Comparing Procurement Methods for Design-Build Projects

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ABSTRACT

The design-build delivery method is increasingly used due to the numerous advantages it can offer to a project. An important issue associated with design-build delivery is the procurement method used to select the design-build team. It is a critical decision that involves several key project team members and requires the owner to carefully select the design-build team expected to successfully deliver the project. This research quantitatively studies the correlation between the design-build procurement method and the performance of the design-build project with regard to cost, time and quality. The procurement methods studied are: sole source, qualifications-based, fixed budget/best design, best value, and low bid selection.

Procurement definitions are presented based on a literature review. Data was collected through a survey from 76 U.S. design-build projects. A careful review and categorization process followed the data collection phase. Various statistical tests were performed to analyze the data. The cost growth metric relationship with the procurement methods was statistically verified, showing projects procured using low bid selection incurred a higher cost growth than projects procured using other methods. Several other trends illustrating the effect of adopting each procurement method on project performance were identified. Design-build projects procured using the sole source selection method seemed to result in the highest project intensity. Also, the lowest schedule growth appeared to be associated with the best value procurement method.

Based on the patterns and relationships identified, a better understanding of the procurement process and how it may affect the project performance is achieved. The impact of project-specific factors, such as the level of project complexity and the level of design completed at the time of the procurement, on the design-build project performance were examined. Guidelines are defined to assist owners in selecting the design-build team procurement method that responds to their project goals. Guided by these recommendations, owners can improve their selection decision process for design-build projects.

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CHAPTER ONE

INTRODUCTION

Construction projects in the United States and throughout the world are increasingly being delivered using the design-build delivery method. In a previous study conducted at Penn State sponsored by the Construction Industry Institute (CII), the design-build delivery system was identified as offering on average the best project performance (Konchar and Sanvido 1998).

The team for a design-build project can be procured using several procurement approaches. The procurement method is the approach an owner follows to select a team that provides services under the chosen project delivery system. Procurement methods ranging from sole source to open competition procurement can be used to procure a design-build team (Beard et al. 2001). Procurement of the design-build team is a critical decision since it defines the method to select the key player of the project team, which is the design-build entity responsible for delivering the project. This decision greatly impacts the project performance since an ill-qualified design-build team can cause serious problems during and after construction. Numerous factors should be considered when selecting the appropriate procurement method. Therefore, the adoption of a comprehensive procurement method can minimize certain risks associated with this process.

Factors such as the type of the design-build contract, the level of design achieved prior to selection, and other factors related to the design-build team should be simultaneously considered during the selection process. Due to the decision complexity, many owners face difficulty in determining the appropriate method to select the design-build team. Although numerous studies have identified selection models and evaluation criteria systems for contractor selection, limited research has addressed the relationship between the use of a particular procurement method for the design-build team and the project performance. Also, of the studies that were directed towards design-build projects, few have attempted to empirically research the impact of the selection method on the various project attributes.

Besides affecting the selection of the design-build team, the procurement method decision (e.g., sole source, best value, low bid, etc.) is also critical because it deeply impacts the entire construction project process. When procuring the design-build team, owners should also consider the appropriateness of the selected project delivery method (e.g., design-build, construction management at risk, design-bid-build, etc.). It is essential that both methods, the team procurement and the project delivery method, are consistent to ensure the optimum and most profitable project performance. Also, the contract type and the award method (e.g., lump sum, unit price, cot plus a fee, etc.) are other decisions that are affected by the selected procurement method. For instance, a low bid procurement method is most likely to be associated with a lump sum contract type. Finally, several contractual agreements and clauses are often dictated by the implemented procurement method of teams for design-build projects.

This study aimed to quantitatively investigate the potential relationships between the procurement methods of design-build teams and project performance. Statistical tests analyzed the data collected to determine whether the procurement method decision significantly impacted the project performance as represented by cost, time and quality metrics. The results show a significant relationship between procurement methods and project cost growth. Also, several patterns of performance that need to be further investigated in a more substantial study were identified. These trends can guide owners to procure the most appropriate design-build selection method.

1.1 The Design-Build Market

This study focused on the procurement of design-build projects teams. Design-build has been experiencing an extraordinary growth in recent years in terms of previous volume and as a percentage of total construction (Konchar and Sanvido 1998). The Design-Build Institute of America (DBIA) indicates that compared to the design-bid-build and construction management at risk delivery methods, the trend for adopting the design-build approach is increasing since 1985, when only 5 % of the projects were delivered via design-build (Beard et al. 2001). In 2001, the number of design-build projects accounted for more than 30 % of the construction in the U.S. (Tulacz 2002). Although the economy is currently experiencing slower growth, which was reflected in decreased revenues for the ENR Top 100 design-build firms in 2001, a minor increase in these revenues was noticed in 2002 and reached 0.3% in 2003 (Tulacz 2003). By 2010, the U.S. Department of Commerce projects that half of the nonresidential construction projects will be delivered through the design-build approach (Rosenbaum 1995).

Different market sectors are increasingly shifting to the design-build approach. In healthcare, design-build accounted for 15% of the medical institutions in 1997 and currently is accounting for 46% (Tulacz 2002). The educational institution sector is providing more opportunities for the design-build delivery method. In addition, the design-build delivery system is not restricted to use by one type of owner. Currently, both public and private owners are considering the design-build delivery approach due to the numerous advantages it can offer. Governmental agencies are also shifting towards the use of the design-build delivery system. This shift was promoted by changes in regulations on the state level that can facilitate the procurement of design-build teams (Tulacz 2002).

One main advantage of the design-build delivery method is the possibility for the owner to contract with a single entity. The design-build team is responsible for providing the owner with all aspects required to deliver the facility, starting from design services to construction, and including equipment selection and procurement (Beard et al. 2001). In this method, the risks associated with design management and control are transferred to the design-build entity. Moreover, the owner relies on the design-build team for coordination, quality and cost control, in addition to schedule monitoring. Design-build, as a project delivery system, emerged to satisfy the owners' recent requirements to complete projects faster and at lower costs (Tulacz 2003).

1.2 Description of the Research

The main goal and objectives of this study are detailed in the following sections. The research approach and the steps undertaken to achieve these objectives are also presented.

1.2.1 Goal

The primary goal of this research was to quantitatively study the correlation between the performance of a design-build project and the method used to procure the design-build team. By identifying the relationship between project performance metrics (including cost, time and quality) and the team procurement method, guidelines are developed to assist owners in the procurement decision.

1.2.2 Objectives

This goal is achieved by meeting the following objectives:

1. *To gather data on the methods used to procure teams for design-build projects*. Through the initial CII study, data regarding design-build projects performance metrics was collected. To complete this research, additional information on the procurement method the owner followed to select and evaluate the design-build team was gathered. In addition, other project-specific information was included in the data collection phase to complete this research. This was achieved through the development of a survey that served as a data collection instrument.

2. *To determine the impact of the procurement method on the project performance metrics*. It is important to determine if there is a correlation between the owner's selected procurement method for the design-build team and the project performance metrics (cost, schedule and quality). Various statistical tests were used to examine the potential relationships.

3. *To provide recommendations to project owners.* Based on the results of the study, recommendations were developed to guide an owner during the design-build

procurement method selection decision. This was achieved by summarizing the trends and patterns identified for the various metrics and classifying them by level of project complexity.

1.2.3 Relevance

Few research studies have addressed the relationship between the procurement method of the design-build team and project performance. The conclusions and guidelines developed in this study can benefit several parties. The guidelines will be specifically directed to owner organizations. The aim of these guidelines is to provide owners with a basis to decide how to select the best design-build team procurement method. Supplying owners with such recommendations will enable them to clearly identify their requirements and follow a systematic process to select the appropriate design-build team.

1.2.4 Research Steps

The following steps were followed to fulfill the purpose of the study. These are defined in greater detail in Chapter Two:

1. *Review the literature:* Because limited research has addressed the impact of the procurement method on the project performance of design-build projects, it was necessary to review the current practices used by owners for contractor selection, especially for the design-build team. The growing trend of design-build projects and the importance of the contractor evaluation as a project success factor were also deemed necessary to address in the literature review.

2. *Develop definitions for the different procurement methods:* Definitions of the five main procurement approaches were developed to serve as a basis for data categorization during the initial data collection phase. The five procurement methods defined included sole source, qualifications-based, fixed budget/best design, best value, and low bid selection.

3. *Collect the data:* Data regarding the evaluation criteria for design-build teams, in addition to the structure of the design-build entity delivering the project, were collected and added to the previously gathered performance metrics database. The total number of projects initially targeted for data collection was 147 and the number of projects later analyzed was 76.

4. *Perform data analysis:* Data was categorized and analyzed to identify data trends, potential correlations, and impacts that the procurement methods had on the projects.

5. *Develop conclusions and recommendations:* Based on the analysis of the data and the corresponding observations, a set of conclusions and guidelines for the selection of the most appropriate design-build selection method was formulated.

1.2.5 Results

Rather than identifying the best procurement method for a design-build team, the research aimed at determining the appropriate selection approach taking into consideration several project-specific factors, such as the level of project complexity. The conclusions of the study illustrate the extent that implementation of the appropriate procurement method is related to successful project performance. Cost, time and quality served as the basis for comparison between the five main procurement methods studied.

Design-build team selection is a major project success factor (Molenaar and Songer 1998). Therefore, it was deemed necessary to use the conclusions of the study to develop a set of guidelines particularly directed to owner organizations. Owners, assisted by these guidelines, will be able to identify their requirements and select accordingly the design-build procurement method that is most qualified to satisfy their expectations. This is an issue of extreme importance to the construction industry because a qualified design-build team can significantly impact the delivery of a project on time, within budget and meeting the owner's expectations. Also, the selection of the procurement method is closely related to the selection of the project delivery method and the contract type. A procurement method that is not selected in accordance with the entire project process can result in numerous problems during and subsequent to construction. Consequently, in order for the construction industry to benefit from the advantages of the design-build delivery systems, it is necessary to ensure that the appropriate procurement method is used to select the right design-build team.

CHAPTER TWO

RESEARCH METHODOLOGY

This chapter introduces the steps followed to develop the research. These steps are further detailed in Chapter Four. The main goal of this study is to quantitatively investigate the correlation between the selection of the design-build team and the performance of the project. Several important research techniques were followed to achieve this goal. The review of the literature helped in defining the different procurement methods, a step important for data analysis. The survey served as an instrument for collecting data on the procurement of design-build projects. It also helped address several issues regarding respondent bias and ease of data gathering. An integral part of the research process includes developing guidelines for owners to assist them through the procurement method selection process. Finally, this chapter is also important because it discusses the limitations to the research methodology arising from the definitions of various metrics and the potential number of responses.

2.1 Research Techniques

This study focuses on the identification of quantifiable relationships between design-build procurement methods and project performance. To achieve this purpose, a survey was developed to gather the data regarding the procurement method of the design-build team for each project. 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 in the research are located in different states. This condition favors the use of the survey collection method because it is relatively inexpensive and easier to administer (Simon 1969). Surveys were sent using mail and e-mail; and followed up with phone calls to all non-responding participants.

Because statistical analysis was deemed the appropriate means to evaluate data, it was important to obtain a considerably large sample to make the results statistically significant, an objective that can be achieved with the help of surveys. Moreover, the survey method relies on a set of standardized questions that ensures precise measurement through enforcing uniform definitions upon the respondents and guarantees that similar data is collected, then interpreted comparatively. Finally, presenting all participants with an identical set of questions results in higher response reliability and reduces possible subjectivity (Simon 1969).

2.2 Research Process

The following sections explain the steps completed throughout the research process.

2.2.1 Literature Review

A review of the existing literature represents an integral part of the study. The literature review identified how authors defined the various methods of contractor procurement, and specifically the procurement methods for design-build teams. Numerous research studies have confirmed that cost, time, quality are the three main criteria used to measure successful project delivery. Finally, the different models and criteria evaluation systems identified the need to shift from the lowest cost criterion to a more comprehensive and systematic approach for contractor selection.

2.2.2 Procurement Method Definitions

Since this research mainly relies on investigating the various selection methods, it was necessary to establish the definitions of the primary procurement methods studied. Five primary methods were identified and defined. These methods are sole source, qualifications-based, fixed budget/best design, best value, and low bid selection. The definitions of these methods are included in Appendix A.

2.2.3 Data Collection

To perform the research, a survey instrument was developed to collect data regarding the design-build projects and how their teams were procured. The survey placed emphasis on identifying the nature of the selection process, the weight assigned to each selection criteria, the level of design completion, and the structure of the design-build organization. Other survey inquiries, such as the presence of incentives clauses, the types of specifications, and design-build subcontractors procurement, were supporting the main emphasis of the research. The survey instrument is included in Appendix B.

Relying on the project data already existing in the previous CII "Comparison of the U.S. Project Delivery Methods" study (hereafter referred to as the CII study) database, the surveys were mailed to the owner organizations since they were responsible for the procurement process of the design-build team. The database for this research consisted of 155 design-build projects, performed for both public and private owners. Data gathered through the survey was recorded and arranged in a format that facilitated its analysis.

2.2.4 Data Analysis

Responses gathered from the surveys were analyzed to determine the potential correlations that may exist between the different parameters. Several metrics were used to measure the project performance and determine the impact of the procurement methods implemented. Cost performance metrics include cost growth, unit cost and intensity. Time performance is measured using the construction speed, delivery speed and schedule growth metrics. Finally, quality performance is evaluated through turnover and system quality measures. The same performance metrics were previously used in the CII study (Konchar and Sanvido 1998).

Various statistical methods were used to determine the effect of the selected procurement method on the previously defined performance metrics. A univariate analysis was chosen to study each individual performance factor at a time and illustrate how it is impacted by the different procurement methods of the design-build team. To allow a better interpretation of the differences observed between the various selection approaches, the facility level of complexity, the operational variations and the structural variations of the design-build entity were also incorporated into the univariate analysis.

A multivariate analysis approach could have produced models to explain the variability within the data sets for each cost and time performance metric. Besides studying the interaction between each metric and the five selection methods, the models would have also included other project specific factors. Results for time and cost metrics did not show statistically significant differences between the different procurement methods. Therefore, the development of multivariate analysis models was not possible. Observations within the data were interpreted using descriptive statistical procedures and preliminary hypothesis testing methods.

The implementation of the previously described statistical analysis was guided by the CII study (Konchar and Sanvido 1998). This study also used univariate and multivariate analyses to study the relationships between the project performance factors and the project delivery methods. Univariate results identified the relation between the facility types and how the different project delivery methods performed. It is worth noting that in their study of the performance of design-build public projects, Molenaar et al. (1999) resorted to a different methodology approach. Based on data gathered through 104 public design-build projects, average values for several metrics were used to judge which procurement method performed better. Cost and time factors were measured by the percentage over or under budget and schedule respectively. Quality metrics included conformance to owner's expectations, satisfaction of owner's requirements and degree of administrative burden. Frequency histograms were also used to illustrate how public and private design-build projects perform with regard to cost, time and quality (Songer and Molenaar 1996). These studies are described in more detail in Chapter Three.

This research investigated the performance of both public and private projects. Project performance was evaluated using a total of six cost and time metrics. Seven quality metrics, grouped into two categories, measured the extent to which the design-build teams satisfied owners' requirements. The median, rather then the mean, was used as a measure of the data central tendency. Different statistical tests, such as analysis of variance (ANOVA) and the Mood's median test, were performed to analyze the data sets and better describe the relationship between the procurement methods and project performance. These methods are described in Chapter Four.

2.2.5 Formulation of a Set of Owners Guidelines

Conclusions drawn from the statistical analysis of the data were used to determine which design-build procurement method performs better with regard to the time, cost and quality metrics previously identified. Based on these deductions, a set of recommendations regarding the most appropriate approach to procure a design-build team was formulated, taking into consideration the degree of project complexity factor. These recommendations were developed with the aim to assist an owner in making an informed decision regarding the type of procurement method of the design-build team selection. Finally, suggestions for additional research efforts were identified.

2.3 Limitations of the Research Methodology

This research study is limited by several factors. The number of potential responses was identified as one of the limitations. The underlying reason is that this research, as a follow-up study, was restricted to only examining the 155 design-build projects available in the CII study database. Another limiting factor is the completion date of these projects. The most recent projects in the database were completed six years ago and the completion year of some of the projects was more than ten years ago. In this way, the current conditions of the construction industry were not reflected. These factors greatly affected the number of responses obtained. Finally, the methods upon which this study relied were primarily quantitative. Investigating the potential relationship between the procurement methods and the project performance would not have been possible through a qualitative analysis or a case-study approach, considering the nature of the data.

Other limitations relate to the project performance metrics. For each construction project, the cost and schedule growths typically originate from a scope addition required by the owner. They also may be caused by poor performance of the design-build team. For the analysis purpose, it was assumed that the design-build team was responsible for cost or schedule growth. Also, the quality metrics data consisted mainly of the owners' viewpoints and were highly subjective. The CII study identified similar limitations (Konchar and Sanvido 1998).

2.4 Summary

The research techniques were reviewed in this chapter. Providing an objective and systematic approach to data collection was essential to the development of representative results. The survey data collection method was selected because it was deemed more appropriate than other instruments in view of the advantages it offers. Specifying the type of statistical methods to be used is of equal importance. The univariate analysis was primarily selected because it enables the general description of the data and identifies patterns within the data sets. These trends can be verified through the multivariate analysis that examines the correlations existing between the procurement methods and the project performance. Limitations to the research methodology originated from the potential response rate; the definitions of the cost growth and schedule growth metrics; and the nature of the quality metrics data. These limitations were carefully considered during both the data collection and analysis phases.

CHAPTER THREE

LITERATURE REVIEW

The review of the literature was of crucial importance to this research. The design-build system is increasingly being selected by owners as a project delivery method. Studies that enumerate the advantages offered by the design-build method and how it may be outperforming other delivery methods are outlined. Another important feature of this chapter is highlighting the importance of the design-build team selection through several studies that regarded the team selection as a critical project success factor. The time, cost and quality metrics used to evaluate project performance are analyzed in the existing literature. Definitions of design-build operational and structural variations are presented as they helped in classifying the data collected and examining it using different perspectives. Most importantly, several contractor selection practices and design-build procurement strategies are discussed. The existing literature has clearly addressed the design-build delivery system and the different methods commonly followed by owners to procure design-build teams. However, the literature shows that few quantitative studies have analyzed whether different levels of performance are achieved using different design-build procurement methods.

3.1 The Importance of the Design-Build Delivery Method

The design-build delivery system definition used in this study refers to an approach where a single entity is contractually responsible for both the design and construction services. These services can be wholly completed by the design-build entity; or in part through subcontractors' agreements (Sanvido and Konchar 1998). Several studies have researched the continuously growing trend towards the use of the design-build delivery method and the shift from other traditional delivery methods. The reasons and factors promoting this trend have been outlined. Sanvido and Konchar (1998) conducted an empirical study whose goal was to compare the different delivery systems that are widely used in the United States. Construction management at risk, design-build, and design-bid-build were the three main delivery approaches compared. The research method consisted of identifying the performance metrics for comparison purposes, data collection through a survey, and data analysis. Seven performance metrics were defined to provide criteria for evaluating the projects and the systems used to deliver them. These seven metrics were defined in cost, schedule and quality categories. The data collection phase was achieved using a survey that gathered data for 351 projects. The survey consisted of questions regarding the project delivery methods, the performance metrics, contract types, project team characteristics, and other project specific information. Finally, the project data was analyzed using several statistical methods, including univariate and multivariate regression analysis.

