cost performance as well as quality of design and workmanship represent the key elements of overall success of D&B projects. Practitioners are advised to focus on teamwork and partnering for successful project completion. More research should be conducted to further explore the relationship between procurement method and project success factors.

INTRODUCTION

Holding the belief that "construction project success is repeatable" (Ashley et al. 1987, p. 69), practitioners and researchers have paid attention to establishing a set of factors contributing to project success. Many empirical studies have been conducted to examine the impact of various project success factors. Ashley et al. (1987) and Pinto and Slevin (1988) are some of the major contributors in the identification and examination of critical success factors empirically in the 1980s. Jaselskis and Ashley (1991) explored how project managers could allocate scarce resources in an effective manner to achieve higher project performance. Sanvido et al. (1992) examined the contribution of factors such as project team experience, contracts, resources, and information available to project success. Mohsini and Davidson (1992) tested the influence of a number of conflict-inducing organizational variables on performance of project using a traditional procurement method. Tiong (1996) identified six critical success factors for build-operate-transfer projects. Pocock et al. (1997) examined the impact of improved project interaction on performance. Although much has been done in this area, there are few empirical studies systematically examining the factors contributing to design and build (D&B) project success. An exception is the study of factors for a successful public-sector D&B project by Songer and Molenaar (1997).

Recently, several surveys focusing on the performance of D&B projects have been reported. Molenaar and Songer (1998) developed prediction models for public-sector D&B project selection, which related specific project characteristics (project, owner, market, and relationship variables) to success. Konchar and Sanvido (1998) conducted an empirical study that examined nearly 100 explanatory and interacting variables to explain project cost, schedule, and quality performance of three procurement systems (construction management at risk, D&B, and design/bid/build). In the U.K., Bennett et al. (1996)

studied D&B project selection and performance from the client's perspective.

Given that the success ingredients of building projects using the traditional (design/bid/build) procurement method may not be equally applicable to D&B projects, it is worthy to put more effort in the identification of the project success factors. For example, the contractor's design management expertise is more critical in D&B projects than in the traditional projects. Practitioners may not find the advice offered by previous studies helpful.

This study was, therefore, conducted to address this gap, and aimed to (1) identify a list of important factors contributing to the success of D&B project; (2) categorize these project success factors into a smaller number of groups using factor analysis; (3) examine the relative importance of these groups of factors on D&B project performance; and (4) explore the relationship between D&B project performance and project participants' satisfaction on project performance. It is expected that this study will give researchers some new insights and practitioners some advice on success factors for D&B projects.

This paper consists of five sections: review of empirical studies of factors contributing to project success, development of a set of project success factors, research methods, results and discussion, and conclusions.

REVIEW OF EMPIRICAL STUDIES

Several empirical studies relevant to the identification of factors influencing D&B project performance were reviewed. All reported significant factors were considered to establish a list of items for empirical testing.

Ashley et al. (1987) identified 46 factors contributing to project success and grouped them into five areas including (1) management, organization, and communication; (2) scope and planning; (3) controls; (4) environmental, economic, political, and social; and (5) technical. Based on the study of eight projects with average performance and eight outstanding projects, they found significant differences between the average and the outstanding projects in six factors including planning effort in construction and design, project manager goal commitment, project team motivation and goal orientation, project manager technical capabilities, scope and work definition, and control systems. They also found that planning effort in construction explained 87% of the variance of functionality performance, while project manager administrative capabilities accounted for 77% of budget performance variance from the regression results. The implications of the findings by Ashley et al. (1987) to D&B projects are that the client should develop a thorough

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project plan in which the scope of work is clearly defined, and the contractor's project manager should understand and commit to the achievement of project objectives because the contractor has the sole responsibility for the D&B project. The contractor's capability and experience in managing D&B projects is critical to project success. Project participants' commitment toward the project goals is also important. In addition, an effective monitoring and approval system should be installed to govern design changes.

