Determinants of Successful Design-Build Projects

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Abstract: A construction project is mostly initiated by the needs of the client. In order to satisfy the client's requirements in terms of time, cost, and quality, various procurement methods are recommended for selection to increase the chance of success for the complex sequence of activities. Design-build (D&B) integrates design and construction to overcome some of the hurdles inherent in the traditional design-bid-build method. It has been extensively used worldwide and its distinctive features are claimed to deal with the problems of the traditional design-bid-build method. An investigation into the determinants of successful D&B projects can therefore help set a benchmark study for industry practitioners to compare their project performance. To better indicate the success level of D&B projects, the writers developed a project success index for D&B projects in the Hong Kong context, which is assessed by the key project performance indicators of time, cost, quality, and functionality. Multiple regression analysis is then applied to show that the project nature, the effective project management action, and the adoption of innovative management approaches are the critical success factors for D&B projects. The identification of success criteria can furnish project participants with indicators to attain success for their D&B projects for benchmarking and control purposes. The predictors for D&B project success were also determined to enrich the knowledge base for the D&B procurement system.

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Introduction

The adoption of the traditional design-bid-build procurement method in the construction industry has become an invariably common practice (Rowlinson and Walker 1995). However, clients are becoming dissatisfied with the drawbacks bought about by the separated procurement system and opt for more integrated options (Deakin 1999). As a result, innovative procurement systems emerge and design-build (D&B) contracts become increasingly popular for building projects (Ndekugri and Turner 1994; Songer and Molenaar 1996).

The D&B project delivery system has gained increased market share in the last few years (Arditi and Lee 2003). Research and surveys reported in the construction press indicate considerable growth in construction procurement by the design-build approach (Ndekugri and Church 1996). It has been used throughout the world extensively for around 40 years and its popularity has gained substantially over the last 10 years (Ernzen and Schexnayder 2000). Achieving success in a construction project is an important goal of project participants. While success means different things to different people, the development of a project success index can quantify such an abstract concept so that project participants can compare the relative success level of their D&B projects. A further investigation into the causal relationships between the factors and the success indicator not only enhances the success level of a D&B project, but also improves both project performance and D&B team management strategies.

The methodology of the research will be outlined first. Then a comprehensive literature review on the criteria and factors of success for D&B projects will be presented. An empirical study has also been conducted with the D&B project participants in the Hong Kong construction industry to develop the project success index for D&B projects (PSI-D&B) with the use of principal components analysis. The success factors identified in the literature are also classified into factor categories by factor analysis for further investigations. The relationships between the dependent variable (project success index) and the independent variables (success factors) in delivering D&B projects are further established by regression analysis. The significance of the research will then be highlighted, followed by the conclusions of the paper.

Research Objectives and Methods

The concept of success remains vague among project participants, which makes it difficult to assess whether the performance of a project is a success or failure. Therefore, it is of great importance for industry practitioners to quantify the success concept in a scientific manner (Lam et al. 2007). The paper introduces the development of a project success index (PSI) for design-build projects and aims to find out the determinants of success for D&B projects. The objectives of the research are to: (1) formulate a project success equation to determine the success indicator of

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Table 1. Success Criteria for D&B Projects (Chan et al. 2002, ASCE)

Types	D&B project success criteria	Previous studies: Chan (2000)	Ndekugri and Turner (1994)	Songer and Molenaar (1996, 1997)
Objective	Time, cost, quality	√	√	√
	Safety	√		
Subjective	Meeting specifications/employer's requirements (ER)			√
	Conformance to expectation of project team members			√
	Satisfaction of project team members		√	
	Functionality	√		
	Aesthetics		√	
	Reduction in disputes		√	√

D&B projects (PSI-D&B); (2) identify the success factors for D&B projects; and (3) investigate the causal relationships between the critical success factors (CSFs) and the success indicator of D&B projects (PSI-D&B).