The median scores reported through the results of the research concluded that projects delivered using the design-build approach performed better than those delivered through the construction management at risk or the design-bid-build delivery systems regarding several performance metrics (Konchar and Sanvido 1998). Specifically, the univariate analysis revealed that design-build projects experienced less cost and schedule growth. Also, the univariate analysis conducted for the quality metrics indicated that the design-build approach resulted in better start-up quality, fewer call backs, in addition to improved operation and maintenance quality. Moreover, design-build projects performed better than the design-bid-build projects with regards to the envelope, roof, structure and foundation metric. Interior space and layout, together with process equipment and layout metrics had higher mean scores in the case of design-build projects. In conclusion, the study revealed that the design-build delivery system often resulted in time and cost savings. With regard to quality performance and owner satisfaction, the design-build delivery led to a higher or equal quality product than construction management at risk and design-bid-build systems.

In another study that emphasized the importance of the design-build delivery system, Songer and Molenaar (1996) pointed out the rapid growth of this delivery approach and the need to examine the owners' attitudes towards it. The research also aimed at determining a number of selection criteria that lead owners to select the design-build delivery method. These criteria were related to the project duration; budget; number of claims; project size and complexity; and project constructability and innovation. Data was collected through a survey questionnaire that targeted 209 owners with experience in design-build projects. Owners were asked to determine how they rank each of the selection criteria.

Based on means and medians calculations, each selection criterion was assigned an overall ranking. The scores indicated that the primary reason that owners select the design-build delivery method is the possibility of reducing the project duration. The factors that received the least ranking were the large project size and the high level of complexity. Frequency histograms confirmed the owners' attitudes regarding the highest and lowest ranking factors. The research also concluded that the other lower-score criteria could serve as a basis for selecting the design-build delivery method, depending on specific project requirements (Songer and Molenaar 1996).

The Songer and Molenaar (1996) study results were also verified by Tookey et al. (2001) study, which indicated that the owner's requirements with regard to cost, time and quality often impact the delivery system selection decision. For design-build projects, time and budget were the main drivers for the selection of the design-build delivery method. Also, the owners' requirements were mostly directed towards benefiting from contracting with a single entity. These findings were established through studying several projects and interviewing owners to help formulate a general conclusion.

Another goal of Songer and Molenaar's (1996) research was to compare private and public owners' attitudes toward the design-build approach. The study showed that private and public owners' rankings for the different factors did not significantly differ. Only the criterion of reducing claims ranked significantly differently for both owner types. Public owners were more concerned with reducing the number of claims and thus were more inclined to choose the design-build delivery method to mitigate the effects of claims. The study attributed this to the likelihood that claims occur more frequently on public projects and handling them could significantly hinder the project performance.

Results from the previously mentioned study led Molenaar et al. (1999) to focus on design-build projects and their evolution within the public sector. Different procurement methods that public owners follow, contract awarding approaches, owners' experience, and the level of design completion are among the issues analyzed in the research. In particular, the findings indicate that nearly 60% of the design-build projects were completed within 2% or better of the original budget. The number of projects completed within 2% or better of the time schedule amounted to 77%. Regarding quality, the case studies indicated that the majority of the design-build projects conformed to owners' expectations, but several owners expressed their opinions that design-build projects had a rather high administrative burden. They may initially believe that contracting with a single entity would impose less administrative burden. This is particularly true for owners that are still experimenting with the design-build approach. Consequently, a slightly higher than average score was reported for the performance regarding the administrative burden. Finally, the study provides guidelines for public agencies to manage a design-build project with regards to procurement aspects that are discussed further below.

A research study performed for The National Institute of Standards and Technology (NIST), aimed at assessing and documenting the economic impacts of adopting the design-build delivery method (Thomas et al. 2002). The study methodology relied on comparing the performance of projects, submitted by either owners or contractors, present in the CII Benchmarking and Metrics database. The research focused only on design-build and design-bid-build projects that were evaluated based on two categories: performance metrics and practice use metrics. The performance category consisted of cost, schedule, safety, changes, and rework metrics. The practice use category consisted of the pre-project planning, constructability, team building, zero accident techniques, project change management, design/information technology, materials management, planning for startup, and quality management metrics.

The results of the performance and practice use comparisons revealed that the design-build delivery approach performed better regarding cost in the case of owner-submitted projects (Thomas et al. 2002). Regarding contractor-submitted projects, although no significant differences were detected between design-build and design-bid-build delivery systems, design-build projects showed better performance in rework and practice use. Statistical tests also concluded that design-build projects were performing significantly better with respect to the changes in project scope measure.

Finally, research that investigated design-bid-build and design-build projects identified several variables that may be affecting project performance (Ling et al. 2004). These variables were incorporated into models that can assist owners in predicting the project performance according to the chosen delivery method.

The review of the literature indicated that several studies examined the performance of the design-build delivery method. These studies point out that this delivery approach outperforms other delivery methods with regards to several measures of project performance. However, Sanvido and Konchar (1998) and the NIST study (Thomas et al. 2002) did not further investigate the methods that may be used by owners to procure the design-build teams. Also, several limitations regarding the Songer and Molenaar (1996) study and the methodology that investigated the design-build selection methods were identified and are discussed in further details in Section 3.2.

3.2 Contractor Selection as an Important Project Success Factor for Projects

This research primarily investigates the procurement methods of the design-build team, a part of the contractor selection decision in general. This decision is among several other factors that are essential to ensure a successful project delivery for different delivery systems types. Several studies have been performed to identify these factors. Research that examined projects pertaining to different delivery methods has identified several critical project success factors (Sanvido et al. 1992). The selection of a team that is effectively structured and integrated to deliver a facility was identified as one of the four critical success factors.

For design-build projects in particular, an empirical study was conducted to identify the different project success factors. Time and cost metrics were used to evaluate and measure project performance (Chan et al. 2001). The results of the study concluded that teamwork and efficient coordination between different project players were the most important among the six main factors identified. In addition, the contractors' competencies factor was also identified as a critical success factor that should be considered by owners when procuring a team for a design-build project. The contractors' competencies include technical and financial capabilities; effective implementation of project planning; design and construction within a design-build environment; and past experience. As noted, it is essential that the contractor engaged in a design-build project possesses the appropriate knowledge and ability to manage the project, as it highly impacts the project performance.

Design-build projects that performed successfully, together with recently introduced changes in procurement regulations encouraged numerous public owners to select the design-build project delivery method. Molenaar and Songer (1998) analyzed 122 case studies of public design-build projects to help public owners make informed decisions when selecting the design-build delivery system. In this study, several project characteristics were used to identify the correlations necessary for the model development. Project-specific attributes; owner's agency experience and staffing; design-build market; and owner/design-build team relationship were identified as the most important characteristics public owners should consider to fully benefit from the design-build delivery method.

Relationship characteristics refer to the design-build team prequalification and selection processes (Molenaar and Songer 1998). Analysis of the case studies indicated that these characteristics are of crucial importance because they deeply impact other factors such as the administrative burden and satisfaction of the owner's requirements. It is recommended that owners dedicate special attention to the design-build team procurement, together with the other characteristics, to improve the learning curve for public design-build projects.

3.3 Contractor Selection Practices

The review of the existing literature revealed that several studies have attempted to provide owners with an objective approach to contractor selection in general. Identifying the current procurement approaches helped in determining whether similar decisions are made when the selected delivery method is design-build. Also, several selection factors considered by owners during the process are identified while examining these practices. Some of the selection models and approaches are presented in the following sections.

3.3.1 Assessment of the Existing Contracting Selection Practices

Several studies have evaluated different contractor selection methodologies. A study conducted within the U.K. construction industry indicated that some of the current practices for contractor selection are characterized by major weaknesses (Holt et al. 1995; Holt 1998). Usually, cost is the decisive factor based on which the contractor is selected. Public owners mostly use the competitive approach because it offers a more structured, justified methodology and, supposedly, results in better value for the owner's money. Contractors' capabilities to deliver a project on time, within budget and satisfactorily complying with requirements are not highly considered during the contractor selection process. The research noted that cost-based contractor selection, used by the majority of owners in the U.K., tends to be less successful. It may achieve lower costs, but not necessarily the best value for the cost. Non-compliance with the project schedule is also noted in some cases of cost-based selection.

Consequently, several owners have shifted towards the use of other procurement methods (Holt et al. 1995). The negotiated and the two-step selection practices result in less cost growth and are more likely to be used by private owners because they are more flexible. The findings of the study also revealed that the negotiated selection methods successfully delivered projects within time limits but sometimes failed to meet budget requirements. These findings were justified by observations noted by Kumaraswamy (1996). Internationally, it was also observed that contractors are more inclined towards selection processes that list several criteria, in addition to cost, to minimize the risks usually associated with the cost-based selection.

Four major areas of deficiency within the current contractor selection approaches were identified by Holt et al. (1995). First, a universal approach to contractor selection is missing. Poorly specified contractor selection guidelines render the selection process rather subjective and fragmented due to the varying level of experience of owner organizations. Also, the prequalification process often leads to long-term confidence regarding the contractors' corporate stability, without soliciting further investigation in future projects. Another deficiency can be found in a complete reliance on cost factors to evaluate the different contractors. Finally, the weighted criteria method is rather subjective and may add risks to the contractor selection process.

Several efforts, particularly in the U.S. and the U.K., were pursued to develop contractor selection systems, rank the current evaluation criteria or use financial ratios analysis to aid in the contractor selection process (Kumaraswamy 1996). A set of recommendations was provided to improve the current selection practices. Through these recommendations, three main different contractor selection approaches were presented. The sole or multiple source negotiation; cost-based tender evaluation; and tender evaluation based on price, capabilities and past performance combination are selection methods that can improve the procurement process of contractors.

Others have recommended that the selection should be composed of a two-step approach: prequalification and tenders evaluation (Holt 1998). The first stage should emphasize more on the contractor's organizational capabilities such as past experience and financial health. The second stage should evaluate the contractor's competencies that enable him to qualify for project-specific criteria such as the proposed construction method or previous expertise in the same geographical area.

3.3.2 Approaches to Contractor Selection

Models and criteria evaluation systems are very important in the contractor selection process (Mahdi et al. 2002; Fong et al. 2000; Alhazmi and McCaffer 2000). They offer an objective approach to evaluate a prospective contractor and allow the incorporation of different evaluation factors. This is particularly important for public agencies, especially those who are shifting from cost-based selection to other procurement methods. Originally, several public and governmental agencies which use public funding were bound to report the basis on which a contract was awarded. In this case, abiding by the lowest cost criteria was efficient in eliminating any doubts regarding corruption. Another major advantage of models and criteria evaluation systems is that they can easily provide justification regarding the reasons a particular contractor was eliminated during the selection process.

The Evidential Reasoning (ER) method is an example of a criteria evaluation system approach that integrates both quantitative and qualitative factors hierarchally to address the contractor selection problem (CSP) (Sonmez et al. 2001). It takes into consideration the fact that owners may be presented with incomplete data and mitigates the risk factors inherent in the selection process. The findings of literature reviews and different research methods indicated that the criteria commonly used for prequalification included the financial and technical capabilities, management competency, and safety records of the contractor (Hatush et al. 1997; Wong et al. 2000). In addition, project specific criteria, such as the ability to complete a project on time, problem-solving strategies, current workload, and others, were also deemed necessary to be included in any evaluation system. Finally, not only selection criteria were reported from the owners points of views. Jennings and Holt (1998) surveyed contractors to illustrate their perspectives regarding the procurement decision.

Models are another systematic procedure to address the contractor procurement decision. They provide a rather comprehensive selection methodology that reduces subjectivity. Public owners like the U.S. Department of Agriculture (USDA) and the Florida Department of Transportation (FDOT) were able to formulate conceptual benchmarking contractor selection models to ensure better project delivery and increased productivity for public owners (Palaneeswaran et al. 2000).

One of the models developed to assist owners is the Multiple Criteria Decision Support System (MCDSS) (Mahdi et al. 2002). This model took into consideration the unique characteristics of each project and related them to numerous contractors' qualifications. The project-specific characteristics identified are 1) budget, 2) quality standard, 3) level of complexity, 4) risk allocation, 5) schedule limitations, and 6) owner's level of experience. A process consisting of shortlisting followed by final selection is followed throughout this model.

Several other selection models were developed based on the Analytic Hierarchy Process (AHP) approach (Alhazmi and McCaffer et al. 2000; Fong et al. 2000). These models tried to address difficulties encountered in previous models such as complex mathematical techniques, high levels of owner's experience, and limited alternatives with regard to contractor selection. Using several screening processes, the models include numerous selection factors that are ranked by owners according to criticality and combine value engineering techniques.

Models and selection criteria were not only developed to address the procurement decision. Research conducted by the Construction Industry Institute (CII) developed a decision support tool to assist owners in selecting the most appropriate project delivery system and contracting strategy (PDCS) (Oyetunji and Anderson 2001). This research focused on identifying a group of factors that are typically considered by owners during selection. These factors were incorporated into a systematic decision approach. By assigning a preference weight for each factor, a corresponding aggregate score is calculated. The PDCS alternative possessing the highest aggregate score should be the one considered by the owner. The advantages of such a quantitative tool are that it presents owners with consistent results, incorporates the owner's requirements in the decision procedure and provides a justifiable approach for selection. However, this decision tool was primarily based on expert opinions and no quantitative data supported the recommended delivery systems.

3.4 Design-Build Project Procurement Approaches

The following sections detail several selection approaches that specifically target toward design-build teams. Review of these approaches is essential as it helped in developing the data collection instrument and classifying the data gathered through the survey responses. Definitions of the main procurement methods presented by several researchers and as studied in this research are also indicated below.

3.4.1 Definitions of Design-Build Procurement Methods

Several definitions have been developed for the various design-build teams procurement approaches. Molenaar and Gransberg (2001) indicated that the fixed–price approach, located at one end of the continuum shown in Figure 1, takes into consideration only the price as the sole criterion for selection. Accordingly, the lowest bidder is awarded the contract in an approach very similar to the traditional general contractors' procurement. In a one-step procurement procedure, the design-build team may be selected based on price only or a best value combination of financial and technical criteria. A two-step selection approach consists of a prequalification of the prospective design-build teams using a Request for Qualification (RFQ), followed by an evaluation of the price and technical aspects. This represents the "best value" approach and the weights given to each of the technical and financial criteria differs from one organization to the other. It is worth noting that management aspects, an organization's financial standing, in addition to previous design-build team experience are also considered in a best value procurement approach (Molenaar and Johnson 2001).

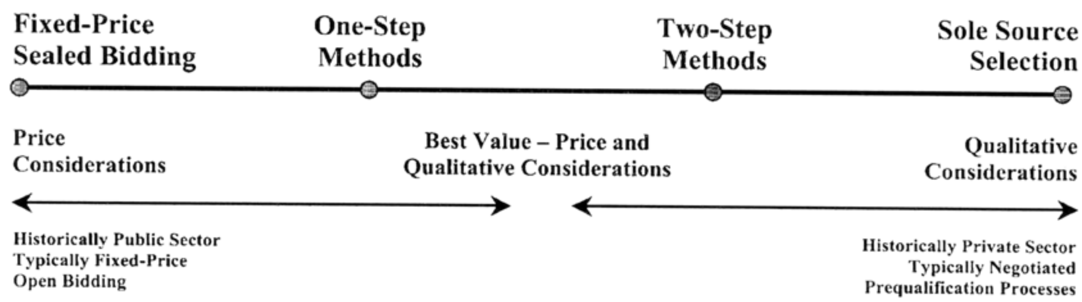

Figure 1 - Selection Methodology Continuum. (Molenaar and Gransberg 2001)

The VTT Technical Research Centre of Finland published a report on the design-build project delivery system that identified the selection process as a critical factor owners should carefully address (Lahdenperä 2001). Several alternative methods for the procurement approach were presented. A qualification-based selection consists of an early procurement of the design-build team based on criteria such as past experience, technical qualifications, managerial capabilities and reputation. This approach is usually associated with minimal design available at the time of procurement. The two-stage selection procedure involves a prequalification phase, followed by a selection phase that is based on the technical and financial aspects of the proposals submitted by the qualified design-build teams. Public organizations are most likely to adopt the later selection strategy. Finally, the report identified the bridging-type selection where the owner retains an architect to provide preliminary design services. The design-build teams submit bid prices in response to Requests for Proposal (RFP) prepared by the owner or architect. Selection is mainly based on price factors and the design-build team is responsible for completing the design and construction documents.

Another study defined three procurement methods for design-build highway contracts, mostly used by several Departments of Transportation (DOT) in the U.S. (Gransberg and Senadheera 1999). The Low-Bid Design-Build (LBDB) process consists of first evaluating the price of the proposal to determine the lowest bidder. Following, the lowest bid proposal is accepted if the design-build team technical aspects were found to be responsive to the RFP. In an Adjusted Score Design-Build (ASDB) procurement method, the proposal price is not disclosed until the technical review committee reviews the technical proposal and assigns specific rating criteria for each team. The design-build team that possesses the lowest adjusted score, obtained by dividing the price by the technical score, is awarded the contract. Finally, the Best Value Design-Build (BVDB) was defined as the procurement method that evaluates simultaneously the technical and price proposal. In this approach, the selected design-build team may not necessarily submit the lowest price proposal.

The five main procurement methods that will be used to categorize the projects in this research data collection phase are based on the definitions identified by Beard et al. (2001). The procurement methods are located in the continuum shown in Figure 2 and are defined as follows:

1. Sole Source Selection

This type of procurement method involves the direct selection of the design-build team without proposals. The lack of price competitiveness factor discourages public owners from selecting design-build teams using this procurement method (Molenaar and Gransberg 2001). However, the sole source selection potentially allows a shorter procurement time and thus, may be used during emergency conditions to ensure a faster project delivery.

2. Qualifications-Based Selection

Using this method, the owner selects the most qualified design-build team through an RFQ and often negotiates only with that entity to a "fair and reasonable" price (Beard et al. 2001). Selection of the team is primarily based on qualitative criteria such as past performance, design-builder reputation, technical competence and financial stability. The later non-cost criteria represent 50% or more of the evaluation process. In this arrangement, owners may choose to award the project to a design-build team with whom they have established long-term relationships, with minimal scope design completed at the procurement time. A negotiation process usually associated with this procurement method increases the probability for the design-build team of meeting the owner's quality expectations.

3. Best Value Selection

In a best value approach, the design-build teams respond to the owner by submitting proposals that are primarily evaluated based on the technical aspects together with the associated cost of the project (Beard et al. 2001). Negotiations may take place after the proposal submittal phase. The owner selects the proposal that offers the best value. A weighting criteria evaluation method is usually used to identify the right design-build team and the weights assigned to each of the factors are specific of the owner's organization, in addition to the type and size of the project. The best value selection is advantageous because it also allows owners to prequalify the design-build teams based on technical criteria before the final selection phase, which is based on the price competitiveness.

4. Fixed Budget/Best Design Selection

The owner specifies the project budget during the RFP process (Beard et al. 2001). The design-build teams compete by placing as much scope as they can in their submitted proposals. Using this approach, the design-build teams are selected based on qualitative and technical aspects, taking into consideration that the project cost is fixed for all competing teams. This procurement method is considered to be competitive regarding scope and quality rather than project cost. It allows the owner to have the optimum for the specified budget value.

5. Low-Bid Selection

The owner primarily selects the design-build team based on the project value and related cost items. Cost criteria represent more than 90% of the design-build team procurement selection process (Beard et al. 2001). This selection method is characterized by a high level of design completion at time of procurement to facilitate the competitive selection process (Molenaar and Gransberg 2001). However, innovation normally associated with the design-build delivery method may be reduced.

