QUANTITATIVE ANALYSIS ON PROJECT PERFORMANCE ANALYSIS AND DELIVERY METHODS

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ABSTRACT: Various project delivery methods have been utilized by owners over the years to maximize project performance. The design-build delivery method is being increasingly used due to the advantages it can offer to an engineering construction industry. Numerous studies have advocated the use of design/build over the traditional design/bid/build delivery approach. This study represents comprehensive analysis of 40 projects from the construction industry and shows that design/build method may not provide all the benefits to project performance. This study found timesaving was a definitive advantage of design/build project delivery, but the positive effects of cost changes was not convincing. Based on the results of the study, the project management expertise and experience of the contractor may have a greater impact on project performance outcomes than focusing on project delivery strategy only.

Keywords: performance measures; cost performance; schedule performance; contract type; project delivery methods

1. INTRODUCTION

The construction industry is one of the largest industries in North America and worldwide (McKim et al. 2000). Measuring the performance of any project in terms of success or failure is a complex process. Notably, due to the increase of project complexity, modern construction projects are often failed to achieve a total success in terms of project performance (Doloi and Lim 2007). Delays in completion and over spending are common problems besetting the project delivery process. The construction industry has been searching for effective project delivery methods to maximize project performance over the past decades. There is the traditional project delivery strategy, design/ bid/build (D/B/B), and alternative delivery methods such as design/build (D/B). Currently, no single project delivery system is most appropriate for any kind of project. Instead, combinations of different strategies are used for different circumstances (Gordon 1994).

The purpose of this study is to compare the effectiveness of an alternative project delivery method (D/B) with the traditional method (D/B/B). This paper quantitatively examines the relationship between impacts on project performance and change by applying different project delivery approaches. Performance data such as cost and schedule are used to compare the average amounts of change for two different project delivery strategies. Data are collected using a questionnaire survey followed by structured interviews with project participants to elicit success-related factors and to identify critical factors affecting project performance. Statistical tests are conducted to analyze the data to determine whether the delivery method decision significantly impacted the project performance as represented by cost and time.

2. LITERATURE REVIEW

Literature reviews have shown that a successful project can be defined as a project that has been completed on schedule and within budget. Effective management has proven to be essential in controlling costs and adhering to schedules for most types of projects (PMBoK 2004). Although there are a significant number of studies in the construction industry in the past, construction project performance is yet to achieve its maturity in terms of management of core knowledge areas defined in PMBoK (2004). Several research studies are available that looked into the factors that influence performance of a project. Different scholars have defined several factors proven to make major impact on cost and schedule of the global project. Also, several studies show that project characteristics such as delivery method, contract language and project complexity are major factors that affect performance of a construction project.

Baccarini (1999) suggested a successful project can be defined in two distinct components namely the "two concepts": project management success and product success. The first concept focuses upon the project success in particular the successful accomplishment of the

project time, cost and quality, which can be measured in terms of meeting the project schedule, budget, and conformance to functional and technical specifications respectively. The later concept deals with the effects of the project final product that has three key components to satisfy the project goal, project purpose and project stakeholders. Project characteristics and their impact on project success, however, were not analyzed.

Konchar and Sanvido (1998) analyzed the relationship between schedule-cost changes and the type of implemented project delivery system. It was found that D/B/B was 11.4% more likely to suffer changes in schedule than D/B during the design and construction process. The changes in schedule and cost for each of the two project delivery methods were separated into the design phase and construction phase to better understand where the delays and changes occurred. Molenaar et al. (1999) studied the impact of D/B project delivery method on the performance of public projects. Performance of several D/B projects was evaluated based on owner's experience with D/B projects, selection of D/B contractor, contract type, award method, and form of D/B contract (one-step, two-steps, qualifications based). Performance criteria were defined by budget performance, schedule performance, administrative burden, and owner satisfaction.

Thomas (2000) studied the changes in cost in relative terms (increase or decrease in time and cost), due to the fact that positive (increase) or negative (decrease) changes can both be good or bad for a project under different circumstances. Ibbs et al. (2003) compared the traditional D/B/B and the D/B project delivery methods. They examined the relationship between impacts on project change by applying those two project delivery approaches while using cost, schedule and productivity as performance data. It was found that D/B did not perform much better than D/B/B in terms of cost and productivity.