A comprehensive literature review was first conducted to provide the source of data on the criteria and factors of success for D&B projects. The literature was selected from the high-ranked journals in the construction field over the past 15 years, and the criteria and factors of success identified from the skeleton of the research questionnaire. Several statistical techniques were employed to analyze the data collected. Principal components analysis was adopted to develop a PSI. Sharma (1996) believed that the principal components analysis is an appropriate technique for developing an index since the squares of the weights sum to one. Factor analysis was used to identify underlying variables or factors that explain the pattern of correlations within a set of observed variables (Norusis 2002). This technique is powerful to reduce and regroup the factors identified from a larger number, to a smaller and more critical one by factor scores of the responses. Multiple linear regression analysis was further employed to establish and analyze the relationship between a single dependent variable and several independent variables. The technique can be used to relate a number of independent variables to a dependent variable by studying the relations among variables.

Success Criteria for Design-Build Projects

Success or failure of any project is greatly influenced by the performance of cost, time, and quality aspects of a project (Ratnasabapathy and Rameezdeen 2006). The last decade has seen considerable research into the development and implementation of performance indicators (Sohail and Baldwin 2004). Molenaar and Gransberg (2001) defined D&B as an alternative project delivery method that encompasses both project design and construction under one contract. Previous studies use D&B project success criteria to explain the reasons for selecting the D&B procurement method. Ndekugri and Turner (1994) stated that if the client's criteria are met, then the performance of the D&B project can be considered a success. Results from Songer and Molenaar (1996) indicated that the primary success criteria for D&B projects are on budget, on schedule, and conforms to user's expectations, which are all consistent with the success criteria of a construction project in general. Moreover, Chan (2000) judged the performance of an enhanced D&B project based on the criteria of time, cost, quality, functionality, and safety requirements. Chan et al. (2002) summarized the criteria of success for D&B projects (Table 1).

Success Factors for Design-Build Projects

Design-build offers a variety of advantages to better the implementation of projects (Rowlinson 1997; Leung 1999). Deakin 1999, and Pearson and Skues (1999) agreed that the factor of project characteristics in terms of a clearly defined scope is vital for the success of a D&B project. Songer and Molenaar (1997) matched the CSFs of D&B projects with project characteristics. The definition and understanding of project scope was concluded as the most important element for D&B project success. Rowlinson (1997) and Deakin (1999) further opined that the way for the project scope to be clearly defined is fundamentally dependent on a clear brief which is believed to be another important prerequisite for success. Leung (1999) suggested the factor of project participants as one CSF for D&B projects. The relationship among project participants has also drawn the attention of Rowlinson (1997) as one of the CSFs since a well-organized and cohesive facility team enables better management by the contractor. The characteristics of the contractor, in terms of D&B knowledge, experience and confidence, and the ability to maintain proper documentation are also highlighted (Songer and Molenaar 1996; Hemlin 1999; Leung 1999). End users' input is also considered necessary to enhance the degree of success for D&B projects (Pearson and Skues 1999). Ling and Liu (2004) further interpreted D&B project success into 11 performance metrics and identified 65 success factors.

While the review of literature provides theoretical background for the research, the writers conducted an empirical study with the D&B project participants in the construction industry of Hong Kong to collect data for further project success investigations.

Research Data

The questionnaires were piloted to the target D&B participants in the Hong Kong construction industry from January to March 2003, and a reminder was sent in 1 month's time in case the participants forgot to reply. As there is no public release on the list of D&B contractors, the respondents were selected from local journals and web pages of the client, contractor, and consultant companies to identify the respondents who should have experience in running at least one D&B building project in the public sector of Hong Kong. The research questionnaires were sent to 248 D&B participants in the construction industry of Hong Kong. Twenty one questionnaires were returned undelivered for reasons such as removal of office, thus reducing the number of questionnaires sent out to 227. As a result, 92 valid responses were re-

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ceived and analyzed, representing an overall response rate of 41%.

The respondents represented major stakeholders in D&B projects and they were asked to identify themselves to which D&B project stakeholders, namely client, contractor, or consultant organizations they belong. Almost half of the respondents (43%) are classified as contractors while nearly one quarter of them (24%) as clients. One third of the respondents (33%) were consultants, with 11% from architectural firms, 10% from quantity surveying (Q.S.) consultancy firms, 10% from engineering consultancy firms, and 2% from project management consultancy firms.