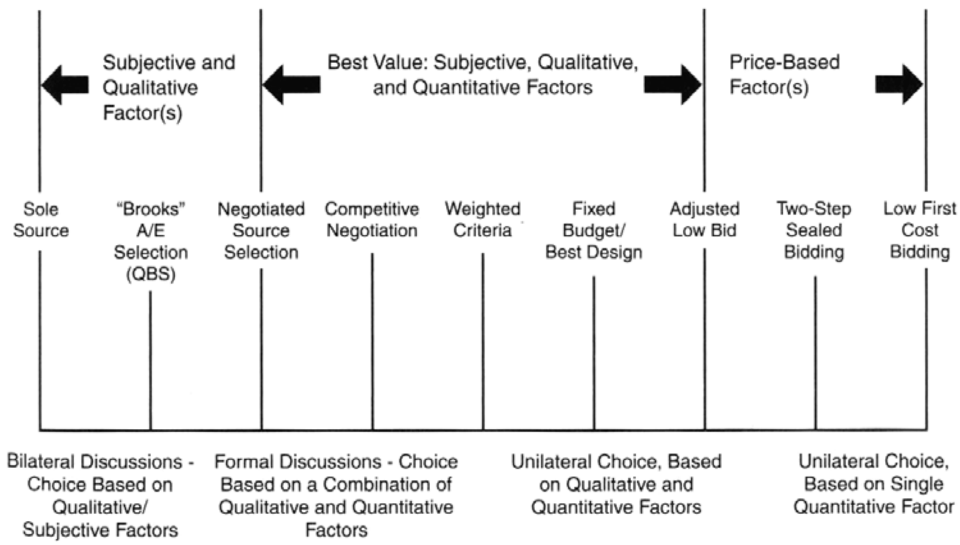

Figure 2 - Procurement Spectrum. (Beard et al. 2001)

3.4.2 Selection Approaches for Design-Build Projects

The contractor selection for a design-build project is more critical and rather complex than for other delivery methods systems. Because this delivery type mainly relies on contracting with a single entity to deliver the project, the procurement method should be as comprehensive as possible to ensure successful performance. Several authors have argued that the low bid selection is not the most appropriate approach to procure a design-build team. A multi-criteria approach for contractor selection is more effective in increasing the probability of the overall project success. It is also more advantageous for both the owner and the design-build team (Potter 1994; Palaneeswaran et al. 2000).

Potter (1994) developed the Design-Build Prequalification System (DBPS) to be used by public owners who wish to identify the appropriate evaluation criteria. The model is composed of six categories that represent a framework of constraints the owner has to consider for each design-build team. These categories are economical, political, technological, corporate policy, labor/personnel and legal. A survey that targeted public agencies showed that owners assigned different levels of importance to each category. This model is particularly significant to assist owners in preparing Request for Proposals (RFP) because it encompasses several project-specific characteristics.

The Departments of Transportations (DOT) across the United States have been implementing several selection methods. To procure design-build teams for transportation and highway projects, these organizations have considered procurement approaches ranging from the lowest bid method to the weighted criteria and best value selections (Gransberg et al. 1999).

3.4.3 Performance of Procurement Methods for Design-Build Projects

A review of the current practices in team procurement for design-build transportation projects revealed that the best value approach is the most flexible since it allows specifying factors that are specific to each project (Gransberg et al. 1999). Although it may be complex and more susceptible to speculations from a non-qualified design-build team, the best value practice also allows the evaluation of different aspects simultaneously. In addition, it was observed that projects that mostly conformed to owner's expectations were procured using the best value approach, which is a combination of price and quality. The level of design completion at the time the RFP is issued, an efficient prequalification procedure, and the project type are factors that should be considered to enhance the success of the best value approach (Molenaar et al. 2000).

Meanwhile, it was observed that the administrative burden was reduced when owners chose the design-build team based solely on qualifications (Molenaar and Songer 1998; Gransberg et al. 1999). The qualifications-based procurement method is usually characterized by a low level of design completion. In this case, the design-build team can exercise more control on the project scope, cost, and time schedule, which coincides with less administrative burden from the owner's side.

Prequalification of the design-build team is also viewed as an important component of the two-step and qualifications-based approaches (Molenaar and Songer 1998). When owners prequalify design-build organizations, less schedule growth and administrative burden are expected. Prequalification also allows for more competitive prices and provides the owner with an opportunity to deeply analyze the design-build teams' past experience and technical competencies.

A case study analysis that studied the performance of public design-build projects provides definitions for the different procurement methods used by owners (Molenaar et al. 1999). The findings of the analysis indicated that 50% of public owners use the one-step method to procure design-builders, which is characterized by a high level of design completion at the time of procurement. However, the majority of the projects that performed well were associated with a level of design completion that was within 25% or less at the time of the design-build team procurement.

The results of the study also illustrated that the two-step procurement method possessed the least cost and schedule growths, and hence the best performance with regards to these two metrics (Molenaar et al. 1999). Projects procured using the two-step method were 3% over budget and 2% over schedule. In contrast, the one step projects were 4% over budget and 3.5% over schedule. Also, the qualifications-based procurement method performed the worst with regard to budget and schedule. Project procured using the qualifications-based method were 5.6% over budget and 3.5% over schedule.

In a qualifications-based procurement, the lack of price competition may result in the poor cost or schedule performance (Molenaar et al. 1999). Also, because the scope of the project is not completely defined in a qualifications-based arrangement, cost-growth is more likely to occur. For one-step procured projects, the lack of prequalification and design documents completion to 35% rendered this approach very similar to the traditional lowest bid procedure. The project may be awarded to the lowest bidder with unsatisfactory previous budget and schedule performance. In conclusion, the research findings support the implementation of the two-step selection procedure whenever the project cost and schedule are considered critical.

With regards to project quality, the two-step procedure was the worst performing. Meanwhile, the one step approach resulted in a project that conforms more to the owner's expectations (Molenaar et al. 1999). This is justified because the later approach is characterized by a relatively high definition of project scope. Accordingly, the design-build team had a better chance in conforming to the owners expectations. In the case of the two-step approach, the team is required to define the project scope to a greater extent. The administrative burden for the qualifications-based selection was the least because the design-build firm was solely selected based on past performance and expertise and the owner had fewer administrative tasks regarding team selection. Overall, public owners were almost equally satisfied with the overall quality performance for the three procurement methods. It is worth noting that although this study investigated the impact of the procurement method on the project performance, it only studied public projects. The metrics that measured the project performance are different than the metrics used in this research. In addition, this research examined more design-build team selection approaches.

A study that targeted small highway projects also investigated the previously discussed procurement methods: one-step, two-step and qualifications-based (Molenaar and Gransberg 2001). The findings indicated that the level of design completion at the time of procurement is very important. The authors argue that a procurement process that involves less than 30% of the design complete cannot be competitively bid, an issue particularly important for public agencies. However, a higher level of design available at the time of procurement decreases the benefits of design-build innovation and may result in an increased number of change orders. A minimal design completion allows more innovation and could be efficiently associated with a two-step process.

Project complexity was also found to impact the procurement process. Fixed price, sealed-bid selection approaches were more likely to be used for less complex projects that require minimal innovation (Molenaar and Gransberg 2001). Therefore, using a fixed price method for simple projects, with high level of design completion, can achieve the project faster and with lower administrative burden. A noticed trend indicates that public agencies are shifting from the use of fixed price method towards the two-step approach. Changes in regulations promoted this transition towards the one-step and two-step approaches, where other criteria than cost are considered. One limitation of this study is that it only investigated small highway projects, which are primarily public projects. Also, the research methodology primarily relied on evaluating project case studies.

3.5 Measuring Project Performance

Various studies have used time, cost, quality and safety to measure project performance. A recent study on design-build projects indicated that objective success factors such as time, cost, profitability, and health and safety, in addition to quality are the main performance measures (Chan et al. 2002). However, they should not be the only criteria to evaluate a project performance. A more comprehensive list should include subjective success factors such as technical performance, several quality measures, functionality, productivity, owner's satisfaction, and environmental sustainability. Based on an exhaustive review of the past 10 year's literature, the study concluded, however, that time, cost and quality remain the three most significant success factors. Several related studies in project delivery and procurement methods, such as Sanvido and Konchar (1997) and Molenaar et al. (1999) studies, have not included safety as a measure for project performance. Time, cost, and quality metrics were used to quantitatively evaluate the performance of the design-build projects examined through this research.

Molenaar et al. (1998), with the aim of developing "an automated tool for public sector design-build project selection," used five criteria to evaluate a design-build project's performance. Schedule variance and budget variance, which respectively refers to performance with regard to time and cost, were among the identified evaluation factors. Schedule performance is important as a measure for design-build projects because, owners are often inclined to use the design-build delivery method to shorten the project duration. Budget variance is another essential measure that illustrates to what extent the project met the owner's financial requirements. Statistical correlations with high-level of confidence were found to exist between budget variance and successful project performance.

3.6 Definitions

The following sections describe the various definitions that are used to define the organizational structure of the design-build entity delivering the project, and the level of design completed at the time of procurement of the design-build team. These are important aspects of the selection process that are addressed in the data collection and analysis phases.

3.6.1 Design-Build Structural Variations

Structural variations are used to identify the role played by different parties in a design-build arrangement. Identifying the type of the design-build organization can be a factor affecting a potential relationship between the procurement of the design-build team and the project performance. Beard et al. (2001) emphasized the importance of the design-build structural variations and how they relate to the structure of the design-build organization and the different arrangements undertaken within. Therefore, several survey questions addressed the structure of the design-build organization to enable the investigation of the impact of such factors. According to Beard et al. (2001), there are five structural design-build variations.

3.6.1.1 Owner and Joint-Venture Design-Builder

Following this arrangement, the owner contracts with a joint venture that consists of two or more parties joined together for the purpose of carrying out the design and construction services of the design-build project. The joint venture could be project specific, formed for the purpose of the project only; or temporarily formed, existing through a specific time period that covers the project duration.

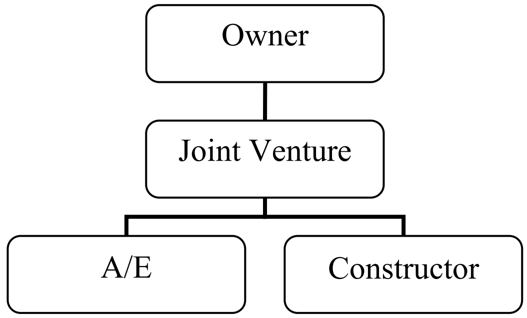

Figure 3 - Joint Venture Design-Builder

3.6.1.2 Owner and Constructor-Led Design-Builder

In this structure, the owner directly contracts with a constructor for all design and construction services necessary to complete the project. The constructor then hires a design consultant to perform professional design services through a subcontract arrangement.

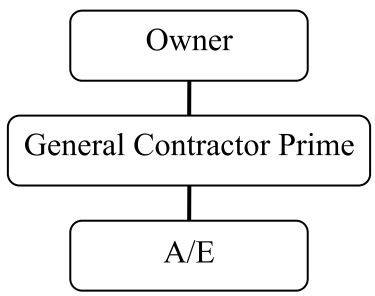

Figure 4 - Constructor-Led Design-Builder

3.6.1.3 Owner and Designer-Led Design-Builder

The owner signs a design-build contract with the designer. Construction services are performed by a constructor under a subcontract arrangement with the prime A/E. In this design-build method, the A/E prime is responsible for the design services, maintaining construction cost and schedule, in addition to supervising construction methods.

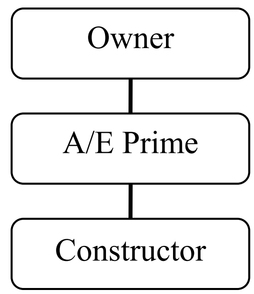

Figure 5 - Designer-Led Design-Builder

3.6.1.4 Owner and Integrated Design-Builder

The owner contracts with an integrated design-build firm acting as a single source of responsibility. The integrated entity provides direct contact with the design professional and the constructor.

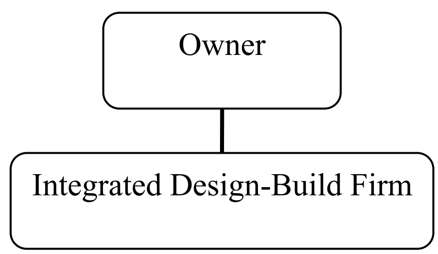

Figure 6 - Integrated Design-Builder

3.6.1.5 Owner and Developer-Led Design-Builder

The owner contracts with an independent developer to design and build the facility that will be owned and operated by the owner. The developer subcontracts the design and construction tasks to external designers and constructors.

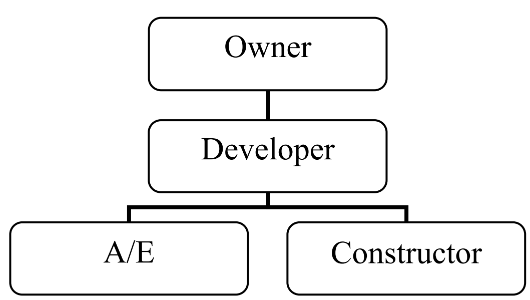

Figure 7 - Developer-Led Design-Builder

3.6.2 Design-Build Operational Variations

Operational variations for design-build delivery systems refer to the level of design completion at the time of team procurement. These variations range from minimal design performed, reaching only 10%, to a preliminary design phase where the design completed amounts to 35%. This level is dependent on two factors. In some instances, the owner decides to achieve some design work prior to contracting with the design-builder, whether from within its organization or through an architectural consultant. Also, the owner's decision regarding when to communicate their requirements to the design-build team determines the amount of design work the design-builder will have to complete. It is a critical decision regarding the selected procurement method, affecting the project performance (Beard et al. 2001). In view of this, sections I and II of the survey in Appendix B show several questions related to the different design-build operational variations. It was also considered during the analysis of the data to attempt determining its potential impact on project performance.

3.6.2.1 Direct Design-Build

In direct design-build, the owner contracts with the provider of the design-build services at the earliest possible time during the facility development process. The owner or the design-build team may develop a program and/or pro-forma. A direct design-build arrangement often results in the owner contracting with an integrated design-build firm, where the design-build team can assist the owner in defining their requirements and set a budget, through estimates and financial feasibility studies.

3.6.2.2 Design Criteria Design-Build

The owner sometimes, assisted by professional consultants, determines the facility criteria and the required performance standards. A Request for Proposal (RFP) may be developed where the owner sets out the criteria for the facility in clearly understood performance terms before contracting with a design-build entity. Following, the owner receives several design solutions from the different design-build teams.

3.6.2.3 Preliminary Design Design-Build

The owner, or their retained design consultant, performs a preliminary design to convey the project information graphically. This preliminary design information is included in the RFP for the design-builder's A/E to complete the design accordingly. This operational variation is mostly applicable for a series of projects that should have similar layout and design and where the project should be completed based on the design concept provided by the owner.

3.6.2.4 Bridging Design-Build

In this arrangement, the owner contracts with a primary design professional to perform partial design that ranges from 30% to 80%. Afterwards, the design documents and the RFP are issued to the prospective contractors. This system is very similar to the traditional approach where the owner manages two separate contracts with the designer and the bridging construction firm respectively. The bridging contractor is expected to complete the detailed design, provide costs and value engineering services, obtain the necessary permits and finally construct the facility. Some advantages of this arrangement are the possibility of the owner's organization to maintain control of the project scope, while transferring the errors and omissions risk to the design-build firm. However, this system is characterized by several inefficiencies. It can be competitively bid in a very similar manner as the traditional approach. Furthermore, it eliminates the possible innovation that should be associated with the design-build delivery system and does not necessarily allocate risks to the party in the best position to undertake them (Beard et al. 2001; Molenaar and Gransberg 2001).

3.7 Contracts Issues for Design-Build Projects

Several important contract items should be considered while studying the appropriate procurement method for the design-build team. Incentive and disincentive contract clauses have significant impacts on critical factors such as completion on time and within budget. In addition, it was found that the type of project specifications is closely related to the design-build team selection approach and the level of design completed at the time of procurement.

3.7.1 Incentive and Disincentive Clauses

Some of the contract issues that are addressed in the survey designed to collect the data for this research include the incentive and liquidated damages clauses. The presence of Incentive/Disincentive (I/D) clauses is often dictated by the owner's requirements to ensure one or many project-specific objectives (Arditi et al. 1997). These objectives can be reducing construction costs and duration, preserving required levels of safety and productivity, or achieving quality standards (Arditi et al. 1998). A "combined incentive/disincentive" clause may be used if several objectives are to be emphasized simultaneously. In a contract that includes a schedule I/D clause, the contractor is awarded a predetermined incentive value for each day the project is completed earlier than the schedule. This arrangement may differ according to the project size and the number of contractors involved during construction (Arditi et al. 1997).

I/D clauses can greatly impact the project performance, in particular completion on time. Numerous studies concluded that the majority of projects whose contracts incorporated an I/D clause were completed on time or earlier, with a minimal percentage of contractors that were subject to pay disincentive clause fees. Time extensions and a large frequency of change orders were less likely to take place for those projects. However, projects with I/D clauses experienced larger budget overruns than those with no I/D clauses (Arditi et al. 1997). It was also concluded that the implementation of contracts with I/D clauses face critical problems such as challenges regarding scheduling, crew productivity and redundancy, working conditions in harsh weather to keep up with the schedule and adversarial relationships within the contractor's team (Arditi et al. 1998).

Liquidated damages clauses are frequently used in construction contracts. They are considered another measure used by owners to compensate for any losses they may incur if the contractor does not complete the project within the specified schedule. The notion of liquidated damages may act as a form of disincentive clause, stimulating contractors to attempt every effort in achieving the work on time. However, liquidated damages are different from disincentive clauses. The effects induced by liquidated damages are weaker than those induced by disincentive clauses, which are larger in value and are usually associated with incentive clauses to promote early completion (Arditi et al. 1997). In general, incentives/disincentives are efficient management tools, provided a project study is performed to ensure benefits would follow their implementation (Arditi et al. 1998).

3.7.2 Types of Project Specifications

The type of specifications used for a project is typically related to the level of design complete prior to procurement of the contractor. Performance specifications usually describe the performance requirement or the end result the contractor must achieve. They are mostly used when minimal design is completed. Prescriptive specifications, mostly used in the traditional approach, describe elaborately the methods and materials necessary to complete the project. They are associated with a simple selection process, usually based on cost criteria only, relying on the fact that the owner's requirements are clearly defined (Molenaar et al. 1999; Palaneeswaran et al. 2000).

Studies of public design-build projects indicated that few owners used purely prescriptive specifications, while the others resorted to different degrees of performance specifications (Molenaar et al. 1999; Palaneeswaran et al. 2000). In a design-build arrangement, performance specifications are used to encourage innovative design solutions from the design-build entity. The specifications normally outline the traditional quality assurance process used in the prescriptive specifications, but allow more alternatives and design options. In general, prescriptive specifications are not preferred for design-build projects, characterized by a reduced role of the owner regarding the quality control process.

3.8 Summary

The review of the existing literature indicates that numerous studies have developed selection models to help in procuring the appropriate contractor. Different systems with evaluation criteria have been formulated to assist owners during the contractor selection process. The main advantages of these models and evaluation systems are that they provide a systematic and objective procurement approach that takes into consideration numerous factors other than the price of the proposal. Other studies have identified the various procurement methods of the design-build teams for public and transportation projects. In addition, one study showed the effect of the procurement method on some measures of project performance.

Few quantitative studies have been performed to analyze the impact of the procurement methods of the design-build team on the project performance. Also, limited studies have been developed to guide owners through the process of selecting the design-build team procurement method. The emphasis of this study is to identify a potential relationship between the selection process and project performance. Providing owners with quantitative data can guide them through the procurement selection process for the design-build team. This is achieved through the analysis of both public and private projects with performance measured by six cost and time metrics, and seven quality measures.

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS METHODS

This research project build upon the CII "A Comparison of the U.S. Project Delivery Methods" study (hereafter referred to as the CII study) performed by Sanvido and Konchar (1997). Several significant aspects regarding the CII study are outlined in this chapter. Collecting data on the procurement of the design-build teams is one objective of this study. To achieve this objective, data collection techniques including designing and implementing surveys were researched and detailed in this chapter. Measures undertaken to ensure accuracy and objectivity during data collection and categorization are listed. These measures and techniques also relate to the data quality and how to ensure it is representative of the entire population. Data adjustment procedures and the study response rate are also described. Finally, analyzing the data is a crucial step in any research. A key aspect of this chapter is that it describes the statistical methods, both univariate and multivariate, used to analyze the data.