Pinto and Slevin (1988) proposed 10 factors including project mission, top management support, project schedule/plans, client consultation, personnel, technical tasks, client acceptance, monitoring and feedback, communication, and troubleshooting. All of them were considered as critical for success at various stages (conceptual, planning, execution, and termination) of project life cycle. From the regression analysis of the data given by 418 project managers through a questionnaire survey, they found that project mission (initial clarity of goals and general directions) explained more than 50 and 12% of project success variance in each of the first three stages and the last stage, respectively, whereas technical tasks (availability of the required expertise and technology to complete the specific technical actions) accounted for 45% of project success variance in the termination stage. Obviously, the results of Pinto and Slevin (1988) highlighted the importance of establishing a set of clear project goals and directions at the outset. This is particularly true for D&B projects because any misunderstanding of what to achieve can be avoided, which is instrumental in completing a building project in a short time. Moreover, the contractor's expertise in using appropriate building technology and input of building knowledge to design development can speed up project delivery time.

Mohsini and Davidson (1992) examined the effect of six variables of interorganizational conflict on project performance in the traditional building process. Based on the stepwise regression analysis of data provided by 21 project participants, Mohsini and Davidson (1992) reported that sufficiency of information and time required to procure further information accounted for more than 60 and 45% of variance of project cost performance and time performance, respectively, while tasks' dependence upon others explained 25% of quality performance variance. The importance of communication among project participants to project performance was evident in the findings of Mohsini and Davidson (1992). Getting required information in a timely manner for prompt decision making in D&B projects is crucial. Project participants are willing to share important information if they cooperate and trust each other. Therefore, mutual trust, cooperation, and communication among project participants contribute to D&B project success.

Recently, Songer and Molenaar (1997) identified 15 characteristics of successful D&B projects through literature review and unstructured interviews of academia and public-sector agency representatives. Eighty-eight public-sector representatives were asked to rate the importance of these characteristics through a questionnaire survey. Songer and Molenaar (1997) found that the top five important project characteristics were well-defined scope, shared understanding of scope, owner construction sophistication, adequate owner staffing, and established budget.

Mo and Ng (1997) conducted a survey on architects' and builders' views on the D&B procurement method in Hong Kong. Their results showed that the quality of the client's brief was rated as the most important project success factor, while the client's and the contractor's experience in D&B, good working relationship, and proper channel of communication were also critical.

DEVELOPMENT OF FACTORS CONTRIBUTING TO SUCCESS OF D&B PROJECTS

Thirty-one factors contributing to the success of D&B projects (see Appendix I) were developed through a review of both empirical studies and opinions of D&B practitioners (clients, contractors, and architects) from archival data. The focus of these factors was on the duties, responsibilities and capabilities of different project participants including end-users, client, contractor, architect, and design consultants in D&B projects. Factors common to all participants were also addressed.

End-Users

Practitioners consider that the end-users' input to project is very important in contributing to D&B project success (Deakin 1999). This factor is even more critical for complex D&B projects. If the end-users' needs are uncertain or ambiguous, it is difficult to develop a comprehensive and clear client's brief for the contractor to propose a suitable design and construct the building. Disputes and claims may be expected if the details of the client's requirements are not adequately stated at the outset (Tam 1997). Significant changes made to the client's brief midway through a D&B project may lead to poor project performance in terms of time and cost. Therefore, end-users should have a thorough understanding of their own needs; the same applies to other project participants.

Client

The client plays an important role in contributing to D&B project success. To improve the chance of project success, the client should perform the following activities: comprehensive pretender site investigation (Leung 1999; Pearson and Skues 1999), develop a clear understanding of project scope (Ashley et al. 1987; Pinto and Slevin 1988; Songer and Molenaar 1997; Leung 1999; Pearson and Skues 1999), prequalify potential tenderers, assess contractors' proposals thoroughly, develop a clear client's brief (Deakin 1999; Leung 1999; Pearson and Skues 1999), establish a capability to manage D&B projects, install an effective monitoring and approval mechanisms for design changes (Ashley et al. 1987; Deakin 1999; Pearson and Skues 1999), and limit the change of client's requirements during construction (Chan et al. 1999).

Contractor

Practitioners believe that the contractor should have strong design management expertise and project management capability for D&B project success (Hemlin 1999; Pearson and Skues 1999). Contractor should also possess a thorough understanding of buildability and develop a good design through the utilization of appropriate construction methods (Cheng, 1995).

Architect and Design Consultants

The contractor's design consultants should have a good grasp of buildability for design development (Cheng 1995). If designers fail to work within budget and on schedule, poor performance would be expected (Hemlin 1999). Design consultants should understand the construction process and develop a cost-effective design on time.