In the questionnaire, the respondents were asked to evaluate the factors affecting the performance of their D&B projects and at the same time they were requested to rate their level of satisfaction on such projects. These variables would be analyzed correspondingly. As a result, factors leading to a good or a bad D&B project would be identified accordingly. Data were collected from the respondents rating each attribute of the respective constructs on a seven-point Likert scale to indicate the level of agreement, ranging from "1" equal to "strongly disagree" to "7" equal to "strongly agree." The data were inputted into SPSS and statistical techniques were employed to analyze the data.

Project Success Index for Design-Build Projects

A comprehensive literature review has demonstrated that previous researchers have developed interests in establishing success criteria for D&B projects (Table 1). Such criteria were then listed in the survey questionnaire for respondents to prioritize according to their level of satisfaction on a seven-point Likert scale based on the following request:

"Please prioritize the success criteria for a D&B project."

Project stakeholders, namely client, contractor, and consultant with experience in running at least one D&B project would be invited to answer the questions. Definitions of the success criteria were conveyed to the respondents by means of sentences requesting their level of satisfaction, and the mean values of the success criteria were determined to indicate the degree of importance of the project success criteria for D&B projects from the perspectives of client, contractor, and consultant. Only those variables with mean scores higher than the average would be considered as the important success criteria for D&B projects, which are time, cost, quality, and functionality.

While Naoum (1994) measured the performance of time and cost by time overrun and cost overrun, Chan (1996) assessed such performance in terms of construction time and unit cost. In the research of a D&B procurement system, Songer and Molenaar (1997) interpreted the measurement for time, cost, quality, and functionality as "on schedule," "on budget," "high quality of workmanship," and "meeting specifications," respectively, whose definitions were adopted in this research since they were easily identified by the respondents in practice and were suggested by researchers in the previous D&B studies. The technique of principal components analysis was then applied to form new variables (indices) which are linear composites of the original variables (success criteria). The statistical results are shown in Table 2.

The eigenvector with the highest eigenvalue is the principal component of the data set, and the eigenvalue determines the number of principal components that should be retained without a substantial loss of information (Sharma 1996). The selection of principal components is based on the eigenvalue greater than one rule, which states that only those variables whose eigenvalues are greater than one are retained. The eigenvalues are then ranked from the highest to the lowest to show the order of significance by naming the first order, the second order, and so on (Smith 2002). As a result, the project success index for D&B projects was calculated by the following equation

$$\text{PSI-D\&B} = 0.54 \times \text{time} + 0.55 \times \text{cost} + 0.47 \times \text{quality} + 0.42 \times \text{functionality}$$

and the value obtained will be taken as the dependent variable (PSI) for regression analysis. From the equation, it is suggested that time and cost are the indicators of success for D&B projects, which agrees well with most D&B literature on the time and cost benefits that project participants can enjoy when compared with the traditional design-bid-build procurement method. In fact, D&B offers reduction in project time from the overlapping of design and construction, and better "value for money" option through the selection of alternative design proposals. Therefore, the performance of time and cost of a D&B project can significantly affect the overall success level as represented by the project success index, PSI-D&B.

Table 2. Principal Components Analysis of Success Criteria for D&B Projects

Order	Item	Criteria	Eigenvectors	Eigenvalues
1st	A	Time	0.54	
	B	Cost	0.55	
	C	Quality	0.47	
	D	Functionality	0.42	2.19
2nd	A	Time	−0.48	
	B	Cost	−0.39	
	C	Quality	0.39	
	D	Functionality	0.69	0.84
3rd	A	Time	0.07	
	B	Cost	0.16	
	C	Quality	−0.79	
	D	Functionality	0.59	0.61
4th	A	Time	0.69	
	B	Cost	−0.72	
	C	Quality	−0.02	
	D	Functionality	0.08	0.36

Factor Analysis on Success Factors

Factor analysis was next employed to analyze the structure of interrelationships among the large number of variables by defining a set of common underlying factors (Hair et al. 1998). It is conducted through a two-stage process: factor extraction and factor rotation (Norusis 1993). The goal of factor extraction is to determine the factors through principal components analysis, whereas that of the second stage, factor rotation, is to make the factors more interpretable. The results of the factor analysis of the 42 independent variables are shown in Table 3.

