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Comparison of design-build and design-bid-build performance of public university projects

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COMPARISON OF DESIGN-BUILD AND DESIGN-BID-BUILD PERFORMANCE OF PUBLIC UNIVERSITY PROJECTS

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ABSTRACT

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of Public University Projects

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With an unsure market and scarce work, owners across the United States, especially universities, are finding themselves in situations where they are unable to complete their projects within cost and schedule using the traditional delivery method: Design–Bid–Build (DBB). Under the DBB project delivery method, many competent contractors are electing to send low bids on projects just to keep work on their books, with plans to receive change orders once the project is underway; this practice is leading to cost and schedule overruns. Public universities across the United States are beginning to elect to use Design-Build (DB) as an alternate project delivery method over the traditional project delivery method of DBB in order to aid in reducing the cost, schedule, and change orders.

Due to current legislation in effect, all 50 states are able to use the DB delivery method. However, only 20 states and their public agencies are permitted to use DB for all types of design and construction projects. In 18 states, DB is widely permitted, but not all agencies are permitted to use this delivery method. In the remaining 12 states, DB is a limited option.

In order to analyze and compare Design-Build (DB) and Design-Bid-Build (DBB) projects, this study collected data, by means of convenient random sampling, from construction projects built by Planning and Construction Departments of U.S. universities. Statistical tests were conducted to determine if the metrics related to cost, schedule, and change orders were significantly different from each other in these two types of projects.

The findings of this study will help public universities decide what delivery method is best for them in terms of controlling costs, schedule, and change orders. The results showed that DB projects significantly outperformed DBB projects in terms of Contract Award Cost Growth, Design and Construction Schedule Growth, Total Schedule Growth, Construction Intensity, Construction Change Order Cost Growth, and Total Change Order Cost Growth.

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This research paper is dedicated to my daughter Alexis Fiori Fernane with the hopes that one day I will be able to hold her in my arms again.

"Alexis, you are in my thoughts every day. I love you."

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In today's ever-changing construction market, owners are finding themselves in many undesirable and unfamiliar situations. With an unsure market and scarce work, owners across the United States, especially universities, are finding themselves in situations where they are unable to complete their projects within cost and schedule using the traditional delivery method: Design–Bid–Build (DBB). Under the DBB project delivery method, many of the competent contractors are electing to send low bids on projects just to keep work on their books, with plans to receive change orders while it is underway, which is leading to cost and schedule overruns. Universities across the United States are beginning to elect to use Design-Build (DB) as an alternate project delivery method over the traditional project delivery method of DBB to aid in reducing the cost, schedule, and change orders.

Furthermore, this has led to unqualified contracting companies also bidding on jobs that utilize the traditional delivery method, DBB. This in turn is leading to even more change orders, cost overruns, and the inability to meet the schedule. With a selection process based on best value or qualifications, this problem can be avoided (Scott et al. 2006).

Public agencies --for example, state funded universities that rely heavily on tight deadlines and compacted or accelerated schedules due to the service they provide for their student population -- are now searching for alternate delivery methods for projects. One delivery method that increasingly is being considered is the DB delivery method. Under the DB delivery method, the owner/client produces bridge documents for the basis of the design and sets forth expectations for the design and construction of the project. Then, the owner/client contracts with a single entity, which then becomes responsible for both the design and the construction of the project. Furthermore, the DB delivery method has criteria built into the selection process that allows the owner to select the DB entity based on the best value for the owner; in this way, the owner is not 'handcuffed' to the low bidder or to aforementioned unqualified contracting companies.

In order to aid in reducing cost and schedule overruns, universities across the U.S. are beginning to elect to use DB as an alternate delivery method over the traditional method of DBB. Due to current legislature in effect, all 50 states are able to use the DB delivery method. However, only 20 states and their public agencies are permitted to use DB for all types of design and construction projects. In 18 states, DB is widely permitted, but not all agencies are permitted to use this delivery method. In the remaining 12 states, DB is a limited option.

1.1 Design-Bid-Build Delivery Method

Under the Design-Bid-Build (DBB) delivery method, the owner selects a design firm to create contract documents consisting of project drawings (the design) and job specifications. Depending on the project size and complexity, the project drawings typically consist of seven main design disciplines: Civil, Architectural, Structural, Mechanical, Electrical, Plumbing, and Telecommunications. After the design is completed, the project drawings become the contract documents and the project is awarded to the low bidder.

The job specifications can be listed on the drawings in note form; however, they are typically listed in special groups with section numbers designated by Construction

Specification Institute (CSI) Divisions 1 through 16. These divisions then are broken down into more categories within each of the 16 divisions, depending on the project size and complexity. Below outlines the typical layout of a 16-division CSI specification Table of Contents. Recently in 2004, CSI introduced a new specification outline that includes 50 divisions; however, it is not widely used or popular at this time. Therefore, the projects completed in this study all used the 16-division format.

- Division 01 — General Requirements
- Division 02 — Site Construction
- Division 03 — Concrete
- Division 04 — Masonry
- Division 05 — Metals
- Division 06 — Wood and Plastics
- Division 07 — Thermal and Moisture Protection
- Division 08 — Doors and Windows
- Division 09 — Finishes
- Division 10 — Specialties
- Division 11 — Equipment
- Division 12 — Furnishings
- Division 13 — Special Construction
- Division 14 — Conveying Systems
- Division 15 — Mechanical
- Division 16 — Electrical

When the designer completes the contract documents (100% design completion), the job is advertised and/or delivered to selected companies to begin the bidding process. General Contracting (GCs) companies acquire the contract documents and meticulously go through the plans and specifications to note all materials and work that need to be completed. Then the GCs prepare their final cost for all labor and materials, and submit this to the owner. This is considered their "Bid" for the job. Typically, the GCs' bids must be submitted to the owner at a specific time and place; no late bids are accepted.

After the bids are accepted, opened, and reviewed by the owner, the GC with the lowest bid is offered the job, contingent on their ability to provide accurate insurance and bond coverage. If the GC is able to meet the insurance and bond requirements and accepts the job, a contract is signed and the work begins. Since the design is considered as the contract document, and was completed and issued by the owner, any changes that need to be done after the work begins are the owner's responsibility. These changes are referred to as 'change orders.'

Figure 1 shows the contractual relationship in the DBB delivery method. The straight arrowed lines indicate direct contractual relationships and the dashed line represents coordination aspects only.

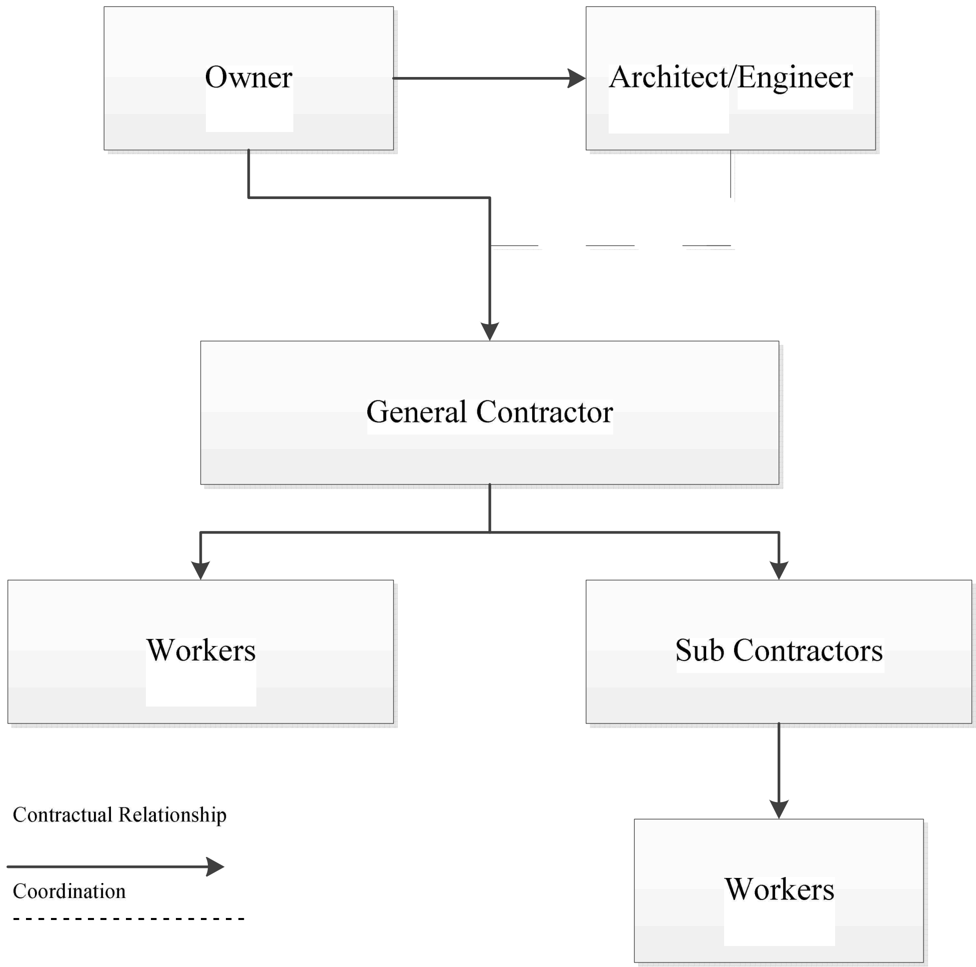

Figure 1. Contractual Relationship of the Design-Bid-Build (DBB) Method.

To understand that no one project delivery method is flawless, Table 1 describes the advantages and disadvantages of the DBB method. This may not include all the advantages and disadvantages known, but it does highlight the main points for a clearer understanding of this delivery method's strengths and weaknesses.

Table 1. Advantages and Disadvantages of the Design-Bid-Build(DBB)Method.

Advantages of DBB	Disadvantages of DBB
1. Owner controls design and construction 2. Design changes easily accommodated prior to start of construction 3. Design is complete prior to construction award 4. Construction cost is fixed at contract award (until Change Orders) 5. Low bid cost, maximum competition 6. Relative ease of implementation 7. Owner controls design/construction quality	1. Requires significant owner expertise and resources 2. Shared responsibility for project delivery 3. Owner at risk to contractor for design errors 4. Design and construction are sequential, typically resulting in longer schedules 5. Construction costs unknown until contract award 6. No contractor input in design, planning, or value engineering (VE).

1.2 Design-Build Delivery Method

Under the Design-Build (DB) delivery method, the owner produces bridging documents created by an Architect hired by the owner; these bridging documents provide the basis of the design that sets forth their expectations for the design and construction of the project. Typically, these bridging documents contain schematic drawings and specifications in order that the DB entity understands how to create their DB proposal so that it can be tailored to the needs and desires of the owner.

When the owner's Architect completes the bridging documents, the job is advertised and/or delivered to selected companies to begin the proposal process. This proposal process is somewhat different from the DBB bidding process since the DB entities have the ability to alter the bridging documents and also have more freedom to tailor the design to what that particular team believes is best for the owner and the project. These changes to the bridging documents, of course, must be approved by the owner.

The DB entities acquire the bridging documents from the owner and meticulously go through them in order to note all design, materials, and other work that needs to be completed for their proposal. At that point, the DB entities prepare their final proposal and submit them to the owner. This proposal is considered their “Bid” for the job, and typically has a guaranteed maximum price (GMP). Also, the DB entities proposals typically must to be turned into the owner at a specific time and place; no late proposals are accepted.

After the proposals are accepted, the owner begins a lengthy review process that includes different levels of criteria by which the proposals are judged and scored. This is sometimes referred to as the ‘best value’ selection process. Criteria are built into the selection process that allow the owner to select the DB entity based on the best value for the owner; in this way, the owner does not have to be committed to a low bidder. The DB entity that scores the highest in a sum of all the categories is offered the job, contingent on their ability to provide accurate insurance and bond coverage. Unlike the DBB method, in which the lowest bidder is awarded the project, the DB entity that is chosen might not have the lowest price. If the DB entity is able to meet the insurance and bond requirements and accepts the job, a contract is signed and the work begins.

Since the DB entity creates the final design and specifications based off the bridging documents, the DB entity is responsible for the design and construction of the project; change orders will not be accepted unless they are owner-requested changes. Hence, the owner contracts with a single entity that is responsible for the design and construction of the project.

Figure 2 shows the contractual relationship with the DB delivery method. The straight arrowed lines indicate direct contractual relationships and the dashed line represents coordination aspects only.

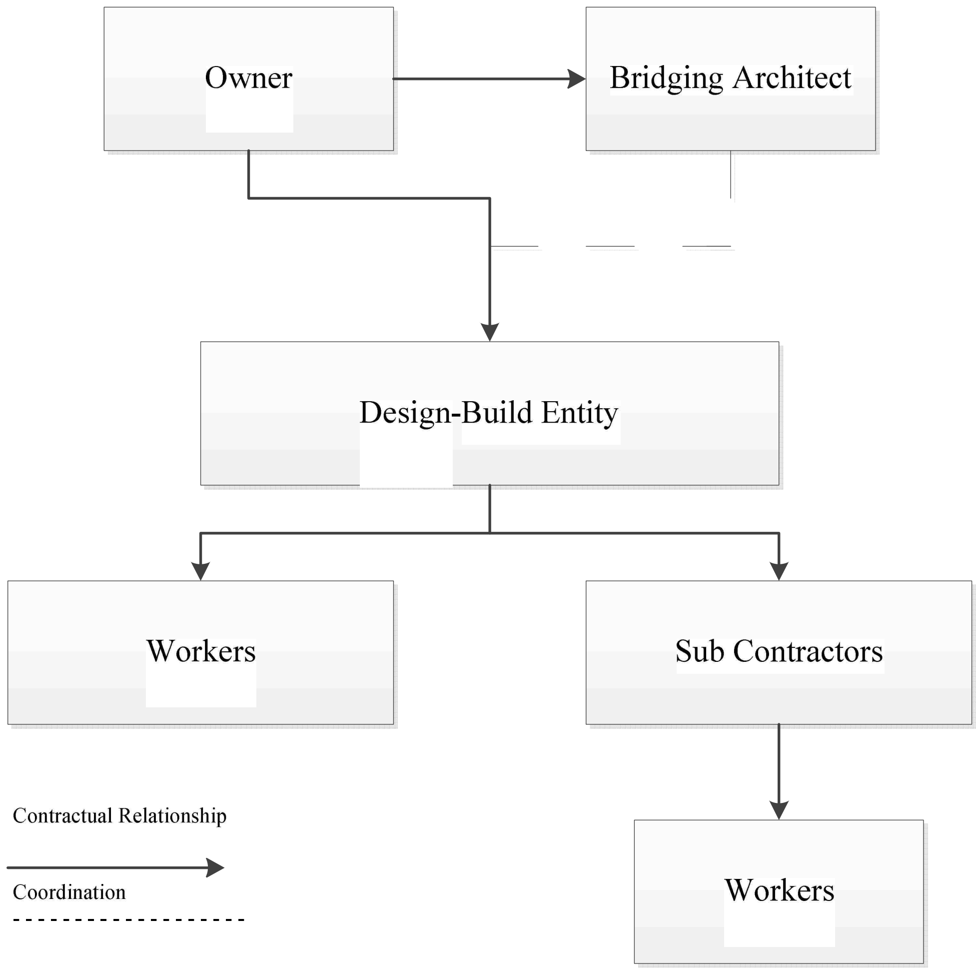

Figure 2. Contractual Relationship of Design-Build (DB) Method.

Table 2 lists the advantages and disadvantages Design-Build (DB) method. This may not include all the advantages and disadvantages known, but highlights the main points for a clearer understanding of this delivery method's strengths and weaknesses.

Table 2. Advantages and Disadvantages of the Design-Build (DB) Method.

Advantages of DB	Disadvantages of DB
1. Single entity responsible for design and construction	1. Minimal owner control of both design and construction quality
2. Construction often starts before design completion, reducing project schedule	2. Requires a comprehensive and carefully prepared performance specification
3. Construction cost is known and fixed during design; price certainty	3. Design changes after construction begins are costly
4. Transfer of design and construction risk from owner to the DB entity	4. Potentially conflicting interests as both designer and contractor
5. Emphasis on cost control	5. No party is responsible to represent owner's interests
6. Requires less owner expertise and resources	6. Use may be restricted by regulation

1.3 Scope and Motivation of the Study

The scope of this research study will be to evaluate several different university projects using the traditional delivery method (DBB) and also the DB delivery method in order to determine which delivery method is the best approach to meet the needs of universities.

This research study was built on previous studies conducted on this topic involving building and highway construction; this study also used questionnaire surveys, by means of convenient random sampling, on projects recently completed by universities under

DB and DBB project delivery systems. Literature reviews on previous studies were analyzed, compared, and interpreted; the results then were applied to the current research problem.

The motivation behind this research study lies in the desire to find a solution to the delivery method problems being faced by universities and also to make universities aware of the different alternatives they have; in other words, they are not obligated to use the traditional delivery method, DBB. Furthermore, motivation is driven by the desire to help universities arrive at a more productive delivery method that meets their schedules and keeps their costs manageable.

Lastly, there are personal reasons. For the past 15 years, I have worked for various universities as a Project Manager. I have been in the industry for over 25 years, and have been faced with the problems and challenges presented by the traditional DBB delivery method. I plan to continue to work in a university environment for years to come, and hope that this research effort will aid in determining the correct delivery method to choose on a project-by-project basis.

1.4 Objectives of the Study

This research project focuses on metrics for cost, schedule, and change orders in both DBB and DB projects built on 11 university campuses across the United States. The main objectives of this study are:

1. To determine whether the DB project delivery method is superior in terms of cost, schedule, and change-order growth than DBB.
2. To develop a questionnaire for collecting data from DB and DBB university projects for purposes of comparisons.

1.5 Sequence and Significance of the Study

The study began with a literature review of various different types of projects using DBB and DB project delivery methods. The study then moved forward to a literature review of public projects that used DBB and DB project delivery methods. During this literature review, presented in Chapter 2, no peer-reviewed papers could be found that were written about the use of the DB delivery method for university buildings. At that point, this research study on comparing DBB and DB project delivery methods for university buildings became a reality.

Chapter 3 of this paper discusses the methodology used to gather and analyze the project data in order to arrive at the conclusions drawn from this study. Chapter 4 describes the data gathered for this study. Chapter 5 presents the study’s findings and discusses which delivery method is superior in terms of cost, schedule, and change-order growth. Conclusions and some suggestions for further study related to the comparison of DB and DBB methods are discussed in Chapter 6.

With the many current budget problems existing across the United States in public agencies, this study appears to be relevant in finding a solution that possibly could save states’ money on their public projects by reducing total cost, schedule, and change-order growth.

CHAPTER 2

LITERATURE REVIEW

Universities across the United States are now starting to move away from the traditional delivery method, DBB, and implement the use of alternate delivery methods, such as DB.

There have been many research studies done regarding DBB and DB delivery methods for public and private projects, highway and military projects, and general building projects. The majority of these studies has been of a qualitative nature, and has relied heavily upon surveys, empirical studies, and case studies. However, none of these papers referred specifically to university buildings. The review of the other papers proved to be extremely valuable in gaining knowledge and understanding different methods for project procurement as well as alternate delivery methods. This in turn contributed to the successful completion of this research project. This chapter will summarize the literature review of DB and DBB project delivery methods used for building projects and highway projects as they relate to university buildings.

2.1Comparisons of DB and DBB Building Projects

In order to conclude if one project delivery method is superior to the other, Hale et al. (2009) compared the performance of DB and DBB projects at U.S. Naval Facilities (NAVFAC) Navy Bachelor Enlisted Quarters built between 1995 and 2004. This study statistically compared time and cost growth of 39 DBB projects and 38 DB projects in terms of total project duration, fiscal year duration, project start duration, project duration per bed, time per bed, project time growth, cost growth, and cost per bed. The final objective was to test the hypotheses for the aforementioned areas that the Design-Build methodoutperformed the Design-Bid-Build method.