4.1 Data Origin

This research is a follow-up study that primarily focused on quantitatively investigating data collected through the CII study on project delivery systems in the U.S. The following section describes the data collection and outlines the features of the CII project delivery systems study. The importance of a non-response study is also discussed.

4.1.1 Initial Data Sets

The projects investigated in this research are derived from the database of projects collected in the CII study on project delivery systems. The survey developed for the later initial study was distributed to 7,600 participants and a total of 378 surveys were returned. The number of responses was reduced to 301 projects gathered through the initial data collection efforts, after eliminating fifty international projects and 27 U.S.

projects not satisfying the research criteria. In addition, fifty projects were collected through the non-response study. Accordingly, the CII study database included a total of 351 projects. The projects pertained to six facility type classifications: light industrial, multi-story dwelling, simple office, complex office, heavy industrial, and high technology. The facility classes were explained in detail in the CII study. Project information was collected from both public and private owners' organizations. Several company types were represented in the study. Projects were submitted by companies belonging to organizations such as the CII, Design-Build Institute of America (DBIA), Associated General Contractors (AGC) and others (Konchar 1997).

There were 155 design-build projects in the database, which represents 44% of the total number of projects. The percentage of design-bid-build projects were 33%, while the construction management at risk projects were 23%. The design-build projects formed the database for this study. As is detailed in the following sections, information was gathered regarding the procurement data for each project.

4.1.2 Non-Response Study

Despite the numerous advantages of the mail surveys, one main disadvantage is the relatively low response rate resulting from a large number of unreturned surveys. These uncompleted surveys may be very different from the received responses, which necessitates a non-response study to eliminate non-response bias (Simon 1969). This issue was addressed and verified in the CII study by resending the survey to 80 of the original non-respondents. The number of surveys returned was 54, fifty of which were usable and were analyzed together with the original data collected. The statistical tests conducted at a 95% level of confidence, the Mood's median and 2-sample t-tests, concluded that no statistically significant difference was present between the original and non-response data sets. Therefore, it was concluded that the sample collected is representative of the entire population and both data sets were combined.

The performance of a non-response study was not deemed necessary for this research. The underlying reason is that the data collection phase was achieved while taking into consideration that the main objective prevailing during that phase was to maximize the response rate. Consequently, several efforts and measures, described below, were considered to accomplish the later objective.

4.2 Data Collection Procedure

Guided by the CII study of project delivery methods, a survey was chosen as the data collection instrument. Several factors supported this decision. Prospective survey respondents contact information had already been collected. Since this step revealed a large geographic dispersion, the survey procedure easily enabled the researcher to target those participants either by mail or electronically through e-mails. In addition, it provided an inexpensive and structured way to collect the data objectively. Conducting surveys involves several types of errors such as sampling error, coverage error, measurement error and response error. The survey phase consists of two main phases: design and implementation, during which several measures have been implemented to minimize the significance of the different types of errors (Dillman 2000).

4.2.1 Survey Design

The researcher should be particularly cautious regarding several decisions that should be considered to eliminate some of the errors associated with the survey design stage. The questions were developed in a manner that enabled an accurate check of responses and detection of any inconsistencies. The sampling procedure, which refers to the decision on how to obtain the sample necessary to conduct the research (Simon 1969), was determined based on the data available from the previous CII study. A pilot survey was developed and tested by a small number of industry participants. This step was beneficial in identifying confusing questions and allowed the survey design to be improved. In addition, the survey was sent to the DBIA research team (which consisted of seven members) for additional review and feedback. After applying several improved modifications, the final revised survey was defined in the following sections. The complete survey is included in Appendix B.

4.2.1.1 Section I: Project Team Selection

The purpose of the questions included in this section of the survey is to determine how the design-build team was selected for the project. To categorize the existing projects in the original CII study, it was necessary to determine the implemented method of procurement. Short definitions were provided to clarify terminology that may not be common to some of the survey respondents. The teams' prequalifications are also an important element in the selection process. A prequalification process is usually associated with a competitive selection, while a negotiated process is accompanied by a direct selection of the design-build team.

Respondents were also asked to assign percentage values to criteria that may have been used to determine which design-build team was selected. These include cost; design and aesthetics; technical proposal; qualification selection factors; and others added by respondents. Finally, it was deemed important to inquire regarding the level of design completed at the time the project team was selected, which was indicated though the type of design-build operational variation and the status of pre-design or design at that time. This information was used later in the analysis to classify the data and attempt to draw consistent patterns for each of the performance metrics.

4.2.1.2 Section II: Delivery System Structure

This part of the survey asked the respondents to determine the structural variation of the design-build team. This information was used to classify the data gathered through the survey and analyze it to determine whether the organizational structure of the design-build entity had an effect on the project performance.

4.2.1.3 Section III: Contract

The presence of incentive clauses in the contract is a factor that may affect the project performance together with the procurement method selected. The survey respondents were asked to identify incentive clauses used in the contract.

4.2.1.4 Section IV: Other Information

In analyzing the project data, it is necessary to identify the type of specifications, whether prescriptive, performance or standard format, used by the owner to define the quality standards required for the project. The specification type is frequently related to the level of design completed at the time of procurement. Also, the owner's experience regarding design-build projects and whether the prime design-build entity hired specialty design-build subcontractors was collected. The procurement method of subcontractors in general was also addressed in the survey.

4.2.2 Survey Implementation

A well-designed survey is only one aspect in guaranteeing a high response rate (Dillman 2000). The survey implementation is an equally important process for the success of any survey. The implementation procedure for this survey consisted of several steps. Since the CII study was performed in a different timeframe, it was necessary to update the contact information of the participants present in the original database. Accordingly, both the mailing and e-mail addresses of the projects participants was collected, with attempts first made to contact the projects owners. Otherwise, the design-build entity was contacted. This was important because owners were the entity primarily responsible for the selection process of the design-build team and thus, would be more capable of answering the survey questions. The potential respondents were also notified that a survey would soon be mailed to them in an effort to increase the response rate.

After gathering the necessary contact information, the respondents were mailed or e-mailed the survey attached to a cover letter that introduced them to the research and how it related to the CII study. Three weeks after the initial survey was sent, the first reminder letters were mailed to the people who did not initially respond. Meanwhile, short "thank you" notes were sent to the respondents after completing the survey to show appreciation for their efforts. Then, follow-up phone calls were made to each non-respondent to secure the maximum possible number of returned surveys.

4.2.3 Issues Considered During Survey Development

Several efforts were undertaken to maximize the response rate to the survey. The use of e-mail and web surveys is continuously growing as it becomes more convenient. Today, people are more familiar with computer technology, which makes it easier for them to respond to surveys placed on the World Wide Web (Dillman 2000). Therefore, letters mailed to the project participants included a link that would direct them to the online version of the survey, if they chose to complete it. Potential respondents, with available e-mail addresses, were sent an electronic copy of the survey and the same link that directed them to the online survey format. Together with mailed paper surveys, this presented the targeted people with several options to complete the survey. The percentage of surveys retuned through the web reached 36% of the total number of completed surveys.

Several techniques defined by Dillman (2000) were used to maximize the response to the survey. Indicating that the study results will be provided at the end of the research process presented a form of reward, which is recommended to encourage people to respond. In addition, the letter that accompanied the survey mentioned that people from the same organization had previously assisted with the previous CII study, to suggest that the participants are socially responsible for completing the task. Most importantly, the survey was designed to be as short and easy as possible to complete, with minimum personal information required. Definitions of key terms and concepts were also provided.

4.3 Study Response Rate

The response rate of the study refers to the number of survey participants who responded with respect to the total number of surveys initially mailed to all project participants. The original number of design-build projects present in the CII project delivery database was 155 projects. During the data collection phase, eight projects were eliminated since available points of contact could not be located. Therefore, the survey was sent by mail or e-mail to a total of 147 people or companies. Responses were received from 76 U.S. projects, representing a 52% response rate. These projects form the database for this research.

4.4 Data Recording and Categorization

After the completed surveys were received, several measures were taken to ensure accuracy in data recording. This was particularly important since surveys were received through different modes of collection including mail, fax and internet surveys. Accordingly, the content of the surveys was reviewed as soon as received to check for missing responses or detect inconsistencies. The review would emphasize these questions related directly to the procurement method selected, the type of selection and the design-build operational variation identified by the respondents. In some instances, respondents were contacted to clarify any conflicting information or supplement responses to incomplete survey questions.

The survey data was entered into a Microsoft Excel® spreadsheet to prepare for the data analysis. Projects were organized using the project number that was previously assigned in the CII study. Data collected from the previous survey was included in the same spreadsheet. This data defined the time, cost and quality project performance metrics. General project characteristics such as facility type, project completion date, building area and percentage of new construction, were all included for potential incorporation into the data analysis phase. Finally, project team characteristics identified in the CII study were added to the spreadsheet for further data analysis.

At the end of the data collection phase, the data gathered from the 76 submitted surveys was carefully reviewed. Adjustments for time were made to the cost metrics that involve project costs. These are the unit cost and the intensity metrics. The location factor was already considered in the CII study. Afterward, the data was exported to Minitab®, a statistic analysis software application. Minitab® possesses several advantages over other statistical applications including its ability to analyze a large number of variables and its sorting capability (Minitab 2000). The procurement methods studied were reduced from five to four categories: sole source selection, qualifications-based selection, best-value selection and low bid selection. The fixed budget/best design procurement method category was eliminated because it included only 2 projects. Statistically, this did not constitute a sample size large enough for data analysis.

4.5 Data Adjustments

Several adjustments were performed to the data to enable meaningful comparisons and provide a better presentation of how each procurement method performed with regard to each project performance metric. A description of these adjustments and categorizations follows.

4.5.1 Cost Adjustment

Unit cost and intensity metrics were standardized because their calculation involves the costs of projects completed in different years. The building cost index (BCI) for the year 2003, referenced in R.S. Means cost estimating manuals (R.S. Means 2003), was used to adjust the cost data for time.

4.5.2 Facility Complexity Classification

Since this study is based on a subset of the original CII study, it was necessary to reduce the number of facility types. Accordingly, two facility complexity categories were developed. The light industrial, multi-story dwelling, simple office categories, identified in the previous study were combined into a low project complexity category. This category includes facilities characterized by relatively simple construction methods and less complicated details. An example of projects located in this category would be large postal facilities; light manufacturing facilities; on-base military housing; and office buildings with basic requirements. The complex office, heavy industrial, and high technology categories were combined into a high project complexity category. The facilities included in this category involve more intricate details and rather complex construction processes such as heavy manufacturing facilities, buildings with monumental finishes, or strict environmental control-type projects. Considering the facility complexity factor is also important because it was identified through the literature as having an impact of the procurement method decision (Molenaar and Gransberg 2001).

4.6 Data Analysis

Two primary data analysis techniques were used: univariate and multivariate analysis. The univariate analysis mainly consists of a set of descriptive statistical tests that measure the central tendency and the variability within the data sets. The multivariate analysis approach aimed at providing a detailed interpretation of the data variation for each performance metric considering several variables simultaneously.

4.6.1 Univariate Analysis

The univariate analysis relies on descriptive statistics that are used to summarize the data. The statistical tests provide measures of central tendency such as the mean and the median values, in addition to measures of dispersion such as the standard deviation and range notions (Gibbons 1985). One advantage of the descriptive tests is that they enable the researcher to preliminarily understand the data in a broad manner and decide on more specific means to analyze the data. Median values for the time and cost performance metrics are reported because the median is a measure less affected by extreme measurements. Since the categorical quality metrics are qualitative, the mean value is more appropriate as the median is only applicable to quantitative data (Ott 1992).

In many instances, central tendency and dispersion tests revealed relatively high standard deviation values and skewed distributions for the majority of metrics. Therefore, a hypothesis testing procedure was deemed necessary for the cost and time variables. Conducting hypothesis testing statistics was more suitable to conclude whether there is a statistically significant difference regarding the performance of the studied procurement methods. The Mood's median test is a non-parametric test that was used for the purpose of hypothesis testing. The Mood's median test is more robust against outliers than other non-parametric tests (Minitab 2000).

4.6.2 Multivariate Analysis

The multivariate analysis consists of developing a model that describes the relationship between each performance metric and the four procurement methods, while including other predictors. These predictors can be project-specific factors that are impacting and explaining the variability within each model. Examples of these factors include the facility complexity, the structure of the design-build entity, and the level of design completed at the time of procurement.

In this research, the analysis of variance (ANOVA) was used to examine the data through a multivariate approach. For each performance metric, ANOVA tests the means of the four procurement methods to determine whether they are statistically different. One advantage of using the ANOVA approach is that it can test more than two populations simultaneously, as opposed to the two sample t-test that could have tested only two procurement methods at a time (Ott 1992). After the data was tested using the ANOVA test, project-specific factors could have been incorporated into the analysis, if significant statistical differences between the means were detected. However, only a maximum of three predictors at a time could have been added to each model due to the small sample size.

It is important to note that data should be satisfying the normality and equal variances assumptions before being analyzed using the ANOVA approach. Preliminary analysis of the data showed that the variables did not follow a normal distribution, except for the cost growth metric. Therefore, a data transformation was necessary. A data transformation process consists of converting the original data set to a new scale of measurement (Ott 1992). A (log y) transformation, applied to each performance metric, yielded a normal distribution for all metrics except the schedule growth. The transformed metrics also satisfied the equal variances assumption.

Other researchers have conducted multivariate analyses differently (Konchar 1997; Ling et al. 2004). The primary goal of these multivariate approaches was to produce predictive models for the project performance using regression analysis. In an iterative process, several predictors are included in each model and the models are evaluated using correlation factors. The process is repeated until the resulting model explains the most variability within the data. Rather than producing a model and attempting to refine it, the multivariate analysis, conducted through this research using ANOVA, tests and evaluates the existing model for each performance metric. The ANOVA approach was deemed more appropriate to examine the data collected for this research. It satisfies one of the primary research objectives, which is identifying statistically significant difference between the design-build procurement methods.

4.6.3 Data Analysis Procedure

The procedure followed to analyze the data is outlined below:

1. Identify projects that are considered to be outliers and eliminate them from the main data set.
2. Calculate descriptive statistics values for the project data after elimination of the outliers. These include the mean, median, standard deviation values, and the upper and lower quartiles.
3. Draw box plots to assist in identifying which procurement method is performing better for each performance metric. Box plots are graphical representations that summarize and study data variability.
4. Check for normality of each of the performance metrics at a confidence level of 95%. 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).
5. Verify whether the variables satisfy the equal variances requirement at a 95% level of confidence. Each performance metric should satisfy both the normal distribution and the equal variances assumptions to conduct the Analysis of Variance (ANOVA) tests.
6. For each performance metric, examine the means of the four procurement methods using the ANOVA test to determine if they are statistically different.

7. Conduct hypothesis testing using the Mood's median test to determine whether the differences between the procurement methods are statistically significant.

4.7 Data Quality

The data quality refers to the measures undertaken to ensure that the data studied is representative of the entire population (Simon 1969). The main emphasis is to minimize both the respondent and research team bias.

4.7.1 Respondent Bias

The implemented survey, used as a data collection instrument, included several questions that are rather subjective and mainly relies on the respondent's perception. Examples of these questions include specifying the procurement method used to select both the design-build team and the design-build specialty subcontractors, in addition to the type of design-build operational variation and the percentage of design completed at the time of procurement. The respondent bias in this research may arise from the subjective interpretation of the respondents to these questions.

To minimize the respondent bias, clear and concise definitions were associated with the different procurement methods and the design-build operational variation questions. By specifying the context within which they were expected to answer, respondents were more likely to objectively define the procurement system specific to the project in question. Questions addressing the later issues were asked several times in different questions to assist in detecting any bias or inconsistency. Finally, responses to several questions were reviewed against the information previously collected in the original CII study.

4.7.2 Research Team Bias

The development of unbiased questions and a careful design of the survey were of crucial importance to eliminate research team bias towards any design-build procurement method. Eliminating this type of bias was equally important during the data recording and analysis phases by making sure that there was no particular preference towards any of the procurement methods. Standardized data collection techniques also enabled an unbiased process.

In addition, analysis and interpretation of the data were consistently and regularly reviewed by the thesis committee members and seven industry team members. This process was essential to ensure the appropriate methods were implemented and avoid misrepresentation of the results concluded from the data analysis. Understanding the nature of the observations and explaining variability within the data sets in an objective and systematic approach were also guided by the review process.

It is worth noting that the non-response bias, which is usually caused by potential participants not responding to the received survey, was already considered in the CII study of project delivery systems. Efforts were made to ensure the sample was representative to the entire population. By studying the two data sets, the original and the non-response, the CII study concluded that the two populations do not significantly differ from each other.

4.8 Summary

Survey design and implementation were critical steps for the data collection phase. Several sources were consulted to identify techniques considered to improve the collection process. This significantly increased the study response rate, which was considered higher than the average expected response rate. Efforts undertaken to address both research and respondent biases are critical to guarantee an objective approach. It was also necessary to adjust the metrics whose calculations involve cost values for time to account for the project completion date factor. Other adjustments were also considered to prepare the data for analysis. Several approaches were considered to analyze the data. Finally, initial data testing revealed that the univariate analysis was regarded as the appropriate approach to describe the data and indicate any statistical significant differences within the procurement methods studied.

CHAPTER FIVE

RESULTS

This chapter presents and discusses the results of the data analysis phase. Besides being primarily classified by procurement method, data sets were also classified by complexity level and project completion date. These secondary classifications are important because they help in better understanding potential relationships. The study results were primarily based on the univariate analysis of the data. Trends and patterns that illustrate the impact of the selection method on the project performance identified through the univariate approach are detailed in this chapter. A Mood's median test helped in addressing several research limitations. Results from the ANOVA tests were inconclusive with regards to the nature of the correlation that exists between the procurement methods and the performance metrics. It follows that although few statistically significant differences were identified, numerous patterns were detected within the data sets. The need for a study that examines a larger sample size is identified at the end of this chapter and further discussed in Chapter Six.

5.1 Data Sets

The initial data collection efforts targeted 147 participants and 76 surveys were completed and returned. Only two projects in the fixed budget/best design category were received. Therefore, this category was excluded from future analysis. In addition, four other projects were considered outliers and were eliminated during the initial stage of data analysis. Among the outlier projects was a 100% renovation project and the other three possessed either unusual high unit cost values or extreme values for the construction and delivery speed metrics.

Using descriptive statistics tests, the median values for all the cost and schedule performance metrics were compared before and after removal of the outliers. Although slight differences were observed with regards to the median values after elimination of the outliers, less skewed distributions were obtained for each metric. This is particularly important for the ANOVA procedures that are known to be greatly affected with the presence of outliers.

The distribution of the projects remaining in the database categorized by facility type is illustrated in Figure 8. The largest number of the projects belongs to the light industrial category, which accounts for 34% of the total number of projects. Following with an equal number of projects and a percentage of 21% are the simple and complex office categories. The projects included in the remaining categories represented between 6% and 10% of the total number of projects.