The eigenvalue represents the total variance explained by each factor. For instance, the linear combination formed by component 1 has a variance of 11.03, which accounts for 26.27% of the total variance of the 42 factor variables. The Kaiser–Meyer–Olkin test

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Table 3. Variances Explained by Success Factor Variables

Component	Eigenvalue	Percent of variance explained	Cumulative percent of variance explained
1	11.03	26.27	26.27
2	3.96	9.43	35.70
3	3.39	8.06	43.76
4	2.82	6.71	50.47
5	2.34	5.58	56.05
6	2.02	4.82	60.87
7	1.82	4.34	65.21
8	1.41	3.36	68.57
9	1.39	3.31	71.88
10	1.24	2.95	74.82
11	1.10	2.61	77.44
12	1.01	2.41	79.85
13	0.89	2.11	81.96
14	0.82	1.95	83.91
15	0.79	1.89	85.80
16	0.68	1.62	87.41
17	0.59	1.41	88.82
18	0.57	1.35	90.18
19	0.46	1.10	91.28
20	0.45	1.07	92.35
21	0.37	0.88	93.24
22	0.32	0.76	94.00
23	0.28	0.66	94.66
24	0.27	0.64	95.30
25	0.25	0.59	95.88
26	0.24	0.58	96.46
27	0.20	0.48	96.94
28	0.18	0.42	97.36
29	0.17	0.41	97.77
30	0.16	0.38	98.15
31	0.14	0.3	98.48
32	0.11	0.26	98.74
33	0.10	0.23	98.97
34	0.08	0.19	99.16
35	0.08	0.18	99.34
36	0.06	0.15	99.49
37	0.06	0.14	99.63
38	0.05	0.12	99.75
39	0.04	0.09	99.83
40	0.03	0.08	99.91
41	0.02	0.06	99.97
42	0.01	0.03	100.00

(KMO) is a measure of sampling adequacy that compares the magnitudes of the partial correlation coefficients. Kaiser (1974) recommended KMO values of greater than the threshold of 0.5 as acceptable and the KMO value obtained in the research is 0.635, which is of mediocre nature and is above the acceptable threshold (Norusis 1993). Moreover, the factor extraction process should be terminated when a threshold for maximum variance extracted (e.g., 75–80%) has been achieved. Table 3 shows that almost 80% of the total variance is attributable to the first 12 factors. Therefore, a model with 12 factors is considered adequate to represent the data.

To identify the factors, it is necessary to group the variables that have large loadings for the same factors (Norusis 1993). In fact, factor analysis does not attach labels to the factors and the substantive meaning given to a factor is typically based on the examination of what the high loading variables measure (Kim and Mueller 1978). The principal components analysis with Promax rotation on the 42 success factor variables produced 12 factor categories, which are labeled and described as Table 4.

In addition to identifying the success factors for D&B projects, multiple regression analysis was adopted to investigate the causal relationships between the CSFs and the success indicator of D&B projects (PSI-D&B).

Multiple Regression Analysis

Multiple regression analysis is a statistical technique used to analyze the relationship between a single dependent variable (project success index) and several independent variables (success factors). It describes the process of constructing a mathematical expression or equation used to represent the behavior of the phenomenon being studied (Black 1997). To compare across regression equations involving different numbers of independent variables or different sample sizes, the adjusted coefficient of determination (adjusted R^2) is calculated to reflect the goodness of fit of the model.

Regression Models

Multiple linear regression analysis was employed to study the relationships between the PSI-D&B (dependent variables) and factors (independent variables) of success for D&B projects. The sets of regression equations can be expressed as follows

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \varepsilon_i; \quad i = 1, \dots, N$$

In the regression equation, β_0 represents the intercept while $\beta_1, \beta_2, \dots, \beta_k$ = regression coefficients which denote the estimated change in the dependent variable Y for a unit change of the independent variables X_2, $X_3, \dots, X_k$. The prediction error, ε, or the residual, is the difference between the actual and predicted values of the dependent variable. While the assumptions of independence, linearity, and constant variance can be tested by plotting the standardized deleted residuals against the standardized predicted values, normality can be observed by the normal probability plot which displays cumulative normal distribution as a straight line (Belsley et al. 1980). It can also be tested by generating skewness values (Table 5). Results show that all except one skewness value fall within the range of $-1 - +1$, indicating an acceptable skewed distribution (Hair et al. 1998). The results of regressions on the single dependent variable (PSI-D&B) and the 12 independent variables (success factors) are presented as Table 6.