Teamwork among All Project Participants

Mutual trust and respect between client and contractor has been emphasized by practitioners as an important ingredient for D&B project success (Kok 1995; Ho 1996). In addition, to ensure project success, all project participants should share a clear understanding of financial and technical performance

required (Songer and Molenaar 1997), install adequate communication channel (Mohsini and Davidson 1992; Kok 1995; Mo and Ng 1997), achieve a high degree of cooperation (Cheng 1995), sharing of common project goals (Ashley et al. 1987), and develop an ability to resolve conflicts quickly.

Moreover, D&B procurement brings changes and challenges to project participants, especially to those who have operated within the traditional procurement system for a long time. Therefore, it is important for all project participants to understand and accept their new roles and duties and the risk and legal liability they have to face in D&B projects. It is also important for project participants to have a fair share of the financial return from D&B projects. Otherwise, claims and disputes easily arise, which in turn hamper project performance.

RESEARCH METHODS

Data Collection

Clients and contractors who have participated in D&B building projects were the main target respondents. Only public sector data were gathered because most D&B projects completed in Hong Kong were public works. A list of completed D&B projects were developed based on information obtained from the Hong Kong Government's tender records, trade magazines, and other relevant sources. Senior staff of client organizations and construction firms were contacted, and through them some key project participants of each D&B project were identified. Self-administered questionnaires were distributed to individual project participants and those who agreed to dispatch questionnaires to their project team members.

Altogether about 120 questionnaires were delivered, and each respondent was given 2 weeks to complete the questionnaire. Reminders were sent to those who did not respond within the period, and an additional 2 weeks were given to them to return the questionnaires. Finally, 53 questionnaires were received, and the respondents came from 19 different D&B projects. Twenty-five (47%) respondents including project manager, architect, quantity surveyor, structural engineer, and building services engineer were from client organizations. Twenty (38%) respondents including project director/manager, contract/design coordinator, site manager, quantity surveyor, and engineering manager were from D&B contractors. Seven (13%) respondents were clients' and D&B contractors' consultants who were the architect, quantity surveyor, and design manager. The identity of one (2%) respondent could not be identified. The number of D&B projects the respondents had involved ranged from 1 to 12 with an average of 3.

Measures

Respondents were requested to rate all project success factors (see Appendix I) according to a five-point Likert scale (1 = strongly disagree and 5 = strongly agree). For those respondents who had no idea about the questions, they could select the answer of "Don't know." Such an answer was treated as a missing value. Respondents were also requested to provide information about time and cost performance of the D&B project in which they were involved. A nine-point scale was adopted to reflect the time and the cost performance (Table 1), while the perceived overall project performance was rated on a five-point Likert scale (1 = very unsuccessful and 5 = very successful). Project participants' satisfaction on time, cost, quality of design, and quality of workmanship of the D&B project were rated on a five-point Likert scale (1 = very low and 5 = very high).

Analysis

The respondents' ratings were regarded as invalid if two answers were selected or no answer was indicated. Invalid

TABLE 1. Scales Used to Measure Time and Cost Performance of D&B Projects

Point assigned (1)	Time performance (2)	Cost performance (3)
1	Behind schedule by >10%	Overrun budget by >10%
2	Behind schedule by 6–10%	Overrun budget by 6–10%
3	Behind schedule by 1–5%	Overrun budget by 1–5%
4	Behind schedule by below 1%	Overrun budget by below 1%
5	On schedule	On budget
6	Ahead schedule by below 1%	Underrun budget by below 1%
7	Ahead schedule by 1–5%	Underrun budget by 1–5%
8	Ahead schedule by 6–10%	Underrun budget by 6–10%
9	Ahead schedule by >10%	Underrun budget by >10%

answers were treated as missing cases and excluded from analysis. Valid cases for project success factors ranged from 46 to 53; time, cost, and overall performance ranged from 49 to 52; and project participants' satisfaction ranged from 51 to 53. Factor analysis was conducted to reduce the 31 items (project success factors) into a smaller number of factors. Multiple stepwise regression was performed to explore the relative influence of the factors extracted from factor analysis on D&B project performance. Independent-samples *t* test of project success factors by time performance of D&B project was also performed. The relationships between project performance and project participants' satisfaction on project performance in terms of time, cost, quality of design, and quality of workmanship were examined by bivariate correlations.