Hao et al. (2008) showed that a change is a common denominator in all construction projects. The study identified changes as the major cause of project delay, cost overruns, defects and project failure. Change management cannot rely on software tools available on the market since they lack many solutions (e.g. change estimation, impact analysis, post-change analysis, statistics, and change traceability. The study proposed a generic change process model that has five stages in a sequence: identify, evaluate & propose, approve, implement and review. An integrated change management system requires technical supports from different technologies, including collaborative workflow, system integration and collaboration technologies, web-based collaborative project management tools, and online document management tools. The study did not take a project delivery method into consideration.

Issac and Navon (2008) have proposed a change control tool which creates requirement traceability through links between client requirements and the building design. They believe that number of changes or the impact of changes can be controlled by capturing client requirements accurately at the beginning of the project and through the requirement traceability that is build up afterwards. This study did not consider many factors that impact the project in terms of project characteristics. Also, they put a major emphasis on the planning phase of a project by studying the client requirements and ignoring all other factors that could have a major impact on controlling a change.

The primary objective of this research is to enhance the current construction industry by achieving a better understanding on modern construction project management and minimize the risk of project failure by quantitatively investigating the correlation between the selection of project delivery method and the performance of the project. This paper examines the relationship between impacts on project performance and project changes by applying different project delivery approaches. The study considers the impact of the traditional delivery method, Design/Bid/Build (D/B/B), and alternative delivery method, Design/Build (D/B) on the project performance and potential change orders generated on these projects. Cost and schedule are used as the main project performance indicators.

3. RESEARCH METHODOLOGY

We collected performance data using a questionnaire survey from 40 construction projects. The survey data collection method was selected because it possesses numerous advantages. Several questions can be asked regarding the topic of the study simultaneously, which adds flexibility to the analysis. The majority of the projects targeted here are located in different states. This condition favors the use of the survey collection method because it is relatively inexpensive and easier to administer. As part of the questionnaire, participants were asked to fill out basic information about the project. This includes project delivery methods and information about the amount of changes that occurred and how the schedule changed during the projects. The survey is followed by structured interviews with project participants to elicit success-related factors. Using the collected data, performance comparison is conducted between these construction projects along with their project delivery methods. Two performance measures are analyzed; cost and schedule in relation with change orders occurred in each project. To analyze and compare between the performances of these construction projects, quantifiable measures of the cost and schedule performances are established. Several metrics were used to measure the project performance. T-test statistical analysis were used to determine the effect of the selected delivery method on the previously defined performance metrics.

4. DATA COLLECTION AND ANALYSIS

Data were collected using a questionnaire survey for followed by structured interviews with project participants. The respondents were asked to provide the following details: Project name and description, Project client, Date started and completed, Project delivery and contract types, Project location, Original contract value,

Contract value on actual completion (after project completion), Original contract duration, Actual contract duration (after project completion), Number of change orders, Total value of the change orders, Number of prime and sub contractors in the project, and Other data available that might be important for this research. After collecting all necessary data for each project, projects were grouped together according to their delivery methods. As a result, two groups were generated and each project fell under one of the following groups/categories: Design/Bid/Build or Design-Build delivery method.

All these projects were 100% construction complete. The data used for the analyses presented in this study are collected from 40 projects; 50% of the total number of projects falls under Design/Bid/Build category and the remaining 50% falls under the Design/Build category. All projects in this study are located in the United States, with total installed cost varying from $160K to $16 M. Also, 82% of these projects has a firm fixed price contract type and the remaining 18% has a cost plus fee contract type. Most projects were between $1 M and $10 M according to their total installed cost. Also, there is a couple of projects ranges between 10M to $15 M and a few others between $160 K to $1 M.

4.1 Changes in Cost versus Project Delivery

Figure 1 shows that the projects using D/B/B experienced about 6.75 % change in cost (cost reduction or increase), while 11.66 % for projects using D/B experienced cost changes. Changes may be negative (if they increase the cost of the project) or positive (if they reduce the cost of the project).

