ANALYSIS OF 2009 ENR BEST PROJECTS IN TEXAS TO DETERMINE THE IMPACT OF PROJECT DELIVERY SYSTEM USED

A Thesis

by

NAVANEETHAN RAJAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2010

Major Subject: Construction Management

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Approved by:

Chair of Committee,	James Smith
Committee Members,	Boong Yeol Ryoo
	Michael O'Brien
Head of Department,	Joe Horlen

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ABSTRACT

Analysis of 2009 ENR Best Projects in Texas to Determine the Impact of Project Delivery System Used. (December 2010)

Navaneethan Rajan, B.Arch., Maulana Azad National Institute of Technology

Chair of Advisory Committee: Dr. James Smith

Competitive Bidding, Competitive Sealed Proposal, construction management agency, construction management at risk, Design-Build, Design-Build-Bridging, and job order contracting are seven project delivery methods that are commonly used in the state of Texas today. This paper empirically compares the cost, schedule, and change order management performance of these project delivery methods in 2009 Engineering News Record (ENR) Best Construction Projects in Texas, using the data collected from the projects representative of the population. Also information is collected on lessons learned from these projects. The thesis included development of survey instrument, getting approval from Institutional Review Board (IRB), data collection from the industry, statistical analysis and inferences. Based on the data collected, project performances were measured in terms of five identified variables and then plotted in the form of probability distribution curves to understand the characteristics of the target population. Then, the results were grouped into six categories based on project delivery methods used and compared to understand their impacts on these projects. Findings revealed predominant usage of CM at Risk PDM, and better cost and schedule performance of CM at Risk, Design-Build, and Owner customized PDM. Detailed performance metrics, results, interpretations and conclusions are presented.

DEDICATION

I dedicate this work to my parents Rajan P and Santhana Lakshmi R.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. James Smith, for his excellent academic guidance and help in data collection. Without his help, this thesis would not have been in its current shape. The support offered by my committee members, Dr. Boong Yeol Ryoo, and Prof. Michael O'Brien, is also appreciated. I also acknowledge the help and advice provided by Prof. Eustace, Dr. Solis, and other faculty members of the Construction Science Department, TAMU.

I offer special thanks to my friends, Anindya, Ashwin, Payal, Trupti, Sruti and Kumar, for making my time at Texas A&M University a great experience. I also want to extend my gratitude to McGraw-Hill Construction for providing the required information and permission for conducting this research and to all the construction companies that participated in this thesis.

Finally, thanks to my mother and father for their love and support, and to my brothers, Saravanan and Vignesh, for their encouragement.

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CHAPTER I

INTRODUCTION AND OBJECTIVES

Research Background

The use of project delivery systems in the construction industry has changed driven by changes in owner expectations and government policies. Traditionally, Design-Bid-Build was the project delivery method (PDM) used by most of the private owners and all public owners. As more and more research findings demonstrated the improved performance of construction projects using alternative project delivery methods like Design-Build and Construction Management at Risk, the government opened many options for the public owners in selecting Project Delivery Methods. Since the Senate Bill 1 (SB1) and Senate Bill (SB583) in 1996/1998 passed, most public owners in Texas can use any of the following seven project delivery methods (Beville, Smith & Peterson, 2007),

1) Competitive Bidding (DBB): In this PDM, the owner has separate contracts with designer and builder. The only criterion for builder selection is "lowest construction cost". Procurement of the builder happens after completion of design documents (Konchar, M. & Sanvido, V. 1998)..

2) Competitive Sealed Proposals (CSP): This PDM is same as Competitive Bidding (DBB), except the criteria for builder selection. Procurement of builder is done on the basis of "Best Value".

This thesis follows the style of *International Journal of Construction Education and Research*.

Best value is a procurement method in which qualifications, design (where applicable) and price or cost are weighed to select designer or constructor that brings greatest value to the owner (AGC, 2004).

3) Construction Management, Agency (CMA): CMA helps the owner in designer/builder selection process; administration; and management services (Beville, Smith & Peterson, 2007). CM Agents represents the owner during the project and the CMA does not take any construction risk.

4) Construction Management at Risk (CMR): In this PDM, the owner has separate contracts with constructor and designer. Typically CMR provides pre-construction services including evaluation of costs, schedule, materials and alternative design implications. CMR guarantees construction cost and schedule. Selection of constructor is done on the basis of "Best Value" (AGC, 2004).

5) Design-Build (D-B): In D-B, the owner has a single contract with the Design-Builder for both design and construction services. Selection is based on Qualifications or "Best Value".

6) Design-Build-Bridging (D-B-B): This method is same as Design-Build, but a bridging architect or consultant helps the owner in developing its requirements or program and to help communicate those requirements to the Design-Builder.

7) Job Order Contracting (JOB): This PDM is used for the works of recurring nature with indefinite delivery times, type and quantities. Pricing is done on the basis of Unit Price Book specified by Government entities; and the bidding occurs on the basis of contractor specified "coefficient" or "multiplier". Contractor selection is based on "Best Value" (Beville, Smith & Peterson, 2007).

With this wide range of options, it is crucial for an owner (both public and private) to select an appropriate project delivery method for his project, to yield maximum benefits. But, selecting the appropriate project delivery method for a project is a challenging task for an owner, as it requires extensive data about performance of similar projects, in the same geographical location and in the recent past. This data could be obtained from the owner's own database or may depend upon studies conducted by research scholars/organizations. So, continuous research studies on efficiency of different project delivery methods are critical to help owners make educated decisions. This thesis is an attempt to contribute towards this need.

In this thesis, the ENR best projects under different categories in the State of Texas, for the year 2009, were analyzed for their performance under different variables and compared with the project delivery methods used. Though ENR best projects are not representative of all the construction projects in Texas, they represent successful projects in the industry. The lessons learned from these projects would provide valuable data for all owners and service professionals in the construction industry. Further, the statistical results derived through this thesis would be helpful in identifying general patterns on all identified variables and preferred project delivery systems in the industry. These statistical results could then be used by owners for understanding how each project delivery method performs, and their pros and cons. It will help in selecting appropriate project delivery methods for new projects that could provide substantial quantitative and qualitative benefits.

Research Objectives

The primary objective of this thesis is to measure the performance of 2009 ENR Best Construction Projects in Texas and determine the impact of Project Delivery Systems used. Achieving this involved two important steps. First, the performance of all the projects was measured based on five key variables including unit cost, cost growth, delivery speed, schedule growth, and builder satisfaction. Then the performance measures were linked to the Project Delivery Systems used in respective projects to understand their efficiency. These two steps helped to establish a relationship between

Performance and Delivery Methods of these projects. But, to achieve the first objective completely, the effects of Change Orders on these projects needed to be analyzed and presented along with the results.

“A Change Order is a written agreement between the owner, contractor and architect upon a change in the work and any appropriate adjustment in the contract sum or the contract time”, (Butler & Cushman, 1994). Change Orders may affect the performance of projects considerably. In this thesis, efforts were made to measure effects of change orders on the performance of 2009 ENR Best Projects in Texas and plot them on graphs against Project Delivery Methods used. This help in understanding how effectively the Change Orders had been managed through respective project delivery methods.

The second objective is to find out the preferred project delivery method(s) in the target population. To achieve this, projects were categorized into different groups based on project delivery methods used. Then pie charts were created reflecting the percentage distribution of usage of different Project Delivery Systems. This help understanding current trends in the selection of project delivery methods in Texas.

The third and final objective is to identify lessons learned from the inputs provided by the builders of 2009 ENR Best Construction Projects in Texas. The data required to accomplish this objective, were collected through online surveys from the contractors of those projects.

CHAPTER II

LITERATURE REVIEW

Various research is being conducted in the fields of performance analysis of construction projects and project delivery methods. A background study on related research studies was conducted to understand common practices in the similar fields of research. Further, information was collected on current trends, data collection strategies, survey instrument design, data analysis methods, and inference mechanics. It provided an overall idea of what to expect from the research. Some of the most relevant literature is discussed in brief below.

Project Delivery Systems: CMR, D-B, and DBB

Introduction

This study was conducted by a group of researchers in the Construction Industry Institute (CII) in the year 1997 in United States of America. It was published in research summary 133-1 by the Bureau of Engineering Research, University of Texas, Austin. (Champagne, 1997).

Objectives

The primary objective of this research was to aid industry in selecting proper delivery methods for the construction projects based on extensive quantitative statistical analysis.

Research Methodology

To represent all the construction projects that were completed between the years 1990 and 1997 in the United States of America, data had been collected from a sample set of 351 randomly selected projects. The size of the projects studied range between 50,000SF and 2,500,000 SF. Also to understand the project performance in the proper context, projects were categorized into six divisions based on the type of facility; 1) Light industrial buildings; 2) Multi-storey dwellings; 3) Simple general buildings; 4) Complex general buildings; 5) Process/heavy manufacturing facilities; and 6) Technology projects.

Five variables were identified for measuring the performance of projects and all data that were required to determine the value of those variables were collected through surveys. Those variables are, Cost growth, Schedule growth; Construction speed; Intensity, and 5) Quality of the Project. After data collection, initial analysis for central tendency was conducted to confirm the existence of differences between the mean, median and mode values. Then, hypothesis testing was used to measure the strength of evidence in the data for or against precise statements about population characteristics. Two sample t-tests and Mood's median tests allowed the researcher to test significance between numbers of critical metrics at a significance level of 95 percent.

Findings

Following are the findings of this research study,

1) D-B had the least cost-growth (2.17%) in comparison to DBB (4.83%) and CMR (3.37%).
2) D-B and CMR had 0% schedule growth while the DBB had 4.4%.

3) The median construction speed of the D-B projects was 10.9% faster than the CMR projects and 77% faster than DBB projects.
4) The intensity [($/SF.)/month] of D-B projects were 1.12% greater than CMR projects and 2.12% greater than DBB projects.
5) D-B scored higher than CMR and DBB in all categories of quality analysis.

Conclusions

With the above findings, researchers concluded that there was a significant difference in the performance of the construction projects based on the project delivery methods used. Also they suggested the industry could utilize the findings of this research to choose the appropriate project delivery method for their projects based on the specific project requirements.

Relevance to My Thesis

This study helped in understanding the data collection strategies and data analysis methods. Also it gave an idea on how to compare different project delivery methods and what to expect from the analysis.

Predicting the Performances of Project Delivery Systems: D-B, and DBB

Introduction

This study was conducted by researchers Florence Yean Yng Ling, Swee Lean Chan, Edwin Chong, and Lee Ping Ee in Singapore. The study was completed in the year 2004 in Singapore (Ling,F., Chan, S.L., Chong, E. & Ee,L., 2002)

Objectives

The primary objectives of this research were to find explanatory variables that significantly affect project performance and to construct models to predict the performance of Design-Build (D-B) and Design-Bid-Build (DBB) Projects.