Prior to factor analysis and multiple regression analysis, all variables of project success factors and overall project performance were examined for potential outlier and normality. For the independent variables (project success factors), no univariate outlier was found since the standardized scores of all cases were within an acceptable range of ± 2.88 ($p < 0.004$, two-tailed test). Normality of all independent variables was checked by significant tests for skewness and kurtosis. The observed values of skewness and kurtosis were tested against the null hypotheses of zero because the values of skewness and kurtosis are zero when a distribution is normal. The test statistics of skewness and kurtosis were within a range of ± 2.575 ($p < 0.01$, two-tailed test). Therefore, all independent variables were found to be reasonably normally distributed. The dependent variable (overall project performance) was also found to be normally distributed since the test statistics of skewness and kurtosis were within an acceptable range of ± 2.81 ($p < 0.005$, two-tailed test). No case of the dependent variable was considered as an univariate outlier since the standardized scores of all cases were within a range of ± 2.96 ($p < 0.003$, two-tailed test).

RESULTS AND DISCUSSION

Factor Analysis of Project Success Factors

Principal factors extraction with varimax rotation was performed through the SPSS FACTOR program on 31 items of project success factors for a sample of 53 responses. The χ^2 test statistic of Bartlett's test of sphericity was significant at $p < 0.001$, which indicated that all correlations were significantly different from zero. Factor loadings, percent of variance explained, and cumulative percent of variance explained are shown in Table 2. Six factors were extracted and altogether accounted for 78% of the variance in responses. The first three factors accounted for 26, 16, and 10% of the variance, respectively. All factor loadings were >0.5 , and 18 of them were >0.7 . In general, the loadings and the interpretation of the

TABLE 2. Factor Structure for Principal Factors Extraction and Varimax Rotation on Project Success Factors Items

Number (1)	Item (2)	Factor loading (3)	Percent of variance explained (4)	Cumulative percent of variance explained (5)
Factor 1: Project Team Commitment				
31	Project participants resolved conflicts quickly	0.830	26.185	26.185
18	Architect had capability of developing good design within budget and on schedule	0.823		
28	All project participants cooperated fully	0.811		
20	Contractor's design consultants had a thorough understanding of construction process	0.811		
29	Adequate channel of communication among all project participants existed	0.810		
30	High degree of trust was shared by all project participants	0.782		
19	Architect had incorporated buildability in developing design	0.724		
13	All project participants shared a clear understanding of functional and technical performance required	0.714		
15	All project participants accepted the changes of their roles and duties in D&B project	0.671		
14	All project participants understood fully their new roles and duties in D&B project	0.664		
27	All project participants shared common project goals	0.648		
8	Client's brief/employer's requirements was clear	0.598		
Factor 2: Contractor's Competencies				
25	Contractor had utilized special/innovative building techniques and materials to speed up building process	0.882	16.401	42.586
24	Contractor had input building knowledge in design development	0.821		
23	Contractor had good project management capability (planning and programming), for D&B project	0.755		
12	Project participants were satisfied with the financial return from the project	0.745		
26	Monitoring and approval mechanisms for design changes were well established	0.583		
22	Contractor had a thorough understanding of the design process	0.579		
Factor 3: Risk and Liability Assessment				
9	Prequalification of potential tenderers was thorough	0.758	10.094	52.681
17	All project participants accepted the risk and legal liability they had to face	0.685		
11	Little change in client's requirements during construction had been made	0.608		
10	Assessment of contractor's proposals was thorough	0.591		
16	All project participants understood fully how great the risk and legal liability they had to face	0.528		
Factor 4: Client's Competencies				
5	Client had a good capability of managing D&B project	0.871	9.217	61.897
6	Client had a precise understanding of the D&B project scope before it was submitted to the contractor	0.752		
2	We had clearly articulated end-users' needs	0.533		
Factor 5: End-Users' Needs				
7	Pretender site investigation was comprehensive	0.718	9.144	71.042
4	End-users had given useful input to the D&B project	0.645		
1	We had a thorough understanding of end-users' needs	0.546		
Factor 6: Constraints Imposed by End-Users				
3	End-users did not have a thorough understanding of their needs	−0.859	7.011	78.053
21	Contractor's design team worked under numerous constraints in D&B project	−0.819		

factors extracted were reasonably consistent. The meaning of the six factors were interpreted as follows:

- Project team commitment (Factor 1)—This factor consists of 12 items that focus mainly on teamwork and project participants' commitment. Project team commitment includes a clear understanding of performance requirements, acceptance of new roles in D&B project, shared common project goals, a high degree of cooperation, adequate communication channel, high degree of trust, and effective conflict resolution skill. Apart from these common capabilities, the contractors' design consultants should develop a good design on schedule and within budget and address buildability principles, while the client should make their requirements clear.
- Contractor's competencies (Factor 2)—This factor has six items with emphasis on contractor's capabilities on the management of various aspects including finance, design, project planning, and construction method of a D&B project.

- Risk and liability assessment (Factor 3)—This factor includes five items. Its main focus is on the assessment of risk and legal liability all participants have to face in a D&B project. Potential risk lies in the thoroughness of the assessment of prospective tenderers' qualification and proposals and change of client's requirements during construction.
- Client's competencies (Factor 4)—In this factor, there are three items concerning client's competencies in managing a D&B project, understanding of project scope, and articulation of end-users' needs.
- End-users' needs (Factor 5)—This factor consists of three items which focus on end-users' needs. Specifically, end-users' needs should be understood thoroughly, end-users should give useful input to the project, and pretender site investigation should be comprehensive.
- Constraints imposed by end-users (Factor 6)—There are two items in this factor that examines whether end-users have a thorough understanding of their own needs, and design consultants work under numerous constraints.

These six factors represented the important areas that all participants of D&B projects should focus on. The capabilities and the commitment of client, contractor, and other project participants to achieve good project performance were clearly reflected in Factors 1, 2, and 4. Apart from these commitment and competencies, assessment and acceptance of potential risks and liability (Factor 3) were also important to D&B project success. Moreover, having a clear idea about what end-users' want and the constraints imposed (Factors 5 and 6) was instrumental to establish a good start. Although these six factors did not cover all aspects of project success factors and this was not the intention of this study, they accounted for various important project success elements. Additionally, they were examined empirically by a multivariate analysis—factor analysis. It is expected that these six project success factors can lay a foundation for future project evaluation research in public-sector D&B projects. More empirical testing of the factor structure observed in this study should be conducted.

Stepwise Multiple Regression Results

A stepwise multiple regression was conducted between the overall performance of the D&B project as the dependent variable and six project success factors as the independent variables using SPSS REGRESSION program. Six factor scores for each respondent were calculated using regression method in SPSS. These factor scores formed the data set for the stepwise multiple regression analysis. An entrance criteria that an F statistic must be significant at the level of 0.01 was set. Table 3 shows the standardized regression coefficients (β), the intercept (R^2), R^2 change, and significant level (p). Risk and liability assessment (Factor 3), end-users' needs (Factor 5), and constraints imposed by end-users (Factor 6) were excluded from the regression model because they failed the entrance criteria. The standardized regression coefficients of project team commitment (Factor 1), contractor's competencies (Factor 2), and client's competencies (Factor 4) were differed significantly from zero at $p \leq 0.002$. Altogether, 61% of the overall project performance variance was explained by these three factors. Project team commitment contributed significantly to prediction of overall performance of D&B project ($R^2 = 0.32$, $p < 0.001$). The client's competencies and contractor's competencies accounted for 16 and 13% of variance in the overall performance, respectively.

The multiple regression results were consistent with the findings of past studies (Ashley et al. 1987; Pinto and Slevin 1988; Mohsini and Davidson 1992; Songer and Molenaar 1997). The commitment of the project team to the D&B project was shown to be the most important factor contributing to overall project success. The results tallied Jefferies's et al. survey findings of factors perceived to be important to successful teaming (ability of team to resolve conflicts quickly, establishing mutually agreed goals early in the project process, and trust exists between team members) (Jefferies et al. 1999). This project success factor also represented some key elements of