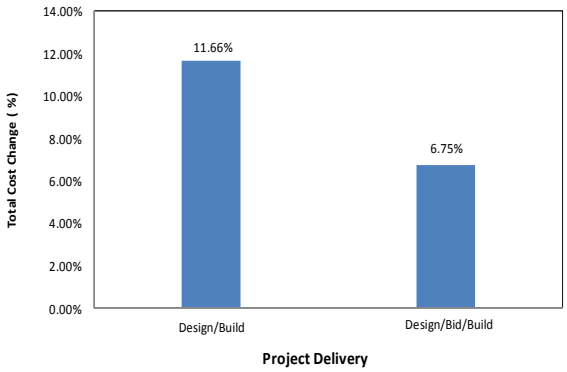

Figure 1. Change in cost versus project delivery

D/B/B projects experienced changes 6.75 % (Approx. $3,554,085). One interpretation is possibly due to changes in the scope of work or other similar changes based on project managers responses interviewed in these projects. Meanwhile, D/B projects have experienced on average about 11.66 % (Approx. $8,454,475) of higher changes, which means that the cost has usually increased when a project used D/B as a project delivery method. This effect is most probably due to the fact that D/B projects do not start with a well-defined scope. These results mean that D/B/B projects did seem to be a cost-saving strategy more than D/B. Cost changes between D/B/B and D/B demonstrate that the number of positive changes occurred that decreased the total installed cost of the project is higher in D/B/B than in D/B projects. The data confirmed the previous study (Ibbs et al. 2003).

4.2 Changes in Schedule versus Project Delivery

Schedule changes were studied in similar to those analyzed in cost changes. Figures 2 and 3 show changes in schedule in relative terms for the total duration of the projects.

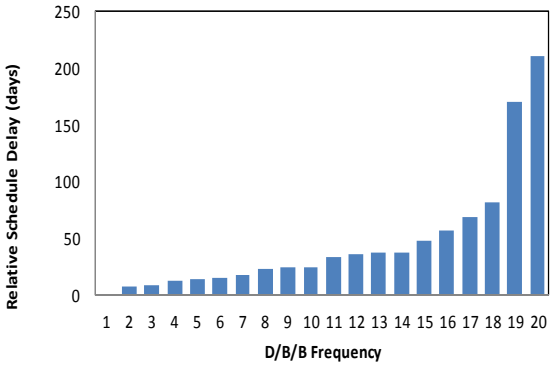

Figure 2. Relative change in schedule for D/B/B

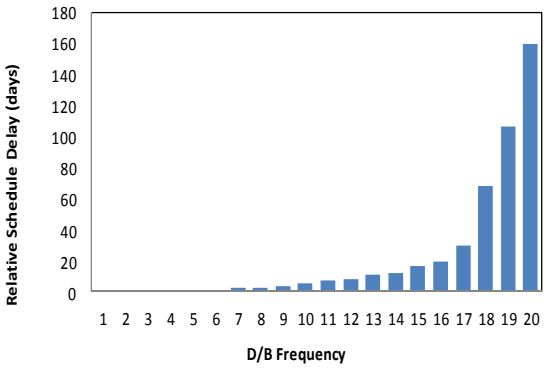

Figure 3. Relative change in schedule for D/B

D/B/B projects experienced about 15.64% (914 days) changes, while D/B projects only had 8.62% (456 days) changes. This means that D/B projects performed better than D/B/B projects, as shown in Figure 4. On the issue of saving time by applying the D/B approach, the data confirmed other studies and literatures (Molenaar et al. 1999).