The data for this study was collected from various different databases from NAVFAC and Eprojects; this data included project description, delivery method, original contract amount, final contract amount, original project start date, project completion date, and a category code. Any data not gathered from NAVFAC and Eprojects, such as project descriptions or cost estimate information, was completed by means of an interview process. Data for a total of 129 projects were collected, out of which 52 projects were eliminated; the data for the remaining 77 projects were analyzed. Statistical analysis was used to determine which project delivery method was better than the other, and ANOVA was used to determine if the differences were statistically significant.

Not all the projects were completed at the same time or location; therefore, adjustments for time and location also were considered. For time adjustments, the team used escalation tables based on inflation forecasts from the U.S. White House's Office of Management and Budget and the *Historical Air Force Construction Cost Handbook*. The area cost factor index, developed by the U.S. Department of Defense, was used for location adjustment.

Values for the mean, median, and standard deviation were evaluated in terms of total contract cost growth. The study's findings showed that the mean, median, and standard deviation values of Cost Per Bed metrics and Cost Growth of DB projects were lower than that of DBB projects. Similarly, the schedule-related metric, Time Growth, was reported in terms of added days to a project's end date instead of a percentage of the total project timeline. The results of this study showed that the mean, median, and standard deviation values for Time Growth of DBB projects were higher than that of DB projects. Similarly, the mean, median, and standard values of Project Duration, Fiscal Year Duration, and Construction Start Duration were higher for DBB than DB projects. This also was true for the mean, median, and standard values of Duration Per Bed.

This study used ANOVA to determine whether the performance metrics of DB and DBB samples in the study were statistically significant. This study's results showed that the means of Cost/Bed for other costs and Cost/Bed for DB and DBB projects were statistically not different. Hale et al. concluded that the Cost Growth for DB projects (2%) was significantly lower than the cost growth for DBB projects (4%) for that sample. Furthermore, this study concluded that the project duration (667 days vs. 1398 days), fiscal year duration (864 days vs. 1064 days), and construction start duration (667 days vs. 771 days.) for DB projects were significantly lower than those for DBB projects. The study also revealed that DB projects were about one half that of DBB projects in project duration per bed (2.6 vs. 7.0), and time growth (76 vs. 194). In addition, DB projects outperformed DBB projects in construction start duration per bed (2.6 vs. 3.7) and fiscal years duration per bed (3.6 vs. 5.1). All these findings were statistically significant at alpha level 0.05. This study was related directly to the NAVFAC projects, and the samples were homogenous. The results showed that DB projects took less time, had less cost growth, and were less expensive to build in comparison to DBB projects.

A study by Konchar and Sanvido (1998) compared cost, schedule, and quality performance of 351 projects completed between 1990-1996 for Construction Manager at Risk (CMAR), DB, and DBB projects. This research was divided into four different phases. Phase 1 developed the process of collecting and analyzing the data in terms of cost, schedule, and quality. Phase 2 collected extensive project data from the U.S. Construction Industry. Phase 3 checked the data for accuracy and completeness, and Phase 4 tested univariate hypotheses to distinguish significant differences in delivery performance.

According to Konchar and Sanvido (1998), “Cost was defined as the design and construction cost of the base facility and did not include land acquisition, extensive site work, and process or owner costs. The three cost measures were unit cost, project cost growth, and intensity.” The time aspect was defined as “the total as planned time,” and was calculated from the planned start date to the planned construction end date.

A survey was used to collect specific data for each project. Seven thousand six hundred surveys were sent; only 378 surveys were completed, and of those, only 301 projects were useable for analysis. To standardize the data, the team adjusted each project cost by using historical cost indices for location and time. Several different statistical methods were used for analysis, such as univariate to compare means, medians, and standard deviations and multivariate linear regression to determine the effect of project delivery method on cost and schedule metrics.

Quality performance was measured in the following seven specific areas:1) start up;2) call backs;3) operation and maintenance;4) envelope, roof, structure, and foundation;5) interior space and layout;6) environment; and finally 7) process equipment and layout. According to Konchar and Sanvido (1998), “Quality was recorded separately for the turn over process and for the performance of specific systems. This was done to eliminate any owner bias present from a highly difficult turn over process.”

The results showed that the performance of DB and CMAR projects were much better than for DBB projects in terms of startup quality, call backs, interior space and layout, and process equipment layout. For operation and maintenance, the study found that DB projects achieved superior performance over both CMAR and DBB projects in terms of quality; however, DB projects only showed significantly higher results than DBB projects for envelope, roof, structure, and foundation. In these specific areas, CMAR projects performed better than both DB and DBB projects.

Using multivariate regression analysis, the team developed three models to evaluate the changes in unit cost, construction speed, and delivery speed. The study showed that DB projects outperformed DBB and CMAR projects by less than 6.1 percent and 4.5 percent, respectively, regarding unit cost. The authors also identified four variables that have the greatest impact on unit cost: Contract Unit Cost, Facility Type, Project Size, and Project Delivery System. The regression analysis showed that these five variables accounted for about 99% of the variations in unit cost.

In addition, the study showed that the construction speed of DB projects was faster than for both DBB and CMAR projects by 12 percent and 7 percent, respectively. The findings were significant at alpha level 0.05. There were six variables that have accounted for 89% of the variation in construction speed: 1) project size, 2) contract unit cost, 3) project delivery system, 4) percent design complete before the construction entity joined the project team, 5) project team communication, and 6) project complexity.

The last finding of this study was related to overall project delivery speed. In terms of overall delivery speed, the study showed that DB projects were approximately 33.5 percent faster than DBB projects and 23.5 percent faster than CMR projects. The significant variables that have an impact on this delivery speed were project size, contract unit cost, percent design complete before construction entity joined the project team, facility type, and project team communication. The authors found two variables that had lesser impact on delivery speed performance:1) excellent subcontractor experience with the facility and 2) project complexity.

Overall, Konchar and Sanvido (1998)evaluated the performance of DB, CMAR, and DBB projects from data collected from 351 projects built in the U.S. from 1990-1996.From this sample of projects, they showed that that DB projects are superior and outperformed CMAR and DBB projects in terms of cost and schedule.

Ling et al. (2004) predicted project performance in terms of cost, schedule, quality, and owner's satisfaction for both DB and DBB projects, using data collected from 87 building projects for 11 variables. According to Ling et al. (2004), "The objectives were to find variables that affect project performance and to construct models to predict DB and DBB project performance. With the outcomes and models produced, owners may be able to choose which delivery method is best for their project."

The research methodology used wasa case study questionnaire based on past projects sent to owners, contractors, and consultants. Forty owners were asked to complete 49 project surveys, 60 contractors were asked to complete 180 project surveys, and 57 consultants were asked to complete surveys for 171 projects. A total of 87 project surveys were completed for 54 DBB projects and 33 DB projects. The data gathered from these projects were inserted into SPSS statistics software, and 24 possible models were produced to predict cost and construction intensity. This study showed that different variables, and sometimes shared variables, affected each metrics performance; a comparison of the 11 models that predict project performance in DB and DBB projects is described below.

The comparison of the cost models of DB and DBB projects showed that only the Unit Cost model did not share any similarities; on the other hand, both Cost Growth and Intensity models shared similar variables, such as the contractors' paid-up capital and design completion when the budget is fixed, that affected project performance. The time-related models for DB and DBB projects showed that both construction speed and delivery speed were affected by the gross floor area of the building, while Schedule Growth models did not share any similarities. The comparison of the quality models showed no similarities that affected project performance in DB and DBB projects. The DB and DBB models that compared owner satisfaction showed that the only similar variable that affected project performance was the contractor's technical expertise.

Furthermore, the results showed that buildings designed and constructed by public entities tended to be more expensive than buildings designed and constructed under private ownership. In DB projects, the cost fluctuated up to 42% more expensive, depending on the extent of the design completion in the bid documents. Typically, the cost will increase when the owner initiates more of the design. The more prescriptive the design, the higher the cost may be. This study further suggested that cost growth for DB and DBB projects would be higher if contractors with less capital were contracted.

In addition, Ling et al. (2004) produced models for forecasting Construction Intensity, in which the larger the project, the greater the construction intensity. This is attributed to the use of more sophisticated equipment and the possibility for prefabrication of certain building elements. This study agreed with one conducted by Molenaar and Songer

(1998),who stated, “The degree of urgency of the project affects schedule growth.”This means that if more pressure were put on DB projects to accelerate the schedule and if DBB projects had the proper amount of manpower, the construction intensity would be improved. Quality also was analyzed during this study; the authors found that reviewing the contractors’ resumes of past projects as well as the outcomes of those projects is a main predictor of the current and future quality of work to be expected from a particular contractor.

The owner’s satisfaction is directly related to the contractor’s track record, expertise, safety, and quality. Ling et al. (2004) found that 68% of owner’s satisfaction for DB projects is related to the contractor’s specialized project experience and safety record. DBB project owners based their satisfaction on previous track record, number of change orders submitted during each project, and flexibility of scope. A good analogy for a DB project building for a university laboratory would be if one contractor completed five laboratory projects with no injuries in the previous three years and another contractor complete done laboratory project with two injuries in the previous five years; comparing these two records, an owner would look favorably upon the first contractor.

Ibbs et al. (2003) compared DB and DBB projects to determine which delivery method was more effective. This study evaluated the influence that a project delivery method, such as DB and DBB, may have on the outcome of the project. Information on cost, schedule, and productivity were collected from the Construction Industry Institute (CII).This study developed a questionnaire that included questions involving project delivery methods as well as changes in cost and schedule, which were was used to request data on project information. The CII sent surveys to over 100 projects located in the U.S., Canada, Middle East, and Latin America that included questions regarding basic project information, cost, schedule, and productivity information. Surveys from 67 projects were collected that included "name, location, contract type, owner information, cost, schedule, and productivity performance." The original budget of each project was subtracted from the final cost to determine the cost change, and the schedule change was calculated by subtracting the estimated duration from the final duration. The productivity was calculated as earned labor-hours divided by expected labor-hours.

This study showed that DB projects had less cost changes (13%) than DBB projects (15.6%). According to this research study, DBB projects had decreased changes (-0.4%) while DB projects had about 7.4% increased changes. This result indicates that when a project used the DB method, the cost increased.

Further research in this study showed that during the construction phase, projects that used the DB method had approximately 4% increase in cost changes, while DBB had about 9% decrease in cost changes. In the design phase, DB projects had an average cost change of 8% and DBB had an average change in cost of 9%. The changes in schedule showed that DB projects outperformed DBB projects by having only a 7.7% change, while DBB projects had an 8.4% change in schedule. This study also compared productivity against schedule and cost changes in regards to the delivery method used by the project. The study showed that when each delivery method had the same amount of schedule change, then DBB projects outperformed DB projects in terms of productivity.

In conclusion, this study by Ibbs et al. (2003) showed that DB projects had a higher total cost change than DBB projects, but DB projects outperformed DBB projects in terms of schedule. Additionally, when productivity was compared, both DB and DBB projects had approximately the same amount of change with respect to the project.

Wardani et al. (2006) stated that, "Several studies have analyzed the growing trend towards the use of Design-Build delivery method and the shift from more traditional delivery methods." This research on the procurement method of project delivery systems strays a bit from the topic of this thesis; however, procurement methodologies of delivery methods are almost as important as the delivery method itself. The data analysis indicated several important trends associated with different performance metrics. Results from this study showed that the low-bid selection process had the highest cost growth, which was 9% higher than the qualifications-based procurement method. This study showed that schedule growth from the best value procurement method had an average of 0% schedule growth. Therefore, even though the DB delivery method can possibly lead to superior project performance, the procurement methodology used to select the DB firm should be evaluated very carefully prior to advertising.

Table 3. Literature Review Summary for Building Projects.

Researchers	Methods	Sample Size	Project Types	Major Findings
Hale et al. (2009)	DB DBB	38 39	Navy Bachelors Living Quarters	DB cost and schedule metrics were significantly better than DBB
Konchar and Sanvido (1998)	DB DBB CMAR	155 116 80	Industrial Buildings	DBB unit cost growth is 6.1% higher than DB and DB construction speed was 12% higher than DBB
Ling et al. (2004)	DB DBB	33 54	Building projects	DB and DBB construction and delivery speed can be predicted with six variables
Ibbs et al. (2003)	DB DBB	24 30	Building projects	DBB schedule growth was 2.4 % higher than DB and DBB cost growth was 7.8% lower than DB
Wardani et al. (2006)	DB	76	Procurement method and performance	LBDB had a 9% higher cost growth than that of BVDB and BVDB had a 0% schedule growth

2.2 Highway Project Literature Review

Gransberg and Senadheera (1999) studied three different methods that State Departments of Transportation are implementing in their DB procurement: low bid DB (LBDB), adjusted score DB (ASDB), and best value DB (BVDB).During the LBDB process, proposals and prices are submitted. The owner agency opens the bids and compares the prices to find the low bidder. Then, the designs are evaluated to ensure technical compliance with the RFP after disclosing the price. The author found that the low-bid approach typically was used when the project was well defined and almost prescriptive. The adjusted score DB approach was used when the project scope was not as well defined and alternatives in the design and materials were being considered. The best value DB approach was used when the owner was seeking creative design alternatives and where the owner would like to consider the technical experience of the contractor in the selection process.

All three of these delivery methods have their positive and negative aspects within the delivery process. LBDB is the easiest to implement and the most politically accepted method of the three because it involves accepting the lowest price. The weakness of the LBDB approach is that it does not allow the DB firms to implement different design solutions for the same project. ASDB allows a rating scale for designers and builders while reaping the benefits of innovative approaches to the project. The disadvantage of this approach is that it may weed out options that are initially more expensive for options that have a shorter life cycle. Finally, BVDB is very amendable and open-ended, allowing for the project needs to be met very closely. Price is only one of several different factors considered during the evaluation process, so this approach encourages innovation. The major drawback of BVDB is the development of the RFP and the complexity of the evaluation planning.

Since all highway projects are unique in their own way, the choice of what procurement method to use needs to be evaluated on a project-by-project basis. In this way, the correct procurement method can be chosen that maximizes the possibility of selecting the best contractor for the project.

Warne (2005) studied 21 highway projects to determine the effectiveness of the DB project delivery method. Questionnaires were sent out to project managers across the country for 21 DB projects, comparing DB performance with the DB process. The questionnaires had several hypothetical questions regarding project information, cost, and the reason for using the DB method; project selection methodology; owner assessment; and quality. After the questionnaires were received, the author reviewed the data for schedule, cost, quality, and owner satisfaction. The results from the analyzing schedule data showed that 13 out of 21 projects chose DB as a project delivery method due to schedule effectiveness. The study showed that 26 percent of the DB projects were completed ahead of schedule, typically one to two months ahead of schedule. When the interviewees were asked how the project schedule would have been affected if the delivery method was DBB, 100% stated that the project would have taken longer than it did with the DB method.

Cost performance also was studied to compare the bid amount with the total completion cost. The author defined cost growth as the difference between the bid amount and the final cost of the project. In this case study, the result for cost growth in DB projects was less than four percent compared to DBB projects, indicating that DB projects have less cost growth than DBB projects.

In addition, owner satisfaction in regards to quality of the work performed while using the DB delivery method was addressed in this study. In all 21 cases, it was determined that DB projects have equal to or better quality than if the project was delivered under the DBB method.

Shrestha et al. (2011) compared the relationship of DBB and DB projects for large highway projects in terms of cost, schedule, and change order per lane mile. According to Shrestha et al. (2011), the criteria used to select the DBB projects were as follows:

> "1) The projects should only involve construction of roadways, 2) the construction completion time of the project should be after 2000 and should not go beyond 2009, 3) the design and construction cost of the projects should exceed $50,000,000.00, and 4) the projects should be constructed in the state of Texas. The criteria for the DB projects were: 1) the projects should only involve construction of roadways, 2) the highway projects are to be selected from FHWA SEP-14 projects, 3) the construction completion time of the project should be after 2000 and should not go beyond 2009, and 4) the design and construction cost of the projects should exceed $50,000,000."

The data was gathered in forms of questionnaires, and subsequent phone interviews, and internet searches. After the data was verified, it was analyzed using ANOVA and a t-test assuming unequal variances. The analysis showed that one lane mile of DB projects was designed in one half of a month and one lane mile in DBB projects were designed in two months. The construction speed per lane mile for DB projects was 11 days, and the construction speed per lane mile for DBB projects was 29.4 days. The cost per change order for DB projects was about 50 percent more than the cost per change order for DBB projects. However, the analysis did show that the number of change orders were lower in DB projects (25 change orders) than DBB projects (65 change orders).

The study also researched project characteristics (input variables) and project performance (output variables) from large highway projects. This study showed that

14input variables had an alliance with one or more of the output variables. The input variables related to cost growth had a significant alliance with the amount of days lost with the increase of cost. The input variables related to cost per mile had significant alliance with the following four output variables. When a bridge area was compared, the cost per lane mile increased as design work hours per week decreased. The cost also increased as right of ways (ROWs) increased; this includes ROWs by eminent domain.

When evaluating schedule growth, the main finding here was that the use of partnering or bonuses resulted in lower schedule growth. Delivery speed could be increased if the project had fewer interchanges, fewer bridges, partnering, and less environmental evaluations. The cost per change order was also evaluated, and showed that new construction had fewer change orders than a reconstruction project. Furthermore, the cost of change orders increased as the work days per week increased.

Table 4. Literature Review Summary for Highway Projects.

Researchers	Methods	Sample Size	Project Types	Major Findings
Gransberg and Senadaheera (1999)	DB DBB	N/A N/A	DB procurement methods	LBDB,ASDB, and BVDB are all valid procurement methods for DB
Warne (2005)	DB	21	Highway projects	DB projects are typically completed one to two months ahead of schedule. Also DB has less cost growth than DBB
Shrestha et al. (2010)	DB DBB	22	Highway projects	Construction speed and project delivery speed per lane mile of DB projects are significantly faster than that of DBB projects per lane mile

2.3 Summary of Literature Review

The literature review conducted during this research project can be summarized as follows. It appears that DB may be a more effective delivery method over DBB in regards to cost, schedule, and change order growth. However, one study by Ibbs et al. (2003) found that the DBB method was more effective than DB.

To date, there have been no studies done comparing DBB and DB delivery methods on public university buildings in terms of cost, schedule, and change order growth. The findings of this current study will help the public universities decide what delivery method is best for them in terms of controlling cost, schedule, and change orders.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Steps

The steps involved in the research methodology are depicted in Figure 4 and are described in this section. The research used statistical analysis to compare performance metrics for cost, schedule, and change-order cost for DB and DBB projects at U.S. universities.