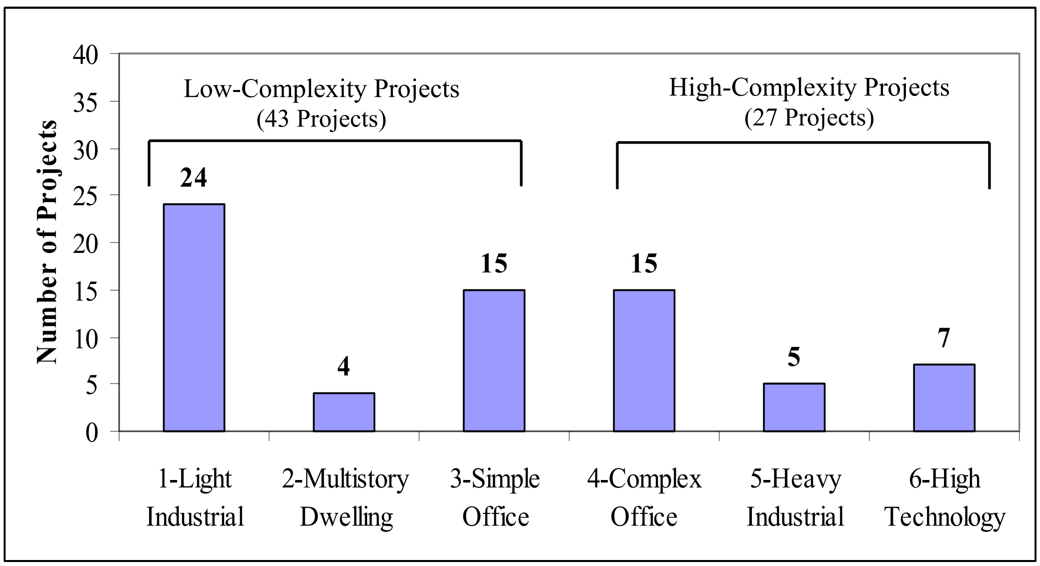

Figure 8 – Number of Projects by Facility Type

Projects were also classified according to the level of project complexity. This classification was based upon the original facility type classification identified in the CII study. As previously mentioned in Chapter Four, this classification contributed to the identification of trends that could not be originally perceived through the analysis of the total number of projects. It also improved the highly skewed distributions of several metrics and rendered them nearly symmetric.

Figure 9 shows the number of low-complexity projects classified by procurement method. It can be seen that the majority of the low-complexity projects are procured using the best value selection approach.

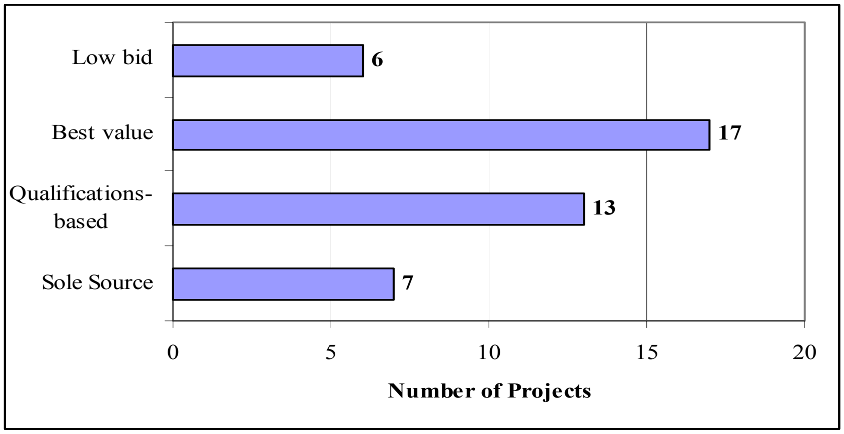

Figure 9 - Distribution of Low-Complexity Projects by Procurement Method

In contrast, the number of high-complexity projects where the design-build teams were procured using the best value, qualifications-based or sole source approaches was rather equal. The percentage of high-complexity design-build projects procured using the low-bid approach is very small and not representative to the entire population. Figure 10 shows the distribution of high-complexity projects with respect to the procurement method selected.

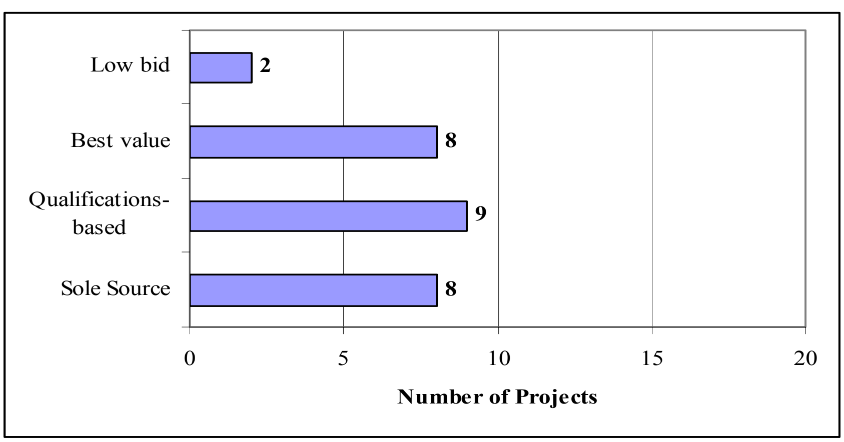

Figure 10 - Distribution of High-Complexity Projects by Procurement Method

Figure 11 shows the distribution of the projects according to the year of project completion. The project completion dates ranged between years 1984 and 1997. However, it can be observed that the majority of the projects were completed between 1992 and 1997. During that period, the best value procurement method was more commonly used to procure a design-build team. The implementation of the sole source selection method was more common in the later years. This may be due to the changes in state procurement laws that allowed selection not to be solely based on cost criteria.

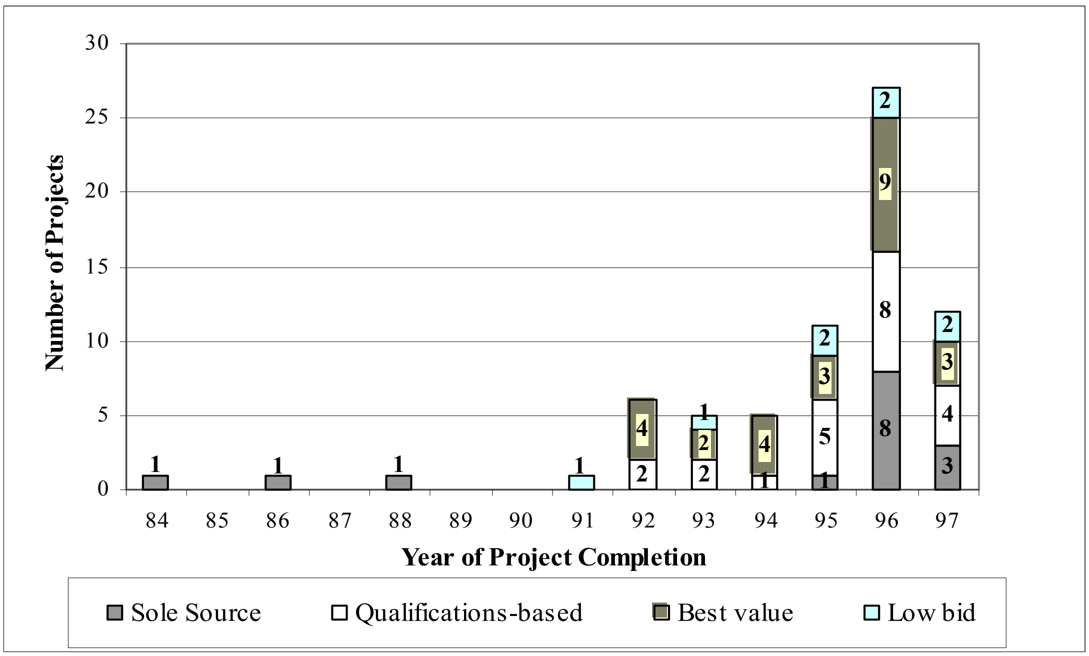

Figure 11 – Project Distribution by Year of Project Completion

5.2 Univariate Results

The univariate analysis describes the central tendency and variability characteristics of the data. The following section discusses the cost and time metrics results classified by procurement methods. Results for each level of project complexity are also presented. Finally, the quality performance metrics results are reported.

5.2.1 Univariate Cost and Time Results

Table 1 shows the median values obtained for each performance metric. The central tendency of the data sets was measured using the median, rather than the mean, because it is less affected by outliers present within the data sets, particularly for smaller sample sizes (Gibbons 1985).

Table 1 – Cost and Time Metrics Median Values by Procurement Method

	Sole Source	Qualifications -Based	Best Value	Low Bid
Unit Cost ($/S.F.)	109.98	100.45	144.83	96.72
Cost Growth (%)	6.41	0.92	2.47	9.82
Intensity ($/S.F./Month)	8.82	8.43	5.78	4.49
Construction Speed (S.F./Month)	4,351	10,421	7,994	9,813
Delivery Speed (S.F./Month)	3,085	6,701	5,449	9,324
Schedule Growth (%)	0.72	5.79	0.00	5.64

To enable a direct comparison of the procurement methods for each metric, a baseline unit value was assigned to one procurement method. The baseline value denotes the best performance for this metric and is either the smallest or the largest median value. For example, the lower the unit cost, the better it is from an owner's perspective. However, a larger construction and delivery speed indicates better schedule performance. Relative percentages for the other procurement methods were obtained by dividing their respective initial median values by the baseline. The percentages noted for the schedule and cost growth metrics indicate the absolute difference between the lowest median value and the respective procurement method median since the baseline percentages are small or zero. Table 2 shows the procurement methods comparisons.

Table 2 - Cost & Time Metrics Comparison by Procurement Method

	Sole Source	Qualifications-Based	Best Value	Low Bid
Unit Cost ($/S.F.)	14% higher than low bid baseline	4% higher than low bid baseline	50% higher than low bid baseline	Baseline (lowest)
Cost Growth (%)	5.5% more* than qualifications-based baseline	Baseline (lowest)	1.6% more* than qualifications-based baseline	9% more* than qualifications-based baseline
Intensity ($/S.F./Month)	Baseline (highest)	4% lower than sole source baseline	24% lower than sole source baseline	49% lower than sole source baseline
Construction Speed (S.F./Month)	58% slower than qualifications-based baseline	Baseline (fastest)	23% slower than qualifications-based baseline	6% slower than qualifications-based baseline
Delivery Speed (S.F./Month)	67% slower than low bid baseline	28% slower than low bid baseline	42% slower than low bid baseline	Baseline (fastest)
Schedule Growth (%)	1% more* than best value baseline	6% more* than best value baseline	Baseline (lowest)	5.6% more* than best value baseline

* These percentages indicate an absolute difference (rather than relative difference as in the rest of the table)

The trends identified for the unit cost metric are very unusual and do not present consistent patterns. The project unit cost, by nature, varies tremendously from one project to another according to the scope definition of the project. Also, the analyzed sample size may not be large enough to explain the significant variability within the data set of the unit cost metric with respect to the procurement methods. These factors may be the cause for the inconsistencies observed.

The low bid-procured projects experienced the highest cost growth, which is 9% higher than the qualifications-based procurement method. This result is statistically significant at a confidence level of 95% as will be detailed in later sections. The nature of the low bid selection could be the reason for this result. Low bid-procured projects typically involve several change orders during the course of construction whose number is highly dependent on the structure of the change orders clause present in the design-build contract (Beard et al. 2001). However, in a study on public design-build projects, Molenaar et al. (1999) concluded that the highest project cost growth is rather associated with the qualifications-based selection method. This was attributed to the lack of competition and the design information available at the time of procurement associated with the qualification-based approach. The high cost growth observed for the sole source procurement method may be due to the minimal scope definition at the time of procurement.

Also, it can be noticed that the sole source selection possesses an intensity value that is two times larger than the low bid value. The high intensity may be attributed to a high unit cost value usually associated with sole source procured projects. This signifies that higher intensity does not seem to result in better project performance.

Regarding the time metrics, the analysis showed that the best value procurement method seems to result in the least schedule growth; 0% growth. This result is consistent with the findings of Molenaar et al. (1999) study on public design-build projects. The best value procurement method incorporates both qualitative and quantitative selection factors, which may greatly reduce the potential for project schedule growth. The qualifications-based and the low bid procurement methods appeared to be performing nearly the same with a growth value that is approximately 6% higher than the best value selection growth. Unusual results were noticed for the delivery speed that was observed to be fastest for the low bid selection method and slowest for the sole source procurement method. This was counter to expected results and may be attributed to the insufficient sample size available for the low bid category, which includes a total of only eight projects.

5.2.2 Univariate Cost and Time Results by Facility Complexity Level

Projects were further classified according to the level of complexity. This classification enabled the identification of more consistent trends, in addition to improving the distribution of several performance metrics. The following sections summarize the results for low and high project complexity levels.

5.2.2.1 Low Complexity Projects

Table 3 summarizes the results for the low complexity projects classified by procurement methods. Cost growth appears to be least when the design-build team is procured through the qualifications-based and best value approaches. The qualifications-based selection projects seemed to result in a better schedule performance with regards to construction and delivery speed metrics as it may be providing the owner with a shorter procurement time. The best value method shows the least schedule growth. The review of the design-build team technical capabilities associated with the best value selection enables owners to evaluate past schedule performance, which can improve the project schedule performance.

It is worth noting that several unusual observations were noticed among the results of the low-complexity projects. These include exceptionally high values of unit cost for the best value and the low-bid selection methods. Poor performance of the best value-procured projects with regards to the construction speed is also unexpected. Limited sample size and a high degree of variability within the data sets may be the cause for these unexpected results and it is important to note that the results for these metrics were not found to have statistical significance.

Table 3 - Procurement Methods Comparison for Low Complexity Projects

		Unit Cost ($/S.F.)	Cost Growth (%)	Intensity ($/S.F./Month)	Construction Speed (S.F./Month)	Delivery Speed (S.F./Month)	Schedule Growth (%)
Sole Source	Median values	74.2	3.8	5.1	10,744	9,677	3.9
	% change from baseline value	Baseline (Lowest)	1.4% more* than qualifications-based baseline	20% lower than qualifications-based baseline	20% slower than qualifications-based baseline	20% slower than qualifications-based baseline	3.9% more* than best value baseline
Qualifications-Based	Median values	78.5	2.4	6.6	13,048	11,671	7.1
	% change from baseline value	10% higher than sole source baseline	Baseline (lowest)	Baseline (highest)	Baseline (fastest)	Baseline Fastest	7.1% more* than best value baseline
Best Value	Median values	126.4	2.4	5.8	5,934	4,224	0.0
	% change from baseline value	70% higher than sole source baseline	Baseline (lowest)	10% lower than qualifications-based baseline	50% slower than qualifications-based baseline	60% slower than qualifications-based baseline	Baseline (lowest)
Low Bid	Median values	105.4	9.8	4.5	9,813	9,324	4.3
	% change from baseline value	40% higher than sole source baseline	7.5% more* than qualifications-based baseline	30% lower than qualifications-based baseline	20% slower than qualifications-based baseline	20% slower than qualifications-based baseline	4.3% more* than best value baseline

* These percentages indicate an absolute difference (rather than relative difference as in the rest of the table)

5.2.2.2 High Complexity Projects

The results of the high complexity projects, shown in Table 4, indicate that the sole source selection seems to produce a very high cost growth that is 8.4% more than the qualifications-based selection. The lack of cost competition and the minimal design level completed at the time of procurement may contribute to the high cost growth value. The large number of change orders common in a low bid selection may be the cause of the observed high cost growth. Although the sole source selection shows the lowest schedule growth for high-complexity projects, the data shows that it resulted in a 90% slower delivery than the low bid selection in terms of construction and delivery speed. Meanwhile, the low bid-procured projects appear to experience a schedule growth that is 14.8% higher than the least growth value. Therefore, when completion on time is critical, the low bid selection is probably not the most appropriate procurement alternative for the design-build team.

Several unexpected trends were also noticed for the high complexity category. These include extremely high values of unit cost reported for both the qualifications-based and the best value procurement methods. These unusual patterns may be attributed to highly variable data for the unit cost metric associated with a limited sample size. Similarly, the results unexpectedly showed high values for the construction and delivery speed metrics of the sole source and the qualifications-based procurement methods. A larger sample size would have been more valuable in detecting more consistent trends for these metrics.

An analysis that investigated the relationship between the design-build operational variation and project performance was also performed. The operational variation refers to the level of design completed at the time of procurement. It ranges from direct design-build, with minimal design achieved, to bridging design-build associated with 30 to 80% design completed. Based on box plots for all metrics and the Mood's median test, no statistically significant differences were identified. The design-build operational variation was found to have no impact on the variables studied and, when further investigated, revealed conflicting responses. If a larger sample size is available, significant conclusions may arise.

Table 4 - Procurement Methods Comparison for High Complexity Projects

		Unit Cost ($/S.F.)	Cost Growth (%)	Intensity ($/S.F./Month)	Construction Speed (S.F./Month)	Delivery Speed (S.F./Month)	Schedule Growth (%)
Sole Source	Median values	158.52	8.4	13.7	2,183	1,876	0.0
	% change from baseline value	70% higher than low bid	7.9% more* than qualifications-based baseline	Baseline (highest)	90% slower than low bid baseline	90% slower than low bid baseline	Baseline (lowest)
Qualifications -Based	Median values	234.64	0.5	11.3	7,920	4,753	0.0
	% change from baseline value	120% higher than low bid baseline	Baseline (lowest)	20% lower than sole source baseline	60% slower than low bid baseline	70% slower than low bid baseline	Baseline (lowest)
Best Value	Median values	151.44	2.5	5.6	10,269	8,529	1.0
	% change from baseline value	70% higher than low bid baseline	2.0% more* than qualifications-based baseline	60% lower than sole source baseline	50% slower than low bid baseline	50% slower than low bid baseline	1.0% more* than baseline
Low Bid	Median values	90.74	7.3	6.5	19,296	16,283	14.8
	% change from baseline value	Baseline (Lowest)	6.8% more* than qualifications-based baseline	50% lower than sole source baseline	Baseline (fastest)	Baseline (fastest)	14.8% more* than baseline

* These percentages indicate an absolute difference (rather than relative difference as in the rest of the table)

A preliminary analysis of the design-build structural variation also revealed that 69% of the design-build teams were constructor-led. The number of integrated design-build firms reached 11%, followed by 9% reported for the number of designer-led design-build teams. The developer-led and joint venture design-build teams categories accounted for only 6% each. The structural variation factor was not further investigated due to the unavailability of an adequate sample size in each of the categories for analysis.

5.2.3 Univariate Quality Results

Seven quality metrics grouped into two categories, turnover project quality and system project quality, measured the projects quality performance. The categorization aimed at eliminating any possible respondent bias resulting from a difficult turnover process (Konchar 1997). The turnover quality category consists of the start up, call backs, and operation and maintenance metrics. The system quality category consists of the envelope, roof, structure and foundations; interior space and layout; environment; in addition to process equipment and layout metrics. Since the median value can only be used for continuous variables, such as the cost and time variables, the mean was used to measure the quality metrics performance. Quality for each metric was rated by the project owner on a scale ranging from 0 to 10, with 10 indicating the best quality performance.

Table 5 illustrates the turnover quality metrics scores for the studied procurement methods. A score of 10 indicates a low difficulty process of turnover, while a score of 5 refers to a medium difficulty process and a score of 0 denotes a large number of callbacks, difficult start up and high costs for operation and maintenance (Konchar 1997). The comparison of the procurement methods showed that the low bid selection resulted in the least difficult startup process and experienced the lowest number of call backs. The best value selection produced the lowest perceived costs for operation and maintenance, followed closely by the qualifications-based approach. In general, the best value selection was outperformed by the other selection approaches.