Research Methodology

The target population of the study was all construction projects that were completed between 1992 and 2002 in Singapore with project cost exceeding $5 million. To represent the whole population, data was collected from 400 sample projects that were selected randomly.

In the list of the 400 projects, many consultants and contractors had undertaken multiple projects. So, a decision was made to request each firm to provide information on a maximum of three projects, to avoid fatigue. Sixty contractors were therefore selected to provide information of 180 projects, 57 consultants to provide information of 171 projects, and the balance 49 projects were requested from 40 owners. 35 owners were asked to provide information on one project each, one owner to provide information of two projects, and four owners to provide information of three projects each. Fewer questionnaires were sent to owners because past research experience showed that very few of them respond to surveys in Singapore. Data was received from the respondents through interviews/self-administered questionnaires. After the completed questionnaires were received, multiple linear regression modeling was undertaken to construct models to predict each of the 11 project performance measures identified. Further validation was done with data collected subsequently.

The eleven identified variables to measure project performance were: 1) Unit cost (dollars/m^2); 2) Cost Growth (%); 3) Intensity (dollars/m^2/month); 4) Construction

Speed (m2/month); 5) Delivery Speed (m2/month); 6) Schedule Growth (%); 7) Turnover Quality (in scale of 1 to 5); 8) System Quality (in scale of 1 to 5); 9) Equipment Quality (in scale of 1 to 5); 10) Owner's Satisfaction (in scale of 1 to 5); and 11) Owner's Administrative burden (in scale of 1 to 5).

Findings

Below provided are the findings of this research study,

1) The delivery speed of DBB projects can be predicted using just two variables: gross floor area and the contractor's design capability.
2) The delivery speed of D-B projects can be predicted using four variables: gross floor area, level of project scope completion when bids are invited, extent to which contract period is allowed to vary during bid evaluation and level of design completion when budget is fixed.
3) The construction speed of DBB projects can be predicted using two variables: gross floor area and adequacy of the contractor's plant and equipment.
4) The construction speed of D-B projects can be predicted using two variables: gross floor area and extent to which contract period is allowed to vary during bid evaluation.

Conclusions

The regression models developed using this study can be utilized to predict certain performance aspects of DBB and D-B projects and hence can be used to decide upon Design-Build and Design-Bid-Build project delivery system in terms of all eleven variables identified in the study.

Relevance to My Thesis

One of the primary objectives of this study was to find explanatory variables that significantly affect performance of construction projects. The eleven variables identified in this study provided an understanding of what parameters need to be measured in analyzing the performance of projects.

Further, the process of constructing a regression model in this research involved detailed performance analysis of projects that were being studied. The data collection strategies and analysis methods used here were helpful in setting a model for my thesis on 2009 ENR Best Construction projects.

CHAPTER III

ENR BEST PROJECTS

Engineering News Record is a weekly magazine that provides news, analysis, data and opinion for the construction industry worldwide. It is owned by The McGraw-Hill Companies. The magazine covers business management, design, construction methods, technology, safety, law, environment, legislation and labor issues (Engineering News Record, 2010).

Engineering News-Record ranks and publishes the largest construction and engineering firms annually, based on their gross revenues. The rankings are carried out for U.S and international firms separately. Its 'Construction Economics' section covers the cost fluctuations of a wide range of building materials. It also provides various annual awards for individuals and newsmakers who best serve the interests of the construction industry and the public (Engineering News Record, 2010).

Every year Engineering News Record selects a group of projects as best projects from multiple regions of the country. The selections are made from wide categories of projects that got completed in that particular year and in that particular region. The selection process involves submission of projects by companies operating in those regions, appraisal of those projects, and announcement/award. In Texas region, the list of selected projects gets published in Texas Construction Magazine (Texas Construction, 2010).

Submission Process

In the submission stage, Engineering News Record accepts projects under each of the following nineteen categories,

1) Civil/Public Works,
2) Cultural ,
3) Government/Public,
4) Green Building,
5) Health Care,
6) Higher Education / Research,.
7) Industrial ,
8) Interior Design/Tenant Improvement,
9) K-12 Education,
10) Landscape/Urban Design,
11) Multi-Family Residential/Hospitality,
12) Office ,
13) Renovation/Restoration,.
14) Retail,
15) Small Project,
16) Specialty Contracting,
17) Sports/Recreation ,
18) Transportation ,
19) Worship.

Construction companies that are practicing in that particular region are encouraged to submit the best of their projects in that particular year with a brief about the project's uniqueness and specialties in a specified format. The companies are usually encouraged to submit multiple entries and to compete under multiple categories. Once the submittals are received, they are compiled and formatted for the appraisal stage. List of names of all

151 projects that got submitted in 2009 ENR Best Projects in Texas and their builders can be found in Appendix B (Table B-1).

Appraisal and Award

The projects received are evaluated by a panel of judges that are recruited by Engineering News Record. The criteria for evaluation includes the following seven topics,

1) Teamwork and Project Management
2) Safety
3) Innovation
4) Contribution to the Community or Industry
5) Overcoming Unique or Difficult Challenges
6) Construction Quality and Craftsmanship
7) Function and Aesthetic Quality of the Design

The percentage of points allotted to each of the above topics is only known to the judges. So, the companies submitting the projects have to give equal importance to all the seven topics or have to make an educated guess based on the category in which it is competing. Then based on the data submitted by the companies, every judge in the panel evaluates the projects individually and assigns a score to them. Once that process is over, the individual scores of the judges are averaged to arrive at a final score for each of the projects. Based on this final score, best projects are then selected under each of the nineteen categories mentioned above.

CHAPTER IV

RESEARCH METHODOLOGY

Data Collection

Analyzing the performance of 2009 ENR Best Projects in Texas required a large quantity of reliable data; and collecting that data was one of the major challenges of this thesis. The literature reviews suggested three ways to collect data essential for the performance analysis of projects; 1) online surveys, 2) phone interviews, and 3) paper based surveys. Considering the large amount of data required, online survey was chosen for this thesis due to its ease of distribution, faster response rate, lower cost, and effectiveness (2004, Granello & Wheaton).

Survey Instrument Design

A copy of the survey instrument used for this thesis can be found at Appendix A.

The complete survey instrument and the research proposal was evaluated and approved by Institutional Review Board (IRB), before sending to the project participants of 2009 ENR Best Projects in Texas. The design of this survey instrument had three main intentions:

1) The survey should take minimum effort and time from the participants,
2) The data collected has to be accurate and reliable, and
3) The data collected should be sufficient to achieve all the three objectives of the research.

To satisfy these intentions, sufficient care was taken to make the survey self-explanatory. Most of the questions were set in the format of multiple choice or single word answers, to make the responding process easier. Explanations were provided wherever it was necessary. Once the participant completed the on-line survey form, he/she were able to submit the response with just a click of a tab at the end of the survey.

The survey was built with three sections. The first section collected general information about the project participant, organization and the project. The details received from first section were not necessary to achieve any of the three research objectives, but helped to establish reliability factor to the entire data set. In case of confusions or shortage of details, the particular person who completed the survey could be contacted for more explanation and details.

The second section had questions designed to receive project specific information which covered the following five topics,

1) Project Delivery Method,
2) Project Size,
3) Project Start/ Completion Dates,
4) Change Orders, and
5) Project Cost.

The questions were focused on collecting information that was necessary to understand the trends of usage of project delivery methods and to measure the value of the five identified variables; and hence analyzing the performance of the projects.

The third and final section of the survey was centered on “Lessons Learned” from these projects. This section enabled the project participants to share important information that were difficult to explain merely through numbers or single text answers. The inputs received from this section were compiled and presented in this thesis, which provides an opportunity to learn from some of the most successful projects in the industry.

Data Collection Process

The next step after survey instrument design was to get the surveys completed by appropriate persons, which involved the following steps:

1) Collecting the list of names of all 151 projects that were submitted for the 2009 ENR Best Projects in Texas and the builders of those projects. With the permission of McGraw-Hill Construction, these two data were obtained from a document containing information of all projects that were submitted for appraisal.
2) Reorganizing the above details in a database that lists the name of all construction companies and links it with the projects submitted by them.
3) Establishing key contacts with the construction companies who then helped identifying persons in their organizations who were participants of the best project(s) built by their companies.
4) Contacting prime participants of best projects with the details of the research and a request to complete the online survey.
5) Providing more information and clarification if required by the participants through online survey response.

After receiving the responses, emails were sent to all respondents thanking them for their participation in the thesis. Also, once the research was completed, a copy of the final report was sent to the participants who opted to receive it.

Data Analysis

A copy of survey results and the calculated values of variables are provided in Appendix C (Table C-1 and Table C-2).The data received from the companies were used to measure the mean values of five identified variables and efficiency of change order management in these projects. A spreadsheet was programmed with built-in formulas to carry out these tasks.

Measurement of Sample Set

Five variables had been identified in this research which significantly affects the performance of the projects that are being studied. To measure the performance of these projects, values of these variables need to be quantified. Below are the formulas that were used to calculate those values:

1) Unit Cost ($/SF): Construction cost in US Dollars that was required to build one square foot of the facility. It was calculated by using the formula
   a. Unit Cost = As-Built Construction Cost / Size of the Facility in SF
2) Cost Growth (%): A percentage value that signifies the increased cost of the project as compared to the contracted cost. It was computed by using the formula,
   a. Cost Growth = (Contracted construction cost - As-built construction cost) / Contracted construction cost
3) Delivery Speed (SF/month): This is the average SF area of the facility was built in thirty days increments of the project. This was calculated by utilizing the below given formula,
   a. Delivery Speed = Size of the Facility in SF / (As-built duration in days/30)

4) Schedule Growth (%): A percentage value that denotes the increased duration of the projects in comparison with the as-planned duration. This was computed by using the following formula,
    a. Schedule Growth = (As-planned duration in days - As-built duration in days) / As-planned duration in days
5) Builder's Satisfaction: This is a scaled measure (1 to 5) of satisfaction of the project participants with the project delivery methods used. The inputs were given by participant itself through survey responses.

Projects with a value for each of the above five variables can be compared with other such projects in the industry for its overall performance. But, it is important to understand that there also exist some other factors that can possibly affect performance of any projects. One of those factors is "Change Orders". "A Change Order is a written agreement between the owner, contractor and architect upon a change in the work and any appropriate adjustment in the contract sum or the contract time." (Cushman & Butler, 1994).