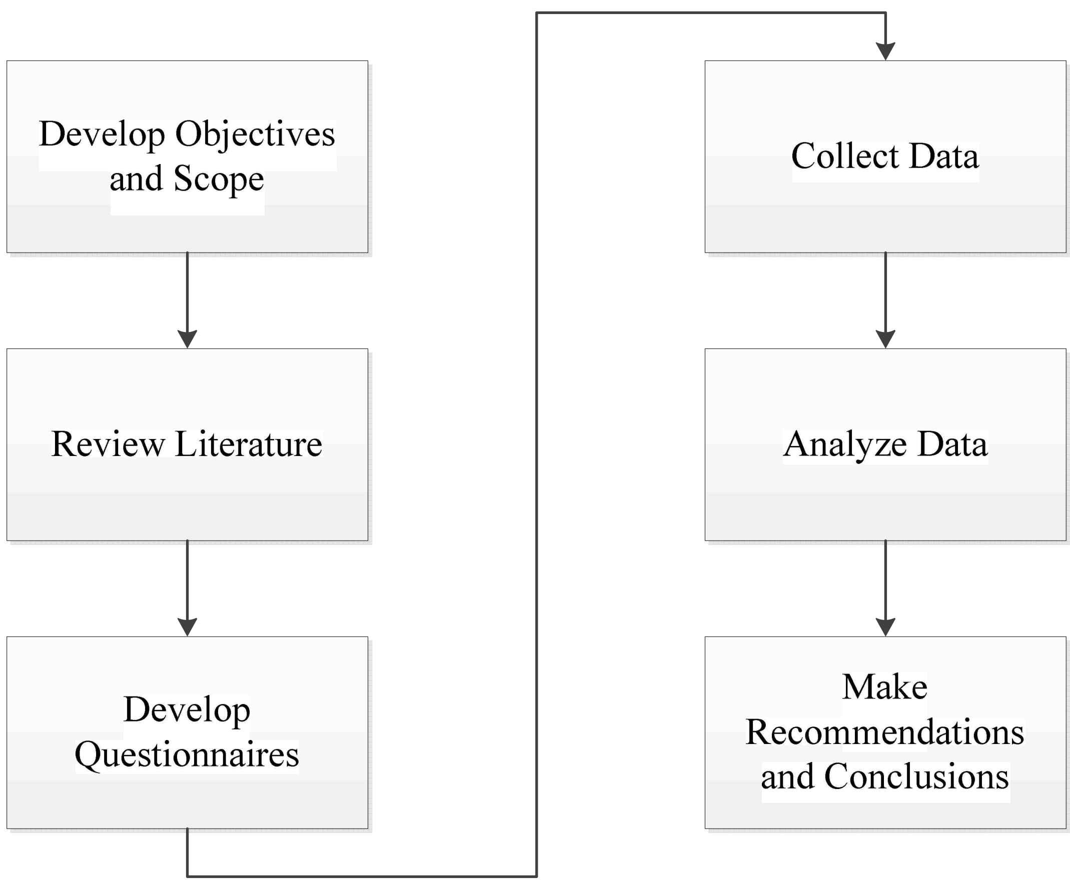

Figure 3. Research Methodology Flow Chart.

3.1.1 Develop Objectives and Scope

The first step of the research project was to formulate a problem statement that describes the objectives, and the research scope. The details, including research background, the purpose of this study, objectives, and scope were addressed in Chapter 1.

3.1.2 Review Literature

A literature review was conducted on DB and DBB project delivery methods on building projects, and highway projects as they relate to university buildings. The literature review was discussed in Chapter 2.

3.1.3 Develop Questionnaire

Separate questionnaires were developed for DB and DBB projects in order to take into account the two different delivery methods and to ensure that the two types of projects were compared as precisely as possible. The literature review provided examples of other questionnaires used in previous studies; this proved helpful in the creation of the questionnaires for this study.

Each questionnaire for this study had a section for general project information, including location and contact information; and a section for project characteristics, such as square feet, construction type, and construction year. There was a section in both the DB and DBB questionnaires for project performance, which included performance metrics for cost, schedule, and change orders. The cost and schedule information was collected differently for these two types of projects. For DB projects, data for cost, schedule, and change orders were combined with data for design and construction; for DBB projects, information was collected separately for design and construction.

3.1.4 Collect Data

When the research began, the intention was to only concentrate on university buildings in the State of Nevada. Since the laws and regulations in Nevada (NRS 408.388) have been in effect only since 1999, and then expanded in 2001, a limited number of projects were delivered under a DB contract. Therefore, the study was broadened to include universities from Southern California. Once again, due to the limitation of completed DB projects, there still was not enough data. At that point, the study was expanded to as many universities as possible across the United States. Even so, during the data collection phase, it was found that many universities chose to use only DBB or Construction Manager at Risk delivery methods, despite legislation that allowed them to utilize DB contracts.

Beginning in April 2010, a total of 300 questionnaires were sent to 230 universities, individual state universities as well as public and private university systems. From May 2010 to January 2011, 119 questionnaires were collected from universities in 11 states. Since the study is concentrating on new building projects, 22 completed questionnaires had to be discarded from the study because the projects included remodeling of existing buildings, athletic fields, and parking structures. Furthermore, 16 questionnaires were returned incomplete; after consulting with the participants, the information was no longer available for 13 of these questionnaires, so they were discarded from the study as well. A total of 84 questionnaires, for 42 Design-Build projects and 42 Design-Bid-Build projects, were used for this study.

During the data collection phase many obstacles and barriers were encountered with the questionnaire response rate. Many of the project managers had difficulty finding the time to complete the questionnaires, locating the data from archives, trying to locate project information that was no longer available (many project files were lost or discarded), and sometimes funding was an issue in filling out the questionnaires. It was mentioned that with the state budget cuts and staff being laid off there wasn't enough time for the project managers to fill out the questionnaires and it would not be wise to spend the states money to have administrative assistants locate the project data and fill out the questionnaires. However, many project managers did have their administrative assistants fill out the questionnaires on their behalf.

3.1.5 Analyze Data

The type of projects collected for data analysis were university projects that were contracted and constructed under DBB and DB delivery methods. A detailed questionnaire was developed and sent to universities across the United States, requesting specific project information for both DBB and DB projects, as described in Section 3.1.4.

After all the questionnaires were reviewed for completeness, and the incomplete questionnaires completed by talking to the participants, the data for all 84 projects were entered into an Excel spreadsheet for processing. To properly sort and create formulas within the Excel spreadsheet, DB projects were labeled "1" and DBB projects were labeled "2."

To precisely perform the statistical tests on cost in relation to time and location, adjustments were made to the data, using the building cost index and the local index. Table 5 displays Engineering News Records (ENR) building cost indices. The costs of all the projects were converted to an equivalent cost of a 2011 project located in Los Angeles, California. ENR records only 20 major cities in the location index; therefore, the location index of projects that were not from those cities was taken from the cities nearest to them. For example, for projects from Las Vegas Nevada, the projects were considered to have been built in Denver, because Las Vegas' city cost can be assumed to be equal as Denver rather than to Los Angeles.

Table 5. Engineering News Record Building Cost Index.

Year	Building Cost Index	Year	Building Cost Index
2001	3574	2007	4485
2002	3623	2008	4691
2003	3693	2009	4769
2005	3984	2010	4883
2006	4205	2011	4988

The cost index factor was calculated in order to change the cost of any year to be equivalent to the cost in 2011. Equation 1 was used to convert the cost of each project to a 2011 equivalent cost.

$$Cost\ of\ Project\ Equivalnet\ to\ 2011\ Cost$$
$$= \frac{Building\ cost\ index\ of\ year\ 2011}{Building\ cost\ index\ of\ year\ the\ project\ was\ built} \times Cost\ of\ the\ project\ \ldots.(1)$$

After the cost was converted to an equivalent cost of 2011, then the location index was used to bring all the project cost equivalent to a project built in Los Angeles. Table 6 displays the ENR building city index.

Table 6. Engineering News Record Building City Index.

Name of Cities	Location Index	Name of Cities	Location Index
Detroit	5198	Denver	4123
Los Angeles	5354	Atlanta	3789
Dallas	3808		

Equation 2 was used to convert the project costs to represent a project built in Los Angeles.

$$Cost\ of\ Project\ Equivalent\ to\ 2011\ Los\ angeles\ Cost$$
$$= \frac{Location\ index\ for\ Los\ Angeles}{Location\ index\ in\ which\ the\ project\ was\ built} \times Cost\ of\ the\ project..(2)$$

The hypothesis for this study is that for university buildings in the United States, the mean cost, schedule, and change order growth are significantly different in Design-Build projects than in Design-Bid-Build projects.

3.16 Statistical Tests

The data was analyzed using Analysis of Variance (ANOVA) test, Levene's test, the Anderson Darling test, and a t-test with unequal variances.

To use the ANOVA test, the following four assumptions must be met: 1) the sample should be randomly selected or by means of a convenient random sampling,, 2) the dependent variables should be in an interval scale or a ratio scale, 3) the dependent variable should be normally distributed, and 4) the variances of the two groups should be equal.

Levene's test is used to assess variance homogeneity, which is a precondition for such parametric tests as the t-test and the ANOVA test. If the significance from Levene's test is less than 0.05, then variances are significantly different and parametric tests cannot be used. Levene's test hypothesized that the variances of two groups are the same.

The Anderson Darling test is used to test for normality. This test rejects the hypothesis of normality when the p value is less than or equal to 0.05. Rejecting the normality test allows the researcher to state with 95% degree of confidence that the data does not fit the normal distribution. Failing to reject the normality test only allows the researcher to state that the data is normally distributed.

The t-test with unequal variances is used to check whether the means of two sets of samples are significantly different in the case where their variances are not equal. The typical way of doing this is by stating that in the null hypothesis, the means of the two sets of samples are equal. The t-test used in this study assumes a normal distribution and unequal variances.

The statistical programs that were used for this study were 1) Predictive Analytics Software (PASW), now known as the Statistical Package for Social Sciences (SPSS) and 2) Microsoft Excel. In order to draw conclusions for this study, the ANOVA and descriptive statistical tests were performed using SPSS; the t-test with unequal variances was performed using the Excel data analysis package.

The ANOVA test compared the means of cost, schedule, and change-order performance metrics of university buildings designed and constructed under both DB and DBB project delivery methods, whose variances were equal. This study consists of 10 research hypotheses and 10 null hypotheses, represented by H_1 and H_0, respectively. The null hypotheses are the direct opposites of the research hypotheses. Each null hypothesis will be rejected if the *p* value is less than 0.05 (Levine et al 2007). The 10 research hypotheses and 10 null hypotheses have been presented in this chapter in Sections 3.2.1 and 3.2.2.

To begin the ANOVA analysis, the data was checked for variation within and among groups. The variation between the two sample sets was determined by the sum of the squared differences between each observation and the overall mean of the sets. The mean squares were calculated by using the Equations 3, 4, and 5:

$$Mean\ of\ Squares\ Among\ (MSA) = \frac{Sum\ of\ Squares\ Among\ (SSA)}{Number\ of\ Groups - 1(c-1)} \ldots\ldots\ldots\ldots\ldots (3)$$

where (*c* - 1) represents the degrees of freedom and *c* is the number of groups.

$$Mean\ Square\ Within\ (MSW) = \frac{Sum\ of\ Squares\ Within\ (SSW)}{Number\ of\ Observations - Number\ of\ Groups(n-c)} \ldots\ldots (4)$$

where *n* is the sum of the sample sizes from all groups.

$$Mean\ Square\ Total\ (MST) = \frac{Total\ Variation\ (SST)}{n-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

If there are no differences seen in the means and the null hypothesis is accepted, then all three mean squares provide the overall variation in the data. To maintain accuracy, the F-test is implemented, which is the ratio of MSA and MSW. The mathematical formula for the F-test is stated in Equation 6.

$$F = \frac{MSA}{MSW} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

A null hypothesis can be rejected if a determined alpha level of significance falls above the critical value F_U because the F-test follows an F distribution with (*c* - 1) degrees of freedom.

$$Reject\ H_0 if\ F > F_U$$

Otherwise, do not reject H_0.

Results and further discussion in regards to the statistical tests performed in this research study are explained in more detail in Chapter 4.

3.1.7 Make Recommendations and Conclusions

The conclusions drawn from the study findings are discussed in Chapter 6. Similarly, the recommendations are also made in Chapter 6.

3.2 Study Hypotheses

The study hypotheses in relation to cost, schedule, and change-order cost were formulated to determine whether one delivery method is superior to another delivery method. Before developing research hypotheses, the performance metrics used to compare these two delivery methods were developed. To compare these two delivery methods, four metrics that are cost-related, three that are schedule-related, and three metrics related to change-order costs were developed. Equations 7-16 show the formulas used to calculate these metrics.

$$\textit{Contract Award Cost Growth } (\%) = \frac{\textit{Design and Construction Cost} - \textit{Estimated Design and Construction Cost}}{\textit{Estimated Design and Construction Cost}} \times 100 \quad (7)$$

$$\textit{Construction Cost Growth } (\%) = \frac{\textit{Final design and Construction Cost} - \textit{Contract Design and Construction Cost}}{\textit{Contract Design and Construction Cost}} \times 100 \quad (8)$$

$$\textit{Total Cost Growth } (\%) = \frac{\textit{Final design and Construction Cost} - \textit{Estimated Design and Construction Cost}}{\textit{Estimated Design and Construction Cost}} \times 100 \quad (9)$$

$$Cost\ per\ Square\ Foot = \frac{Final\ Design\ and\ Construction\ Cost}{Total\ \ Square\ Feet\ of\ Building} \dots \dots \dots \dots \dots \dots \dots (10)$$

$$Design\ and\ Construction\ Schedule\ Growth\ (\%)$$
$$= \frac{Final\ Design\ and\ Construction\ Duration - NTP\ Design\ and\ Construction\ Duration}{NTP\ Design\ and\ Construction\ Duration} \times 100..(11)$$

$$Total\ Schedule\ Growth (\%)$$
$$= \frac{Final\ Design\ and\ Construction\ Duration - Estimated\ design\ and\ Construction\ Duration}{Estimated\ Design\ and\ Construction\ Duration} \times 100..(12)$$

$$Construction\ Intensity\ (\text{SF/Day})$$
$$= \frac{Total\ Square\ Feet\ of\ Building \times 22}{Final\ design\ and\ Construction\ Duration\ in\ Months} \dots \dots \dots \dots \dots \dots \dots \dots \dots ..(13)$$

$$Design\ Change - Order\ Cost\ Growth\ (\%)$$
$$= \frac{Final\ Design\ Change - Order\ Cost}{Final\ Design\ and\ Construction\ Cost} \times 100 \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (14)$$

$$Construction\ Change - Order\ Cost\ Growth\ (\%)$$
$$= \frac{Final\ Construction\ Change - Order\ Cost}{Final\ Design\ and\ Construction\ Cost} \times 100 \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .(15)$$

$$Total\ Change - Order\ Cost\ Growth\ (\%)$$
$$= \frac{Final\ Design\ and\ Construction\ Change - Order\ Cost}{Final\ Design\ and\ Construction\ Cost} \times 100 \dots \dots \dots \dots \dots \dots .(16)$$

3.2.1 Research Hypotheses

There are 10 research hypotheses formulated fort this study. They are:

1. The mean Contract Award Cost Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
2. The mean Construction Cost Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
3. The mean Total Cost Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
4. The mean Total Cost Per Square Foot is significantly lower in DB projects than in DBB projects for U.S. university buildings.
5. The mean Design and Construction Schedule Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
6. The mean Total Schedule Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
7. The mean Construction Intensity is significantly higher in DB projects than in DBB projects for U.S. university buildings.
8. The mean Design Change-Order Cost Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
9. The mean Construction Change-Order Cost Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.
10. The mean Total Change-Order Cost Growth is significantly lower in DB projects than in DBB projects for U.S. university buildings.

3.2.2 Null Hypothesis

To conduct the statistical test, the above research hypotheses are converted to null hypotheses. The null hypothesis always assumes that the means of two groups are equal. The null hypotheses are described below.

1. The mean Contract Award Cost Growth in DB projects is equal to the mean Contract Award Cost Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 17.

$$\mu_{Contract\ Award\ Cost\ Growth\ (DB)} = \mu_{Contract\ Award\ Cost\ Growth\ (DBB)} \quad ..(17)$$

2. The mean Construction Cost Growth in DB projects is equal to the mean Construction Cost Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 18.

$$\mu_{Construction\ Cost\ Growth\ (DB)} = \mu_{Construction\ Cost\ Growth\ (DBB)} \quad ..(18)$$

3. The mean Total Cost Growth in DB projects is equal to the mean Total Cost Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 19.

$$\mu_{Total\ Cost\ Growth\ (DB)} = \mu_{Total\ Cost\ Growth\ (DBB)} \quad \ldots\ldots(19)$$

4. The mean Total Cost per Square Foot in DB projects is equal to the mean Total Cost Per Square Foot in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 20.

$$\mu_{Total\ Cost\ per\ Square\ Foot\ (DB)} = \mu_{Total\ Cost\ per\ square\ Foot\ (DBB)} \quad \ldots\ldots(20)$$

5. The mean Design and Construction Schedule Growth in DB projects is equal to the mean Design and Construction Schedule Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 21.

$$\mu_{Design\ and\ Construction\ schedule\ Growth\ (DB)} = \mu_{Design\ and\ Construction\ schedule\ Growth(DBB)} \ldots\ldots\ldots\ldots(21)$$

6. The mean Total Schedule Growth in DB projects is equal to the mean Total Schedule Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 22.

$$\mu_{Total\ Schedule\ Growth\ (DB)} = \mu_{Total\ Schedule\ Growth\ (DBB)} \ldots\ldots\ldots\ldots(22)$$

7. The mean Construction Intensity in DB projects is equal to the mean Total Schedule Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 23.

$$\mu_{Construction\ Intensity\ (DB)} = \mu_{Construction\ Intensity\ (DBB)} \ldots\ldots\ldots\ldots(23)$$

8. The mean Design Change-Order Cost Growth in DB projects is equal to the mean Design Change-Order Cost Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 24.

$$\mu_{Design\ Change-Order\ Cost\ Growth\ (DB)} = \mu_{Design\ and\ Construction\ schedule\ Growth\ (DBB)} \ldots\ldots\ldots\ldots(24)$$

9. The mean Construction Change-Order Cost Growth in DB projects is equal to the mean Construction Change-Order Cost Growth in DBB projects for university buildings. The null hypothesis is mathematically written as in Equation 25.

$$\mu_{Construction\ Change-Order\ Cost\ Growth\ (DB)} = \mu_{Design\ and\ Construction\ schedule\ Growth\ (DBB)} \ldots\ldots\ldots\ldots (25)$$

10. The mean Total Change-Order Cost Growth in DB projects is equal to the mean Total Change-Order Cost Growth in DBB projects for U.S. university buildings. The null hypothesis is mathematically written as in Equation 26.

$$\mu_{Total\ Change-Order\ Cost\ Growth\ (DB)} = \mu_{Design\ and\ Construction\ schedule\ Growth\ (DBB)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

3.3 Limitations of the Study

This research study was conducted using data from public universities across the United States and did not include private universities. This was because project information for public universities is considered "public information," unlike private universities. Therefore, it was easier for the project managers of public university to obtain this information and to get the questionnaires returned. In addition, when private universities failed to return questionnaires and an inquiry was made, the project managers stated that they were directed not to fill out the questionnaires. Therefore, the findings of this study are applicable only to the public university projects of U.S. Care should be taken to interpret the results of this study for other types of projects.

CHAPTER 4

DATA DESCRIPTION

The type of projects collected for data analysis were university projects that were contracted, designed, and constructed under both the DB and DBB delivery methods. A detailed questionnaire was developed and sent to University Planning and Construction departments across the United States. The questionnaires requested specific project information for both DBB and DB projects.

The histogram in Figure 4 shows the number of DB projects with respect to location. This histogram indicates shows that the maximum number of projects was collected from universities in California and Arizona. California and Arizona began using the DB delivery method in public projects in 1999 and 2000, respectively, and determined this method worked well in their procurement system. Since then, both California and Arizona began to implement the DB project delivery method on a more regular basis; as a result, these states have more projects completed under the DB delivery method than other states. This histogram is a result of this study, and is showing that California and Arizona returned more completed questionnaires on DB than the other states listed.