partnering—commitment to respect, trust, and cooperation (Cowan et al. 1992) and dedication to common goals (Hancher 1989). Through the recognition and respect of all parties' goals, momentum toward project success is created (Moore et al. 1992). In fact, a partnering charter has been established by the client and the contractor of the first D&B project of a hospital in Hong Kong, and partnering has been regarded as an effective dispute resolution strategy and a commitment to achieve project success by all parties (Ng and Mo 1997). Nevertheless, one should not equate teamwork with partnering. Partnering involves the development of a long-term relationship and commitment among the partners, while teamwork does not necessarily have this characteristic (Albanese 1994). Project participants' understanding and acceptance of the new roles and responsibilities in D&B projects were also shown to be vital to project success. This is even more important in a place like Hong Kong where most project participants have operated in the traditional manner for a long time. Unless all project members can adapt themselves to new working relationships and be open-minded, it is difficult to achieve project success.

As indicated by the regression findings, the client's competencies in managing the D&B project were found to be the second key factor contributing to overall project success. Although the role of a D&B contractor has been heavily emphasized by researchers and practitioners, the position held by the client is by no means trivial. Rather, it was shown in the findings that the client played an even more important role than the contractor. Since the contractor relies mainly on the client's brief to develop design and determine the construction method in D&B projects, unnecessary misunderstanding, conflicts, and delay easily arise if ambiguity and error exist in the client's brief. Given the fact that the client should understand end-users' requirements much better than other project participants, the client's contribution to the briefing process is great. Active client involvement in the early stage of the D&B project enables the client to get a thorough understanding of the project scope and articulation of end-users' needs. Changes to the project scope and end-users' needs could be reduced with an effective briefing process. Obviously, the client's input in the development of a clear project brief that reflects project requirements accurately is critical to project success (Murray 1995). It is not surprising that inexperienced clients, who are not sophisticated enough to develop a clear and comprehensive brief, are advised not to use D&B procurement (Ndekugri and Turner 1994).

The third factor that contributes to project success was the contractor's competencies, which tallied with the findings of Ashley et al. (1987). The contractor's experience in D&B procurement is particularly important to project success in places (e.g., Hong Kong) where well-qualified D&B contractors are insufficient (Mo and Ng 1997). The D&B contractor's expertise in similar facilities is important for some uncommon projects (e.g., some Navy installations) (Emmons 1995). Apart from applying appropriate technical capabilities, the contractor, who is not trained to be a designer, should gain a thorough understanding of the design process and how the design work integrates with other activities. As an experienced contractor commented, "any contractor that does not have that knowledge and ability should avoid Design & Build like the plague, because your designers are likely not to produce what you want when you want it and you won't know until it's too late" (Hemlin 1999, p. 19). The contractor should also recognize that project team formation would be hindered if members are operating on tight profit margins and unrealistic deadlines (Jefferies et al. 1999).

Although the significance of the other three factors (risk and liability assessment, end-users' needs, and constraints imposed

TABLE 3. Stepwise Multiple Regression Results

Independent variable (critical success factors) (1)	Standardized coefficients (β) (2)	p (3)	R^2 (4)	ΔR^2 (5)	p (6)
Factor 1: Project team commitment	0.564	0.000	0.322	—	—
Factor 4: Client's compe- tencies	0.403	0.001	0.485	0.163	0.004
Factor 2: Contractor's com- petencies	0.354	0.002	0.611	0.127	0.005
Constant	3.94				
$n = 33$ (listwise deletion)					

Note: Dependent variable is overall performance of D&B project.

by end-users) was found to be lower than project team commitment, client's competencies, and contractor's competencies, their effects on project outcome should not be ignored.

Two Independent-Samples t Test Results

Two independent-samples t test was performed to test the null hypothesis that in the population the average of project success factors of D&B projects with good time performance and D&B projects with poor time performance are the same. Prior to the t test, all 19 D&B projects were divided into two groups according to the project time performance achieved. The time performance was rated on a nine-point scale (1 = behind schedule more than 10%, 5 = on schedule, and 9 = ahead schedule more than 10%) as shown in Table 1. Time performance was considered to be good if the performance rating was greater than 4 (behind schedule <1%) and poor if the score was ≤ 4 . Based on this criteria, the time performance of 13 D&B projects (score ranged from 4.17 to 6) were considered to be good and four projects (scored ranged from 1 to 2) were poor. Mean ratings were used to compute the 6 project success factors for each of the 19 projects.