A project's performance can be affected by both "cost of change orders" and "number of change orders issued". Even if one of these two is less and other is high, there could be a considerable impact on the cost and schedule of the project. So, in this thesis an effort has been made to measure, how efficiently each of these projects had handled the Change Orders. Following are some formulas that has been used to achieve this task,

X = (Estimated Cost + Cost of Change Order - Final Cost)/1000

- Function X is formulated to measure the impact of "Cost of Change Orders" on the final cost of these projects. The higher the value of realization of X, the better the project performed in terms of cost and change order management.

Y = X * [1+ (no. of Change Orders)]

- Function Y is formulated to measure the impact of "Number of Change Orders" on the final cost of these projects. The higher the value of realization of Y, the better the project performed in terms of cost and change order control/management.

Z = [(As Built Duration - As Planned Duration) / (1+no. of Change Orders)] * 10

- Function Z is devised to measure the impact of "Number of Change Orders" on the duration of these projects. The lower the value of realization of Z, the better the project performed in terms of schedule and change order management.

The values of realization of functions X, Y, and Z for the sample set can be found in Appendix C (Table C-3). The impact of other factors was considered negligible and not measured for the purpose of this thesis.

Inference on Population of Interest

The values achieved through above measurements depict the performance of individual projects for which the data had been received (i.e., the sample set). To understand the central tendencies about the whole 2009 ENR Best Projects (i.e., the target population), inference needed to be made with appropriate statistical methods. Below provided are the statistical methods used in this thesis.

Probability Distribution

Probability distribution is defined as "a graph that describes the range of possible values that a random variable can attain and the probability that the value of the random variable is within any measurable subset of that range" (Ott & Longnecker, 2001). Plotting this graph required estimated values of population mean "μ" and standard deviation "σ" which were calculated approximately with the sample mean "$\bar{x}$" and standard deviation of the sample set "s" respectively. It is used to estimate the mean values and the distribution of all variables of the 2009 ENR Best Projects. This method allowed to estimate the required values with significant level of confidence. Following are some of the formulas that were utilized in this thesis,

z	=	Standard Score or Normal Score
	=	$(x - \mu) / \sigma$
μ	=	Population Mean
Interval Estimate of μ	=	$\{[\bar{x} - (z_{\alpha/2} * \sigma_{\bar{x}})], [\bar{x} + (z_{\alpha/2} * \sigma_{\bar{x}})]\}$

Where,

x	=	Random Variable
$\bar{x}$	=	Mean of the Sample Set
	=	$(x_1 + x_2 + x_3 \ldots + x_n) / n$
s	=	Standard Deviation of the Sample Set (in this case used as a substitute for σ)
	=	$\{\Sigma^n_{i=1} [(x_i - \bar{x})^2 / (n-1)]\}^{\wedge 1/2}$
$\sigma_{\bar{x}}$	=	$\sigma / \sqrt{n}$
$z_{\alpha/2}$	=	Upper $\alpha/2$ point of standard normal distribution
α	=	Significance level (in this case it is 0.05)

In the above formulas, "n" represents the size of sample set and x_i, x_1, x_2, x_3 etc., represents the values of random samples.

The normal distribution curves and the interval estimate curves presented in this thesis were plotted using "Graphing Normal Distribution Excel File" downloaded from "vertex42.com" (Witter, J.W. 2004).

Bar Charts and Pie Charts

Bar charts are used to compare the mean and median values of variables of projects with different project delivery systems. Also it is used to compare the effectiveness of project delivery systems in change order management. Pie charts are used to demonstrate the trends of usage of project delivery systems in the industry and its percentage distributions.

CHAPTER V

RESULTS AND DISCUSSIONS

Data Limitations

The data collected on thirty two projects through online survey instrument were sufficient to make inference on the characteristics of target population with 95% level of confidence. However, for comparisons of performances of different project delivery methods (PDM), significance testing was not performed due to limited availability of projects under each PDM. The comparisons presented in this thesis are done with the mean and median values of the variables calculated from the projects in the sample set.

Other limitations include the possible effects of external factors on the unit cost calculations. These effects might be caused by variations in the scale of the projects, or type of the projects. Suggestions for minimizing these effects in future studies are presented in the recommendations section of this thesis.

Inference on 2009 ENR Best Projects-Texas

Probability distribution curves and interval estimate curves were used to infer the characteristics of the population from the mean and median values obtained from the sample set data. Errors were minimized by carefully detecting and omitting the outliers in the sample set. The significance level of the inferences made on population characteristics is 95%; which means that "in repeated sampling, 95% of the time the intervals computed with the same function will contain mean μ, although the intervals themselves are changing" (Ott & Longnecker, 2001).

Unit Cost ($/SF)

The cumulative probability curve (Figure 1) explains the probability of getting a unit cost less than or equal to any randomly selected value. For example the probability of getting a unit cost value of $118/SF or less is 13.57%.The calculated mean cost of the population is $182.03/SF and is predicted with a confidence of 95% to lie between $156.23/SF and $207.83/SF (Figure 2). With a standard deviation of 57.68, the probability distribution curve of unit cost predicts the probability of a randomly selected variable to lie between $108/SF and 256 $/SF as 80%.

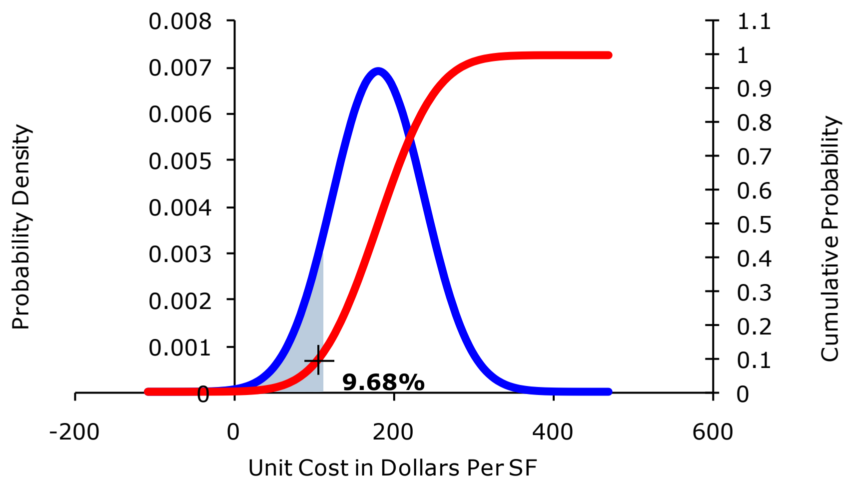

Figure 1: Probability distribution and cumulative probability of unit cost.

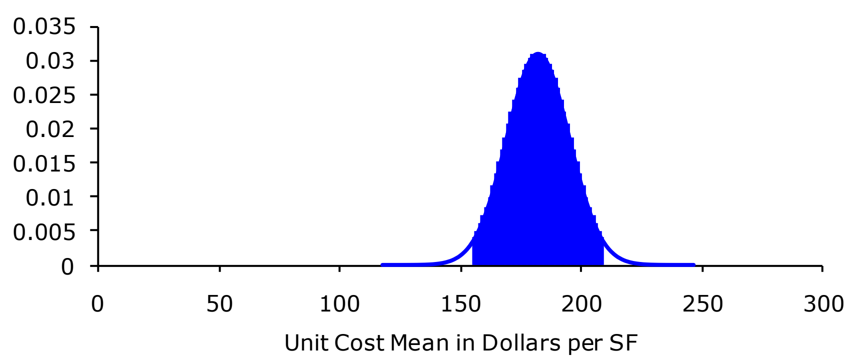

Figure 2: Interval estimate for unit cost mean μ with a significance level of 95%.

Cost Growth (%)

The cost growth percentage of the 2009 ENR Best Projects was less with a mean value of 2.12 and standard deviation of 4.62. The distribution curve predicted the probability for getting a randomly selected project to have a cost growth value lie between -3.8% and 8.04% as 80% (Figure 3). The portion of distribution curve with negative values signifies the probability of a randomly selected project to get completed with a cost less than or equal to the contracted construction cost; which is 32.3%. Interval estimate for the mean cost growth is shown in Figure 4.

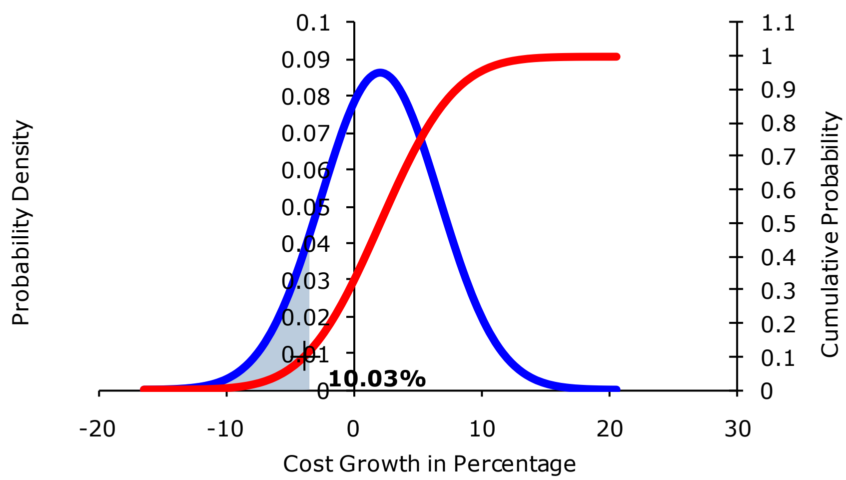

Figure 3: Probability distribution and cumulative probability of cost growth.

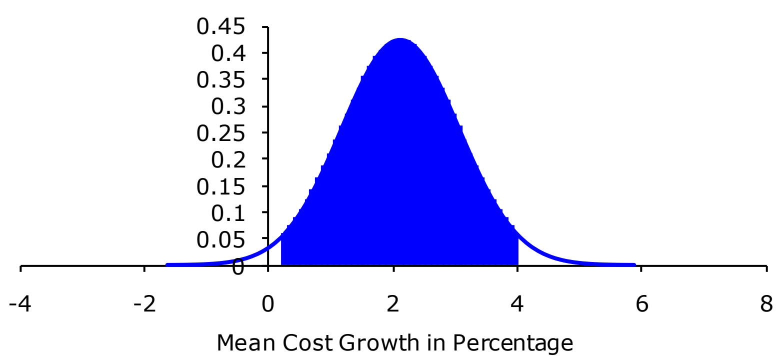

Figure 4: Interval estimate for cost growth mean μ with a significance level of 95%.