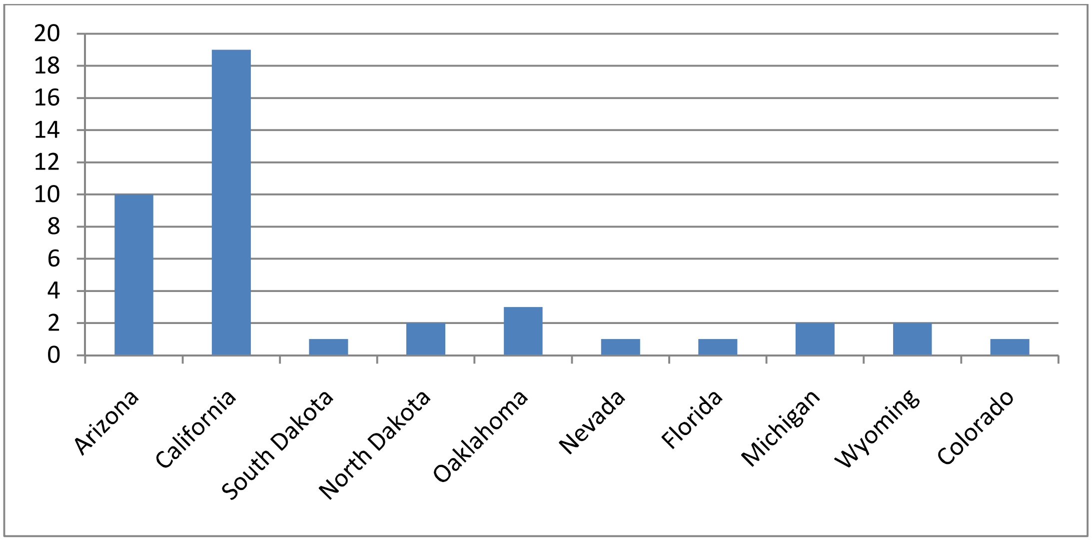

Figure 4. Number of Design-Build (DB) Projects in Each State.

The histogram in Figure 5 shows the total number of projects started or completed within a specific year. This histogram indicates a growing trend of implementing DB projects for university buildings; this trend began in 2002 and was at its highest level in 2007.

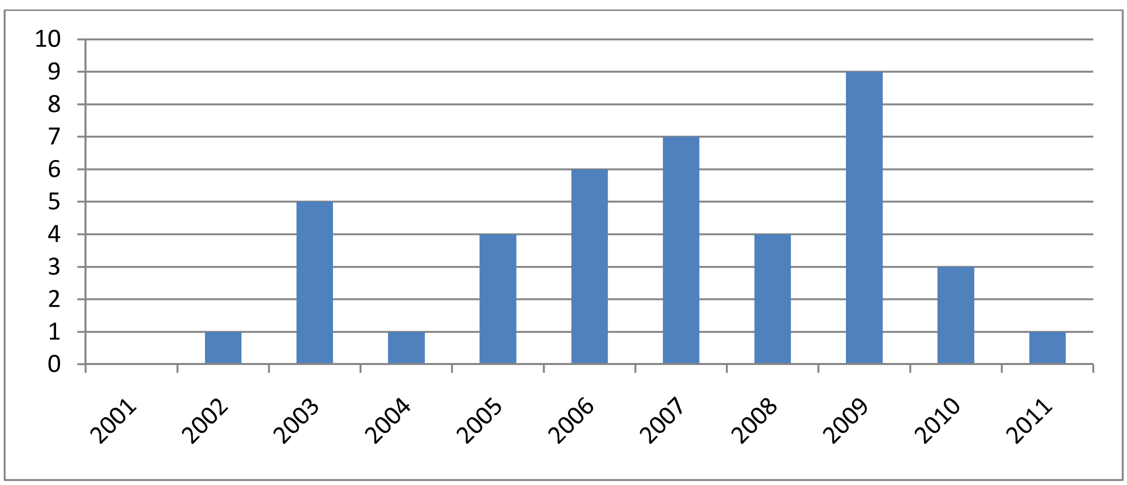

Figure 5. Number of DB Projects Completed in Each Year.

The histogram in Figure 6 shows the total cost range for the DB projects collected in this study. Approximately 31% of the DB projects collected in this study had a cost range of $10 million to $20 million. About 33% of the DB projects collected was a combination of projects ranging from $1 million to $10 million and projects ranging from $20 million to $30 million. The remaining 36% of the DB projects ranged from $0 to 1 million and from $40 million to above $90 million.

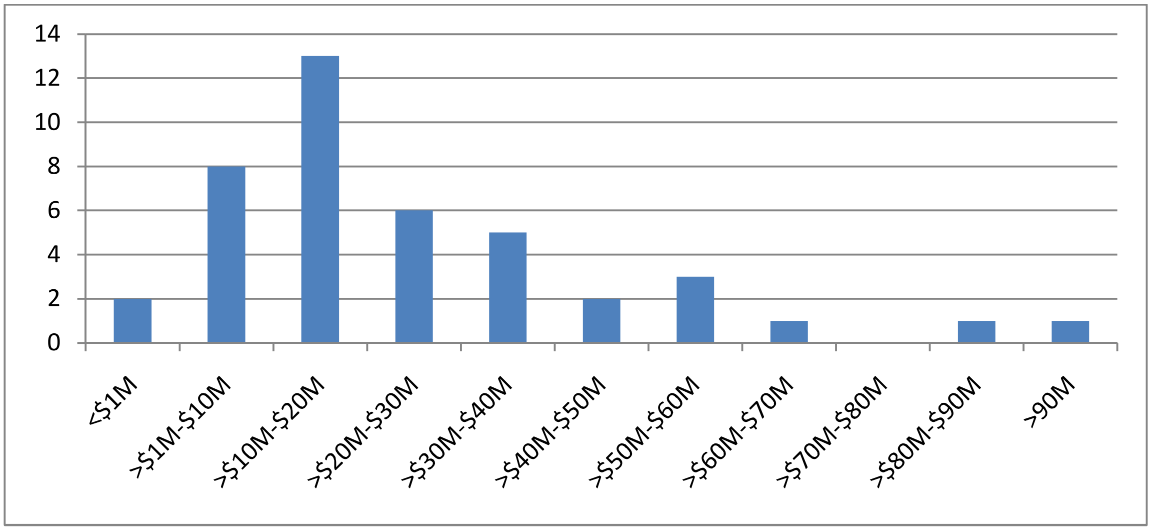

Figure 6. Total Cost Range for DB Projects.

The histogram in Figure 7 shows the total number of DB projects with respect to the total duration of design and construction, in months. For this study, only one DB project was collected for the range of 0-6 months and one DB project for the range of 54-60 months; the other 40 DB projects collected in this study ranged from 6 months to 42 months total duration.

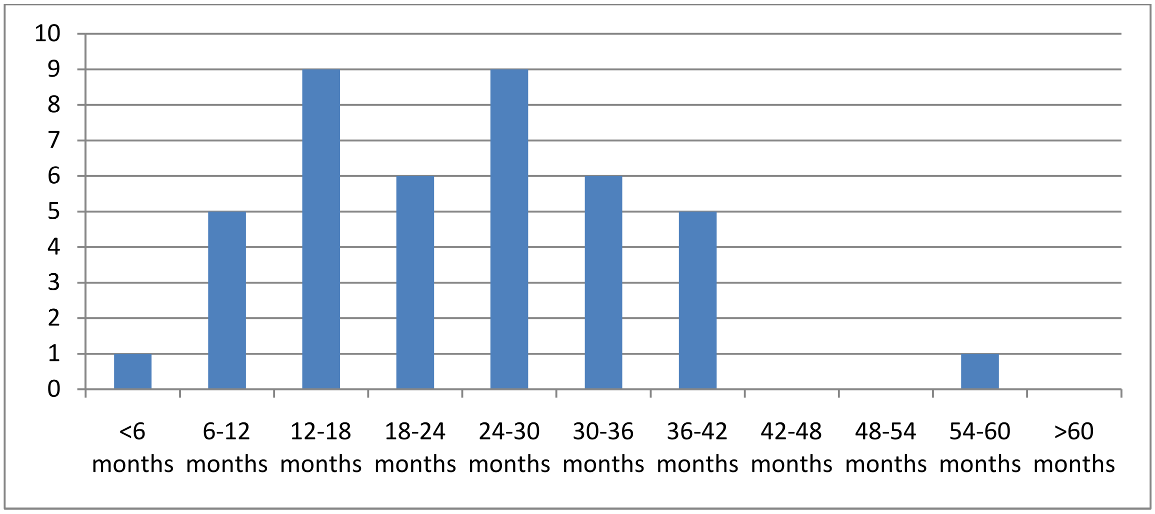

Figure 7. Total Design and Construction Duration in Months for DB Projects.

The histogram in Figure 8 shows the number of DBB projects with respect to location. The study received the highest response rate from Wisconsin on DBB questionnaires, followed closely by California, Nevada, and Arizona. Again, this histogram does not suggest that Wisconsin completed more DBB projects than the other states listed; however, Wisconsin returned more questionnaires on DBB projects than any of the other states listed.

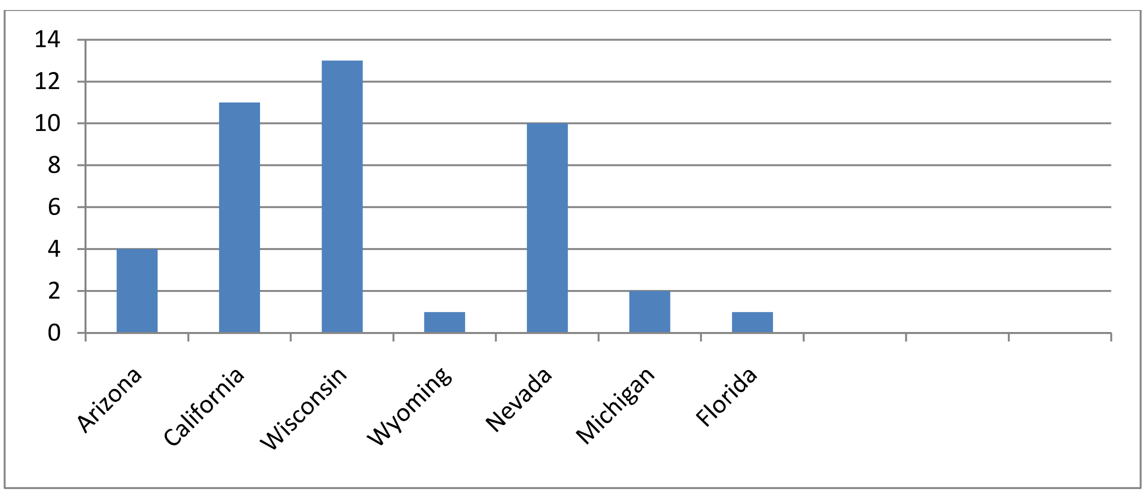

Figure 8. Number of Design-Bid-Build (DBB) Projects in Each State

The histogram in Figure shows the total number of DBB projects started or completed within a specific year. This figure shows that this study collected the highest amount of DBB questionnaires for projects beginning or ending in 2006, followed by 2007, 2008, and 2004.

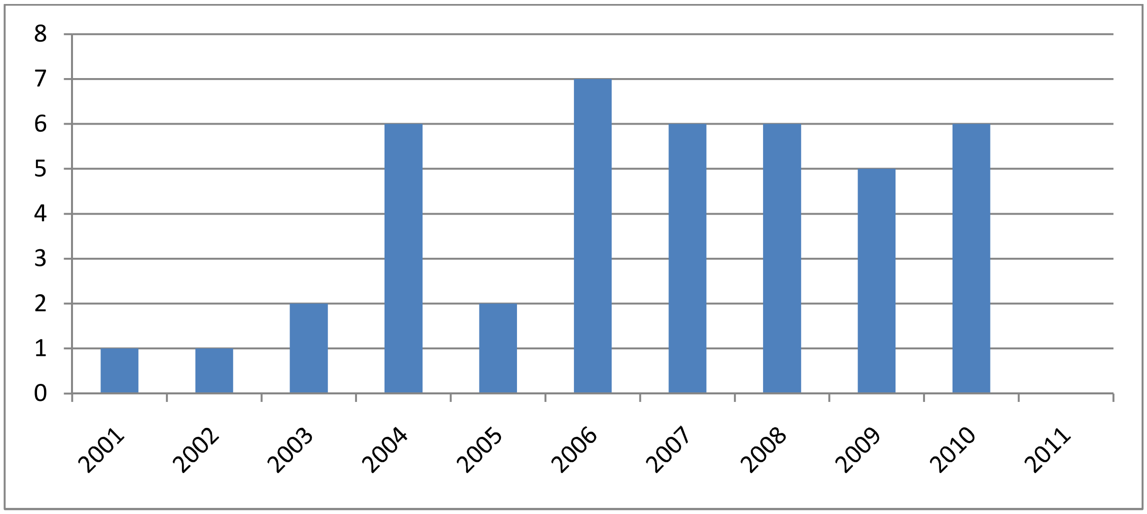

Figure 9.Number of DBB Projects Completed in Each Year.

The histogram in Figure 10 shows the total cost range for the DBB projects collected in this project. Approximatley 44% of the DBB projects collected in this study had a cost range of $1 million to $10 million. The remaining 56% of the DBB projects ranged from $0 to $1 million and from $10 million to above $90 million.

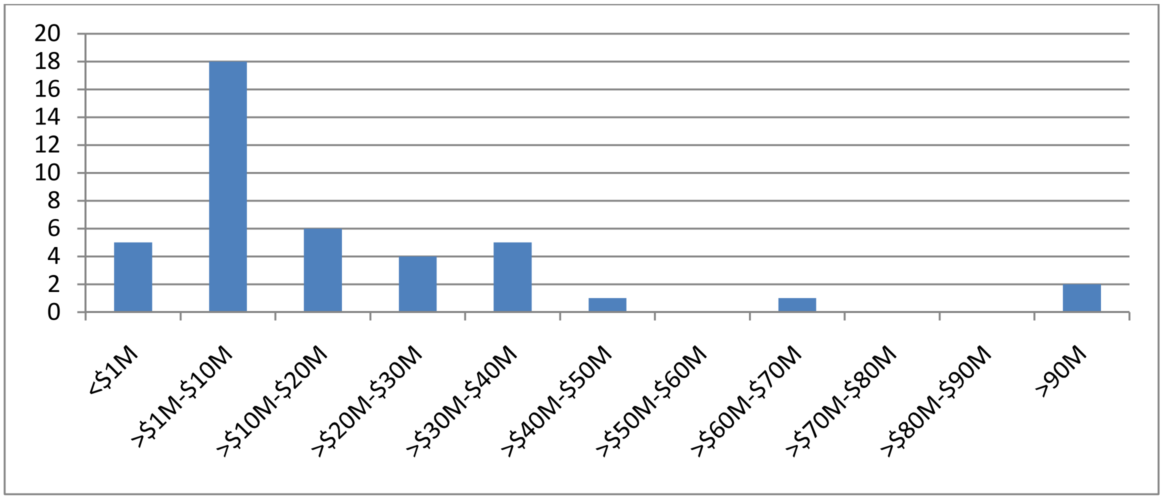

Figure 10. Total Cost Range for DBB Projects.

The histogram in Figure 11 shows the total number of DBB projects with respect to total duration of design and construction, in months. Over 85% of the DBB projects collected for this study had a total design and constrcution duration ranging from 12 months to 54 months. The remaining 15% of the DBB projects ranged from 0 to 12 months and 54 to over 60 months.

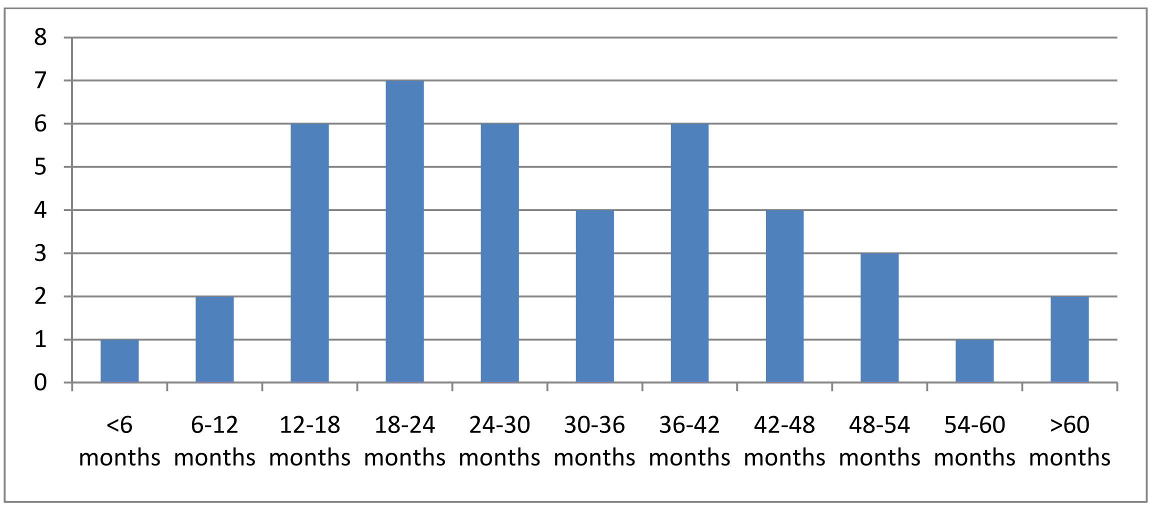

Figure 11. Total Design and Construction Duration in Months for DBB Projects.

CHAPTER 5

FINDINGS

The performance data of DB and DBB projects were analyzed. First, the descriptive statistics of performance metrics related to cost, schedule, and change orders were calculated. Then, a one-factor Analysis of Variances (ANOVA) test and a t-test with unequal variance were conducted to determine whether the performance metrics of DB and DBB projects were statistically different from each other.

5.1 Descriptive Statistics

Table 7 shows the mean, median, and standard deviation of the cost performance metrics. The results indicate that the mean Contract Award Cost Growth of DB projects (-11.1%) is lower than that of DBB projects (-2.8%). The median values for both DB and DBB projects are similar to their mean values. These results also indicated that both the DB and DBB contractors were bidding below the estimated costs, however, the DB contractors were bidding the contract below the DBB contractors.

In addition, the results indicate that the mean construction cost growth of DB projects (16.9%) is higher than that of DBB projects (11.5%). The median values for both DB and DBB projects are similar to their mean values. This indicates that the DB projects were experiencing higher construction cost growth than the DBB projects.

The mean Total Cost Growth of DB projects (3.1%) is lower than that of DBB projects (8.1%). The median values for both DB and DBB projects are less than their mean values. This indicates that the DB projects had lower total cost growth than the DBB projects.

The mean Cost per Square Foot of DB projects ($416/SF) is higher than that of DBB projects ($409/SF). The median values for both DB and DBB projects are less than their mean values. These results indicate that the DB projects had a higher Cost per Square Foot than that of the DBB projects.

Table 7. Descriptive Statistics of Cost Metrics.

No.	Cost Metrics	Design-Build Projects (N= 42)			Design-Bid-Build Projects (N= 42)		
		Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
1	Contract Award Cost Growth (%)	-11.1	-10.9	12.6	-2.8	-1.0	13.5
2	Construction Cost Growth (%)	16.9	15.1	16.2	11.5	8.0	9.2
3	Total Cost Growth (%)	3.1	-1.4	16.6	8.1	5.6	15.8
4	Cost Per Square Foot ($/SF)	416	375	267	409	354	260

Table 8 shows the mean, median, and standard deviation of schedule performance metrics. The results indicate that the mean Design and Construction Schedule Growth of DB projects (-5.3%) is lower than that of DBB projects (7.3%). The median values for both DB and DBB projects are lower than their mean values. It showed that the DB projects were experiencing approximately 2.5 times less Design and Construction Schedule Growth than the DBB projects.

The results showed that the mean Total Schedule Growth of DB projects (-3.7%) is lower than that of DBB projects (28.6%). The median values for DB and DBB are lower than their mean values. These results indicate that the DB projects were experiencing approximately four times less Total Schedule Growth than the DBB projects.

The mean Construction Intensity of DB projects (203 SF/Day) is higher than that of DBB projects (75 SF/Day). The median values for the DB and DBB projects are less than their mean values. These results indicate that the DB projects were completed approximately three times faster than the DBB projects.

Table 8. Descriptive Statistics of Schedule Metrics.