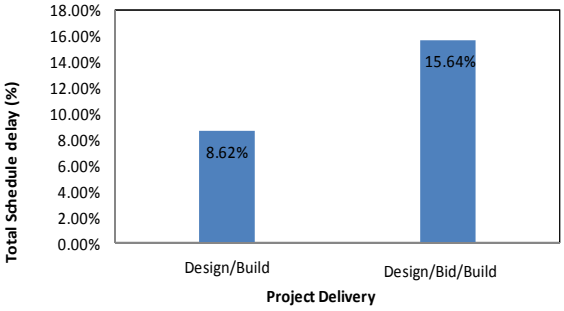

Figure 4. Change in schedule versus project delivery

4.3 Statistical Analysis

In order to further analyze the data, statistical analysis using t- test technique was performed to compare project performance between two project delivery methods. The objective of using t-statistic was to further describe the nature of the relationship that may exist between delivery methods and project performance. This technique was used to make an inference on the mean of the population differences with the assumption that the distribution of differences is approximately normal. The point estimate of the mean is the mean of the sample difference. Figure 5 shows the distribution of the data of equal samples as scattered diagram, which compares the average change order values in dollar amount between D/B/B and D/B approaches.

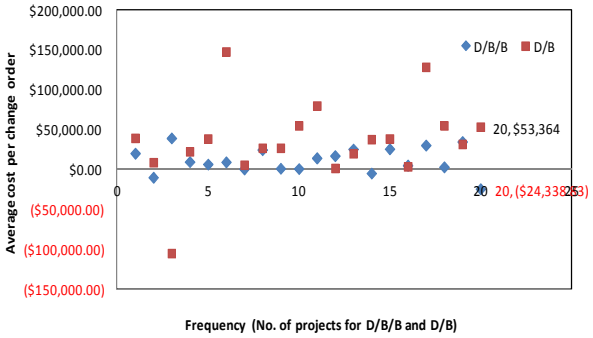

Figure 5. Comparison of average cost per change order

Similarly, Figure 6 shows the distribution of the average delay for change orders between D/B/B and D/B. In this case, three outliers were found (two for D/B/B and one for D/B). The definition of an "outlier" is an observation that "appears" to be inconsistent with other observations in the data set and is numerically distant from the rest of the data (Walfish 2006). Grubbs (1969) defined an outlier as "An outlying observation, or outlier, is one that appears to deviate markedly from other members of the sample in which it occurs." Outliers indicate that some data points are further away from the sample mean than what is deemed reasonable and that some observations are far from the center of the data. Outlier points can therefore indicate faulty data. Since including an erroneous value in the analyses will give invalid results, therefore outliers were removed. After eliminating the outliers, descriptive statistics values for the project data; mainly for average cost value and schedule delay per change order, were calculated. These include the mean, median and standard deviation values.

The hypotheses to test whether the average cost value per change order for D/B delivery method (µDB) obtained from the data exceeds the average cost value per change order for D/B/B (µDBB) are Ho: µDB - µDBB = 0 and Ha: µDB - µDBB > 0. In order to identify which delivery method is performing better for each performance metric, normality for each of the performance metrics at a confidence level of 95% was checked (this means the significance level is 5% or 0.05). This value of confidence interval was chosen because it represents the interval where 95% of the sample estimates lie and is commonly used through statistical data testing (Ott 1992).

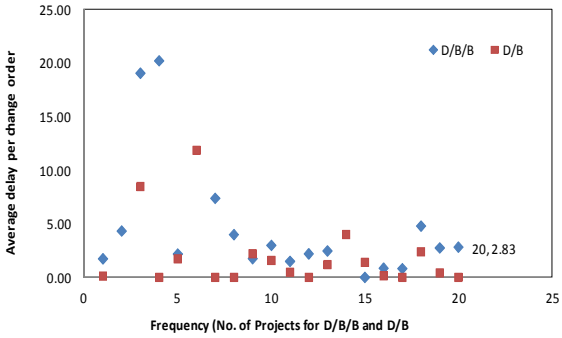

Figure 6. Comparison of average schedule delay per change order

Table 1 tabulates the statistical results for the average values between the two delivery approaches. The average cost values for change orders in D/B/B and D/B were found as $11,533.19 and $35,872.11. For the test analysis of the average cost value, we reject the null hypothesis because the observed significance level of p-value of 0.02 is less than the significance level (0.05). Therefore, we have sufficient evidence to conclude that the mean difference is greater than zero or the mean values for average cost per change order for D/B exceeds the values for average cost per change order for D/B/B. In other words, and according to the data analysis, D/B/B resulted in higher cost saving than D/B method.