Table 5 - Turnover Quality Metrics by Procurement Method

		Sole Source	Qualifications-Based	Best Value	Low Bid
Start Up	Mean values	7.5	8.2	7.5	9.4
	% change from baseline value	20% higher than low bid baseline	12% higher than low bid baseline	20% higher than low bid baseline	Baseline (lowest difficulty)
Call Backs	Mean values	8.2	8.5	7.8	9.4
	% change from baseline value	12% more call backs than low bid baseline	9% more call backs than low bid baseline	17% more call backs than low bid baseline	Baseline (lowest number of call backs)
Operation & Maintenance Costs	Mean values	7.1	8.1	8.3	7.9
	% change from baseline value	14% higher than best value baseline	2% higher than best value baseline	Baseline (lowest costs)	6% higher than best value baseline

With respect to the system quality metrics, a score of 10 indicates that the owner's system requirements were exceeded, while a score of 5 shows that the system has satisfied the owner's expectations and a score of 0 signifies that the owner's expectations have not been met (Konchar 1997). Table 6 shows that the sole source selection outperformed the other types of procurement in the case of the envelope, roof, structure and foundation metric; the interior space and layout metric; and the environment metric. This may be attributed to the nature of this selection approach that allows the owner to primarily select the design-build team based on qualitative criteria. The system quality performance of the low bid and the best value procurement methods fluctuated between average or slightly higher than average values. In general, the design-build teams of projects procured through the sole source approach were more able to meet the owner's system requirements. The sole source selection is usually associated with a negotiated process that may provide a better understanding of the owner's requirements and expectations.

Table 6 - System Quality Metrics by Procurement Method

		Sole Source	Qualifications -Based	Best Value	Low Bid
Envelope, Roof, Structure, Foundations	Mean values	6.4	5.6	5.7	5.6
	% change from baseline value	Baseline (best performance)	13% less than sole source baseline	12% less than sole source baseline	13% less than sole source baseline
Interior Space & Layout	Mean values	7.5	6.8	5.2	5.7
	% change from baseline value	Baseline (best performance)	10% less than sole source baseline	30% less than sole source baseline	14% less than sole source baseline
Environment	Mean values	6.4	6.2	4.5	5.6
	% change from baseline value	Baseline (best performance)	4% less than sole source baseline	29% less than sole source baseline	13% less than sole source baseline
Process Equipment & Layout	Mean values	5.6	6.7	5.3	5.0
	% change from baseline value	17% less than qual.-based baseline	Best performance	21% less than qual.-based baseline	25% less than qual.-based baseline

Figure 12 shows the average overall quality performance for each design-build procurement method. The overall quality represents the average of the combined turnover and the system quality metrics for each project. Trends with respect to this measure indicated that the low bid and the qualifications-based selections appear to perform better as opposed to the sole source selection. The best value method does not perform as well on the overall quality when compared to the other procurement methods.

Statistical analysis, at a level of confidence 95%, indicated that the procurement methods do not have significant impact on the overall quality performance of the projects. This is also illustrated in Figure 12, where the average values reported for all the procurement methods seem to be in close range. It is also worth noting that the quality metrics data was collected through qualitative methods and may be the least objective. They represent the owners' expectations and reflect their individual experience regarding the selected procurement method. These may greatly vary from one organization to another and consequently affect the quality responses. The expectations may also vary be on the procurement method used by the owner, e.g., the owner may not have the same quality expectations if they hire a contractor based on a low bid method.

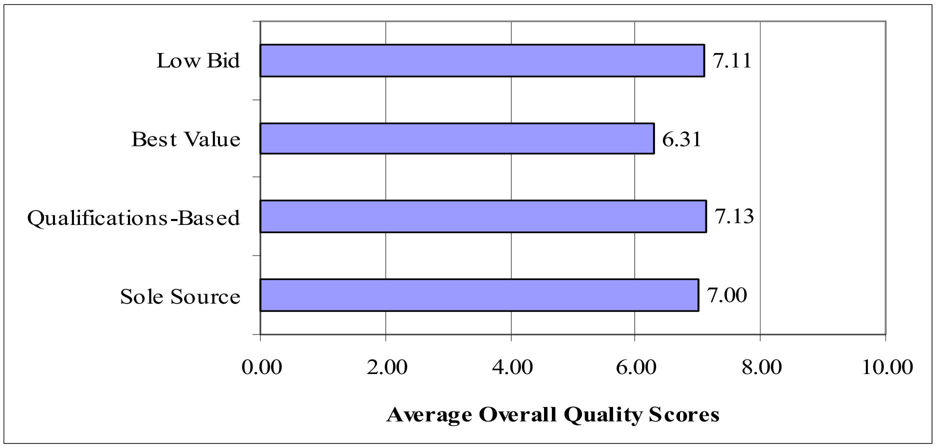

Figure 12 - Average Overall Quality Performance

5.3 Hypothesis Testing Using the Mood's Median Test

The objective of examining the data using the Mood's median test was to further describe the nature of the relationship that may exist between procurement methods and project performance. Additional outliers within the data sets were identified through the descriptive statistics. The removal of these outliers could not be justified. Because the Mood's median test is more robust with respect to outliers then the ANOVA tests, it was used to examine the data (Minitab 2000). Another advantage of this non-parametric test is the ability to test parameters that are not necessarily satisfying the normality or the equal variances assumptions. This is particularly important in studying the schedule growth metric, which could not be tested using the ANOVA method.

In addition, several limitations to this study, further discussed in Chapter Six, led the researcher to test the data using the Mood's median test. These limitations include the inequality of the sample sizes for each of the procurement methods. The low bid procurement category included only eight projects, while the best value and qualifications-based categories included more than 20 projects. Also, the overall small sample size was another limitation that restricted the type of statistical tests that could be conducted to explain the data variability. The need for a testing procedure such as the Mood's median test that could take into considerations the above limitations was therefore justified.

Table 7 shows that the results of testing the six cost and time metrics using the Mood's median test, conducted at a confidence level of 95%, revealed a p-value for the cost growth metric that is 0.024. Statistically, this indicates that the cost growth medians for the procurement methods are significantly different from each other. The p-values for the other metrics were larger than 0.05, and hence, no statistically significant relationship between the procurement methods and these metrics could be identified.

Table 7 - The Mood's Median Test and the P-Values for the Performance Metrics

	Unit Cost	Cost Growth	Intensity	Construction Speed	Delivery Speed	Schedule Growth
p-values	0.354	0.024	0.419	0.962	0.764	0.240

Accordingly, the owner's decision towards which procurement process to implement for selecting the design-build team significantly affects the project cost growth. As previously mentioned, the qualifications-based selection had the lowest cost growth. The low bid selection resulted in the highest cost growth value that is on average 9% higher than the growth observed for the qualifications-based selection. This conclusion is consistent with the preliminary analysis of the cost growth box plot, shown in Figure 13, where it is apparent that the medians are significantly different. Box plots for the other cost and time metrics are included in Appendix C.

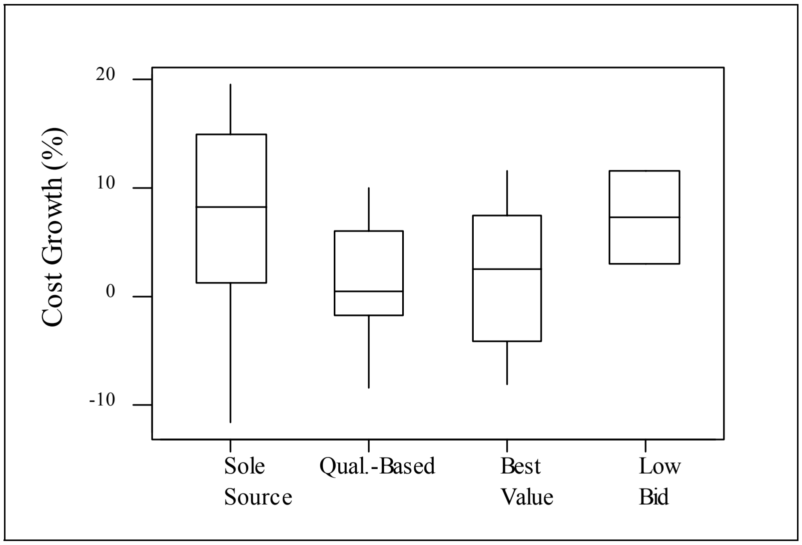

Figure 13 – Cost Growth Box Plot

5.4 ANOVA Analysis

An analysis of variance (ANOVA) test was important to determine the potential impact of the procurement method on project performance. A similar analysis could have been completed using a multiple t-tests process. However, only two procurement methods at a time would have been tested, with a probability of falsely rejecting one of the hypotheses at a level of significance, α, that could be more than 0.05. Therefore, ANOVA was considered more appropriate than the multiple t-tests process.

Several assumptions were checked to determine the validity of the data collected for the ANOVA method. The first assumption states that the samples collected for the different procurement methods should be independent random samples. This assumption is already verified in the original CII study database. The other two assumptions are discussed below.

5.4.1 Normal Distribution Assumption

At a 95% confidence level, the six cost and time performance metrics distributions were tested for normality of distribution. All metrics, with the exception of the cost growth metric, did not follow a normal distribution. The fulfillment of this assumption is particularly important because the available sample size is not large enough to assume a normal distribution for the performance metrics. After applying a log base 10 transformation to the data collected for the unit cost, intensity, construction and delivery speeds, the respective distributions satisfied the normality assumption. Several attempts were made to transform the schedule growth metric data but they failed to result in a normal distribution.

5.4.2 Equal Variance Assumption

The p-values obtained from the Levene's test for equal variances were smaller than the significance level, $\alpha = 0.05$, for all metrics. This indicates that the metrics possess error variability that is constant by treatment, and hence, equal variances. The schedule growth variable was not tested for equal variance as it was not satisfying the normality assumption. Table 8 summarizes the results for both the normality and equal variances tests.

Table 8 – Normality and Equal Variances Tests

Test	Data Transformation	Unit Cost	Cost Growth	Intensity	Construction Speed	Delivery Speed	Schedule Growth
Normal Probability Test (CI =95%)	none	Not satisfied	Satisfied	Not satisfied	Not satisfied	Not satisfied	Not satisfied
	Log base 10	Satisfied	N/A	Satisfied	Satisfied	Satisfied	Not satisfied
Equal Variances Test (CI = 95%)		Satisfied p = 0.145	Satisfied p = 0.092	Satisfied p = 0.475	Satisfied p = 0.478	Satisfied p = 0.638	-

5.4.3 ANOVA Results

The ANOVA analysis, conducted at a 95% confidence level, consists of testing the means of the response variables, which are the performance metrics. The analysis of variances for the unit cost, intensity, construction and delivery speed resulted in p-values that are larger than the significance level, $\alpha = 0.05$. The results for the cost growth metric were also statistically insignificant, although they were shown significant using the Mood's median test. The statistically insignificant difference observed for all metrics denoted that the means of the performance metrics are not significantly different from each other. In other terms, the procurement methods do not have a statistically significant impact on the project performance and the differences observed could be due to random or sampling errors. The schedule growth metric was not investigated using the ANOVA approach since it did not satisfy the previously mentioned assumptions. A summary of the test is illustrated in Table 9.

Table 9 - Summary Results for ANOVA Tests

	Unit Cost	Cost Growth	Intensity	Construction Speed	Delivery Speed	Schedule Growth
p-values	0.900	0.103	0.180	0.393	0.518	-

It is important to note that a multiple pairwise comparisons using the Tukey and the Bonferroni's procedures were performed as part of the ANOVA analysis. These comparisons analyzed the data sets to detect any significant differences that may exist between each two procurement methods, at a level of significance of $\alpha = 0.05$. No statistically significant differences were identified for any of the variables studied. Also, several unusual observations, possessing large standard residual values, were identified during the pairwise comparisons procedure. These unusual observations are outliers that could not be justifiably removed.

5.5 Summary

The univariate analysis of the data clearly identified several trends and patterns within the data sets. Although not statistically significant, the results of the univariate analysis concluded several important observations. The low bid procured projects experience the highest cost growth value. The sole source selection is characterized by the highest intensity while resulting in the lowest construction and delivery speed. The schedule growth seems to be lowest when the design-build team is procured using the best value approach. Other important results have been concluded when projects were classified according to the level of complexity.

The Mood's median test results were important in concluding that the procurement methods medians for cost growth were significantly different from each other. The later result signified that the owner needs to carefully consider the procurement decision because it significantly affects the project cost growth. Owners concerned with the least cost growth should follow the qualifications-based selection procedure. The ANOVA tested the means of the performance metrics but the results were inconclusive. The differences detected between the performances of the different procurement methods were found to be statistically insignificant. Finally, the impact of project factors such as the level of the design achieved at the time of procurement was investigated but did not appear to yield significant trends within the data set. The structure of the design-build team factor was preliminary examined and indicated the majority of the design-build teams belong to constructor-led entities.

CHAPTER SIX

CONCLUSIONS

This chapter presents a summary of the main research findings. Key results are highlighted for all projects and by level of project complexity. Contributions to both the research community and owner organizations are outlined. A discussion of the limitations originating from the research methodology together with the size of the sample analyzed is also presented. Recommendations were developed based on the trends identified for the performance metrics. These guidelines are of crucial importance as they can assist owners and industry practitioners during the selection process. Also, they could be further developed into a decision support tool. Other suggested areas for future research are also discussed in this chapter followed by concluding remarks.

6.1 Research Summary

The primary goal of this research was to identify the impact of the procurement methods of design-build teams on design-build project performance. To achieve this goal, a survey was developed and data was collected from 76 projects. This data was categorized and examined. The research conclusions were primarily based on a univariate analysis of the data. Most importantly, the cost growth metric, whose results were found to be statistically significant through the Mood's median test, was observed to be highest for low bid procured projects. The qualifications-based selection method should be considered whenever completion on budget is critical since it resulted in the lowest cost growth.

Although not statistically significant, the univariate tests also identified several other key findings and patterns. The sole source selection is characterized by the highest intensity and results in the lowest construction and delivery speeds. It was also observed that the schedule growth was lowest when the design-build team was procured using the best value approach. Drawing conclusions for the unit cost metric was difficult due to the inconsistencies detected in the unit cost data. These inconsistencies may be resulting from the nature of the metric together with highly variable data for this metric. Table 10 summarizes the findings for all cost and time metrics.

Table 10 – Cost and Time Metrics Summary Findings

		Sole Source	Qualifications - Based	Best Value	Low Bid
Unit Cost ($/S.F.)	Median values	109.98	100.45	144.83	96.72
	% change from baseline value	14% higher than low bid baseline	4% higher than low bid baseline	50% higher than low bid baseline	Baseline (lowest)
Cost Growth (%)	Median values	6.41	0.92	2.47	9.82
	% change from baseline value	5.5% more* than qualifications-based baseline	Baseline (lowest)	1.6% more* than qualifications-based baseline	9% more* than qualifications-based baseline
Intensity ($/S.F./Month)	Median values	8.82	8.43	5.78	4.49
	% change from baseline value	Baseline (highest)	4% lower than sole source baseline	24% lower than sole source baseline	49% lower than sole source baseline
Construction Speed (S.F./Month)	Median values	4,351	10,421	7,994	9,813
	% change from baseline value	58% slower than qualifications-based baseline	Baseline (fastest)	23% slower than qualifications-based baseline	6% slower than qualifications-based baseline
Delivery Speed (S.F./Month)	Median values	3,085	6,701	5,449	9,324
	% change from baseline value	67% slower than low bid baseline	28% slower than low bid baseline	42% slower than low bid baseline	Baseline (fastest)
Schedule Growth (%)	Median values	0.72	5.79	0.00	5.64
	% change from baseline value	1% more* than best value baseline	6% more* than best value baseline	Baseline (lowest)	5.6% more* than best value baseline

* These percentages indicate an absolute difference (rather than relative difference as in the rest of the table)

The data analysis revealed that no one design-build procurement method outperforms the other methods with regards to the performance metrics analyzed. However, the limited sample size did not allow the statistical verification of this conclusion. A more substantial study is required to identify the best performing procurement method.

Meanwhile, several trends that were identified indicated that different procurement methods are recommended to meet different performance requirements. Although these patterns are not statistically significant, with the exception of the cost growth metric results, they can assist owners during the selection process. Owners can first identify their critical project requirements, consider the resulting trends for the performance metrics, and select the procurement approach accordingly.

Valuable results have been concluded regarding the quality performance of the design-build projects. The low bid and the qualifications-based selections were found to be better performing with respect to the average overall quality measure. The best value method possessed the lowest score, and hence, was the least method meeting owners' expectations. However, it is important to note that the differences in quality scores are not significantly large. The underlying reason is that owners' expectations may vary according to the selected procurement type. For example, an owner can still be satisfied with an average performance from a team selected through a low bid process. This may result in the observed score of the low bid method that is higher than the best value selection score.

The projects were classified by level of complexity for further investigation. The classification greatly improved the data distribution and reduced the skewness observed for the unit cost, intensity, construction and delivery speed metrics. It also enabled the researcher to identify more consistent trends for the different procurement methods that were discussed in detail in Chapter Five. Finally, the ANOVA tests did not conclude any significant results regarding the impact of the procurement methods on the project performance.

Other project factors have also been investigated with the aim of providing a comprehensive analysis of the data. The classification of the project data according to the design-build operational variation, which refers to the level of design achieved at the time of procurement, did not reveal consistent trends in the data. The preliminary analysis of the design-build structural variation factor, which refers to the structure of the design-build entity, illustrated that the majority of the design-build teams analyzed were constructor-led. The number of projects available in the remaining categories did not allow further analysis of the structural variation factor.

6.2 Guidelines to Owners and Industry Practitioners

The construction industry is increasingly adopting the design-build delivery method to benefit from the advantages it may offer. To ensure the benefits are realized for both owners and industry practitioners, the most appropriate design-build team selection method should be used. Based on the statistical analysis of this research and the summary results of the cost and time metrics illustrated in Table 10, the following guidelines were developed to provide recommendations regarding design-build team procurement method for a project. Guidelines are indicated below for the different critical project requirements and summarized in Table 11. Guidelines based on unit cost and the delivery speed metrics could not be derived due to inconsistencies in the data obtained.

Table 11 - Guidelines Summary Table

	Recommended Procurement Method		
Critical Requirement	**All Projects**	**Low-Complexity Projects**	**High-Complexity Projects**
Cost growth	Qualifications-based method results in the lowest cost growth.	Qualifications-based and best value methods seem to result in the lowest cost growth.	Qualifications-based method results in the lowest cost growth value.
Intensity	Sole source selection method seems to result in the highest intensity.	Qualifications-based selection method showed the highest intensity.	Sole source method seems to result in the highest intensity.
Construction Speed	Qualifications-based seems to result in the fastest construction speed.	Qualifications-based seems to result in the fastest construction speed.	No consistent trends were identified.
Schedule growth	Best value method appears to experience the least schedule growth.	Best value method seems to experience the least schedule growth.	Sole source selection appears to be resulting in the least schedule growth.
Quality	All procurement methods performed similarly.	All procurement methods performed similarly.	All procurement methods performed similarly.

1. **Cost Growth**

   a. When completion within the specified project budget is critical, owners should consider the qualifications-based selection as it resulted in the lowest cost growth value. In this case, the low bid procurement method is probably not the most appropriate method since it is associated with the highest cost growth.

   b. Owners who view completion within budget as critical for high-complexity projects should take into consideration that the low bid and the sole source selections may not be the most appropriate approaches. Projects procured through these methods seem to experience high values of cost growth.

2. **Intensity**

   Owners concerned with achieving projects at the highest intensity (($/S.F.)/Month) should consider procuring the design-build team using sole source selection as it appears to result in the highest intensity.

3. **Construction and Delivery Speeds**

   a. Owners who regard the construction speed as critical should consider the qualifications-based procurement method. Projects whose teams were procured using qualifications-based selection illustrated the fastest construction speed.

   b. For low-complexity projects, owners should consider qualifications-based selection because it seems to relate to the fastest construction speed.

4. **Schedule Growth**

   a. The best value procurement method should be considered by owners when completion on time is crucial because it resulted in the lowest schedule growth value.

   b. Low-complexity projects procured using best value selection seem to experience the least schedule growth.

c. When completion on time is critical for high-complexity projects, sole source selection should be considered as it appears to result in the least schedule growth. Low bid projects seem to result in the highest schedule growth.

5. **Quality**

Owners concerned with satisfaction of their quality expectations should take into consideration that the procurement method decision did not appear to have a significant impact on the quality performance of design-build projects. The four procurement methods performed similarly with regards to quality.