No.	Schedule Metrics	Design-Build Projects (N= 42)			Design-Bid-Build Projects (N= 42)		
		Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
1	Design and Construction Schedule Growth (%)	-5.3	-8.6	16.4	7.3	5.4	8.2
2	Total Schedule Growth (%)	-3.7	-8.6	19.8	28.6	14	57
3	Construction Intensity (SF/Day)	203	127	342	75	60	61

Table 9 shows the mean, median, and standard deviation of Change-Order Cost performance metrics. The results show that the mean Design Change-Order Cost Growth of DB projects (1.3%) is lower than that of DBB projects (2.1%). The median values for DB projects are 0% and 1.6% for DBB projects. This indicates that the DB projects had less Design Change-Order Cost Growth than that for the DBB contractors.

The results indicate that the mean Construction Change-Order Cost Growth of DB projects (1.6%) is lower than that of DBB projects (5.7%). The median values for both DB and DBB projects are less than their mean values. This result indicates that the DB projects had approximately 3.5 times less Construction Change-Order Cost Growth than that of the DBB projects.

The mean Total Change-Order Cost growth of DB projects (2.3%) is lower than that of DBB projects (7.7%). The median value for DB projects is similar to its mean value. However, the median value of DBB projects is less than the mean value. It showed that the DB projects had approximately three times less Total Change-Order Cost Growth than that of the DBB projects.

Table 9. Descriptive Statistics of Change-Order Cost Metrics.

No.	Cost Metrics	Design-Build Projects (N= 42)			Design-Bid-Build Projects (N= 42)		
		Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
1	Design Change-Order Cost Growth (%)	1.3	0.0	2.4	2.1	1.6	1.6
2	Construction Change-Order Cost Growth (%)	1.6	0.0	2.4	5.7	4.6	4.6
3	Total Change-Order Cost Growth (%)	2.3	2.0	3.9	7.7	6.0	5.0

5.2 One-way Analysis of Variance

One-way Analysis of Variance (ANOVA) was conducted to determine whether the DB projects outperformed the DBB projects in terms of cost, schedule, and change orders. To conduct this test, the following four assumptions must be met: 1) the sample should be randomly selected or by means of a convenient random sampling, 2) the dependent variables should be in interval or ratio scale, 3) the dependent variables should be normally distributed, and 4) the variances of the two groups should be equal.

The first assumption is that the factorial ANOVA requires the observations to be mutually independent of each other. The data should be randomly selected or by means of a convenient random sampling, which is true in this case. The questionnaires were sent out randomly all over the United States to collect the data.

The second assumption requires that the dependent variable should be in either a ratio scale or an interval scale. Similarly, the independent variable should be in a nominal scale. If the independent variables are not nominal, they need to be grouped first before the factorial ANOVA can be done. In this case, all the dependent variables that are performance metrics are in the ratio scale. The independent variable in this study is a project delivery type that is in the nominal scale.

The third assumption is that ANOVA assumes that the dependent variable approximates a normal distribution. This assumption can be verified either by checking histograms or by the Anderson-Darling test. The histograms and test results are shown in the Section 4.3.

The fourth assumption is that the factorial ANOVA assumes that the variances of the two groups are equal. Levene's test was conducted to test this assumption. The results of this test are described in the following sections.

5.3 Normality Assumptions Test Results

One of the main assumptions of the ANOVA test is that the data should be normally distributed. The Anderson Darling Test is conducted to check whether the data are normally distributed. The null hypothesis of this test is that the data are normally distributed. If the *p* value is less than 0.05, it shows that the data distribution is not normal.

Normality needs to be verified in order to be used in the one-way ANOVA test. In order to obtain this information, a histogram was created from the SPSS software program for each performance metric. For verification purposes, Anderson-Darling tests were also performed.

Figure 12 shows the histograms for Contract Award Cost Growth for DB and DBB projects. The graphs follow a normal distribution, with a slight skew to the left. The DBB curve skews slightly more to the left than the DB curve. The Anderson darling test was performed to determine whether the data follows the normal distribution.

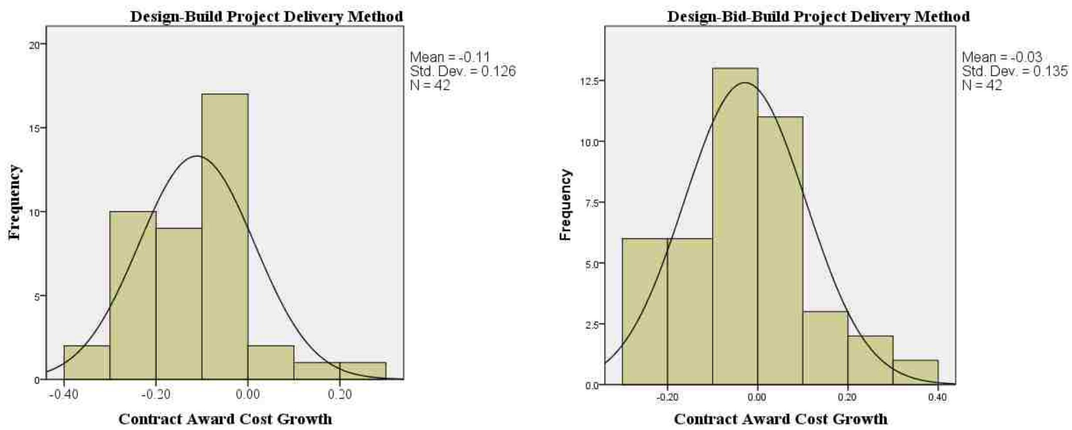

Figure 12. Histograms of Contract Award Cost Growth.

Table 10 shows the results of the Anderson Darling test, indicating that the Contract Award Cost Growth data in both DB and DBB projects were normally distributed because the *p* value is higher than 0.05. Even though the nomality graph did not show that the data were normally distributed, the Anderson Darling test showed otherwise.

Table 10. Anderson Darling Test for Contract Award Cost Growth.

Performance Metrics	Statistics	*p* Value
DB Contract Award Cost Growth	0.40	0.368
DBB Contract Award Cost Growth	0.72	0.058

Figure 13 shows the histograms for Construction Cost Growth for DB and DBB projects. In this case as well, the graph follows a normal distribution with a slight skew to the left. The DB distribution curve resembles more normality than the DBB curve. The Anderson Darling test was performed to verify numerically whether the data follows a normal distribution.

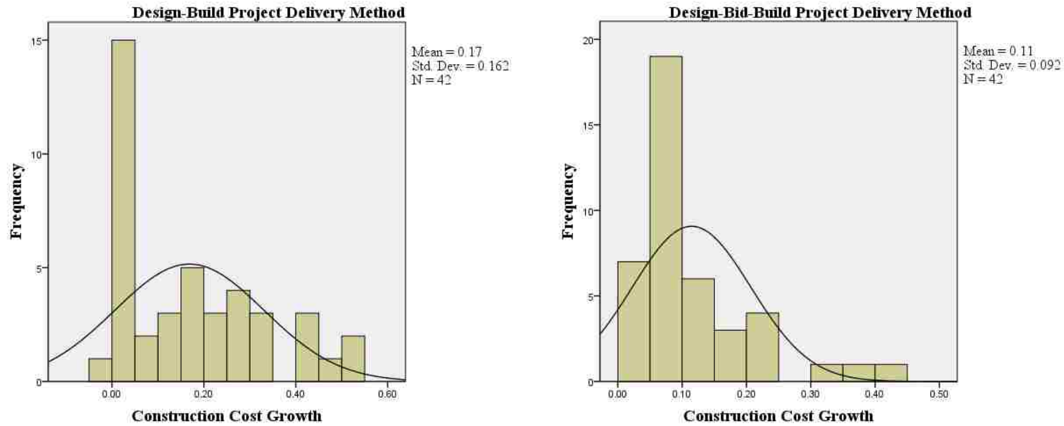

Figure 13. Histograms of Construction Cost Growth.

Table 11 shows the results of the Anderson Darling test, indicating that the Construction Cost Growth data in DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. Results of this test rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 11. Anderson Darling Test for Construction Cost Growth.

Performance Metrics	Statistics	*p* Value
DB Construction Cost Growth	1.40	<0.001*
DBB Construction Cost Growth	3.27	<0.001*

*Significant at alpha level 0.05

Figure 14 shows the histograms for Total Cost Growth for both DB and DBB projects. The Total Cost Growth follows a normal distribution with a slight skew to the left. These two normality curves are similar to the two curves presented in Figure 1. The Anderson Darling test was performed to determine numerically whether the data follows the normal distribution.

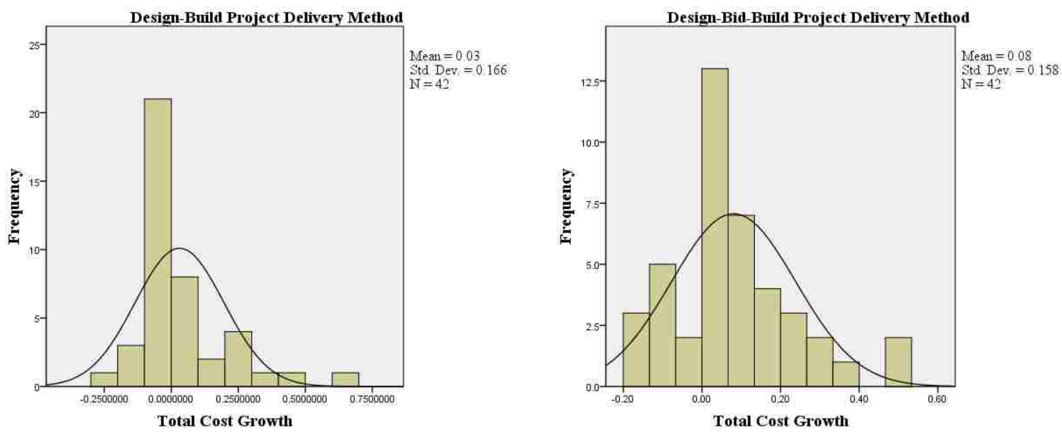

Figure 14. Histograms of Total Cost Growth.

Table 12 shows the results of Anderson Darling test, indicating that the Total Cost Growth data in DB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).The results indicate that the Total Cost Growth data in DBB projects were normally distributed because the *p* value is higher than 0.05. Even though the nomality graph did not that show the data were normally distributed, the Anderson Darling test showed otherwise.

Table 12. Anderson Darling Test for Total Cost Growth.

Performance Metrics	Statistics	*p* Value
DB Total Cost Growth	2.60	<0.001*
DBB Total Cost Growth	0.67	0.082

*Significant at alpha level 0.05

Figure 15 shows the histograms for Cost Per Square Foot for DB and DBB projects. The Cost Per Square Foot follows a normal distribution with a slight skew to the left to approximately the same degree for both DB and DBB projects. Since the Cost Per Square Foot does not follow the normal distribution curve, the Anderson Darling test was performed to determine numerically whether the data follows the normal distribution.

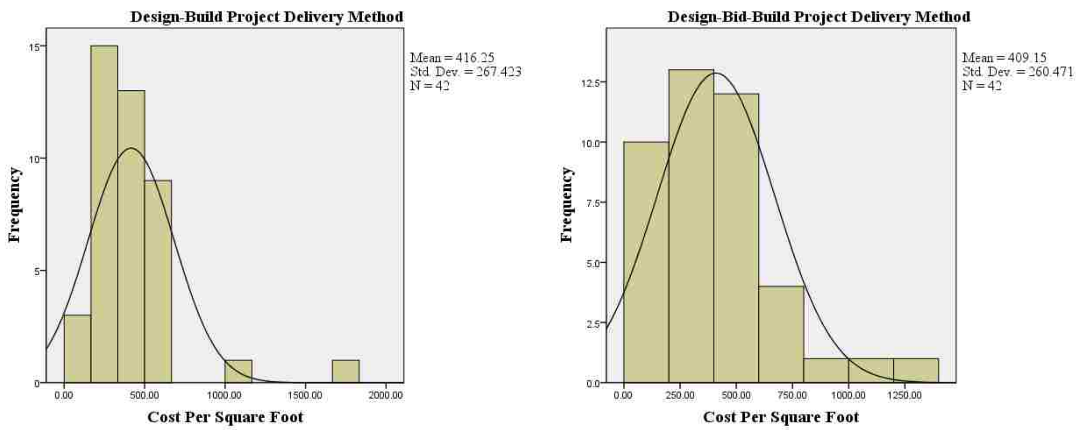

Figure 15. Histograms of Cost Per Square Foot.

Table 13 shows the results of Anderson Darling test, indicating that the Cost per Square Foot data in DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 13. Anderson Darling Test for Cost Per Square Foot

Performance Metrics	Statistics	*p* Value
DB Cost Per square Foot	3.22	<0.001*
DBB Cost Per Square foot	1.58	<0.001*

*Significant at alpha level 0.05

Figure 16 shows the histograms for Design and Construction Schedule Growth for DB and DBB projects. The graph follows a normal distribution with a slight skew to the left. Since the Design and Construction Schedule Growth does not follow the normal distribution curve, the Anderson Darling test was performed to determine numerically whether the data follows normal distribution.

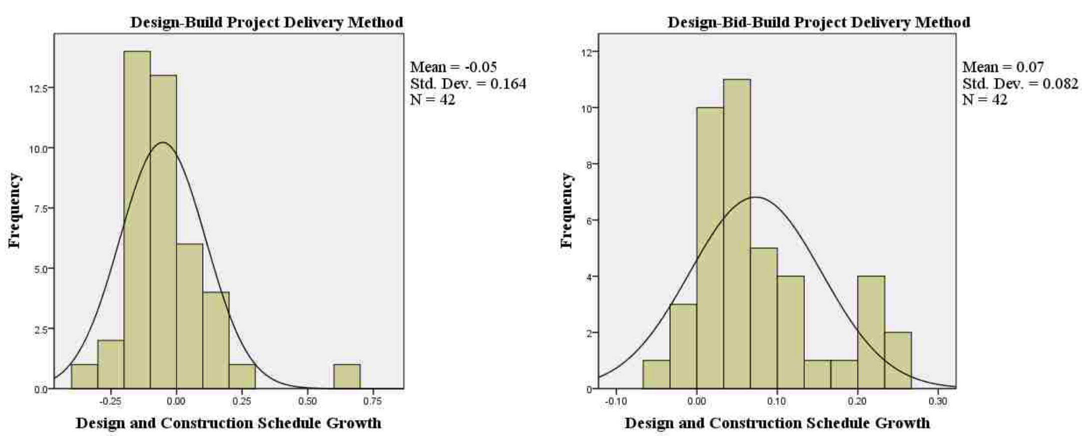

Figure 16. Histogram of Design and Construction Schedule Growth.

Table 14 shows the results of the Anderson Darling test, indicating that the Design and Construction Schedule Growth data in DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 14. Anderson Darling Test for Design and Construction Schedule Growth.

Performance Metrics	Statistics	*p* Value
DB Design and Construction Schedule Growth	1.73	<0.001*
DBB Design and Construction Schedule Growth	1.39	<0.001*

*Significant at alpha level 0.05

Figure 17 shows the histograms for the Total Schedule Growth. The graph follows a normal distribution with a slight skew to the left. The DB curve skews more to the left, and the DBB curve is close to normal. Since Total Schedule Growth does not follow the normal distribution curve, the Anderson Darling test was performed to determine numerically whether the data follows normal distribution.

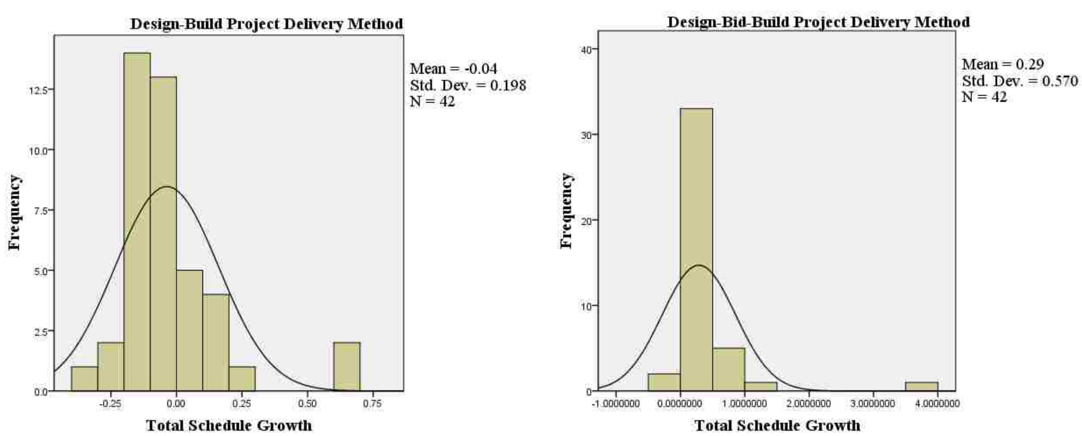

Figure 17. Histograms of Total Schedule Growth.

Table 15 shows the results of the Anderson Darling test, indicating that the Total Schedule Growth data in DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 15. Anderson Darling Test for Total Schedule Growth.

Performance Metrics	Statistics	*p* Value
DB Total Schedule Growth	2.74	<0.001*
DBB Total Schedule Growth	6.38	<0.001*

*Significant at alpha level 0.05

Figure 18 shows the histograms for the Construction Intensity (SF/Day). The graph follows a normal distribution with skewness to the left in both the DB and DBB projects. Since the Construction Intensity does not follow the normal distribution curve, the Anderson Darling test was performed to determine numerically whether the data follows the normal distribution.

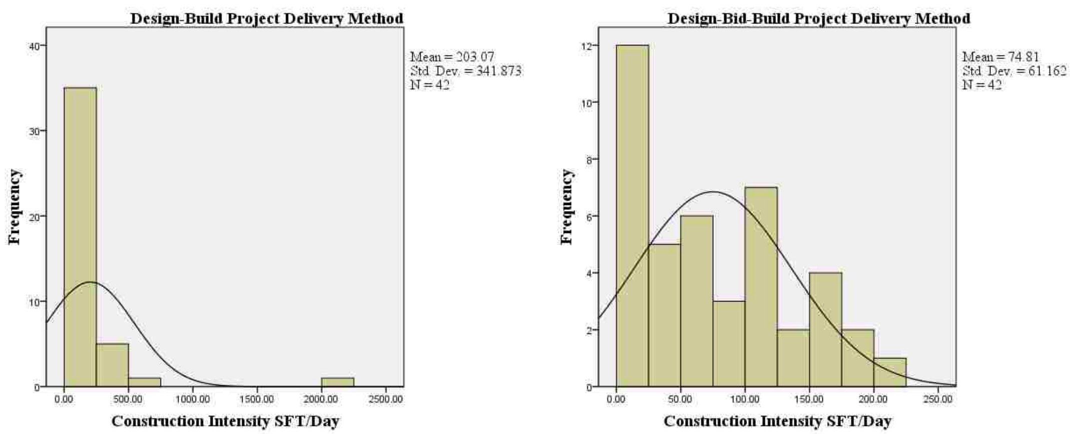

Figure 18. Histograms of Construction Intensity.

The results of Anderson Darling test shown in Table 16 indicate that the Construction Intensity of DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 16. Anderson Darling Test for Construction Intensity (SF/Day).

Performance Metrics	Statistics	*p* Value
DB Construction Intensity (SF/Day)	7.38	<0.001*
DBB Construction Intensity (SF/Day)	3.27	<0.001*

*Significant at alpha level 0.05

Figure 19 shows the histograms for the Design Change-Order Cost Growth. The graph follows a normal distribution with a slight skew to the left. The DBB curve skews more to the left than the DB curve, which appears to be close to normal. Since the Design Change-Order Cost Growth does not follow the normal distribution curve, the Anderson Darling test was performed to determine numerically whether the data follows the normal distribution.