Delivery Speed (SF/month)

The delivery speed of the target population has a mean of 8379SF/month with a high variance of 5,338 (Figure 5). The 80% of the probability curve is spread between the values of 1,550 and 15,208 square foot per month of delivery speed. The interval estimate for the mean is calculated as 6,200-10,558 square foot per month, with a confidence of 95% (Figure 6).

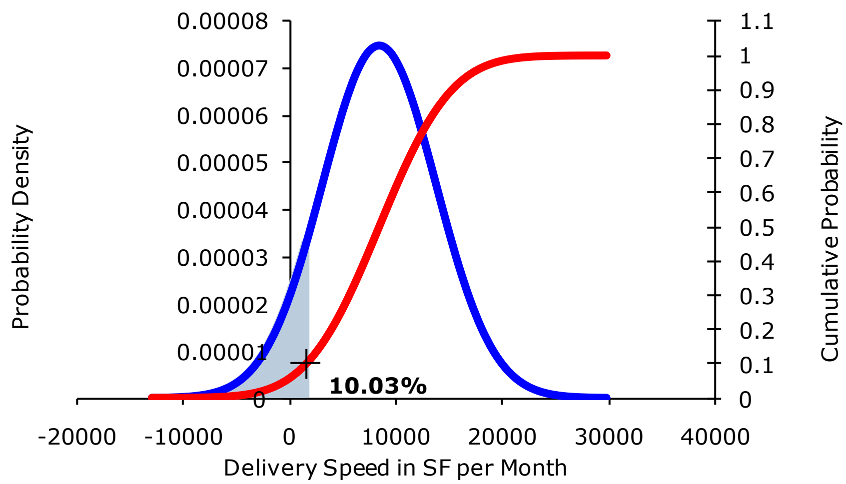

Figure 5: Probability distribution and cumulative probability of delivery speed.

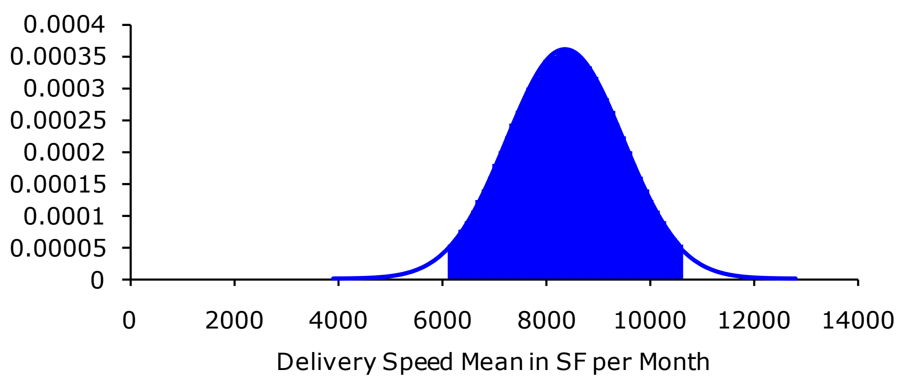

Figure 6: Interval estimate for delivery speed mean μ with a significance level of 95%.

Schedule Growth (%)

Majority portion of the probability distribution for schedule growth is located in the negative side of the graph signifying the earlier completion date of majority of projects (Figure 7). The probability distribution curve has a mean of -0.86 with a variance of 4.97. Based on the inferences made, the probability of a randomly selected project to get completed on or before schedule is 56.87%. Interval estimate for the mean schedule growth is presented in Figure 8.

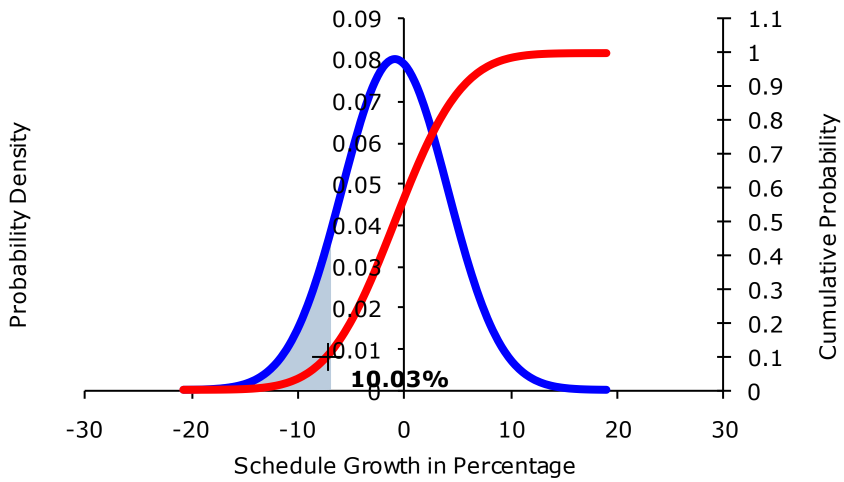

Figure 7: Probability distribution and cumulative probability of schedule growth.

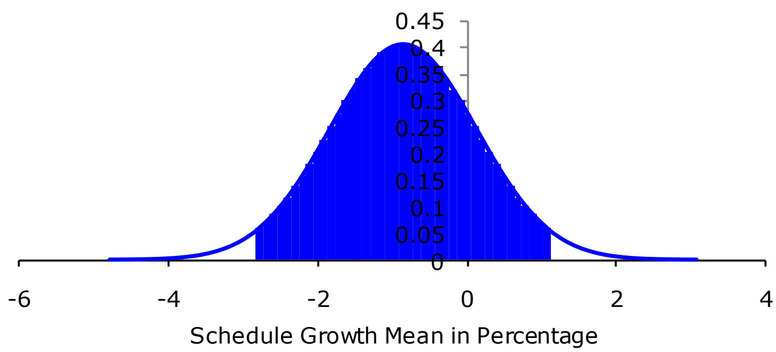

Figure 8: Interval estimate for schedule growth mean μ with a significance level of 95%.

Builder Satisfaction (in scale of 1 to 5)

This variable explains the satisfaction level of the builders with the project delivery methods used in the projects they built. This is purely a qualitative measure with subjective qualities. The results reveal that in most of the projects the builders were highly satisfied with the project delivery methods used. The probability distribution curve for this variable is narrow spread with a mean of 4.27 and standard deviation of 1.08 (Figure 9). The distribution of mean values of builder satisfaction is presented in Figure 10.

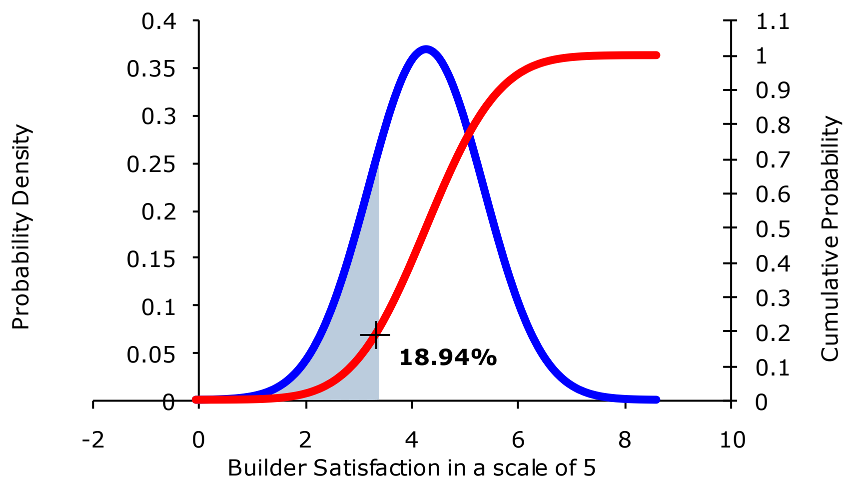

Figure 9: Probability distribution and cumulative probability of builder satisfaction.

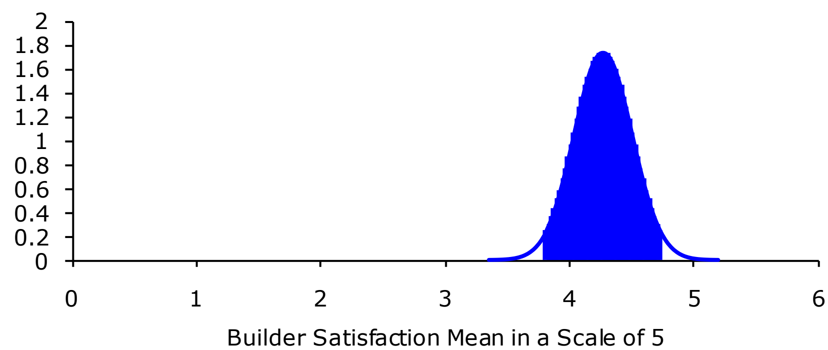

Figure 10: Interval estimate for builder satisfaction mean μ with 95% significance level.

Trends of Usage of Project Delivery Methods (PDM)

The percentage distribution of usage of different project delivery methods (PDM) in the target population is provided in the below given pie chart (Figure 11). Excluding CM at Risk which was used in 62% of projects, the usage of other project delivery methods were evenly distributed with values less than or equal to 10%. These findings clearly imply the shift of trend towards CM at Risk PDM in Texas State.

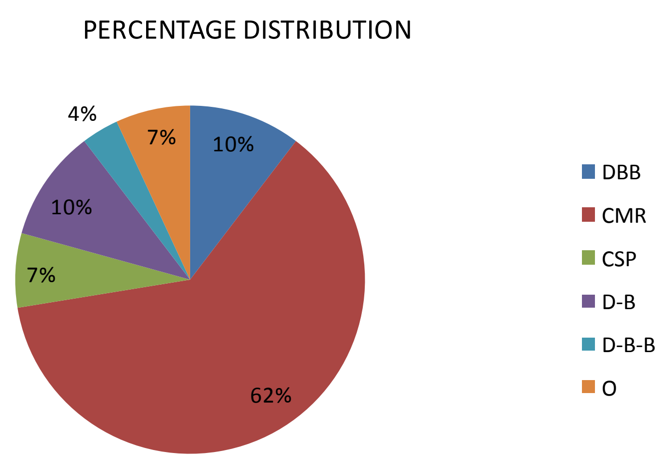

Figure 11: Percentage distribution of usage of different PDM.

Similarly, the study conducted by Kevin Beville in 2007 for his research project on "Preferences for project delivery systems utilized by Texas public universities" find out that, approximately 70-80% of the projects constructed in Texas public universities used CM at Risk project delivery method for two consecutive years 2006 and 2007 (Beville, Smith & Peterson, 2007).