Table 4 shows that the observed difference of 1.21 for the means of contractor's competencies differed significantly from zero at $p \leq 0.001$ (two-tailed t test). The null hypothesis that the two population means are equal was therefore rejected. The reported mean rating of the contractor's competencies (3.65) was higher in the group with good time performance than the rating (2.44) in the group with poor time performance. For the other five factors, no significant difference of the means of the two groups at the level of 0.05 was found. To further explore the relationship between the contractor's competencies and time performance of the D&B project, bivariate correlation was then conducted. A strong positive association between these two variables was indicated since the Pearson correlation

coefficient of 0.694 was found to be significant at the level of 0.001 (two-tailed, $n = 19$).

These findings were consistent with expectations. Since the control of the progress of a D&B project mainly lies on the hands of contractors, it was not surprising to find that a strong, positive relationship between the contractor's competencies and project time performance existed. Contractors should adopt a new, proactive mindset to assume the leader role in both design and construction. They should also improve the capability of managing the design process and design professionals to complete the D&B project on time. On the other hand, the client should recognize the importance of assessing tenderers for D&B projects thoroughly. More weight could be put on contractors' design capability and experience in the evaluation process.

Bivariate Correlation of Project Performance and Project Participants' Satisfaction

The relationships between project performance (time, cost, and overall) and project participants' satisfaction on time, cost, quality of design, and quality of workmanship were examined by bivariate correlations. Table 5 displays the Pearson correlation coefficient (r), sample size (n), and level of significance. Strong, positive relationships were found between overall project performance and project participants' satisfaction on quality of design ($r = 0.608$, $p < 0.001$), quality of workmanship ($r = 0.560$, $p < 0.001$), cost ($r = 0.463$, $p = 0.001$), and time ($r = 0.459$, $p = 0.001$). In addition, project performance on time and project participants' satisfaction on time were positively associated ($r = 0.723$, $p < 0.001$). However, it was surprising to find that there was no association between project performance on cost and project participants' satisfaction on cost. Bivariate correlation between cost performance and satisfaction on cost was then rerun for both the client's ($n = 25$) and the contractor's ($n = 19$) samples. Although no association was found in the client's sample ($r = -0.071$, $p > 0.05$), a positive nonsignificant relationship was observed in the contractor's sample ($r = 0.343$, $p > 0.05$).

These findings suggested that project participants did not just focus on a single aspect to judge the overall project performance (e.g., time performance in the D&B project). Rather, time and cost performance as well as quality of design and workmanship were considered. Project participants may put more emphasis on quality of design and workmanship in D&B projects because the client's direct involvement in the control of these aspects were reduced, while the contractor could not find a scapegoat but had to assume the full responsibility for any fault in these areas. Nevertheless, contractors and other project team members should strive for a balance of their performance on these four areas because the client does not place emphasis on only one performance aspect.

Obviously, project participants would be satisfied on time performance if the time performance of D&B projects is good, but, contrary to expectations, no association between project participants' satisfaction on cost and project cost performance

TABLE 4. Independent-Samples t Test of Project Success Factors by Time Performance of D&B Project

Project success factors (1)	Mean		p (two-tailed) (4)
	Good time performance ($n = 13$) (2)	Poor time performance ($n = 6$) (3)	
1—Project team commitment	3.52	3.04	0.072
2—Contractor's competencies	3.65	2.44	0.000
3—Risk and liability assessment	3.53	3.47	0.728
4—Client's competencies	3.61	4.04	0.304
5—End-users' needs	3.64	3.67	0.923
6—Constraints imposed by end-users	3.26	2.92	0.410

Note: Project success factors were rated on a five-point Likert scale (1 = strongly disagree, 3 = neutral, and 5 = strongly agree).

TABLE 5. Bivariate Correlation Results

Project performance (1)	Satisfaction on Time		Satisfaction on Cost		Satisfaction on Quality of Design		Satisfaction on Quality of Workmanship	
	r (2)	n (3)	r (4)	n (5)	r (6)	n (7)	r (8)	n (9)
Time performance	0.723 ^a	51	—	—	—	—	—	—
Cost performance	—	—	0.081	49	—	—	—	—
Overall performance	0.459 ^b	52	0.463 ^b	509	0.608 ^a	52	0.560 ^a	51

^a $p < 0.001$.