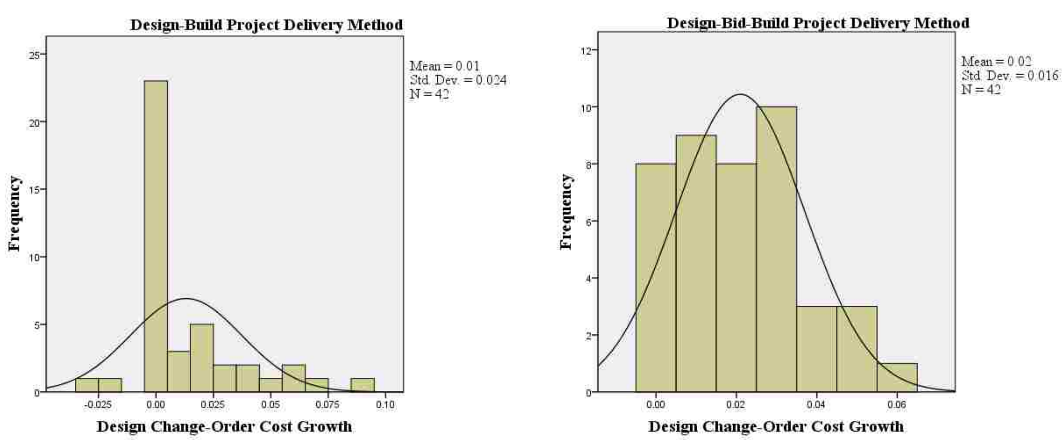

Figure 19. Histogram of Design Change-Order Cost Growth.

Table 17 shows the results of Anderson Darling test indicating that the Design Change-Order Cost Growth data for DB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).The results showed the Design Change-Order Cost Growth data for DBB projects were normally distributed because the *p* value is higher than 0.05. The nomality graph did not show that the data were normally distributed; however, the Anderson Darling test showed otherwise.

Table 17. Anderson Darling Test for Design Change-Order Cost Growth.

Performance Metrics	Statistics	*p* Value
DB Design Change-Order Cost Growth	3.61	<0.001*
DBB Design Change-Order Cost Growth	0.45	0.274

*Significant at alpha level 0.05

Figure 20 shows the histograms for the Construction Change-Order Cost Growth. The graph follows a normal distribution with a slight skew to the left. Since the Construction Change-Order Cost Growth does not follow the normal distribution curve, the Anderson Darling test was performed to determine numerically whether the data follows the normal distribution.

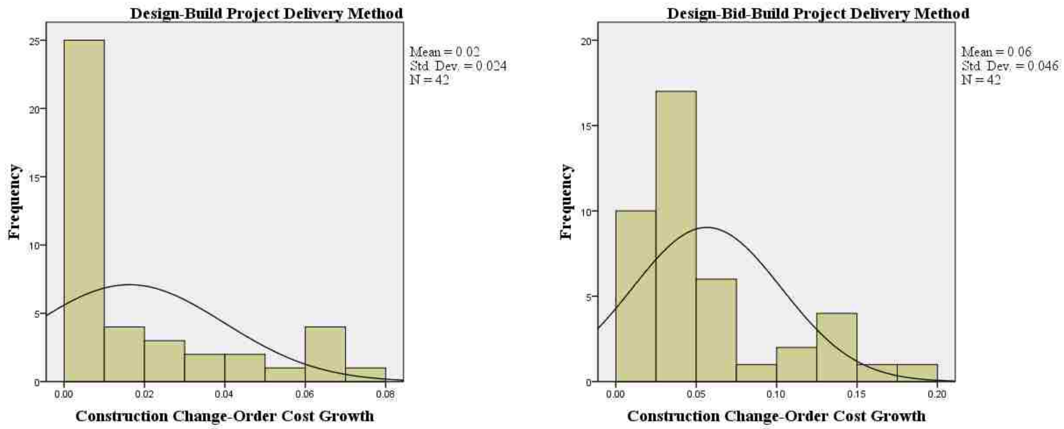

Figure 20. Histogram of Construction Change-Order Cost Growth.

Table 18 shows the results of Anderson Darling test, indicating that the Construction Change-Order Cost Growth data in DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. It rejects the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 18. Anderson Darling Test for Construction Change-Order Cost Growth

Performance Metrics	Statistics	*p* Value
DB Construction Change-Order Cost Growth	5.02	<0.001*
DBB Construction Change-Order Cost Growth	3.14	<0.001*

*Significant at alpha level 0.05

Figure 21 shows the histograms for the Total Change-Order Cost Growth. The graph follows a normal distribution with a slight skew to the left. Since the Total Change-Order Cost Growth does not follow the normal distribution curve, the Anderson Darling test was performed to determine whether the data follows the normal distribution.

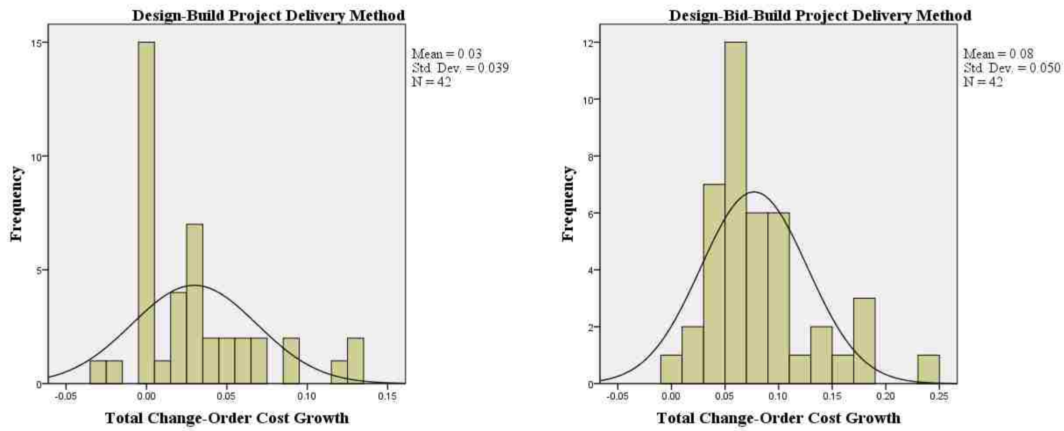

Figure 21. Histogram of Total Change-Order Cost Growth.

Table 19 shows the results of Anderson Darling test, indicating that the Total Change-Order Cost Growth data in DB and DBB projects were not normally distributed because the *p* value is lower than 0.05. These results reject the null hypothesis that the data is normally distrubuted. However, the ANOVA test is a robust test and the violation of the normality will not affect the test results if the sample is large (> 30 samples).

Table 19. Anderson Darling Test for Total Change-Order Growth.

Performance Metrics	Statistics	*p* Value
DB Total Change-Order Cost Growth	1.86	<0.001*
DBB Total Change-Order Cost Growth	1.87	<0.001*

*Significant at alpha level 0.05

4.4 Results of Equal Variance Test

Levene's test was conducted to check the homogeneity of variance in DB and DBB projects. The null hypothesis for this test is that the variances of these two groups are equal. If the *p* value is less than 0.05, then the null hypothesis of equal variances is rejected.

Table 20 shows the Levene statistic of cost metrics. All the cost metrics except the Construction Cost Growth metric has a *p* value of more than 0.05. Therefore, the variance of the Construction Cost Growth metric in DB and DBB projects is not equal. To overcome the violation of this assumption, the means for the Construction Cost Growth of these two groups should be statistically compared by using the t-test, assuming unequal variance.

Table 20. Results of Homogeneity of the Variance Test for Cost Metrics.

Performance Metrics	Levene Statistic	*p* value
Contract Award Cost Growth	0.01	0.911
Construction Cost Growth	17.84	<0.001*
Total Cost Growth	0.01	0.980
Cost Per Square Foot	0.46	0.457

* Significant at alpha level 0.05

Table 21 shows the results of Levene's tests for schedule metrics. The null hypothesis for this test is that the variances of these groups are equal. If the *p* value is less than 0.05, then the null hypothesis of equal variances is rejected. All the schedule metrics have a *p* value less than 0.05. Therefore, the variances of all schedule growth metrics in these two groups of projects are not equal. To overcome the violation of this assumption, the means of these three metrics should be statistically compared using the t-test, assuming unequal variance.

Table 21. Results of Homogeneity of the Variance Test for Schedule Metrics

Performance Metrics	Levene Statistic	*p* value
Design and Construction Schedule Growth	4.47	0.037*
Total Schedule Growth	4.58	0.035*
Construction Intensity	4.73	<0.001*

* Significant at alpha level 0.05

Table 22 shows the results of Levene's tests for Change-Order Cost metrics. The null hypothesis for this test is that the variances of these groups are equal. If the *p* value is less than 0.05, then the null hypothesis of equal variances is rejected. All the Change-Order Metrics, except for the Construction Change-Order Growth metric, have *p* values of more than 0.05. Therefore, the variance of Construction Change-Order Cost Growth in DB and

DBB projects is not equal. To overcome the violation of this assumption, the means for the Construction Change-Order Cost Growth of these two groups should be statistically compared using the t-test, assuming equal variance.

Table 22. Results of Homogeneity of the Variance Test for Change Order Metrics.

Performance Metrics	Levene Statistic	*p* value
Design Change-Order Cost Growth	3.75	0.056
Construction Change-Order Cost Growth	10.73	0.002*
Total Change-Order Cost Growth	1.67	0.200

* Significant at alpha level 0.05

The results of ANOVA test for cost metrics, shown in Table 23, indicate that only the Contract Award Cost Growth mean is significantly different between DB and DBB projects. The results also indicated that the mean Contract Award Cost Growth of DBB projects are significantly higher than that of DB projects.

Table 23. ANOVA Results for Cost Metrics.

No.	Cost Metrics	DB Mean (N=42)	DBB Mean (N=42)	Test Statistic	Critical Values	*p* Value
1	Contract Award Cost Growth (%)	-11.1	-2.8	8.48	3.96	<0.001*
2	Construction Cost Growth (%)	16.9	1.15	1.86	1.99	0.067
3	Total Cost Growth (%)	3.1	8.5	1.99	3.96	0.162
4	Cost Per Square Foot ($/DAY)	416	409	0.02	3.96	0.902

* Significant at alpha level 0.05

The box plots of the cost performance metrics, shown in Figure 22, indicate that there are higher outliers for the Total Cost Growth metrics than for the other two metrics. Contract Award Cost Growth has just one outlier in DBB projects. There are a few outliers for Construction Cost Growth of DBB projects. Cost Per Square Foot has just two outliers in DB projects and two outliers in DBB projects. However, in Total Cost Growth, both DB and DBB projects have a number of outliers.

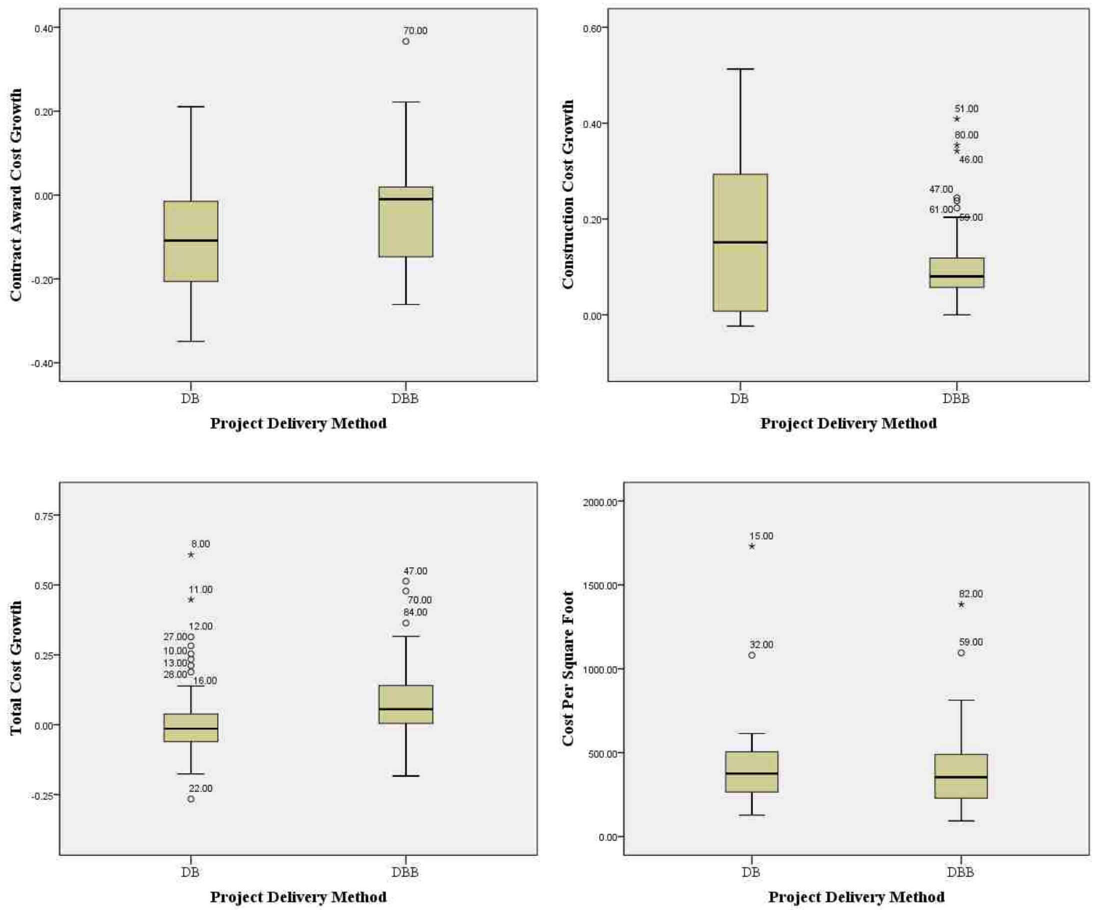

Figure 22. Box Plots of Cost Performance Metrics.

Table 24 shows the results of the ANOVA test for schedule metrics. The assumption of equal variances was rejected by all three performance metrics. Therefore, a t-test with unequal variances was conducted to find the statistically significant difference. The results of this test showed that the means for Design and Construction Schedule Growth, Total Schedule Growth, and Construction Intensity are significantly different between DB and DBB projects. The results indicate that the means for Design and Construction

Schedule Growth and Total Schedule Growth of DBB are significantly higher than that of DB projects. In addition, the mean for Construction Intensity of DBB projects is significantly lower than for DB projects.

Table 24. T-test for Unequal Variance Results for Schedule Metrics

No.	Schedule Metrics	DB Mean (N=42)	DBB Mean (N=42)	Test Statistic	Critical Values	*p* Value
1	Design and Construction Schedule Growth (%)	-5.28	7.3	4.45	2.00	<0.001*
2	Total Schedule Growth (%)	-3.7	28.6	3.47	2.00	<0.001*
3	Construction Intensity (SF/DAY)	203	75	2.39	2.01	0.021*

* Significant at alpha level 0.05

The box plots for the schedule performance metrics, shown in Figure 23, indicate that there are higher outliers in the Construction Intensity metrics than in the other two metrics. Design and Construction Schedule Growth has two outliers for DB projects. There are three outliers in DB Total Schedule Growth and two in DBB Total Schedule Growth. However, in the Construction Intensity metrics, both DB and DBB projects have a number of outliers.

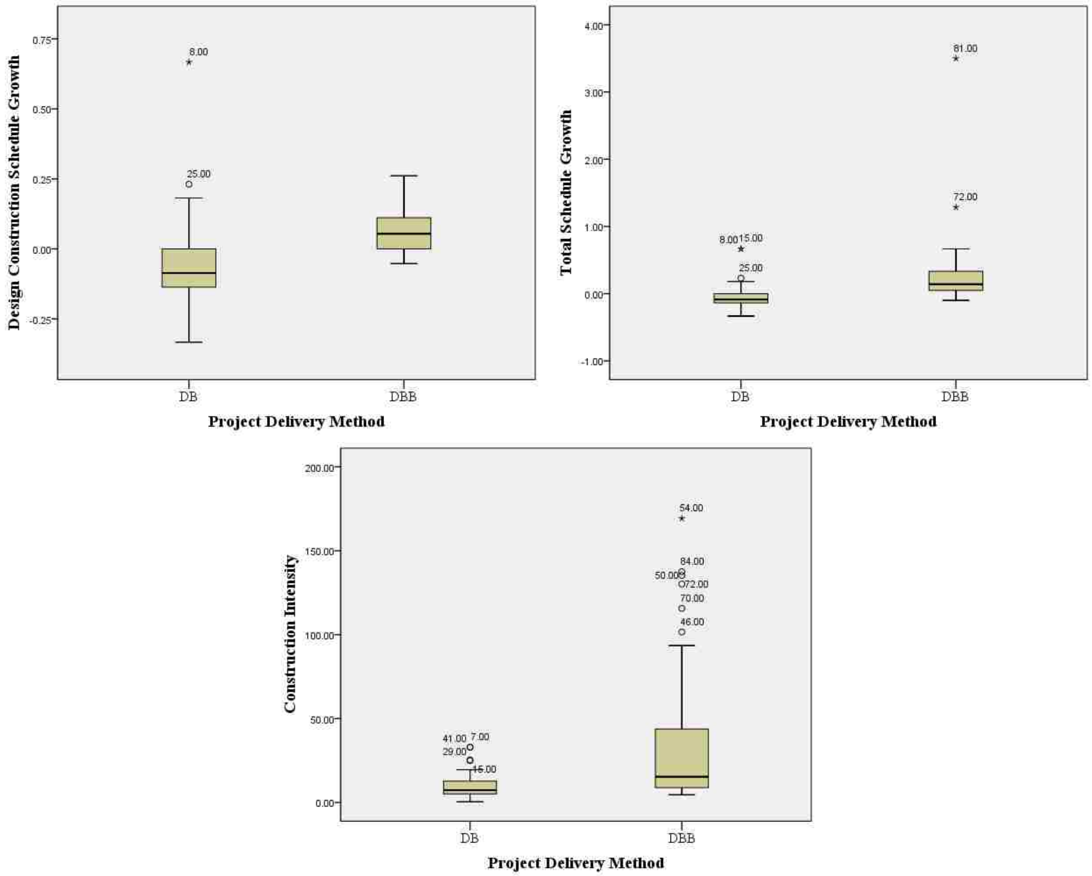

Figure 23. Box Plots of Schedule Performance Metrics

Table 25 shows the results of the ANOVA and t-test for Change-Order Cost metrics. The ANOVA test was conducted for the Design Change-Order Cost Growth and Total Change-Order Cost Growth to determine whether their means were significantly different. However, for Construction Change-Order Cost Growth, since the variances of these groups were not equal, a t-test for unequal variances was conducted. The results showed that the means for the Construction Change-Order Cost Growth and Total Change-Order Cost Growth are significantly lower in DB than in DBB projects.

Table 25. ANOVA and t-test for Unequal Variance Results of Change-Order Cost Metrics.

No.	Change Order Metrics	DB Mean (N=42)	DBB Mean (N=42)	Test Statistic	Critical Values	*p* Value
1	Design Change-Order Cost Growth (%)	1.3	2.1	3.07	3.96	0.08
2	Construction Change-Order Cost Growth (%)	1.6	5.7	5.03	1.99	<0.001*
3	Total Change-Order Cost Growth (%)	2.3	7.7	23.69	3.96	<0.001*

* Significant at alpha level 0.05

The box plots of the change-order cost growth metrics, shown in Figure 24, indicate that there are a greater number of outliers in Construction Change-Order Cost Growth than in the other two metrics. Design Change-Order Cost Growth has three outliers in DB projects and no outliers in DBB. There are two outliers in Construction Change-Order Cost Growth for DB projects and six outliers in DBB projects. There are two outliers in Total Change-Order Cost Growth for DB projects and five outliers for DBB projects.