These findings contradict the predictions made by Design-Build Institute of America (DBIA) in 2005, which claimed the shifting of trend towards design-build PDM in United States of America (Design Build Institute of America, 2005); which indicate the need of further research studies in this field for finding the actual trend in the usage of PDM in Texas and other States of America.

Comparison of Projects with Different PDM

For comparison purposes, the measured values of variables were grouped under six categories based on the project delivery methods (PDM) used. Then the mean and median values under each PDM were plotted in the form of column charts to compare their effectiveness. Below provided are the graphs and discussions on the results of these comparisons.

Unit Cost ($/SF)

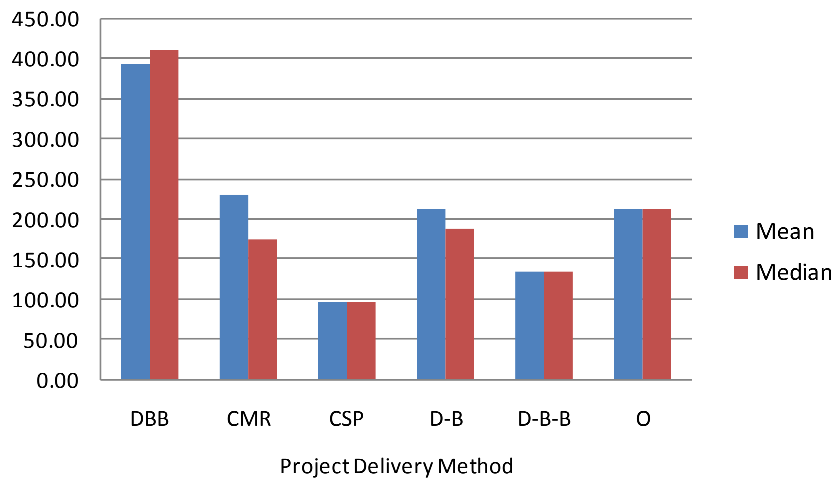

Figure 12: Comparison of unit costs of projects with different PDM.

The unit cost values ranged from approximately $100/SF for Competitive Sealed Proposal projects to $400/SF for Competitive Bidding projects. Design-Build and CM at Risk delivery methods were able to deliver projects with a median unit cost of approximately $210/SF of building. Majority of Competitive Sealed Proposal projects were renovations, which was the cause for the considerably low unit cost for that category (Figure 12).

Cost Growth (%)

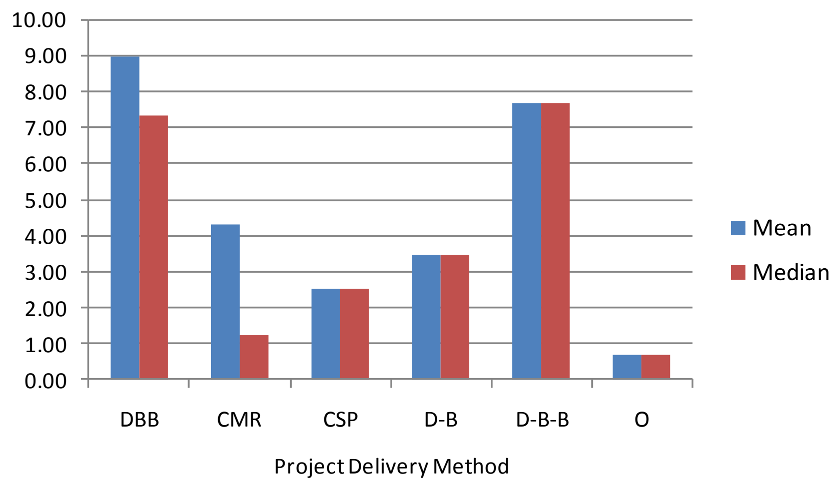

Figure 13: Comparison of cost growth of projects with different PDM.

Competitive Bidding had the highest cost growth of around 9%; CM at Risk and Design-Build had a median cost growth of approximately 4%; and the other project delivery methods division had the lowest cost growth percentage with value close to 0.8% (Figure 13).

Delivery Speed (SF/month):

Competitive Sealed Proposal delivered buildings at a pace three fold faster than the Competitive Bidding, which delivered at the slowest rate. Design-Build and CM at Risk were able to deliver projects at approximately same rate of speed and are second to the Competitive Sealed Proposal which is the fastest in the group (Figure 14).

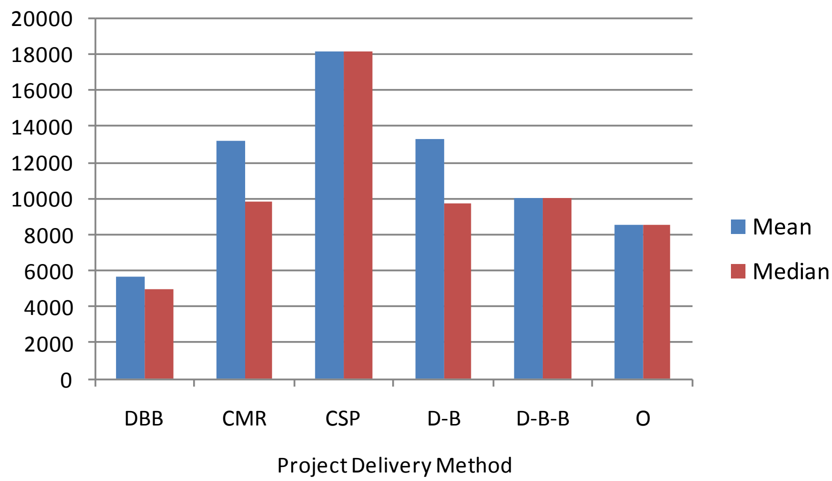

Figure 14: Comparison of delivery speed of projects with different PDM.

Schedule Growth (%)

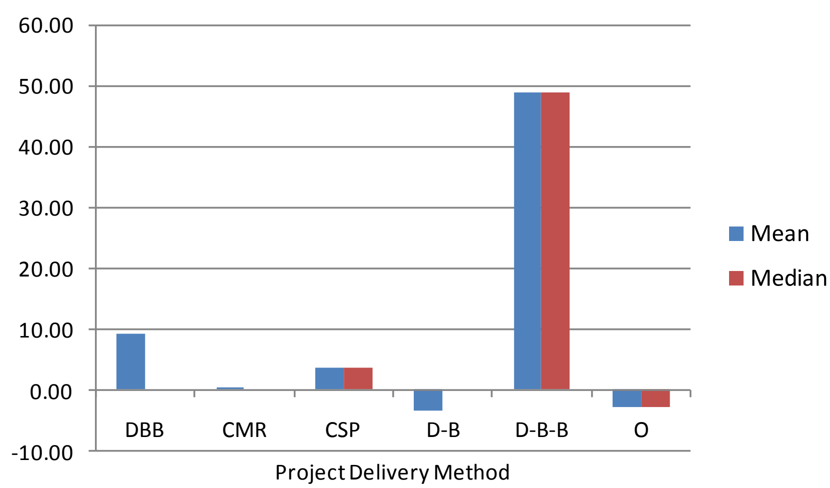

Figure 15: Comparison of schedule growth of projects with different PDM.

In general, most of the project delivery methods delivered the projects on or before the as-planned project completion date. Design-Build-Bridging and Competitive Bidding projects had more schedule delays than other project delivery methods used. Design-Build was able to deliver projects in duration 4% less than planned (Figure 15). The excessive schedule growth of D-B-B was due to major change orders in the specific project from which the data had been collected. Since, it is the only project available in that PDM, care should be taken before making major decisions about D-B-B based on the results generated in figure 15.

Builder Satisfaction (in a scale of 1 to 5)

Except Competitive Bidding, builders that used other project delivery methods were highly satisfied with their performance and effectiveness (Figure 16).

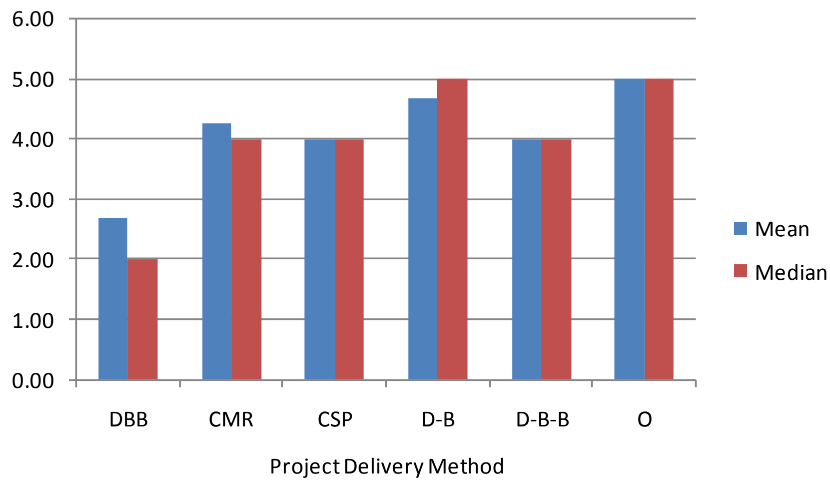

Figure 16: Comparison of builder satisfaction with different PDM.

Change Order Management

Performance of projects depends on how effectively change orders were managed during the project execution phase. Following are the results of the analysis of change order management in 2009 ENR Best Projects-Texas organized according to the project delivery methods used. The formulas used for the calculation of parameters x, y, and z can be found in Chapter IV.

Functions "x" and "y" measure how effectively the final project cost was managed when change orders were introduced. The higher the value of these parameters, the better the project performed. In both cases projects under Design-Build, CM at Risk and other project delivery methods performed better than the rest (Figure 17 & Figure 18).

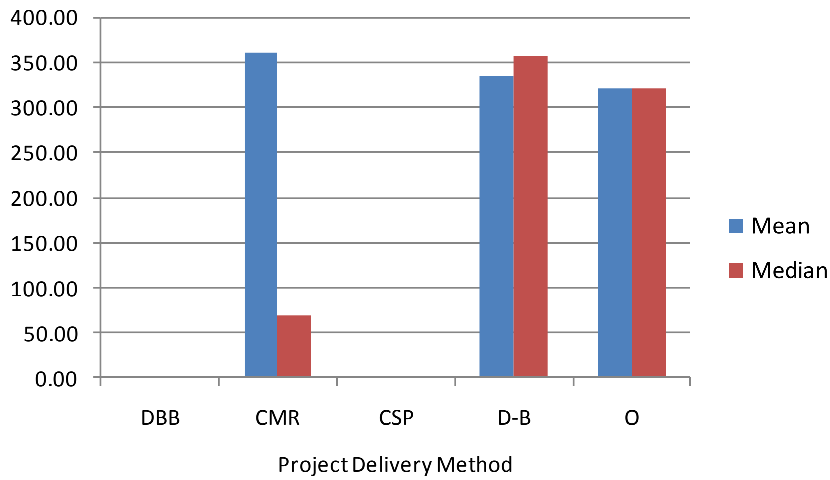

Figure 17: Comparison of realizations of X for different PDM.