^b $p = 0.001$ (two-tailed).

was found. This may be due to the establishment of an inappropriate goal for cost performance at the outset of the project. If the initial target set for cost performance was lower than it should be, project participants would not be satisfied with the outcome even though the project was completed on budget. If a too challenging goal on cost performance had been established, project participants would be satisfied with the outcome even though the project was completed over budget. In addition, the initial cost performance target may be changed midway through the project due to some unexpected reasons. Such a change could also alter the positive relationship between project time performance and project participants' satisfaction on cost.

CONCLUSIONS

Six project success factors were extracted by factor analysis on 31 variables developed through a synthesis of empirical studies and project participants' opinions. These factors formed the basis for D&B project evaluation. Three of the factors were found to be critical in explaining the overall D&B project performance from the multiple regression results. Specifically, the project team commitment, client's competencies, and contractor's competencies are important to bring about the successful outcome for public-sector D&B projects. The contractor's competencies also contribute to project time performance. All of these factors highlight that the D&B project success rests on the commitment of and efforts input by all parties to the project.

More is now known, as a result of this research, about what factors and how these factors affect success of design and build projects. Results from this empirical study have shown some interesting findings about construction project success pertaining to some key factors, performance measures, and their dependencies. This research provides greater insight into the key factors/criteria relationships that may impact project success and provide clients, contractors, and designers with an understanding of how to achieve outstanding results on their design and build projects.

Information from the research can benefit both the practice and the education of project management. In practice, the results can assist the selection of project team members, identification of their development needs, and forecast of performance level of a project before it commences. In education, the results can be used to design the content of management education programs for project managers running design and build projects.

It is hoped that through the participation in D&B projects, project team members can gradually improve their perpetual adverse relationships developed in the tradition procurement system. Practitioners are advised to adopt a new mindset to face the challenges presented by D&B projects. Playing one's own part well may be sufficed in the past, but it is the teamwork and partnering that bring project success in the years ahead. Project participants should also recognize that time and cost performance as well as quality of design and workmanship represent the key elements of overall success of D&B projects. More research should be conducted to further explore the relationship between the procurement method and project success factors.

APPENDIX I. SURVEY QUESTIONS

A list of 31 factors contributing to the success of D&B projects is shown below. Respondents were asked to rate each factor according to a five-point Likert scale (1 = strong disagree, 3 = neutral, and 5 = strongly agree).

The project success factors are as follows:

1. We had a thorough understanding of end-users' needs.
2. We had clearly articulated end-users' needs.
3. End-users did not have a thorough understanding of their needs.
4. End-users had given useful input to the D&B project.
5. The client had a good capability of managing the D&B project.
6. The client had a precise understanding of the D&B project scope before it was submitted to the contractor.
7. Pretender site investigation was comprehensive.
8. The client's brief/employer's requirements was clear.
9. Prequalification of potential tenderers was thorough.
10. Assessment of the contractor's proposals was thorough.
11. Little change in the client's requirements during construction had been made.
12. Project participants were satisfied with the financial return from the project.
13. All project participants shared a clear understanding of functional and technical performance required.
14. All project participants understood fully their new roles and duties in the D&B project.
15. All project participants accepted the changes of their roles and duties in D&B project.
16. All project participants understood fully how great the risk and legal liability they had to face.
17. All project participants accepted the risk and legal liability they had to face.
18. The architect had the capability of developing good design within budget and on schedule.
19. The architect had incorporated buildability in developing design.
20. The contractor's design consultants had a thorough understanding of construction process.
21. The contractor's design team worked under numerous constraints in the D&B project.
22. The contractor had a thorough understanding of the design process.
23. The contractor had good project management capability (planning and programming) for the D&B project.
24. The contractor had input building knowledge in design development.
25. The contractor had utilized special/innovative building techniques and materials to speed up the building process.
26. Monitoring and approval mechanisms for design changes were well established.
27. All project participants shared common project goals.
28. All project participants cooperated fully.
29. Adequate channel of communication among all project participants existed.
30. A high degree of trust was shared by all project participants.
31. Project participants resolved conflicts quickly.

APPENDIX II. REFERENCES

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