Regression Results on Project Success Index

The critical success factors for PSI-D&B include the project nature, the effectiveness of project management action, and the application of innovative management approaches, and the multiple regression equation (PSI) is

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Table 4. Factor Loadings of Success Factor Variables

Success factor item	Factor loading	Percent of variance explained	Cumulative percent of variance explained
(a) Factor 1: Competency of client body ($F1$: CPC_CLT)			
Project management skills of client's representative	0.807		
Client's involvement in the project	0.802		
End users' involvement in the design-build process	0.788		
Commitment and adaptability of client's representative	0.771		
Decision-making power of client	0.762		
Delegation of decision-making authority from the client	0.760		
Experience and capabilities of client's representative	0.680		
Technical skills of client's representative	0.667	26.268	26.268
(b) Factor 2: Competency of construction team leader ($F2$: CPC_CTR)			
Project management skills of the construction team leader	0.937		
Experience and capabilities of the construction team leader	0.910		
Commitment and adaptability of the construction team leader	0.871		
Technical skills of the construction team leader	0.853		
Support from the parent company of the construction team leader	0.677	9.434	35.702
(c) Factor 3: Effectiveness of project management action ($F3$: EFF_PMA)			
Up-front planning efforts	0.805		
Effectiveness of communication	0.796		
Effectiveness of control systems	0.791		
Effectiveness of management systems	0.781		
Effectiveness of organizational structure	0.726	8.059	43.761
(d) Factor 4: Competency of contractor's design consultants ($F4$: CPC_COT)			
Experience and capabilities of contractor's design consultants	0.870		
Technical skills of contractor's design consultants	0.846		
Commitment and adaptability of contractor's design consultants	0.828		
Project management skills of contractor's design consultants	0.767		
Support from the parent company of contractor's design consultants	0.623	6.707	50.468
(e) Factor 5: Working relationships among project team members ($F5$: WKR_MBR)			
Harmonious working relationships among project team members	0.831		
Confidence level of the construction team leader	0.827		
Cohesiveness of the D&B team	0.813		
Delegation of decision-making authority from the construction team leader	0.753	5.581	56.050
(f) Factor 6: Client's input in the project ($F6$: CLT_INT)			
Scope of the project	0.692		
Client's ability to brief the design team	0.655		
Clarity of client's requirements	0.626	4.818	60.868
(g) Factor 7: Project nature ($F7$: PJT_NTR)			
Room for contractor's input	0.792		
Attractiveness of the project	0.770		
Complexity of the project	0.619	4.340	65.208
(h) Factor 8: Client's emphasis on time and cost ($F8$: CLT_T&C)			
Client's emphasis on time	0.826		
Client's emphasis on cost	0.649		
Political environment	0.583	3.361	68.569
(i) Factor 9: Application of innovative management approaches ($F9$: APP_IMA)			

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Table 4. (*Continued.*)

Success factor item	Factor loading	Percent of variance explained	Cumulative percent of variance explained
Adoption of innovative management approaches	0.836	3.308	71.877
(j) Factor 10: Client's emphasis on risk transfer ($F10$:CLT_RTR)			
Client's emphasis on single point of responsibility	0.721		
Client's emphasis on transfer of risk	0.581	2.947	74.824
(k) Factor 11: Physical and social environments ($F11$:P&S_ENV)			
Physical environment	0.738		
Social environment	0.604	2.611	77.435
(l) Factor 12: Economic environment ($F12$:ECO_ENV)			
Economic environment	0.729	2.414	79.849

$$PSI = 10.291 + 0.664 \times PJT\_NTR + 0.602 \times EFF\_PMA + 0.441 \times APP\_IMA$$

and 54.9% of variance of PSI can be explained by the variables.