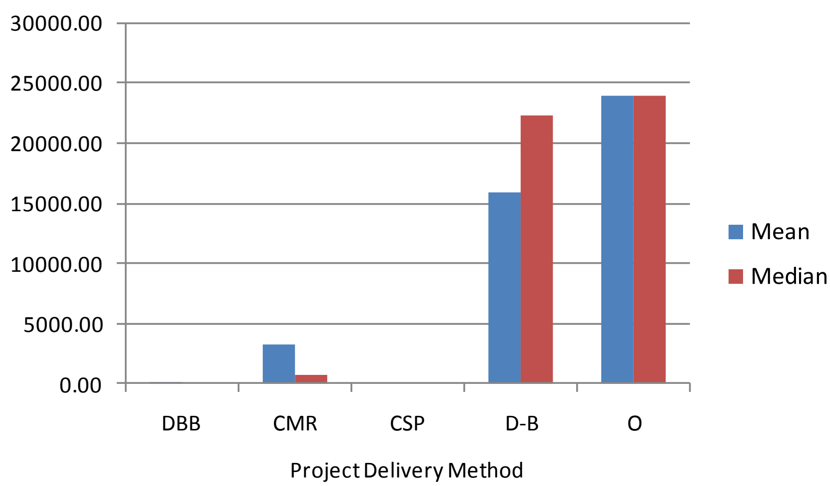

Figure 18: Comparison of realizations of Y for different PDM.

The effectiveness of the projects in controlling the schedule of the project when change orders were introduced was measured with the function “z”. The lower the value, the better the project performed. CM at Risk, Design-Build and other project delivery method project performed better than the rest. Relatively less performed projects were under Competitive Sealed Proposal category and better performed projects were under CM at Risk category (Figure 19).

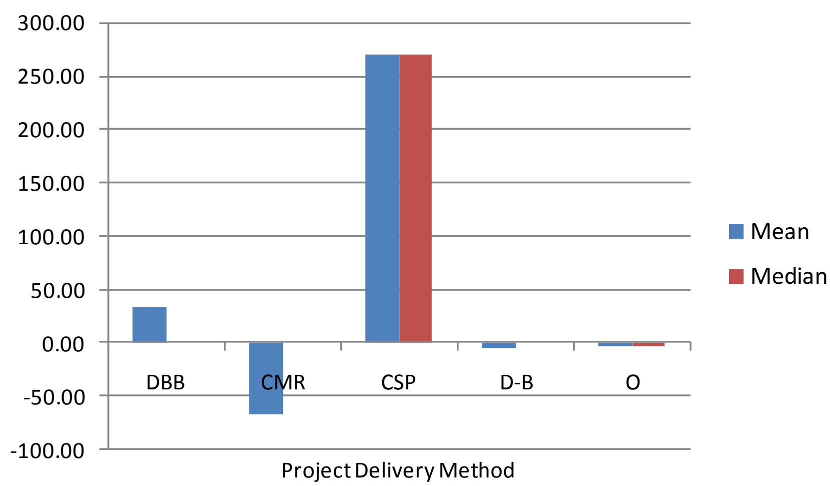

Figure 19: Comparison of realizations of Z for different PDM.

Lessons Learned

Construction Industry Institute (CII) defines Lessons Learned as “knowledge gained from experience, successful or otherwise, for the purpose of improving future performance” (CII, 2008). In this thesis, efforts were made to identify lessons learned from the 2009 ENR Best Projects in Texas by getting inputs from the builders of these projects. Based on their experience with the project delivery methods (PDM) used in these projects, the builders were asked to provide suggestions for the future users of these PDM to improve the project performance. The inputs / suggestions provided by the builders of 2009 ENR Best Projects in Texas can be found in Appendix D. Following is the summary of Lessons Learned from the 2009 ENR Best Projects in Texas based on the inputs provided by the builders of these projects:

- Construction Management at Risk (CMR): For CMR projects, having a good contingency plan is essential to avoid adversarial situations in the course of the projects; a good working relationship need to be maintained between architects, builders and owners, involved in the projects for successful completion of projects; and is important to thoroughly verify the contract terms and agreements before the establishment of guaranteed maximum price (GMP) and execution of contract, to achieve profitable venture for the builders.
- Design-Build (D-B): D-B project delivery method is suitable for projects with time constraints since it allows the start of construction while the design is still in process without adding risk to the owner.
- Design-Build-Bridging (D-B-B): For D-B-B projects the design related issues must be resolved in the early phases of projects to finish the projects on time.
- Other PDM (O): Prior relationship with the owners is critical for builders to win projects that use owner customized project delivery methods like Sole Source.

Sole Source is a non-competitive purchase or procurement process that is accomplished after soliciting and negotiating with only one source (RFP Templates, 2008).

CHAPTER VI

CONCLUSIONS, LESSONS LEARNED, AND RECOMMENDATIONS

Summary

The main objective of this thesis was to measure the performance of 2009 ENR Best Projects in Texas and determine the impact of project delivery systems used. Other minor objectives include finding the preferences of project delivery methods (PDM) in the target population and to identify the lessons learned from the inputs provided by the builders of these projects. The required data for the thesis were collected from the builders of these projects through online surveys. Total survey responses summed to thirty two, which were enough to statistically represent the target population of one hundred and fifty one projects. A summary of findings of this research is provided in the table below (Table 1).

Table 1

Summary of mean values of principle metrics

PDM	Unit Cost ($/SF)	Cost Growth (%)	Delivery Speed (SF/month)	Schedule Growth (%)	Builder Satisfaction (1-5 Scale)	Change Order Management	
						X (No Unit)	Z (No Unit)
DBB	392	8.95	5623	9.27	2.67	0.33	33.06
CMR	231	4.30	13238	0.17	4.25	360.02	-67.72
CSP	96	2.51	18185	3.69	4.00	0.00	270.00
D-B	212	3.46	13317	-3.53	4.67	335.10	-4.44
D-B-B	134	7.69	9984	48.87	4.00	-	-
O	212	0.67	8499	-2.79	5.00	321.85	-2.68

Conclusions

The findings of the thesis obtained through statistical calculations, probability distribution curves, bar charts, and lessons learned lead to the following conclusions on the performance of 2009 ENR Best Construction Projects in Texas and the effect of project delivery systems used:

1) CM at Risk was predominantly used as the preferred project delivery method in 2009 ENR Best Projects in Texas.
2) CM at Risk and Design-Build performed consistently better than other project delivery methods in change order management. In most of the projects, these two PDM were able to keep the cost and schedule under control when change orders were introduced.
3) Projects that used Design-Build and owner customized project delivery methods were able to be constructed in considerably less duration than the as-planned durations.
4) The overall performance of projects that used Competitive Bidding (DBB) as their project delivery method was considerably lower than other projects.

Recommendations

The conclusions achieved through this thesis on the performance of 2009 ENR Best Projects in Texas can be utilized to understand how well some of the most successful construction projects of the Texas State are performing and how their performance is influenced by the project delivery methods used. However, to make inference on a larger population, or other target population, more research studies are required. For future studies, researchers are encouraged to use the survey instrument and research methodology developed in this thesis.

Following are the recommendations for the future research studies in this field based on the findings of this thesis:

1) More research studies are required to find out the actual trend in the preference of project delivery methods (PDM) in Texas State and other States of America. This will help the builders and designers in getting prepared for the changing market needs and demands.
2) More studies are required to eliminate the possible effects of external factors including, scale of projects, and type of projects, on their performance. To achieve this, the study could be repeated by carefully selecting the target population that contains projects from the specific type, or scale that need to be studied.
3) More research studies are required to establish the mean and median performance metrics for all seven project delivery methods used in Texas. For achieving this, the study could be repeated for target populations that contain projects from the specific project delivery method (PDM) that need to be studied.

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APPENDIX A

SURVEY INSTRUMENT

Analysis of 2009-ENR Best Projects, Texas

Introduction

This research is being conducted by Navaneethan Rajan, a graduate student from Construction Science Department, Texas A&M University. Your participation in this survey is critical for the successful completion of this thesis. For this thesis, three different survey instruments have been designed for the purpose of collecting information from each of the three primary project participants (Owner / Designer / Constructor) of 2009 ENR Best Construction Projects. This particular survey is designed for Constructors.

Research Objectives

This research has multiple objectives that can aid the construction industry. They are, 1) To analyze the 2009 ENR Best Construction Projects in Texas and determine the impact of project delivery systems used; 2) To understand the trends in the industry in selecting project delivery methods for projects under each identified family of buildings in the target data; 3) To collect, study and publish the lessons learned from the designers, builders and owners of the 2009 ENR Best Construction Projects in Texas; and 4) To aid Texas owners in selecting appropriate project delivery methods for new construction projects, based on quantitative and statistical analysis of performance of similar projects in the target data.

About This Survey

This survey has been designed carefully to minimize the effort and time required from the participants. It has three sections and will take approximately 15 minutes to complete. Below is a synopsis of contents of this survey: Section-I will collect general information about the project and project participants; Section-II will collect project specific details such as project delivery methods, project size, schedule, change orders and project costs; Section-III will collect information on lessons learned from the project.

I - General Information

Name of the Project *

Name of the Survey Participant *

Name of the Company / Organization *

Role Played in the Project *

II - Project Specific Information

This section will collect project specific details such as, 1) Project Delivery Method 2) Project Size 3) Project Start/Completion Dates 4) Change Orders and 5) Project Costs

1) Project Delivery Method Used

For answering the question below, please refer the following narrative description of different project delivery methods.

- Competitive Bidding: Owner has two separate contracts with Designer and Builder. Criterion for builder selection is lowest construction cost. Procurement of builder happens after completion of design documents.
- Competitive Sealed Proposal: Same as Competitive Bidding, except the criteria for builder selection. Procurement of builder was done on the basis of Best value. Construction Management Agency (CMA): CM agency help the owner in the selection of designer and builder for the project. CM agency represent owner during the project and does not take any risk.
- Construction Management at Risk (CMR): Owner has separate contracts with constructor and designer. Typically constructor provides pre-construction services and guarantees construction cost and schedule. Selection of constructor was done on the basis of Best Value.
- Design-Build: Owner has single contract with the Design-Builder for both design and construction service. Selection based on Qualification and Best Value.
- Design-Build Bridging: Same as Design-Build. But, a bridging architect or consultant helps the owner in developing its requirements or program and to help communicate those requirements to the Design-Builder.
- Others: Any other project delivery method different from the above mentioned project delivery methods.