Table 1. Statistical Analysis for Cost Changes

Schedule	D/B/B	D/B
Sample (n)	20	20
Mean	$11,533.19	$35,872.11
Std. Dev.	$15,990.80	$50,516
t-value (p-value)	2.05 (0.02)	

Respectively, the hypotheses to test whether the average schedule delay per change order for D/B delivery method (µDB) exceeds the average schedule delay per change order for D/B/B (µDBB) are Ho: µDB - µDBB = 0 and Ha: µDB - µDBB < 0. Normality for each of the performance metrics at a confidence level of 95% was checked in order to identify which delivery method is performing better in terms of schedule. Table 2 tabulates the statistical results for the average values of schedule delay between the two delivery approaches.

Table 2. Statistical Analysis for Schedule Changes

Schedule	D/B/B	D/B
Sample (n)	18	20
Mean	4.56	1.90
Std. Dev.	5.76	3.17
t-value (p-value)	-1.37 (0.048)	

The average schedule delay for change orders in D/B/B and D/B were found as 4.56 (days) and 1.90 (days). For the test analysis of the average schedule delay, we reject the null hypothesis because the observed significance level of p-value of 0.048 is less than the significance level (0.05). Therefore, we have sufficient evidence to conclude that the mean difference is less than zero or the mean values for average schedule delay per change order for D/B/B exceed the values for average schedule delay per change order for D/B. In other words, D/B experienced less schedule delay and performed better than D/B/B in terms of keeping the project within the original schedule limit.

5. DISCUSSIONS

The D/B project delivery method has gained a lot of interest in recent years. Construction magazines and various reports presented D/B as the most appropriate choice to bring a project to completion on time and on schedule (Capps 1997). Another study showed that D/B may not provide all the benefits to project performance. The study found timesaving was a definitive advantage of D/B project delivery, but the positive effects of budget and the benefit of cost saving and productivity changes were not convincing (Ibbs et al. 2003). Other papers have focused on developing guidelines for contractors and owners to avoid misuse of the D/B method (Tarricone 1996). Also another study showed that a combination of strategies could work more effectively than D/B or D/B/B alone (Pocock and Liu 1996). Also, another study pointed out, the design-build method may not provide the owner with a true advocate during either the design or construction phases. Additionally, it has been noted that the design-build approach does not necessarily reap the benefits of collaboration where the design-build entity utilizes a more traditional command and control approach with the key trades (Tanner and Leiby 2012).

In this study, and during the interview, the participants were asked about reasons for cost and schedule overrun. Responses indicated that undefined scope was the major factor contributed to cost overrun for D/B projects. On the other hand, the respondents' answers related to the reasons for cost and schedule overrun in D/B/B indicated that unforeseen site condition, procurement problem and scope changes by owner were the most cited factors contributing to cost and schedule overrun in D/B/B projects. Although, results in this study showed that most construction projects that used D/B/B had a higher number of change orders during construction, their real value in dollar amount of change was lower than for D/B projects.

6. CONCLUSIONS

This paper presents a comparison study that revealed that D/B did not perform much better than D/B/B. While timesaving is a definitive benefit for using D/B as a project delivery strategy, the benefits in cost savings are debatable. Cost changes were more toward the increase side for D/B, while they tended to decrease for D/B/B projects. The data analysis revealed that no procurement method outperforms the other methods with regards to the performance metrics analyzed. Meanwhile, several trends that were identified indicated that different procurement methods are recommended to meet different performance requirements. Both project delivery methods may work well because the outcomes depend on the expertise and experience of those administrating the project in design and construction. Also, the owner needs to be educated and informed about conveying ideas to the contractor in preparing the design specifications to ensure success when adopting the D/B approach. There are many issues that a client or contractor may want to address before selecting one or various appropriate delivery methods according to the projects' needs. Owners can first identify their critical project requirements, consider the resulting trends for the performance metrics, and select the delivery approach accordingly. This paper and its analyses may be used as a source of information with which stakeholders may observe the sensitivity of the budget and schedule of a project to changes under a D/B or D/B/B project delivery method.

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