6.3 Contributions

Several contributions were made in this research. The contributions achieved are detailed below:

1. Tools and techniques for data collection that could serve as a basis for future data collection efforts were defined.

An important aspect that this research initially addressed was the lack of information on the different approaches owner organizations may follow to procure a design-build team. Accordingly, it was necessary to develop a survey that could be used as a data collection instrument. The developed survey was used to gather information on the different project procurement approaches, the various structures of design-build organizations, and other data deemed relevant to the research process. Before its implementation, the survey was carefully designed, reviewed and preliminarily tested. Several efforts were considered to maximize the response rate and minimize the bias originating from the participants' survey responses. In this way, the survey development and implementation phases can be observed as providing a set of tools and techniques that can guide similar data collection efforts in the future.

2. *A basis for understanding the impact of the design-build procurement methods on project performance was established.*

The data collected on the design-build procurement methods and the analysis that followed offered additional insight on the significance of the procurement method decision. Based on the results previously presented, owners should take into consideration the different patterns and trends identified for each of the performance metrics while defining the best method for procuring the design-build team. Of particular importance is the impact of the procurement method decision on the project cost growth. The level of project complexity is also an equally important factor that should be incorporated into the decision process of the design-build team selection.

The importance of this research arises from the fact that it attempts to illustrate the effect of combining various selection criteria on design-build project performance. Although several studies researched the contractor selection process in general, few have investigated the impact of the team selection approach on project performance. Many public owners, in view of recent policies and regulations reforms, have shifted from the cost-based selection methods towards other methods that allow them to consider the technical capabilities of the design-build team together with the cost competitiveness. It is particularly crucial for these organizations to consider how the procurement decision may affect the project performance. This research provides insight to owners for selecting the most appropriate design-build procurement method that responds to critical cost, time or quality requirements. This was also achieved through the development of guidelines to owners and industry practitioners that can be referenced during the procurement method selection process.

3. A broad quantitative project analysis of procurement methods for design-build teams was performed.

The review of the literature indicated that the relationship between the design-build procurement methods and the performance of public projects has been previously investigated (Molenaar et al. 1999). This research, however, studied the performance of both public and private projects. Although a systematic and objective selection process is crucial to public owners, private owners share similar concerns. In many cases, private owners are extremely concerned with completion on time or within budget, and would like to ensure that the selected design-build team is capable of achieving these requirements. This research provides a framework for both owner types. It enables them to objectively select the design-build team procurement method, while considering the impact of this decision on the critical project requirements.

6.4 Limitations

Several limitations to this research originate from the quantity of project data collected. Besides eliminating four outlier projects at the start of the analysis, additional outliers were identified through the descriptive statistics tests and the ANOVA tests and could not be justifiably excluded from the analysis. The inequality of the sample sizes for each of the procurement methods resulted in another limitation. For example, the low bid procurement category included only eight projects, while the best value and qualifications-based selection categories included more than twenty projects. Finally, the overall limited sample size restricted the type of statistical tests that could be conducted to explain the data variability. These limitations led the researcher to examine the data using a non-parametric alternative test that does not require strict compliance to distribution assumptions. The statistical validation of potential trends identified in the data could have been greatly improved if data from more projects was obtained.

Other limitations were attributed to the nature of the cost, time and quality data collected through the CII study. Among the limitations identified is the definition of the cost growth performance metric. Typically, project cost growth may be caused by a project scope addition that is owner-required or a budget overrun caused by the design-build team. Similarly, any growth in the project schedule can be either owner or design-build team–driven. For the analysis, it was assumed that the design-build team performance was accountable for any cost or schedule growth. The quality metrics represented another limitation. Besides denoting the subjective viewpoints and expectations of owners, the quality metrics are highly dependent on the owner's level of expertise with the design-build method and the implemented procurement approach. Accordingly, they were considered the least objective measure in this research. Similar limitations were also identified in the CII study (Konchar and Sanvido 1998).

6.5 Future Research

The research results have identified several areas that require further research efforts. The following sections discuss suggestions for expanding upon the current research.

6.5.1 A Follow-Up Study on Design-Build Procurement Methods

Since this research is a follow-up to the CII study, it was limited to the analysis of the design-build project data already existing in the database. Projects were completed between years the 1984 and 1997. The later factor has limited the rate of response and resulted in a small sample size for the type of statistical data analysis. Therefore, additional research efforts should focus on collecting additional project data on procurement methods for design-build projects. Recent data could be valuable. The analysis of recent data would help in revealing any newly introduced variables that are impacting the trends and patterns identified through this research.

To help detect significant differences between the procurement methods studied, it is preferable to have a sample size of at least 30 projects for each procurement method category. Such size would be statistically adequate to lessen the effect of violations of the normality and equal variances assumptions. A larger data range would also improve the data set distribution and decrease undue skewness together with the impact of the outliers on the statistical tests.

A follow-up study that further researches the impact of the design-build procurement methods on the project performance would be beneficial. The database for the follow-up study should include additional data on design-build projects together with the data collected through this research. In this way, a larger sample size would produce results that are more representative of the entire population. It may also allow detection of statistically significant differences between the different procurement methods for each performance metric studied.

However, data collected through this research would first need to be evaluated before being combined with any new project data. The underlying reason is that the initial data was collected from projects performed during a time frame that may be different from the current market conditions. Future researchers should test each data set separately to determine whether significant differences prevail or not. The presence of significant differences between the two data sets would indicate that different variables have affected the projects performance. These variables may be policies or regulations recently introduced to the construction industry, in addition to changing economic and industry conditions. Otherwise, the two data sets could be grouped to constitute a database for a larger study.

6.5.2 Qualitative Research that Investigates the Relationships between Design-Build Procurements Methods and Project Performance.

This research investigated the relationship between the design-build procurement methods and the project performance using primarily quantitative methods. A qualitative approach that addresses the same research questions could be valuable. Its results may be used to form the database necessary for the development of an owner's decision support tool, as is detailed in the following section.

The qualitative approach could be achieved using a case-study research methodology. The researcher could examine in-depth the performance of several projects together with the design-build procurement methods implemented. A case study approach might help in identifying how project factors such as the facility type, the structure of the design-build entity, and the level of design completed at the time of procurement may be affecting the studied relationships. Such level of detail can be reached by conducting interviews with owners and design-build teams to discuss the impact of the factors in the procurement method decision process. This would also allow insights into variability within the performance metrics data sets.

6.5.3 The Development of an Owner's Decision Support Tool

As previously mentioned, owners can truly benefit from realizing the importance of incorporating several factors into the selection process. However, it is still necessary to provide owners with a systematic and objective selection process such as a decision support tool. Future research conducted with a larger sample size would enable the development of models for each performance metric that identify the type of relationship between each performance metric and procurement methods. These models could include project-specific factors such as the facility type, the structure of the design-build entity, level of design completed at the time of procurement, and others. Based on these models, a decision support tool, based on quantitative data analysis, could be developed to guide owner organizations through the design-build team procurement process.

This decision support tool could take into account the different criteria considered by owners at the time of the method selection. Critical requirements would be identified through assigning different weights to each criterion and the procurement method would be recommended accordingly. A similar approach was used to develop a decision support tool that helps owners select the most appropriate project delivery system in Oyetunji and Anderson (2001).

Another approach for developing the owner's decision support tool can rely on a model-based retrieval and analysis system. Using this system, the owner could specify several project parameters such as the facility type, the project cost, gross square footage and area. Following, the system could retrieve projects that are present in the database and of similar nature. Based on the statistical analysis results and recommendations, owners could select the most suitable procurement method for the project design-build team.

6.6 Concluding Remarks

The design-build delivery system is increasingly used by both public and private owners due to the potential time and cost savings it can offer. The selection of the most appropriate procurement method is crucial to the successful performance of a design-build project with regards to time, cost and quality. It can also ensure a smooth project delivery process and eliminate problems during construction.

This research provides quantitative data that will assist the owners' procurement method decision for a design-build project. In general, the data analysis clearly indicated several important trends associated with each of the performance metrics. Specifically, significant results were concluded for the cost growth metric. Further research into this area will better depict the relationships between procurement methods and project performance. In addition, it will foster a better understanding of the role played by several project-specific factors in the procurement process of the design-build team.

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APPENDIX A

GLOSSARY OF TERMS

Design-Build: Design-build is a project delivery system where the owner contracts with a single entity that is responsible for both the design and construction services. These services can be wholly completed by the design-build entity; or in part through subcontractors' agreements.

Procurement Methods of Design-Build Teams

Sole Source Selection: The sole source procurement method involves the direct selection of the design-build team without proposals.

Qualifications-Based Selection: In a qualifications-based selection, the owner selects the most qualified design-build team through an RFQ and often negotiates only with that entity to a "fair and reasonable" price. Selection of the team is primarily based on qualitative criteria such as past performance, design-build team reputation, technical competence and financial stability.

Fixed Budget/Best Design Selection: The fixed budget/best design is a procurement method where the owner specifies the project budget during the RFP process. The design-build teams compete by placing as much scope as they can in their submitted proposals. The design-build teams are selected based on qualitative and technical aspects.

Best Value Selection: The best value procurement method is an approach where the design-build teams respond to the owner by submitting proposals that are primarily evaluated based on the technical aspects together with the associated cost of the project. Negotiations may take place after the proposal submittals phase. The owner selects the proposal that offers the best value.

Low Bid Selection: The low bid is a procurement method where the owner primarily selects the design-build team based on the project value and related cost items. Cost criteria represent more than 90% of the design-build team procurement selection process.

Project Performance Metrics

Unit Cost: The unit cost metric refers to the relative cost of a facility with respect to its gross square footage. It is measured by dividing the final project cost by the total facility size ($/SF). The final project cost represents the final design and construction costs.

Cost Growth: The cost growth metric measures the growth of project costs over the budgeted costs. It is measured by dividing the difference between the final project cost and the contract project cost by the contract project cost (%).

Intensity: The intensity performance metric indicates the unit cost of design and construction performed per project unit time. It is measured by dividing the project unit cost by the total time (($/S.F.)/Month). The total time represents the duration that starts from the as-built design phase to the end of the construction.

Construction Speed: The construction speed refers to the rate at which the facility is constructed. It is measured by dividing the facility area by the as built construction duration (S.F./Month).

Delivery Speed: The delivery speed metric indicates the rate at which the facility is designed and constructed. It is measured by dividing the facility area by the total project time (S.F./Month).

Schedule Growth: The schedule growth metric measures the percentage of duration growth over the project life. It is measured by dividing the difference between the total time and the total as planned time by the total as planned time (%).

APPENDIX B

RESEARCH SURVEY

PROCUREMENT METHODS FOR DESIGN-BUILD PROJECTS

DESIGN-BUILD INSTITUTE OF AMERICA
THE PENNSYLVANIA STATE UNIVERSITY

DESCRIPTION

Penn State has been selected by the Design-Build Institute of America (DBIA) to conduct a survey of the procurement methods for design-build projects in the U.S. The survey is part of a follow-up study to a Construction Industry Institute (CII) "Comparison of U.S. Project Delivery Systems" research project.

You or someone in your company provided information on a project for the initial CII study. Using the same project you used for that study, please respond to the following short survey. This information is being used to further investigate design-build procurement methods. Upon receipt of your data, Penn State will number each copy, remove all personal information and remove project identification. The information you provide will be kept strictly confidential and solely used for research purposes.

Please provide the contact information of the person completing the survey and the company information for the purpose of any further clarification. We will e-mail the results of the study to all participants after completion.

Please return the completed questionnaire by mail or fax before 06/11/2003 to:

Dr. John Messner, Dept. of Architectural Engineering
Penn State University, 104 Engineering Unit A
University Park PA 16802
Fax: 208-248-7702 Phone: 814-865-4578

RESPONDENT INFORMATION

Name : ____

Company : ____

E-Mail Address: ____

Project Name : ____

Phone Number : ____

SECTION I: PROJECT TEAM SELECTION

1. How were the design-build services procured for this project?
[ ] Sole source selection: Direct selection without proposals.
[ ] Qualifications-based selection: Through an RFQ, the owner selects the most qualified design-build team and negotiates only with that entity to a “fair and reasonable” price.
[ ] Best value source selection: The design-build entities respond with proposals that contain technical aspects and price; the owner selects the proposal it deems to be of best value.
[ ] Fixed budget/best design: The owner announces the budget for the project and the design-build teams compete by submitting proposals containing as much scope as they can place in their package.
[ ] Low bid.

2. Was there a prequalification process? [ ] Yes [ ] No
If yes, how many teams were prequalified for the project? __________

3. Was the primary process for selecting the design-build team competitive or negotiated?
[ ] Competitive (without detailed negotiation)
[ ] Negotiated

4. Rate on a percentage basis the importance of each of the following factors to the final selection process. Select all that are relevant. Make sure the percentages total 100 %.
[ ] Cost
[ ] Design Aesthetics and Functionality
[ ] Technical Proposal
[ ] Qualifications
[ ] Other _____________________
[ ] Other _____________________
[ ] Other _____________________
[100%] Total

5. What was the type of design-build delivery used on this project?
[ ] Direct Design-Build: The team is chosen early in the process to accomplish feasibility, programming and other pre-design services prior to executing design and construction.
[ ] Design Criteria Design-Build: The entity is chosen after responding to a solicitation that contained performance requirements for the project and criteria for design (not design itself).
[ ] Preliminary Design Design-Build: The team is chosen after responding to a solicitation that contained conceptual or schematic design.
[ ] “Bridging” Design-Build: The team was chosen after responding to a solicitation that contained designs that were completed into the design development phase.

6. What was the phase of pre-design or design status at the time of procurement of the design-build team?
[ ] Inception
[ ] Feasibility/Programming
[ ] Conceptual Options
[ ] Schematic Design
[ ] Design Development
[ ] Construction Documents

7. What was the design status at the time of procurement? ____ % design complete

SECTION II: DELIVERY SYSTEM STRUCTURE

8. What type of entity (organizational structure) holds the design-build contract with the owner?
[ ] Designer-led design-builder
[ ] Constructor-led design-builder
[ ] Developer-led design-build entity
[ ] Joint venture firm
[ ] Integrated design-build firm (in-house design and construction)

SECTION III: CONTRACT

9. Did the contract include any incentive clauses? [ ] Yes [ ] No

10. Incentives clauses were tied to what aspects of the work?
[ ] Quality
[ ] Early completion
[ ] Cost
[ ] Customer satisfaction
[ ] Safety
[ ] Other ______________________________ (Please list)

SECTION IV: OTHER INFORMATION

11. Did the owner have past work experience with the selected design-build organization? [ ] Yes [ ] No

12. What form of specifications was used for the project?
[ ] Prescriptive specifications
[ ] Performance specifications
[ ] Standard format ____________________________ (please list)

13. Did the design-build team have design-build specialty subcontractor(s) for the following trades?

[ ] Mechanical	[ ] Curtain wall
[ ] Electrical	[ ] Other: _______________
[ ] Steel	[ ] Other: _______________

14. How were the major design-build subcontractor services procured by the prime?

[ ] Qualifications-based selection: Through an RFQ, the design-build prime selects the most qualified design-build subcontractors and negotiates only with that entity to a "fair and reasonable" price.

[ ] Best value source selection: The design-build subcontractors respond with proposals that contain technical aspects and price; the design-build prime selects the proposal it deems to be of best value.

[ ] Fixed budget/best design: The design-build prime announces the budget for the project and the design-build subcontractors compete by submitting proposals containing as much scope as they can place in their package.

[ ] Low bid.

15. When were the major subcontractors selected?

[ ] Before prequalification of the design-build prime.

[ ] Before proposal submittal by the design-build entity.

[ ] At or about the time of the award of the prime design-build contract.

[ ] After award of the prime design-build contract.

SECTION V: GENERAL COMMENTS

Please provide any other relevant comments or lessons learned.

____

____

____

Penn State Research Team
Dr. John I. Messner
Dr. Michael J. Horman
Marwa El Wardani

APPENDIX C

PERFORMANCE METRICS BOX PLOTS

The box plots developed for all metrics during the analysis of the total number of projects are included in this section. Also, projects were classified according to the level of complexity and the corresponding box plot for each metric was studied. This step was performed in an attempt to identify differences between the procurement methods that could not be distinguished with the overall analysis.