Project Delivery Method used in this Project *

- ◉ Competitive Bidding
- ○ Competitive Sealed Proposals
- ○ Construction Management Agency (CMA)
- ○ Construction Management at Risk (CMR)
- ○ Design-Build
- ○ Design-Build Bridging

- Other

If other, please specify.

2) Project Size

Area of New Construction **In Square Feet*

Area of Renovation / Restoration *In Square Feet*

3) Project Start / Competition Dates

Procurement of Designer Start Date (*MM/DD/YY*)

Procurement of Constructor Start Date(*MM/DD/YY*)

Construction Start Date (Notice to Proceed) *(*MM/DD/YY*)

Construction Completion Date - As Planned (Substantial Completion) *(*MM/DD/YY*)

Construction Completion Date - As Built (Substantial completion) *(*MM/DD/YY*)

4) Change Orders

In case there were no change orders in one of the following divisions, please enter "Zero" as the value.

Number of Owner-Caused Change Orders

Cost of Owner-Caused Change Orders *In USD*

Number of Designer-Caused Change Orders

Cost of Designer-Caused Change Orders *In USD*

Number of Builder-Caused Change Orders - *Including Differing Site Conditions*

Cost of Builder-Caused Change Orders *In USD*

5) Project Costs

Design Cost(In USD)

Contracted Construction Cost *(In USD)

As-Built Construction Cost *(In USD)

Other Owner Costs Includes, cost of supervision, real estate and owner-furnished equipments and furnishings (In USD)

III - Lessons Learned

Please rate your overall satisfaction with the project delivery method utilized *

	1	2	3	4	5	
Not Satisfied	○	○	○	○	○	Most Satisfied

Any suggestions that you would like to give for the future owners on this project delivery method, based on your experience in this project?

Any other Lessons Learned through this project that you would like to share with the industry?

Will you use this project delivery method again for future projects? *

- ☐ Yes
- ☐ No
- ☐ Maybe

If not, why? ____

If not, what project delivery method will you use in the future?

- ☐ Competitive Bidding
- ☐ Competitive Sealed Proposals
- ☐ Construction Management Agency (CMA)
- ☐ Construction Management at Risk (CMR)
- ☐ Design-Build (DB)
- ☐ Design-Build Bridging
- ☐ other
- ☐ Depends on Project Parameters

To complete this survey, please check one of the boxes below and press "Submit" button. Thank you for your participation.

- ☐ I would like to receive a copy of this research study.
- ☐ No thanks.

Submit

APPENDIX B

Table B-1

List of 2009 engineering news record best projects in Texas and their builders

Name of Builders	Project Names
Adolfson & Peterson Construction	Forest Park Medical Center Eastfield Colleges Pleasant Grove Campus
Aguirre Roden Building Systems	WinStar World Casino
American Constructors	John F. and Nancy Anderson House Residence Hall
Andres Construction	So.7 Shops and Lofts Mosaic Old Parkland
Anslow Bryant Construction, Ltd.	Cemex Center
Austin Commercial	Methodist Hospital Sugar Land (Bed Tower and D/T expansion) Omni Hotel Fort Worth Palisades West
Balfour Beatty Construction (CM Agent)	La Valencia at Starwood
Barbed Cross Construction LLC	Dr. Manuel Carrasco
Bob Moore Construction	Pioneer 360 Business Center First Park Dalport Distribution Center Trammell Crow Company’s I-30 Distribution Centers I & II

Table B-1

Continued

Name of Builders	Project Names
Bovis Lend Lease	WinStar World Casino Hotel
Cadence McShane Construction	DEA McAllen District Office
CF Jordan LP	Foster - Stevens Basketball Center
Charter Builders, Ltd.	Addition & Renovation of the Historic Cotton Bowl Phase II
Chasco Constructors	Dell Diamond Renovation and Expansion
Chicago Bridge & Iron (CB&I)	Golden Pass Liquefied Natural Gas Terminal
Construction Enterprises, Inc.	The Lofts at Wolf Pen Creek
Constructors & Associates	Dallas Center for Architecture Thompson & Knight
David E. Harvey Builders, Inc.	One Park Place Houston Pavilions Hubbell & Hudson Market and Bistro 1254 Enclave Parkway
DDC Construction	The Millennium Greenway
DE Harvey Builders	1254 Enclave Parkway

Table B-1

Continued

Name of Builders	Project Names
DL Bandy	La Vernia Intermediate School
EBCO General Contractor, Ltd.	Remington Medical Resort of San Antonio S&W Cancer Center @ Scott & White Memorial Hospital River Village - Courtyard by Marriott
EE Reed	Texas Steel Processing
Flintco Inc	Embassy Suites San Marcos Hotel and Spa OSU Boone Pickens Stadium Phase III Texas State University Baseball/Softball Complex Enhancements Phase 1
Flynn Construction Inc.	Center for Child Protection
Fretz Construction Company	Memorial Lutheran Church Education Buildings Christ the Redeemer Catholic Church First Colony Church of Christ Cynthia Woods Mitchell Pavilion
Gamma Construction	Office Pavilion
Gilbane Building Company	Humble ISD - Summer Creek High School Discovery Tower City of Houston Fire Station 37

Table B-1

Continued

Name of Builders	**Project Names**
Harrison, Walker & Harper	McLennan Community College New Science Building Brookshire's Food Store #46 Addition and Renovation
Hensel Phelps Construction Co.	Dell Pediatric Research Institute The Element Fort Bliss UEPH Darrell K Royal Texas Memorial Stadium, North End Zone Expansion
Hoar Construction, LLC	Petrobras America Interior Buildout
Hunt Construction Group, Inc.	Central Park Campus Learning Resource Center Frisco Lone Star High School
JE Dunn Construction	St. Luke's Episcopal Healthcare System's Kirby Glen Cyberknife Radiation Therapy Montage @ Hermann Park (Formerly Mosaic @ Hermann Park II)
Jerdon Construction Company; Florida Traffic Control Devices	IH 10 Managed Lanes
Joeris General Contractors, Ltd.	Concordia Lutheran Church New Sanctuary

Table B-1

Continued

Name of Builders	Project Names
Jordan Construction	2818 Place
	Forum at Denton Station
	Newport on the Lake
	The Vidorra
	The Vistana
	Watervue at North Beach
Journeyman Construction, Inc.	Del Valle 9th Grade Campus & Opportunity Center - Del Vale, Austin, Tx
	Bexar County Adult Probation Facility - San Antonio
	Bexar County Juvenile Detention Center- San Antonio
KDW	Advance Polybag Inc.
Key Construction Texas, LLC	NYLO Hotel
	The Beat Condominiums
	CIGNA Pointe Regional Headquarters
Key Construction Texas, LLC	Border Fence K
Lee Lewis Construction-Dallas	Heritage High School
Legacy Partners Residential Development	Legacy on the Lake

Table B-1

Continued

Name of Builders	**Project Names**
Linbeck	Medical Clinic of Houston
	St. Lukes Sugar Land Hospital
	The ProCure Proton Therapy Center- Oklahama City
Lippert Brothers, Inc.	United Way of Central Oklahoma
Lyda Swinerton Builders, LLC	Aloft Hotel
Maccini Construction Company	HSEarchitect's Office
Manhattan Construction Company	Energy Center Office Building - Phase II - Houston
	Energy Center Office Building - Phase II - Houston
MAPP Construction, LLC	The Aveda Institute of Dallas
	Confidential Financial Services Firm-Dallas
Mazanec Construction Company	McLennan Community College Dennis F. Michaelis Academic Center
McCarthy Building Companies, Inc.	United Regional Hospital South Tower Addition - Witchita Falls, Tx
	Dallas County Institute of Forensic Science
	Dallas Center for the Performing Arts Dee & Charles Wyly Theatre
	Dallas County Detention Center South Tower

Table B-1

Continued

Name of Builders	**Project Names**
MEDCO Construction	Baylor Regional Medical Center at Grapevine 5th & 6th Floor Tower Shell Baylor Regional Medical Center at Grapevine Central Utility Plant Baylor University Medical Center 3rd Floor Truett Universal ICU Expansion Baylor University Medical Center 7th Floor Truett Hospital Baylor University Medical Center Parking Garage 4 Baylor Administrative Office Building
Metzger Construction Company	Casimir Sawdust
MW Builders of Texas, Inc	High View Place Apartments - San Antonio Horny Toad Harley-Davidson – Temple
Oscar Renda Contracting	North MacGregor Drive Storm Sewer Relief Project
PBS&J (bridge contractor: HNTB Corporation)	Lewisville Lake Toll Bridge (LLTB)-Dallas
Ratcliff Constructors	Jack Hatchell Administration Building
Robins & Morton	Hillcrest Baptist Medical Center / Womens & Childrens Hospital – Waco

Table B-1

Continued

Name of Builders	**Project Names**
Rogers-O'Brien Construction	Billingsley International Business Park 15-Plano (near Dallas)
Rosenberger Construction	Seismic Exchange-Houston
Satterfield & Pontikes	North Lake College General Purpose Building G - Irving Glenda Dawson High School, Pearland ISD
SEDALCO Construction Services	2200 on West 7th Street Caceria Building Fischer Dining Pavilion Trinity River Audubon Center
Skanska USA Building	University of Houston System at Sugar Land Brazos Hall-Houston La Joya ISD Palmview High School -
Smith & Pickel Construction	Donald W. Reynolds Center - Infant Crisis Services

Table B-1

Continued

Name of Builders	**Project Names**
SpawGlass Construction Corp	Sam Houston State University College of Humanities and Social Sciences Building
	Citation Oil & Gas Corporate Headquarters
	H-E-B Buffalo Speedway
	Texas A&M University McFerrin Athletic Center
	Union Pacific Railroad San Antonio Intermodal Facility
	Texas A&M University Cox-McFerrin Center for Aggie Basketball
SpawGlass Contractors, Inc.	McKenna Village at Sundance
SpawMaxwell	Enclave Administrative Campus-houston
	Lance Armstrong Foundation -Austin
Speed Fab-Crete	Dale Keeling Field House
Steele & Freeman, Inc.	Caprock Elementary School
Tellepsen Builder's	Houstons First Baptist Church Sanctuary Renovation
Texas BBL, L.P.	Eastside