In order to test the validity of the model, the research collected five test samples from the Hong Kong construction industry and the data were collected to compute the factor scores for substitution into the multiple regression equations. As a result, the computed values of the success measure (PSI-D&B) for the five test samples can be obtained from substituting the respective factor scores into the project success equation. At the same time, the respondents were asked to express their satisfaction level with the performance of the four identified success criteria for the D&B projects, which were described as the "actual" values for the project success index. The paired-samples t test was next employed to detect whether there is a significant difference between the computed and actual values of PSI-D&B (Table 7).

Since the two-tailed significance for PSI-D&B is larger than 0.05, there is insufficient evidence to reject the null hypothesis that there is no difference for the paired data (computed and actual values) of the project success index. Therefore, it can be concluded that the research outcomes are valid for predicting success for D&B projects.

Discussions on Effects of Success Factors on PSI

Project Nature

Multiple regression analysis has assisted in developing a conceptual model to link the critical success factors to the PSI, based on the data from the Hong Kong construction industry. The research suggests that

> "The nature of D&B projects is positively associated with its overall success level."

The nature or characteristics of a D&B project can be described by whether the project provides room for the contractor's input, the attractiveness of the project, and the complexity of the project. If a D&B project is prestigious and has a high value to the contractor, the contractor naturally will put forth extra effort to accomplish the project. If the D&B project provides room for the contractor to input his knowledge and expertise, the D&B project can become more buildable to enhance the success level. Moreover, the D&B project should be flexible so that the contractor can provide alternative solutions for the client to choose the best value option. Leung (1999) suggested that the contractor should be allowed to design structures to suit their construction method so that the performance of the D&B project can be improved. The contractor may also be attracted to the unique nature of the D&B

Table 5. Skewness Values for Regression Analysis

Factor	$F1$	$F2$	$F3$	$F4$	$F5$	$F6$	$F7$	$F8$	$F9$	$F10$	$F11$	$F12$
Skewness	−0.40	−0.51	−0.01	−0.63	−0.54	−0.26	−0.08	−0.50	1.17	−0.06	−0.07	−0.50

Table 6. Multiple Regression Analysis for PSI-D&B

Variables	Unstandardized beta coefficients	Standardized beta coefficients	Significance level	VIF	Adjusted R^2
Project nature (PJT_NTR)	0.664	0.417	<0.001	1.112	—
Effectiveness of project management action (EFF_PMA)	0.602	0.371	<0.001	1.106	—
Application of innovative management approaches (APP_IMA)	0.441	0.275	0.005	1.125	0.549

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Table 7. Validation for PSI-D&B

	PSI-D&B	
	Computed	Actual
Case 1	9.75	10.32
Case 2	8.85	9.71
Case 3	10.41	11.88
Case 4	10.18	7.92
Case 5	12.27	13.63
Mean	−0.399	
Standard deviation	1.530	
Standard error of mean	0.684	
t value	−0.58	
Significance (two-tailed)	0.59	

project so that each tenderer can submit a distinctive proposal based entirely on the expertise of the D&B team

Effective Project Management Action

Effective project management action is another critical success factor for D&B projects, and the research suggests that

> "More effective project management action increases the overall success of a D&Bproject."

Effective project management action can shorten project time since proper planning from site to office can allow optimum overlaps between design and construction phases. Deakin 1999 reported that project management action and proper contract documentation can improve the quality performance of a D&B project. Effective means of communication can also safeguard transmission of messages among project participants from site to office in order to reduce abortive work. Pearson and Skues (1999) described the specific controls in the design development process and the approval of design applied to a D&B project, which are fundamental to satisfying functional requirements. Regular monitoring of construction works can further improve the quality of workmanship, and the implementation of an approved quality system can guarantee the quality standard of the D&B project (Leung 1999). Therefore, D&B projects require proper contract documentation, specific controls in the design development process, and the approval of design and project procedure manuals defining the roles and responsibilities of the key participants

Adoption of Innovative Management Approaches

Application of innovative management approaches has a significant impact on achieving successful performance of D&B projects, and the research suggests that

> "More frequent use of innovative management approaches such as value management and partnering can result in the overall higher success level of D&B projects."