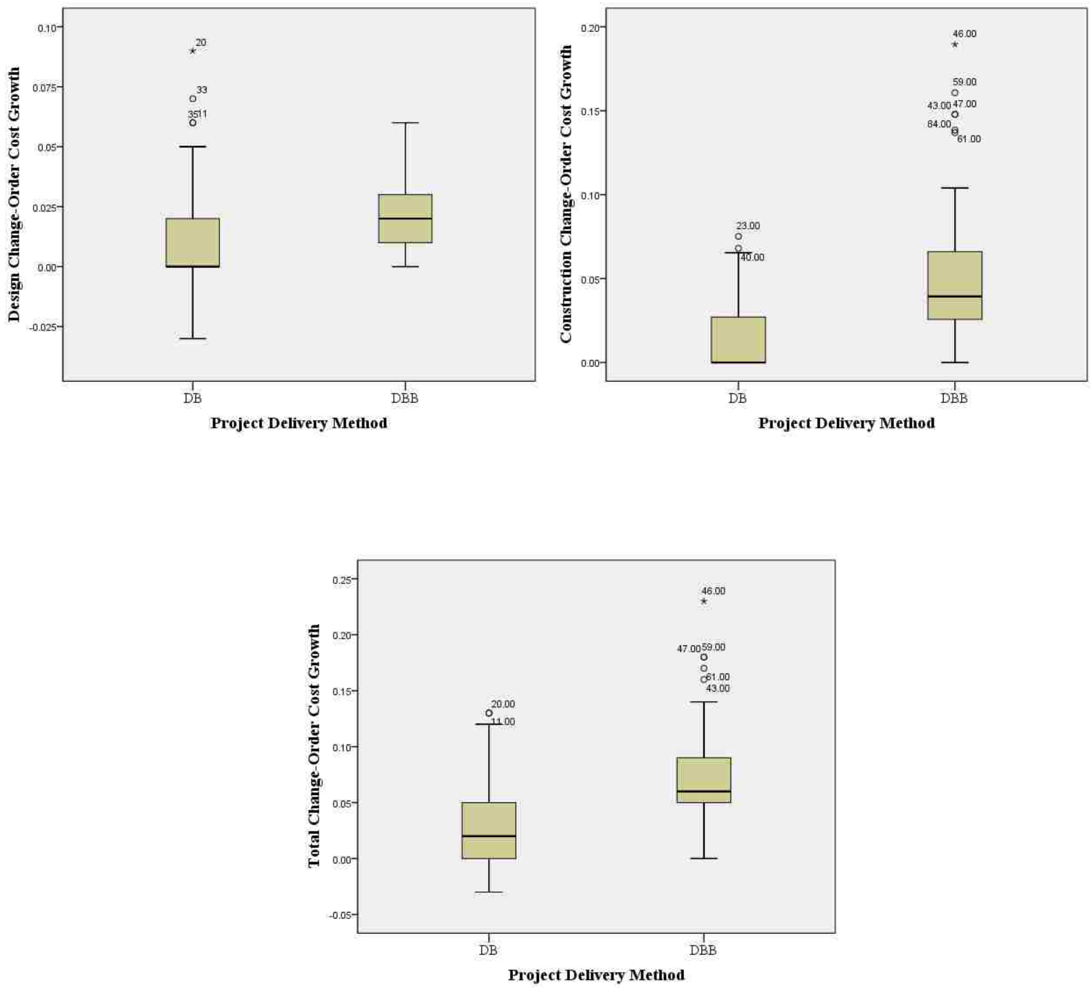

Figure 24. Box Plots of Change-Order Cost Performance Metrics

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

This thesis has collected data, by means of convenient random sampling, and analyzed two similar types of DB and DBB projects recently built by universities within the U.S. All the projects were used for building classrooms, offices, or laboratories. All the projects were administered by similar construction departments established within the university systems. The samples are large enough, with 42 DB projects and 42 DBB projects. These two project types are unique since they are newly constructed buildings on an operating and occupied university campus; therefore, care should be taken while interpreting these results for other types of university structures (parking lots or football fields), tenant improvement buildings (classroom renovation), or such projects as shopping malls or a public library.

6.1.1 Cost Growth

This study analyzed the cost growth in four separate categories: Contract Cost Growth, Construction Cost Growth, Total Cost Growth, and Cost Per Square Foot. The results showed that only the mean Contract Award Cost Growth of DB projects is significantly lower than that of DBB projects. The data also showed that DB projects had a higher Construction Cost Growth and a higher Cost Per Square Foot than DBB projects; however, that finding was not found to be statistically significant. The Total Cost Growth data showed that DB projects had a lower Total Cost Growth, but this result also was found to be statistically insignificant.

6.1.2 Schedule Growth

This study analyzed the three categories of project schedule growth: Design and Construction Schedule Growth, Total Schedule Growth, and Construction Intensity. The results showed that the means of Design and Construction Schedule Growth, Total Schedule Growth, and Construction Intensity were significantly different in DB projects than that of DBB projects. The results also showed that the mean Design and Construction Schedule Growth and the mean Total Schedule Growth of DB projects were significantly lower than that of DBB projects. In addition, the mean Construction Intensity of DB projects were significantly higher than that of DBB projects.

6.1.3 Change Order Growth

This study analyzed change-order cost growth in three separate categories: Design Change Order Growth, Construction Change Order Growth, and Total Change Order Growth. The results showed that the means of Construction Change Order Cost Growth and Total Change Order Cost Growth was significantly lower in DB projects than that of DBB projects. The results also showed that the mean of Design Change-Order Cost Growth of DB projects were lower than that of DBB projects; however, these results were not found to be statistically significant.

For this research project, a comprehensive questionnaire was developed for ease of data collection for this study and for future studies as well. Obstacles and barriers existed while using this questionnaire; for future studies, it is recommended that the questionnaire be shortened to allow for a better response rate. Furthermore, this study can be a valuable asset to the construction industry in the university environment as well as the industry as a whole because different research outcomes of DB and DBB delivery methods were evaluated, analyzed, and interpreted. The results of this research will enable owners in the university environment as well as across the industry to become more familiar with comparisons between the DB and DBB delivery methods, which will enable them to logically choose which delivery method is appropriate for use on a project–by-project basis.

6.2 Recommendations for Further Study

The following recommendations are suggested for further research:

1. The data collected for this study consisted of 42 samples of DB and 42 samples of DBB. To justify the findings of this study, it is reccommended to conduct the study with a larger sample size.
2. This study was spread across the United States but received completed questionnaires from only 11 states. It is recommended that future surveys receive completed questionnaires from every state in order to evaluate that data appropriately and increase external validity.
3. Once DB is widely used in the university system, it is reccommended that data be evaluated by regional territories, such as North, South, East, and West to determine if location has an effect on the delivery method.

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APPENDIX A

BENCHMARKING OF DB FOR UNIVERSITY PROJECTS

QUESTIONNAIRE SURVEY

We would like to thank you in advance for the time and effort involved in your agency's participation in this research.

This interview guide is divided into four sections; Project General Information; Project Characteristics; Project Performances; and Stakeholders' Success. If not enough space is provided for the brief questions, please feel free to attach extra sheets to the document.

In the questions, we ask for detailed information on project characteristics and performance. Please do what you can to assemble this information as fully as possible. Your detailed responses will allow us to understand to what extent these project characteristics and performance measurements affect the benchmarking of University projects.

The confidentiality of this interview will be maintained. This interview data will not be placed in any permanent record, and will be destroyed when no longer needed by the researchers. The identity of person who provided all this information will remain anonymous. The data obtained during this interview will not be linked in any way to participants' names.

Please return this questionnaire via email, or by mail to the following address:

James D. Fernane
Construction Project Manager/Graduate Student
The University of Nevada Las Vegas
7069 Harbor View Dr
Las Vegas, NV 89119
Email: James.Fernane@unlv.edu

Section 1:

1 Project General Information

1.1 Name of Owner Organization: ___________________________________

*1.2 Name of Project:*____

*1.3 Project ID:*____

*1.4 Project Description:*____

*1.5 Project Site Location:*____

*1.6 Contact Person (Name of person filling this questionnaire):*_______________

*1.7 Contact Person's Phone:*____

1.8 Contact Person's Fax: ____

1.9 Contact Person's Email Address: ___________________________________

1.10 Contact Person's Role / Title in this Project: _________________________

1.11 Date of Assessment: ____

Section 2:

2 Project Characteristics

2.1 Current State of Project

2.1.1 Describe current state of this project.

Substantial Completion on ____________________________________

OR

% of completion ______________________________________

Current planned completion date _________________________

2.2 Project Scope

Please provide following project data.

2.2.1 Total Square Feet ________________________________

2.2.2 Total Stories ___________________________________

2.2.3 Type of Construction ______________________________

2.3 Project Calendar

2.3.1 Please fill the start and end dates (month / year) of different phases of this project.

Project phases	**Date in months & years**
Total project	
Design	
Construction	

Section 3:

3 Project Performance:

3.1 Project Cost Related Performance:

Please provide the following cost related performance data of your project.

No.	Cost related project performance	Cost (US $)
1.	Owner estimated design and construction cost	
2.	Contractor's bid / negotiated amount	
3.	Contract amount	
4.	Total project completion cost	
5.	Owner estimated design cost	
6.	Final design cost	
7.	Owner estimated construction cost	
8.	Final construction cost (including change orders)	

3.2 Project Schedule Related Performance:

Please provide the following schedule-related performance data of this project.

No.	Schedule related project performance	Duration (Days or Months)
1.	Owner estimated design and construction duration	
2.	Contractor's bid duration	
3.	Actual project completion duration	
4.	Owner estimated design duration	
5.	Final design duration	
6.	Owner estimated construction duration	
7.	Contractors schedule duration at NTP. (What was the Contractors original number of days to complete)	
8.	Final construction duration	

3.3 Project Change Order- Related Performance:

Please provide the following change order-related performance data of this project.

No.	Change order-related project performance	
1.	Total number of design change orders	
2.	Total cost of design change orders (US$)	
3.	Total number of construction change orders	
4.	Total cost of construction change orders (US$)	

Section 4:

4 Stakeholders' Success:

4.1 Who was the design-build contractor for this project? Please provide the following information.

Name of Contractor: ____

Website address (If any): ____

Email Address____

Phone Number____

4.2 How would you rate the overall performance of this project compared to other design-build (DB) projects?

☐ Excellent	Good	☐
☐ Fair	Poor	☐

APPENDIX B

BENCHMARKING OF DBB FOR UNIVERSITY PROJECTS

QUESTIONNAIRE SURVEY

We would like to thank you in advance for the time and effort involved in your agency's participation in this research.

This interview guide is divided into four sections; Project General Information; Project Characteristics; Project Performances; and Stakeholders' Success. If not enough space is provided for the brief questions, please feel free to attach extra sheets to the document.

In the questions, we ask for detailed information on project characteristics and performance. Please do what you can to assemble this information as fully as possible. Your detailed responses will allow us to understand to what extent these project characteristics and performance measurements affect the benchmarking of University projects.

The confidentiality of this interview will be maintained. This interview data will not be placed in any permanent record, and will be destroyed when no longer needed by the researchers. The identity of person who provided all this information will remain anonymous. The data obtained during this interview will not be linked in any way to participants' names.

Please return this questionnaire via email, by fax, or by mail to the following address:

James D Fernane
Construction Project Manager/Graduate Student
The University of Nevada, Las Vegas
7069 Harbor View Dr
Las Vegas, NV89119
Email: James.Fernane@unlv.edu

Section 1:

5 *Project General Information*

5.1 *Name of Owner Organization:* ____________________

5.2 *Name of Project:* ____________________

5.3 *Project ID:* ____________________

5.4 *Project Description:* ____________________

5.5 *Project Site Location:* ____________________

5.6 *Contact Person (Name of person filling this questionnaire):* ____________________

5.7 *Contact Person's Phone:* ____________________

5.8 *Contact Person's Fax:* ____________________

5.9 *Contact Person's Email Address:* ____________________

5.10 *Contact Person's Role / Title in this Project:* ____________________

5.11 *Date of Assessment:* ____________________

Section 2:

6 *Project Characteristics*

6.1 *Current State of Project*

6.1.1 Describe current state of this project.

Completed on ____________________

Operational from ____________________

OR

% of completed ____________________

Current planned completion date ____________________

6.2 *Project Scope*

Please provide following project data.

6.2.1 Total Square feet ____________________

6.2.2 Total Stories ____________________

6.2.3 Type of construction ____________________

6.3 Project Calendar

6.3.1 Please fill the start and end dates (month / year) of different phases of this project.***(Changed from DB Questionnaire)***

Project phases **Date in months & years**

Design

Contract

Procurement

Construction

Section 3:

7 Project Performance:

*7.1 Project Cost Related Performance****:***

Please provide the following cost related performance data of your project.

No.	Cost related project performance	Cost (US $)
1.	Owner estimated design cost	
2.	Actual design cost	
3.	Owner estimated construction cost	
4.	Contractor's bid / negotiated amount	
5.	Construction contract amount	
6.	Final design cost	
9.	Final construction cost (including change orders)	

7.2 Project Schedule Related Performance:

Please provide the following schedule-related performance data of this project.

No.	Schedule related project performance	Duration (Days or Months)
1.	Owner estimated design duration	
2.	Actual design duration	
3.	Owner estimated construction duration	
4.	Contractor's bid duration	
5.	Contractors schedule duration at NTP. (What was the Contractors original number of days to complete)	
6.	Final construction duration	

7.3 Project Change Order- Related Performance:

Please provide the following change order-related performance data of this project.

No.	Change order-related project performance	
1.	Total number of design change orders	
2.	Total cost of design change orders (US$)	
3.	Total number of construction change orders	
4.	Total cost of construction change orders (US$)	

Section 4:

8 Stakeholders' Success:

8.1 Who was the contractor for this project? Please provide the following information.

Name of Contractor: ______________________________

Website address (If any): ______________________________

Email Address: ______________________________

Phone Number: ______________________________

8.2 How would you rate the overall performance of this project compared to other design-bid-build (DBB) projects?

☐ Excellent Good ☐

☐ Fair Poor ☐

APPENDIX C

Cost Data for DB and DBB Projects

Serial Number and Location	Project Delivery Method	Estimated Design Cost	Bid Design Cost	Final Design Cost
01 CA	DB	Incld in DB estimate	Incld in DB contract	Incld in DB contract
02 AZ	DB	1,550,000	Incld in DB contract	1,485,000
03 AZ	DB	2,500,000	Incld in DB contract	2,395,450
04 AZ	DB	1,850,000	Incld in DB contract	1,800,000
05 ND	DB	1,250,000	Incld in DB contract	1,100,000
06 OK	DB	Incld in DB estimate	Incld in DB contract	Incld in DB contract
07 OK	DB	400,000	Incld in DB contract	410,000
08 OK	DB	166,882	Incld in DB contract	286,020
09 NV	DB	13,432,000	Incld in DB contract	13,821,000
10 CA	DB	2,300,000	Incld in DB contract	2,500,000
11 CA	DB	4,100,000	Incld in DB contract	3,766,000
12 CA	DB	5,000,000	Incld in DB contract	5,062,000
13 CA	DB	2,900,000	Incld in DB contract	2,685,000
14 FL	DB	1,011,000	Incld in DB contract	907,000
15 CA	DB	8,000,000	Incld in DB contract	8,000,000
16 MI	DB	801,000	Incld in DB contract	562,000
17 CA	DB	1,907,000	Incld in DB contract	1,697,000
18 CA	DB	1,071,000	Incld in DB contract	745,879
19 CA	DB	1,500,000	Incld in DB contract	1,498,447
20 CA	DB	1,772,000	Incld in DB contract	1,004,440
21 CA	DB	3,477,932	Incld in DB contract	1,941,837
22CA	DB	371,000	Incld in DB contract	365,500
23 CA	DB	1,234,000	Incld in DB contract	1,100,000
24 CA	DB	1,043,000	Incld in DB contract	874,852
25 MI	DB	350,000	Incld in DB contract	359,670
26 AZ	DB	2,000,000	Incld in DB contract	2,283,157
27 AZ	DB	965,000	Incld in DB contract	885,650
28 WY	DB	Incld in DB estimate	Incld in DB contract	Incld in DB contract
29 WY	DB	Incld in DB estimate	Incld in DB contract	Incld in DB contract
30 CO	DB	Incld in DB estimate	Incld in DB contract	Incld in DB contract
31 AZ	DB	12,000,000	Incld in DB contract	9,876,650
32 AZ	DB	8,000,000	Incld in DB contract	7,575,000
33 AZ	DB	2,300,000	Incld in DB contract	1,900,000
34 AZ	DB	3,500,000	Incld in DB contract	3,475,000
35 AZ	DB	1,000,000	Incld in DB contract	985,000
36 ND	DB	Incld in DB estimate	Incld in DB contract	Incld in DB contract
37	DB	203,000	Incld in DB contract	149,283
38 CA	DB	2,057,500	Incld in DB contract	1,980,950

Serial Number and Location	Project Delivery Method	Estimated Design Cost	Bid Design Cost	Final Design Cost
39 CA	DB	Incld in DB estimate	Incld in DB contract	806,398
40 CA	DB	950,000	Incld in DB contract	936,659
41 CA	DB	500,000	Incld in DB contract	400,000
42 CA	DB	817,000	Incld in DB contract	673,740
43 WI	DBB	475,000	440,000	465,000
44 WI	DBB	800,000	750,000	778,007
45 WI	DBB	1,500,000	1,800,000	1,914,000
46 AZ	DBB	375,000	355,000	425,000
47 AZ	DBB	350,000	395,000	434,000
48 AZ	DBB	825,000	810,000	855,310
49 AZ	DBB	414,250	415,000	431,161
50 WY	DBB	98,000	100,000	103,638
51 NV	DBB	1,500,000	803,000	1,300,000
52 NV	DBB	200,000	156,000	185,000
53 CA	DBB	3,750,000	2,550,555	3,489,056
54 NV	DBB	63,000	58,500	69,567
55 WI	DBB	2,000,000	1,914,000	2,100,000
56 WI	DBB	5,000,000	5,000,000	5,100,000
57 WI	DBB	2,000,000	1,867,060	2,001,520
58 WI	DBB	8,562,095	8,650,000	8,792,000
59 WI	DBB	12,750,000	12,950,000	13,500,000
60 WI	DBB	2,250,000	2,280,000	2,431,413
61 CA	DBB	673,000	602,561	1,044,903
62 WI	DBB	850,000	840,000	925,000
63 CA	DBB	1,236,460	1,632,858	1,984,699
64 CA	DBB	1,043,000	954,303	1,332,448
65 CA	DBB	990,234	582,204	740,571
66 WI	DBB	500,000	490,000	506,800
67 CA	DBB	461,554	399,710	505,870
68 WI	DBB	2,500,000	2,486,950	2,600,000
69 WI	DBB	40,000	45,850	45,850
70 NV	DBB	95,000	95,000	123,500
71 NV	DBB	3,000,000	2,700,000	3,200,000
72 NV	DBB	50,000	36,000	39,500
73 CA	DBB	522,000	596,557	807,455
74 CA	DBB	232,000	168,542	218,759
75 CA	DBB	1,091,000	1,319,834	1,727,691
76 MI	DBB	657,700	682,700	770,188
77 MI	DBB	1,072,809	1,048,000	1,048,000
78 FL	DBB	410,000	469,000	469,000
79 CA	DBB	1,482,855	1,113,155	1,551,750
80 NV	DBB	5,000,000	3,200,000	4,600,000
81 NV	DBB	45,000	43,000	45,520
82 NV	DBB	10,000,000	8,388,677	8,388,677
83 NV	DBB	15,000	11,000	11,000
84 CA	DBB	95,000	146,000	190,000