Table B-1

Continued

Name of Builders	**Project Names**
The Beck Group	St. Mark's School of Texas Campus Expansion
	Allaso Ranch
	Texas Capital Bank
	Renion Tower Renovation
	Union Station Renovation
The Hanover Company	Cirque Apartment Tower
The Neenan Company	CentroMed Health and Wellness Center
The Whiting-Turner Contracting Company	JCPenney Store #2982 at The Village at Fairview
Thos. S. Byrne, Ltd.	Booker T. Washington High School for the Performing and Visual Arts
Trimbuilt Construction, Inc	Austin Immediate Care
Turner Construction	Cedar Valley College-Science, Vet Tech & Allied Health Building
	Dallas County Community College District
	Enterprise Plaza Fountain
	City of La Porte Municipal Court Building
	Fort Bend County Jail Expansion
	Westin at the Galleria Dallas

Table B-1

Continued

Name of Builders	Project Names
VCC Irving, TX	
W. S. Bellows Construction Corp	Texas Children's Hospital Feigin Research Center
W.G. Yates & Sons Construction Company	Birdville Center of Technology and Advanced Learning Port Isabel Spool Base Dock Facility Mitchell Historic Properties
Waldrop Construction	Brownwood High School
Zachry	NRG Cedar Bayou
Zenith Construction	Holy Family Parish Hall

APPENDIX C

Table C-1

Summary of Survey Responses

PDM	Project Size (SF)	Area of New Const.	Area of Renovation (SF)	Estimated Const. Cost ($)	As-Built Const. Cost ($)	As-Planned Duration of Project (days)	As-Built Duration of Project (days)
CMR	415,000	385,000	30,000	-	168,000,000	820	820
CMR	14,893	-	14,893	7,000,000	6,500,000	244	228
CMR	180,824	170,824	10,000	45,288,020	48,830,402	656	656
CMR	289,000	229,000	60,000	41,693,252	39,744,673	718	718
CMR	36,838	-	-	9,864,775	10,363,734	408	408
CMR	150,000	-	-	26,580,013	26,014,968	677	602
CSP	380,000	-	-	54,113,850	54,034,343	732	786
DBB	112,000	-	-	44,288,000	4,6101,000	685	679
D-B-B	417,671	-	-	52,000,000	56,000,000	843	1,255
O	270,000	-	-	38,400,000	38,348,000	640	640
CMR	673,675	-	-	67,911,479	68,740,147	695	690
CMR	910,000	-	-	-	-	1098	1,098
CMR	184,596	-	-	17,807,438	20,421,023	540	564
CMR	360,000	-	-	-	66,000,000	520	557

Table C-1

Continued

PDM	Project Size (SF)	Area of New Const.	Area of Renovation (SF)	Estimated Const. Cost ($)	As-Built Const. Cost ($)	As-Planned Duration of Project (days)	As-Built Duration of Project (days)
O	73,372	-	-	20,456,500	20,757,040	537	507
CMR	320,000	-	-	37,000,000	39,000,000	513	561
CMR	88,000	-	-	48,000,000	63,000,000	870	1,008
DBB	330,000	-	-	61,731,000	66,259,000	923	923
D-B	517,000	-	-	31,000,000	97,000,000	794	710
CMR	191,076	-	-	31,668,072	31,665,656	911	863
CMR	68,000	-	-	16,797,312	17,284,491	633	574
D-B	200,000	-	-	53,000,000	53,000,000	614	614
CMR	176,000	160,000	16000	7,600,000	7,400,000	139	138
CMR	-	1	-	11,997,660	13,527,680	287	287
D-B	45,000	30,000	15000	7,843,000	8,386,000	162	162
CMR	59,800	-	59800	10,459,600	10,459,600	252	252
CMR	501,500	28,000	473500	62,500,000	62,500,000	804	804
DBB	22,000	-	-	10,789,400	12,454,669	429	552
CSP	150,878		-	7,423,894	7,808,106	207	207

Table C-2

Calculated values of five variables

PDM	Unit Cost ($/sq.ft)	Cost Growth (%)	Delivery Speed (sq.ft/month)	Schedule Growth (%)	Builder Satisfaction (out of 5)
CMR	404.82	-	15,182	0.00	4
CMR	436.45	-7.14	1,959	-6.56	-
CMR	270.04	7.82	8,269	0.00	4
CMR	137.52	-4.67	12,075	0.00	5
CMR	281.33	5.06	2,708	0.00	4
CMR	173.43	-2.13	7,475	-11.08	4
CSP	142.20	-0.15	14,503	7.38	-
DBB	411.62	4.09	4,948	-0.88	2
D-B-B	134.08	7.69	9,984	48.87	4
O	142.03	-0.14	12,656	0.00	-
CMR	102.04	1.22	29,290	-0.72	5
CMR	-	-	24,863	0.00	-
CMR	110.63	14.68	9,818	4.44	1
CMR	183.33	-	19,389	7.12	5
O	282.90	1.47	4,341	-5.59	5

Table C-2

Continued

PDM	Unit Cost ($/sq.ft)	Cost Growth (%)	Delivery Speed (sq.ft/month)	Schedule Growth (%)	Builder Satisfaction (out of 5)
CMR	121.88	5.41	17,112	9.36	4
CMR	715.91	31.25	2,619	15.86	5
DBB	200.78	7.34	10,725	0.00	2
D-B	187.62	212.90	21,845	-10.58	5
CMR	165.72	-0.01	6,642	-5.27	4
CMR	254.18	2.90	3,554	-9.32	5
D-B	265.00	0.00	9,771	0.00	5
CMR	42.05	-2.63	38,260	-0.72	5
CMR	-	12.75	-	0.00	4
D-B	186.36	6.92	8,333	0.00	4
CMR	174.91	0.00	7,119	0.00	4
CMR	124.63	0.00	18,712	0.00	5
DBB	566.12	15.43	1,195	28.67	4
CSP	51.75	5.18	21,866	0.00	4

Table C-3

Values of realization of x, y, and z

PDM	No. of Change Orders	Cost of Change Orders ($)	X (Unit Less)	Y (Unit Less)	Z (Unit Less)
CMR	-	-	-	-	-
CMR	-	-	-	-	-
CMR	27	3,629,103	86.72	2,428.19	0.00
CMR	0	0	1,948.58	1,948.58	0.00
CMR	6	498,959	0.00	0.00	0.00
CMR	0	0	565.05	565.05	-750.00
CSP	1	-79,505	0.00	0.00	270.00
DBB	17	1,813,000	0.00	0.00	-3.33
D-B-B	-	4,000,000	0.00	-	-
O	97	231,700	283.70	27,802.60	0.00
CMR	14	878,668	50.00	750.00	-3.33
CMR	21	3,200,000	-	-	0.00
CMR	29	2,613,585	0.00	0.00	8.00
CMR	-	-	-	-	-
O	55	660,540	360.00	20,160.00	-5.36

Table C-3

Continued

PDM	No. of Change Orders	Cost of Change Orders ($)	X (Unit Less)	Y (Unit Less)	Z (Unit Less)
CMR	63	2,000,000	0.00	0.00	7.50
CMR	136	-	-	-	10.07
DBB	17	4,529,000	1.00	18.00	0.00
D-B	62	66,357,303	357.30	22,510.09	-13.33
CMR	23	1,215,277	1,217.69	29,224.63	-20.00
CMR	10	5,79,379	92.20	1,014.20	-53.64
D-B	10	250,000	250.00	2,750.00	0.00
CMR	8	160,000	360.00	3,240.00	-1.11
CMR	9	1530,020	0.00	0.00	0.00
D-B	55	941,000	398.00	22,288.00	0.00
CMR	0	0	0.00	0.00	0.00
CMR	-	-	-	-	-
DBB	11	1,665,269	0.00	0.00	102.50
CSP	-	-	-	-	-

APPENDIX D

Following are the direct quotes of some of the inputs / suggestions provided by the builders of the 2009 ENR Best Projects in Texas. Due to privacy and confidentiality issues, names of the companies and persons who shared this information are not provided.

Construction Management at Risk

- "Prior to the start of construction, contingencies should be developed. There will always be changes in the project either due to owner requests, drawing conflicts or design considerations which were not identified during the contract document preparation. The establishment of a contingency fund removes much of the adversarial or defensive postures that often develop throughout the course of the project."
- "Hiring the contractor on a CMR basis will generate the best partnership and allow the most input by the owner. CMR method allows the owner to proceed without design completion and save financing costs. Partnership between all parties is paramount to the success of a complicated project."
- "Prior to establishment of the Guaranteed Maximum Price (GMP) and execution of the contract between the developer and contractor/construction manager, the documents must be revised to reflect all agreements and terms of the contract. Any procedure to the contrary will result in an unprofitable venture for the contractor/construction manager."
- "CMR is a great delivery method when everyone works together as a team. Use Building Information Modeling (BIM) to help coordinate the project. BIM is a great communication tool, and it makes conflict detection much easier."
- "Do not start construction until construction documents are complete. Success of the project depends on careful selection of the designer and contractor."

- “The relationship of the Owner, Designer and Contractor working as a team, is beneficial in overcoming many obstacles. Whether it is unknown existing conditions resulting in design changes, or value engineering to maintain the budget and keep the design with varying materials and/or methods.”

Design-Build

- “Texas State chose the delivery method based on the time frame to get the project built between baseball/softball seasons. The design time was a little short, but based on the cost of the project, with teamwork between Texas State and the Design Build team, we produced a project that all parties were happy with.”
    - “Design-Build had a definite advantage with a project that has time constraints. We were able to start construction while the design was still in process.”

Design-Build-Bridging

- “Make sure design related issued are resolved, agreed to early in project and executed timely.”

Other Project Delivery Methods

- “Sole Source is one of our favorite delivery methods. There is nothing better than getting a call from an owner and then saying, ‘We have a $40M hotel we want you to build.’ The team worked well together as we have worked with the owner organization previously.”
- “This delivery method allowed the general contractor to be selected early in the project and monitor the budget and schedule as the project progressed

through the design phase of the project. During the design material cost escalations were consistently coming in and our company priced several iterations of the design to maximize the owner's budget in keeping with the architects design."

- "Carrying a contingency that directly correlates to the complexity of the project is very important. In addition, utilizing a guaranteed maximum price (GMP) contract with a savings split which allowed us to return a large savings at the end of the project that helped temper the cost of the additional work added by the owner. Finally, the selection of the team that has a good working relationship cannot be emphasized enough. Working through difficult details is made that much easier if everyone is working to the same goal."

VITA

Navaneethan Rajan received his Bachelor of Architecture degree from Maulana Azad National Institute of Technology at Bhopal, India in 2007. He entered the Construction Management program at Texas A&M University in August 2008 and received his Master of Science degree in December 2010. His research interests include project delivery methods, and project controls and management.

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