C.1 Performance Metrics Box Plots for the Total Number of Projects

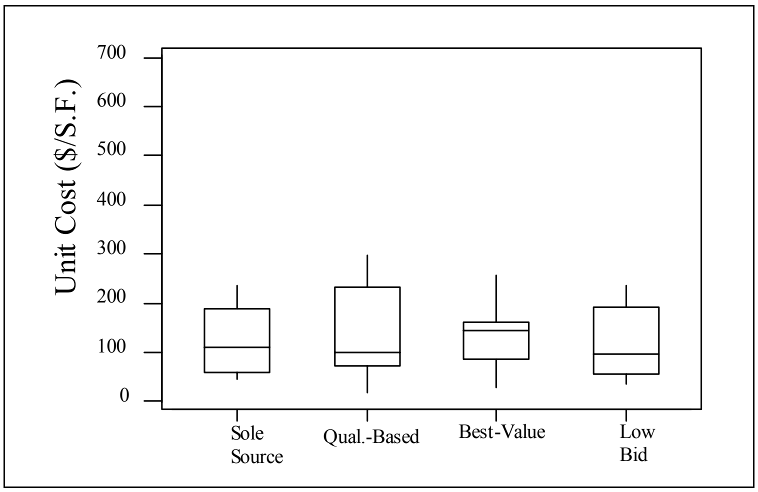

Figure C.1 - Unit Cost by Procurement Method

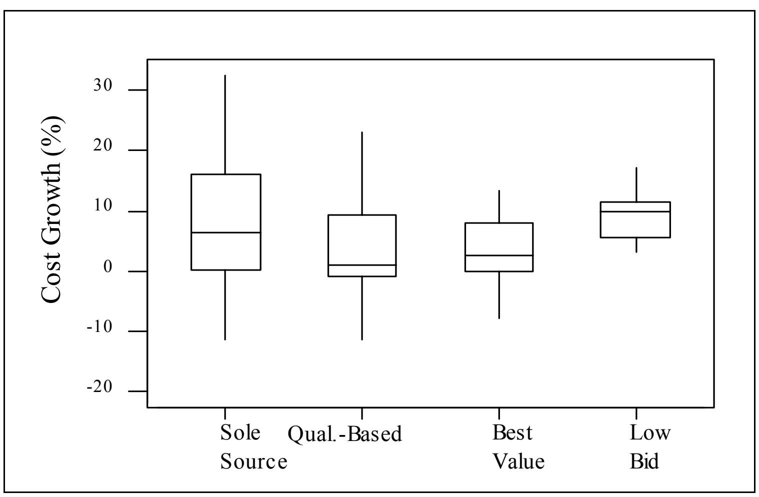

Figure C.2 - Cost Growth by Procurement Method

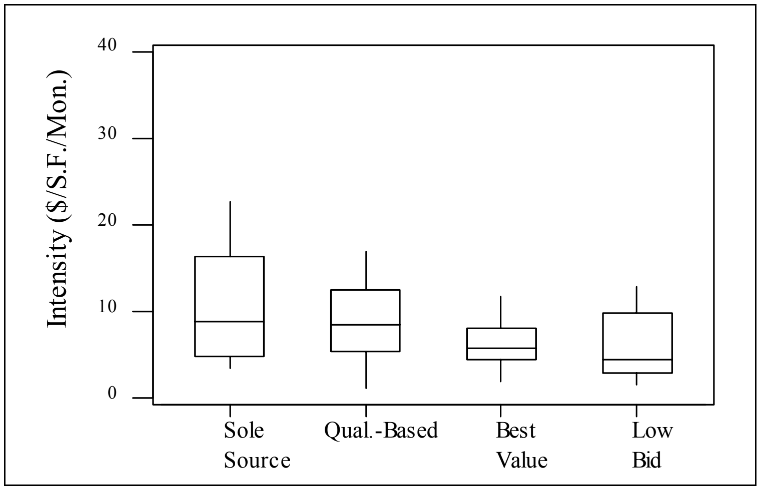

Figure C.3 - Intensity by Procurement Method

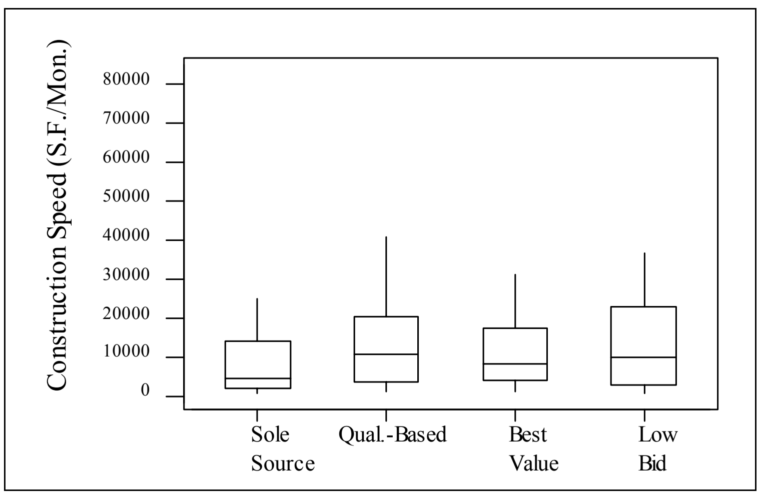

Figure C.4 - Construction Speed by Procurement Method

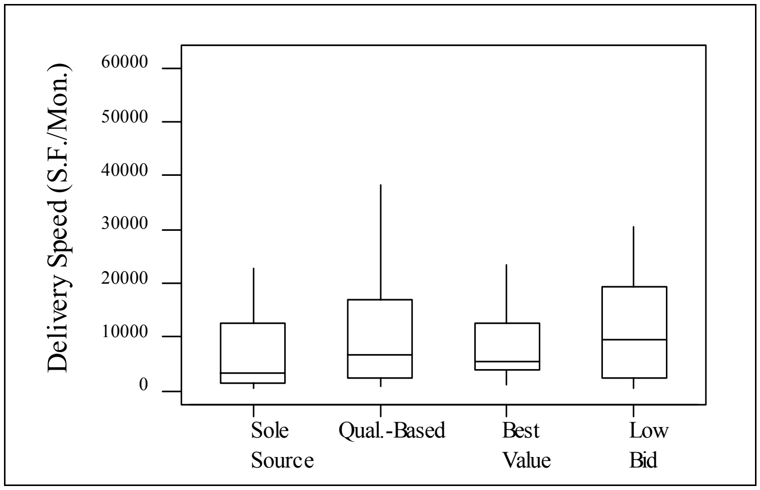

Figure C.5 - Delivery Speed by Procurement Method

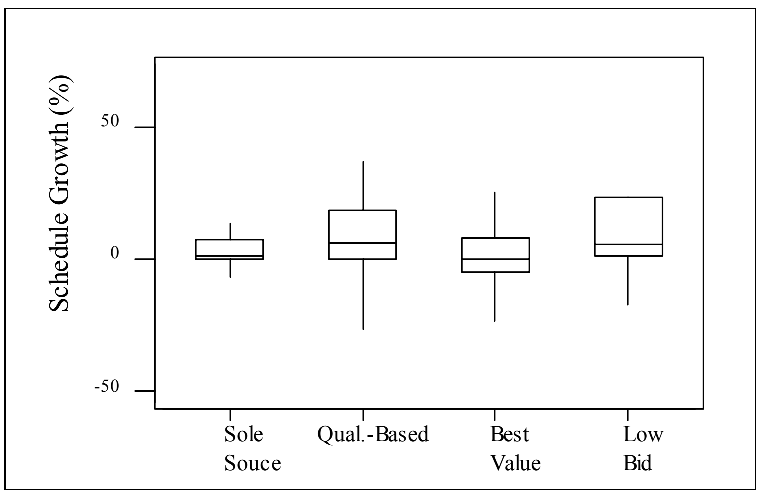

Figure C.6 - Schedule Growth by Procurement Method

C.2 Box Plots for Low-Complexity Projects

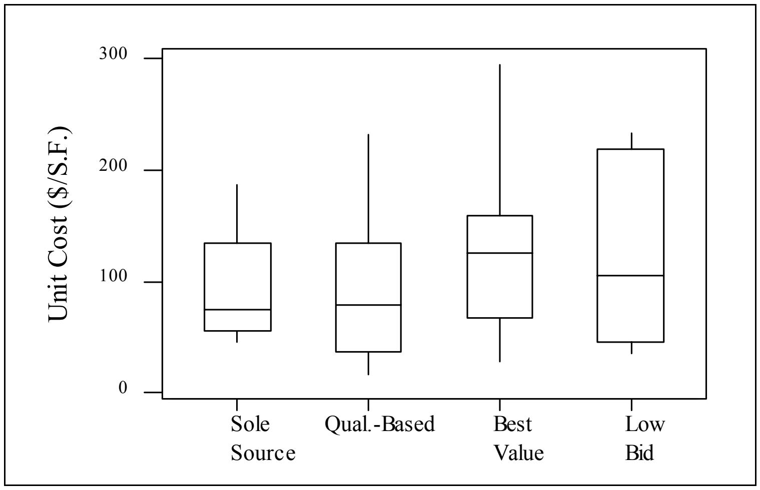

Figure C.7 - Unit Cost for Low Complexity Projects

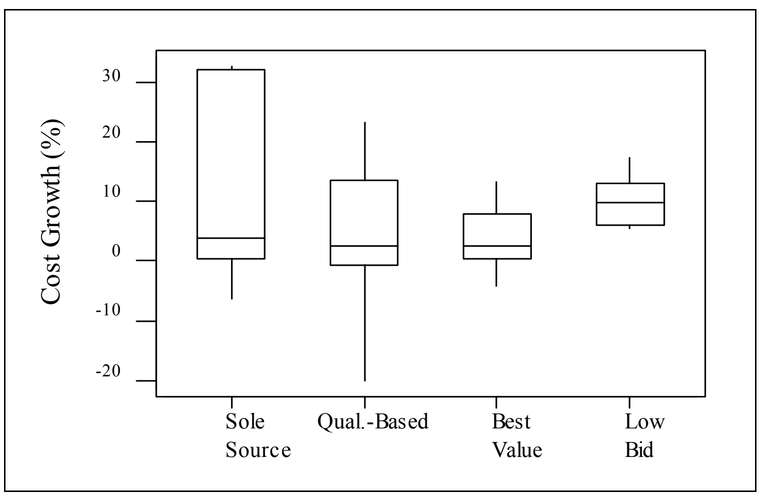

Figure C.8 - Cost Growth for Low Complexity Projects

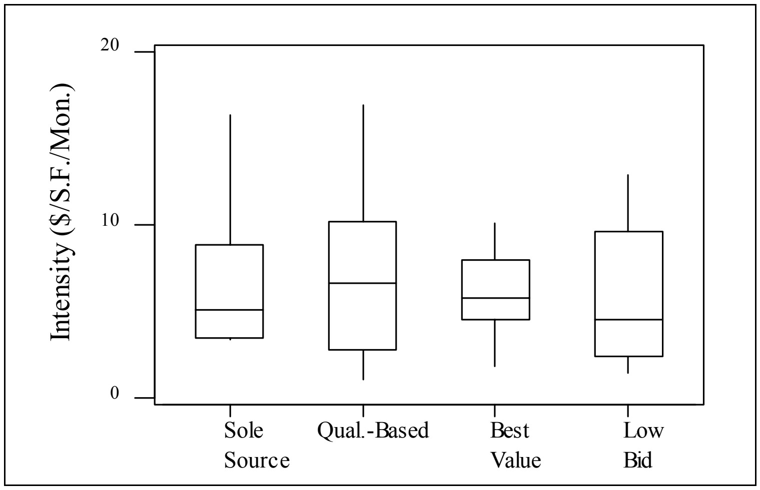

Figure C.9 - Intensity for Low Complexity Projects

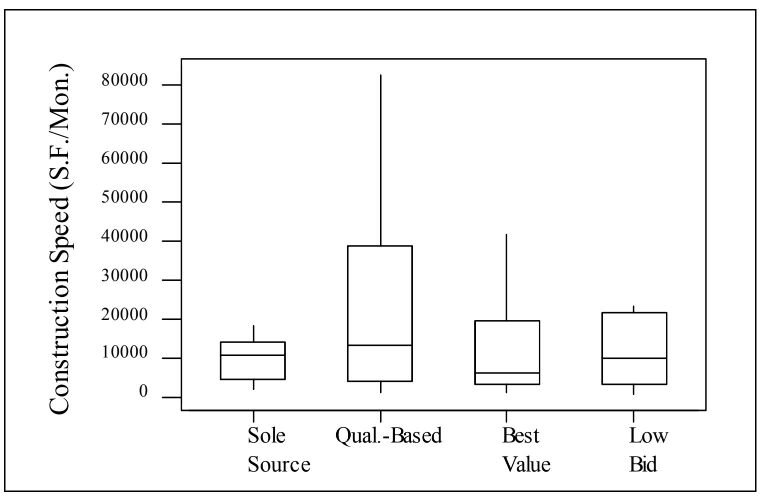

Figure C.10 - Construction Speed for Low Complexity Projects

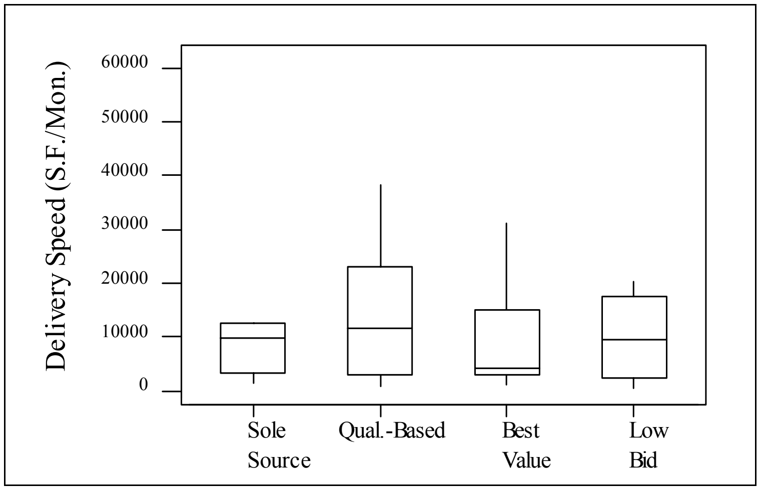

Figure C.11 - Delivery Speed for Low Complexity Projects

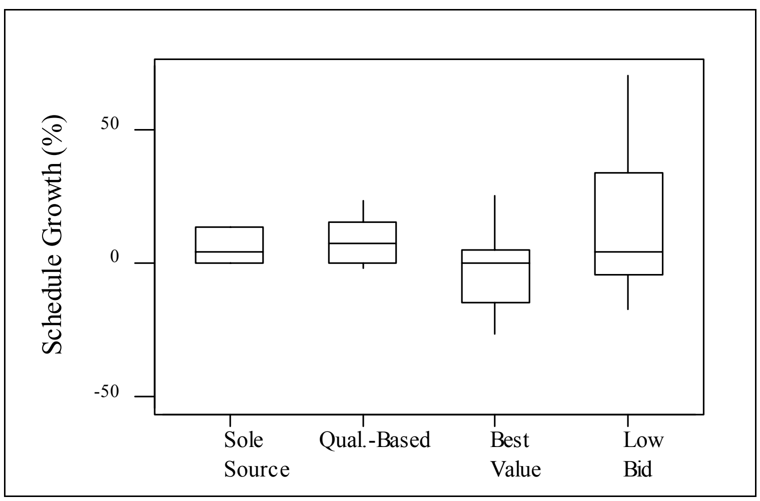

Figure C.12 - Schedule Growth for Low Complexity Projects

C.3 Box Plots for High-Complexity Projects

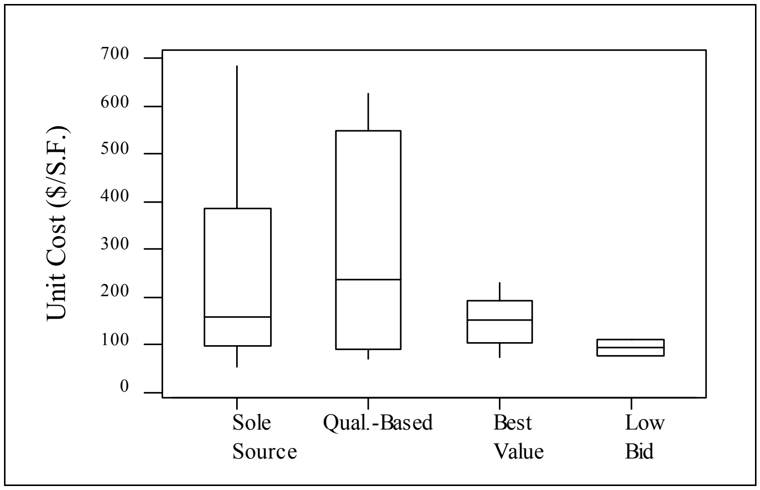

Figure C.13 - Unit Cost for High Complexity Projects

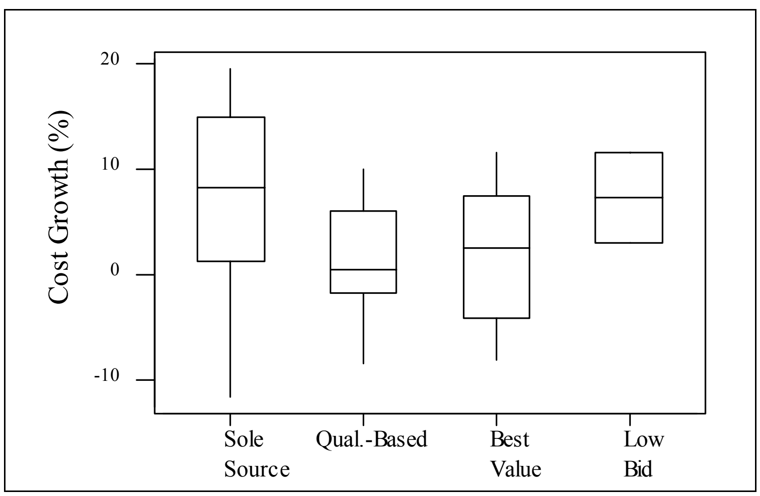

Figure C.14 - Cost Growth for High Complexity Projects

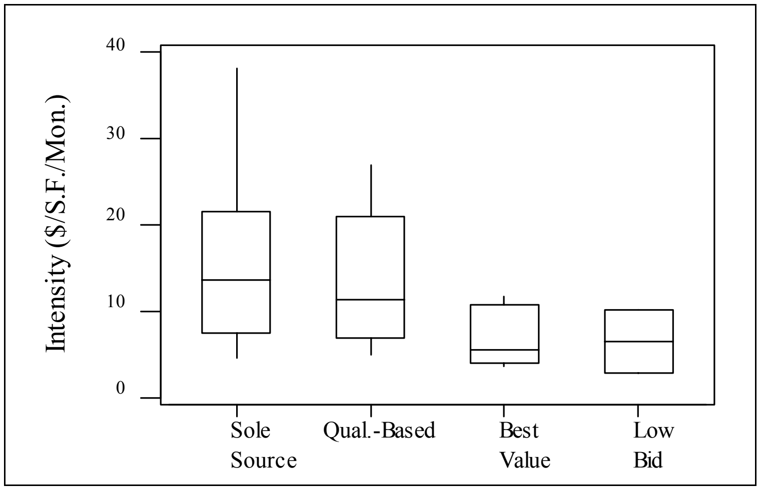

Figure C.15 - Intensity for High Complexity Projects

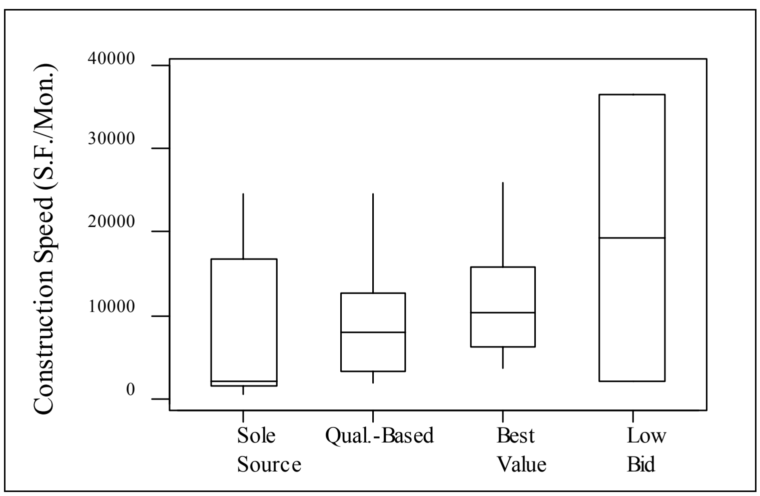

Figure C.16 -Construction Speed for High Complexity Projects

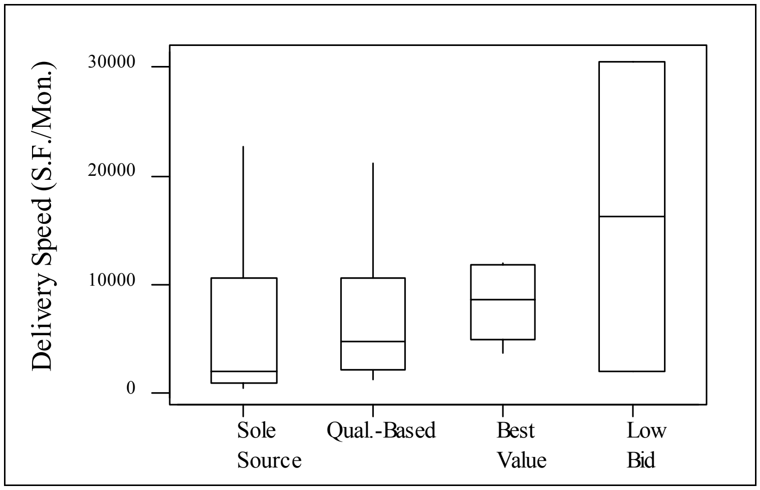

Figure C.17 - Delivery Speed for High Complexity Projects

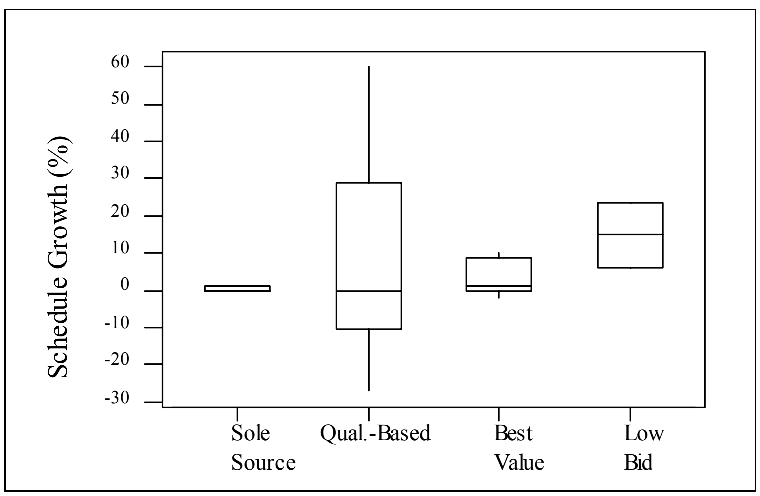

Figure C.18 - Schedule Growth for High Complexity Projects