Value management is a value enhancement exercise that seeks to provide the best value for money option for the project. Cheng (1995) reported that value management has been carried out in D&B projects to eliminate costs without additional value. Therefore, the adoption of value management can lead to better cost-performance without adversely affecting the quality of performance. Shen et al. (2004) noted that value management has been considered in the process of client's requirements, and its essential feature is function analysis, which enables a systematic identification and clear definition of the client's requirements. In fact, value management requires teamwork at the early stage of a project where project participants meet together with the aim of optimizing cost in the project. Such an arrangement can be further achieved by the use of partnering which stresses mutual trust among project participants.

Partnering is a simple process of establishing good relationships between contracting parties, and it is designed to minimize job costs and schedule overruns (Chan et al. 2004). Therefore, significant time can be saved from communication among project participants who share common goals for the D&B project. Deakin 1999 pointed out that the use of partnering can enhance the quality performance of a D&B project while Hemlin (1999) suggested that the true D&B team should be a partnership among the client, contractor, and consultant. Pearson and Skues (1999) also described the importance of a team approach to the successful delivery of D&B projects, and believed that partnering enables the contractor to proceed with work prior to resolving disputes. Indeed, project partnering was found to provide construction projects with improved time and cost benefits to both clients and contractors (Chan et al. 2004).

Significance and Limitations of Research

Design-build integrates the design and construction phases to alleviate the problem of fragmentation confronting the construction industry. It has been widely adopted in most western countries and it is increasingly applied to construction projects in Hong Kong. A comprehensive investigation of success for D&B projects in the local context has been initiated in this research which identified time, cost, quality, and functionality as the key performance indicators (KPIs) of D&B projects. The identification of success criteria can furnish project participants with indicators to attain success for their D&B projects for benchmarking and control purposes. Moreover, CSFs can provide participants with a focus of what they should be aware of in order to ensure the success of a project. Such an improved understanding can generate essential strategies to alleviate the root causes of poor performance and ineffective communication. Effective strategies can also be suggested for preparing project procedure manuals for project control, as well as for conducting D&B workshops and compiling guidance manuals to enhance overall project delivery performance.

One major limitation is the limited scope of the research. Moreover, the sample size used in factor analysis has drawn much attention. In general, larger samples may reduce sampling error and the factor analysis solutions can more accurately recover the true population structure (MacCallum et al. 1999). Another limitation of the research is concerned with small samples which may increase the likelihood of nonconvergent solutions. Some previous researchers still applied factor analysis to their research with a smaller ratio, probably because the data have uniformly high communalities without cross loadings (Ling 2003; Li et al. 2005; Ling et al. 2005). Indeed, the move from KPI to PSI-D&B has provided valuable insights into the performance measures of D&B projects in the construction industry. By bringing together the construction experience of the contractor with the design experience of consultants, the resulting building can be technically more efficient and the overall buildability of the project can be improved. It also allows truly collaborative decision making to

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create an environment of collaboration for effective cooperation (Akintoye and Fitzgerald 1995).

Conclusions

Success is achievable. It is necessary to quantify such an abstract concept so that project participants can compare their project performance levels for benchmarking purposes. This research modeled the success of a D&B project with its critical success factors. This is because success is attributed to a number of factors which are large in number and project participants can only focus on the few most important ones. It investigated the causal relationships between the CSFs and the success indicator of D&B projects (PSI-D&B). The model can be used by the D&B project participants to compare the degree of success among different D&B projects by substituting the scores on the success criteria and comparing the resultant PSI-D&B scores with different D&B projects (Lam et al. 2007). It enables industrial practitioners to identify those more crucial factors affecting the success level of their D&B projects so that proper management approaches can be applied. Future research can be done on analyzing various views of clients, contractors, and consultants when more samples are collected. Other research methodologies like fuzzy logic theory and artificial neural network can also be applied when more data are gleaned for comparative studies with the groundwork of the current research.

D&B project participants suggests that time, cost, quality, and functionality should be the principal success criteria for D&B projects. A success indicator (PSI-D&B) has also been created from the project success equation for industrial practitioners to apply different weightings to the respective success criteria with different levels of significance. Moreover, the determinants of D&B project success include the project nature, the effectiveness of project management action, and the application of innovative management approaches. Findings from the research can provide a series of practical recommendations for project stakeholders to help better implement the D&B delivery method. It is teamwork and partnering that will result in overall project success in the years ahead.

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