Serial Number and Location	Project Delivery Method	Estimated Construction Cost	Construction Contract	Final Construction Cost
01 CA	DB	Incld in DB estimate	37,070,705	37,606,826
02 AZ	DB	20,450,000	20,300,000	20,300,000
03 AZ	DB	28,500,000	30,200,000	30,200,000
04 AZ	DB	14,650,000	15,874,000	15,874,000
05 ND	DB	13,750,000	14,875,500	14,875,500
06 OK	DB	Incld in DB estimate	2,880,435	2,880,435
07 OK	DB	1,600,000	1,897,563	1,897,563
08 OK	DB	205,000	272,400	272,400
09 NV	DB	13,432,000	13,821,000	13,821,000
10 CA	DB	26,403,000	25,497,000	27,837,032
11 CA	DB	36,643,180	40,743,180	44,461,835
12 CA	DB	45,404,000	50,404,000	51,804,297
13 CA	DB	26,146,000	28,997,000	29,853,274
14 FL	DB	13,309,000	13,898,000	13,898,000
15 CA	DB	60,000,000	60,000,000	60,000,000
16 MI	DB	13,350,000	15,478,688	16,040,688
17 CA	DB	24,593,000	19,901,701	19,901,701
18 CA	DB	18,704,000	16,639,179	16,709,058
19 CA	DB	31,241,000	30,434,235	30,831,805
20 CA	DB	28,463,946	24,166,179	25,466,266
21 CA	DB	47,104,870	47,159,416	47,159,416
22CA	DB	3,261,000	2,667,270	2,667,270
23 CA	DB	16,507,000	13,381,896	14,521,835
24 CA	DB	21,333,600	18,617,452	19,284,530
25 MI	DB	5,535,330	4,676,271	5,016,299
26 AZ	DB	52,000,000	53,564,244	53,771,146
27 AZ	DB	12,247,000	12,000,000	12,726,498
28 WY	DB	Incld in DB estimate	9,933,000	9,933,000
29 WY	DB	Incld in DB estimate	1,264,853	1,264,853
30 CO	DB	Incld in DB estimate	12,829,268	13,002,518
31 AZ	DB	110,000,000	103,000,000	103,000,000
32 AZ	DB	47,000,000	44,325,000	44,325,000
33 AZ	DB	10,700,000	9,278,000	9,278,000
34 AZ	DB	29,600,000	32,600,000	32,600,000
35 AZ	DB	12,000,000	10,450,000	10,788,150
36 ND	DB	Incld in DB estimate	3,400,000	3,400,000
37	DB	3,939,720	3,631,003	3,890,063
38 CA	DB	42,892,000	40,795,171	41,495,671
39 CA	DB	20,249,000	18,849,000	19,036,410
40 CA	DB	9,968,000	7,108,756	7,839,935
41 CA	DB	4,000,000	3,573,000	3,573,000
42 CA	DB	Incld in DB estimate	23,749,618	23,749,618
43 WI	DBB	5,500,000	4,250,595	5,138,693
44 WI	DBB	7,250,000	6,975,999	7,328,800
45 WI	DBB	27,000,000	27,895,500	29,056,000
46 AZ	DBB	1,950,000	1,925,275	2,634,678
47 AZ	DBB	1,500,000	1,855,650	2,366,000
48 AZ	DBB	3,750,000	3,975,500	4,267,000
49 AZ	DBB	4,807,000	4,839,101	5,117,218

Serial Number and Location	Project Delivery Method	Estimated Construction Cost	Construction Contract	Final Construction Cost
50 WY	DBB	858,100	944,547	1,064,912
51 NV	DBB	812,000	906,000	1,108,000
52 NV	DBB	2,150,000	1,875,550	2,206,522
53 CA	DBB	40,000,000	38,627,000	41,581,677
54 NV	DBB	273,800	204,750	210,150
55 WI	DBB	24,000,000	27,550,000	29,056,000
56 WI	DBB	60,000,000	59,750,000	62,712,631
57 WI	DBB	17,000,000	16,500,000	17,562,000
58 WI	DBB	85,000,000	95,990,320	100,383,276
59 WI	DBB	135,000,000	142,350,950	176,413,000
60 WI	DBB	35,000,000	35,375,950	36,492,731
61 CA	DBB	14,200,000	14,100,000	17,158,521
62 WI	DBB	32,500,000	33,150,975	35,786,294
63 CA	DBB	22,779,397	17,292,000	19,033,411
64 CA	DBB	21,333,600	17,742,600	18,818,691
65 CA	DBB	9,095,157	7,143,600	7,493,680
66 WI	DBB	2,500,000	2,485,000	2,646,000
67 CA	DBB	9,869,154	8,115,600	8,940,200
68 WI	DBB	27,000,000	27,500,000	29,800,000
69 WI	DBB	500,000	485,950	515,900
70 NV	DBB	950,000	1,332,964	1,420,953
71 NV	DBB	2,700,000	2,700,000	3,300,000
72 NV	DBB	500,000	388,255	430,020
73 CA	DBB	12,204,000	10,199,000	11,040,804
74 CA	DBB	2,643,000	2,283,395	2,369,477
75 CA	DBB	19,870,000	19,695,000	20,793,260
76 MI	DBB	8,756,000	8,756,000	9,700,857
77 MI	DBB	9,997,500	9,997,500	11,137,565
78 FL	DBB	4,735,000	4,722,000	4,722,000
79 CA	DBB	18,559,000	17,450,000	18,581,231
80 NV	DBB	3,200,000	3,700,000	4,744,000
81 NV	DBB	295,000	295,388	315,044
82 NV	DBB	6,500,000	6,968,000	8,004,000
83 NV	DBB	40,000	56,200	57,536
84 CA	DBB	2,000,000	2,264,072	2,666,960
Serial Number and Location	Project Delivery Method	Estimated Design and Construction Cost	Contract Design and Construction Cost	Final Design and Construction Cost
01 CA	DB	40,000,000	37,070,705	37,703,278
02 AZ	DB	22,000,000	20,300,000	20,300,000
03 AZ	DB	31,000,000	30,200,000	30,200,000
04 AZ	DB	16,500,000	15,874,000	15,500,650
05 ND	DB	15,000,000	14,875,500	14,875,500
06 OK	DB	2,900,000	2,880,435	2,880,435
07 OK	DB	2,100,000	1,897,563	1,897,563
08 OK	DB	225,000	272,400	361,855
09 NV	DB	16,467,000	13,821,000	16,659,000
10 CA	DB	29,000,000	25,497,000	35,780,000

Serial Number and Location	Project Delivery Method	Estimated Design and Construction Cost	Contract Design and Construction Cost	Final Design and Construction Cost
11 CA	DB	40,743,292	40,743,180	58,975,000
12 CA	DB	50,816,000	50,404,000	66,774,000
13 CA	DB	29,046,500	28,997,000	36,416,000
14 FL	DB	14,320,000	13,898,000	16,300,000
15 CA	DB	90,000,000	60,000,000	90,000,000
16 MI	DB	14,151,000	15,478,6880	16,818,453
17 CA	DB	26,500,000	19,901,701	25,842,343
18 CA	DB	19,775,000	16,639,179	18,975,000
19 CA	DB	32,741,000	30,434,235	32,476,156
20 CA	DB	30,235,946	24,166,179	28,985,326
21 CA	DB	50,582,802	47,159,416	47,530,086
22CA	DB	3,632,000	2,667,270	2,667,270
23 CA	DB	17,741,000	13,381,896	15,176,582
24 CA	DB	22,376,600	18,617,452	19,241,320
25 MI	DB	5,895,000	4,676,271	6,235,028
26 AZ	DB	54,000,000	53,564,244	56,054,303
27 AZ	DB	13,212,000	12,000,000	16,940,712
28 WY	DB	8,500,000	9,933,000	10,298,955
29 WY	DB	1,250,000	1,264,853	1,297,861
30 CO	DB	15,089,756	12,829,268	14,164,501
31 AZ	DB	125,000,000	103,000,000	103,000,000
32 AZ	DB	55,000,000	44,325,000	53,700,000
33 AZ	DB	13,000,000	9,278,000	12,000,000
34 AZ	DB	33,100,000	32,600,000	32,600,000
35 AZ	DB	13,300,000	10,450,000	12,500,000
36 ND	DB	3,550,000	3,400,000	3,400,000
37	DB	4,142,720	3,631,003	4,219,759
38 CA	DB	50,225,000	40,795,171	49,555,443
39 CA	DB	26,677,716	18,849,000	27,671,930
40 CA	DB	10,918,000	7,108,756	10,755,556
41 CA	DB	4,500,000	3,573,000	4,562,871
42 CA	DB	30,000,000	23,749,618	28,103,799
43 WI	DBB	5,975,000	4,690,595	5,603,693
44 WI	DBB	8,050,000	7,725,999	8,106,807
45 WI	DBB	28,500,000	29,695,500	30,970,000
46 AZ	DBB	2,325,000	2,280,275	3,059,678
47 AZ	DBB	1,850,000	2,250,650	2,800,000
48 AZ	DBB	4,575,000	4,785,500	5,122,310
49 AZ	DBB	5,221,250	5,254,101	5,548,379
50 WY	DBB	956,100	1,044,547	1,168,550
51 NV	DBB	2,312,000	1,709,000	2,408,000
52 NV	DBB	2,350,000	2,031,550	2,391,522
53 CA	DBB	43,750,000	41,177,554	45,070,732
54 NV	DBB	336,800	263,250	279,717
55 WI	DBB	26,000,000	29,464,000	31,156,000
56 WI	DBB	65,000,000	64,750,000	67,812,6310
57 WI	DBB	19,000,000	18,367,060	19,563,520
58 WI	DBB	93,562,095	104,640,320	109,175,276
59 WI	DBB	147,750,000	155,300,950	189,913,000

Serial Number and Location	Project Delivery Method	Estimated Design and Construction Cost	Contract Design and Construction Cost	Final Design and Construction Cost
60 WI	DBB	37,250,000	37,655,950	38,924,144
61 CA	DBB	14,873,000	14,702,560	18,203,424
62 WI	DBB	33,350,000	33,990,975	36,711,294
63 CA	DBB	24,015,857	18,924,858	21,018,110
64 CA	DBB	22,376,600	18,696,902	20,151,138
65 CA	DBB	10,085,391	7,725,804	8,234,251
66 WI	DBB	3,000,000	2,975,000	3,152,800
67 CA	DBB	10,330,708	8,515,310	9,446,070
68 WI	DBB	29,500,000	29,986,950	32,400,000
69 WI	DBB	540,000	531,800	561,750
70 NV	DBB	1,045,000	1,427,964	1,544,453
71 NV	DBB	5,700,000	5,400,000	6,500,000
72 NV	DBB	550,000	424,255	469,520
73 CA	DBB	12,726,000	10,795,557	11,848,259
74 CA	DBB	2,875,000	2,451,937	2,588,236
75 CA	DBB	20,961,000	21,014,834	22,520,951
76 MI	DBB	9,413,700	9,438,700	10,471,045
77 MI	DBB	11,070,309	11,045,500	12,185,565
78 FL	DBB	5,145,000	5,191,000	5,191,000
79 CA	DBB	20,041,855	18,563,155	20,132,981
80 NV	DBB	8,200,000	6,900,000	9,344,000
81 NV	DBB	340,000	338,388	360,564
82 NV	DBB	16,500,000	15,356,677	16,392,677
83 NV	DBB	55,000	67,200	68,536
84 CA	DBB	2,095,000	2,410,072	2,856,960
Serial Number and Location	Project Delivery Method	Contract Award Cost Growth	Construction Cost Growth	Total Cost Growth
01 CA	DB	-7.32%	1.71%	-5.74
02 AZ	DB	-7.73%	0.00%	-7.73
03 AZ	DB	-2.58%	0.00%	-2.58
04 AZ	DB	-3.79%	-2.35%	-6.06
05 ND	DB	-0.83%	0.00%	-0.83
06 OK	DB	-0.67%	0.00%	-0.67
07 OK	DB	-9.64%	0.00%	-9.64
08 OK	DB	21.07%	32.84%	60.82
09 NV	DB	-16.07%	20.53%	1.17
10 CA	DB	-12.08%	40.33%	23.38
11 CA	DB	0.00%	44.75%	44.75
12 CA	DB	-0.81%	32.48%	31.40
13 CA	DB	-0.17%	25.59%	25.37
14 FL	DB	-2.95%	17.28%	13.83
15 CA	DB	-33.33%	50.00%	0.00
16 MI	DB	9.38%	8.66%	18.85
17 CA	DB	-24.90%	29.85%	-2.48
18 CA	DB	-15.86%	14.04%	-4.05
19 CA	DB	-7.05%	6.71%	-0.81
20 CA	DB	-20.07%	19.94%	-4.14
21 CA	DB	-6.77%	0.79%	-6.04
22CA	DB	-26.56%	0.00%	-26.56

Serial Number and Location	Project Delivery Method	Contract Award Cost Growth	Construction Cost Growth	Total Cost Growth
23 CA	DB	-24.57%	13.41%	-14.45
24 CA	DB	-16.80%	3.35%	-14.01
25 MI	DB	-20.67%	33.33%	5.77
26 AZ	DB	-0.81%	4.65%	3.80
27 AZ	DB	-9.17%	41.17%	28.22
28 WY	DB	16.86%	3.68%	21.16
29 WY	DB	1.19%	2.61%	3.83
30 CO	DB	-14.98%	10.41%	-6.13
31 AZ	DB	-17.60%	0.00%	-17.60
32 AZ	DB	-19.41%	21.15%	-2.36
33 AZ	DB	-28.63%	29.34%	-7.69
34 AZ	DB	-1.51%	0.00%	-1.51
35 AZ	DB	-21.43%	19.62%	-6.02
36 ND	DB	-4.23%	0.00%	-4.23
37	DB	-12.35%	16.21%	1.86
38 CA	DB	-18.78%	21.47%	-1.33
39 CA	DB	-29.35%	46.81%	3.73
40 CA	DB	-34.89%	51.30%	-1.49
41 CA	DB	-20.60%	27.70%	1.40
42 CA	DB	-20.83%	18.33%	-6.32
43 WI	DBB	-21.50%	19.47%	-6.21
44 WI	DBB	-4.02%	4.93%	0.71
45 WI	DBB	4.19%	4.29%	8.67
46 AZ	DBB	-1.92%	34.18%	31.60
47 AZ	DBB	21.66%	24.41%	51.35
48 AZ	DBB	4.60%	7.04%	11.96
49 AZ	DBB	0.63%	5.60%	6.27
50 WY	DBB	9.25%	11.87%	22.22
51 NV	DBB	-26.08%	40.90%	4.15
52 NV	DBB	-13.55%	17.72%	1.77
53 CA	DBB	-5.88%	9.45%	3.02
54 NV	DBB	-21.84%	6.26%	-16.95
55 WI	DBB	13.32%	5.74%	19.83
56 WI	DBB	-0.38%	4.73%	4.33
57 WI	DBB	-3.33%	6.51%	2.97
58 WI	DBB	11.84%	4.33%	16.69
59 WI	DBB	5.11%	22.29%	28.54
60 WI	DBB	1.09%	3.37%	4.49
61 CA	DBB	-1.15%	23.81%	22.39
62 WI	DBB	1.92%	8.00%	10.08
63 CA	DBB	-21.20%	11.06%	-12.48
64 CA	DBB	-16.44%	7.78%	-9.95
65 CA	DBB	-23.40%	6.58%	-18.35
66 WI	DBB	-0.83%	5.98%	5.09
67 CA	DBB	-17.57%	10.93%	-8.56
68 WI	DBB	1.65%	8.05%	9.83
69 WI	DBB	-1.52%	5.63%	4.03
70 NV	DBB	36.65%	8.16%	47.79
71 NV	DBB	-5.26%	20.37%	14.04
72 NV	DBB	-22.86%	10.67%	-14.63

Serial Number and Location	Project Delivery Method	Contract Award Cost Growth	Construction Cost Growth	Total Cost Growth
73 CA	DBB	-15.17%	9.75%	-6.90
74 CA	DBB	-14.72%	5.56%	-9.97
75 CA	DBB	0.26%	7.17%	7.44
76 MI	DBB	0.27%	10.94%	11.23
77 MI	DBB	-0.22%	10.32%	10.07
78 FL	DBB	0.89%	0.00%	0.89
79 CA	DBB	-7.38%	8.46%	0.45
80 NV	DBB	-15.85%	35.42%	13.95
81 NV	DBB	-0.47%	6.55%	6.05
82 NV	DBB	-6.93%	6.75%	-0.65
83 NV	DBB	22.18%	1.99%	24.61
84 CA	DBB	15.04%	18.54%	36.37

APPENDIX D

Schedule Data for DB and DBB Projects

Serial Number and Location	Project Delivery Method	Contract Procurement Duration (months)	Estimated Design Duration (months)	Month of Notice to Proceed
01 CA	DB	2	10	Jun-07
02 AZ	DB	2	10	Sep-02
03 AZ	DB	2	12	Nov-05
04 AZ	DB	1	6	May-05
05 ND	DB	2	12	Nov-07
06 OK	DB	2	3	Sep-04
07 OK	DB	2	3	Aug-04
08 OK	DB	2	1	Nov-09
09 NV	DB	4	9	Aug-05
10 CA	DB	4	12	Aug-98
11 CA	DB	7	4	Nov-06
12 CA	DB	5	5	Dec-06
13 CA	DB	4	4	Jul-07
14 FL	DB	3	10	Feb-06
15 CA	DB	3	24	Jan-07
16 MI	DB	10	10	May-05
17 CA	DB	2	10	Apr-04
18 CA	DB	6	6	May-06
19 CA	DB	3	12	Jul-05
20 CA	DB	5	11	Mar-04
21 CA	DB	3	12	Sep-06
22CA	DB	3	6	May-07
23 CA	DB	2	12	Mar-00
24 CA	DB	4	8	Jun-06
25 MI	DB	1	10	Feb-02
26 AZ	DB	1	24	Aug-99
27 AZ	DB	6	5	Jan-04
28 WY	DB	1	don't have	Jun-06
29 WY	DB	1	don't have	Aug-05
30 CO	DB	1	don't have	Apr-08
31 AZ	DB	2	7	Dec-06
32 AZ	DB	3	8	Apr-02
33 AZ	DB	2	6	Nov-04
34 AZ	DB	2	4	May-03
35 AZ	DB	2	3	Jan-07
36 ND	DB	3	5	Sep-02
37	DB	5	6	January-08
38 CA	DB	3	6	May-06
39 CA	DB	2	6	May-04
40 CA	DB	1	8	January-07
41 CA	DB	8	8	January-07

Serial Number and Location	Project Delivery Method	Contract Procurement Duration (months)	Estimated Design Duration (months)	Month of Notice to Proceed
42 CA	DB	2	10	June-04
43 WI	DBB	4	8	August-08
44 WI	DBB	4	4	May-06
45 WI	DBB	2	16	March-04
46 AZ	DBB	6	6	June-08
47 AZ	DBB	5	5	February-00
48 AZ	DBB	6	9	March-02
49 AZ	DBB	3	3	August-00
50 WY	DBB	1	12	July-07
51 NV	DBB	1	6	March-07
52 NV	DBB	4	15	May-96
53 CA	DBB	2	10	July-03
54 NV	DBB	3	3	September-08
55 WI	DBB	3	10	June-04
56 WI	DBB	4	8	February-04
57 WI	DBB	2	36	January-01
58 WI	DBB	7	25	January-02
59 WI	DBB	4	24	July-06
60 WI	DBB	2	10	July-07
61 CA	DBB	2	10	May-03
62 WI	DBB	4	24	June-06
63 CA	DBB	2	20	May-01
64 CA	DBB	1	15	March-02
65 CA	DBB	2	20	March-00
66 WI	DBB	5	9	August-05
67 CA	DBB	4	6	November-03
68 WI	DBB	15	6	October-03
69 WI	DBB	3	8	May-05
70 NV	DBB	5	11	October-01
71 NV	DBB	2	5	February-02
72 NV	DBB	6	4	March-03
73 CA	DBB	3	16	January-03
74 CA	DBB	10	10	October-02
75 CA	DBB	2	11	May-02
76 MI	DBB	10	16	June-06
77 MI	DBB	1	6	October-07
78 FL	DBB	6	8	March-07
79 CA	DBB	3	12	June-05
80 NV	DBB	2	4	May-03
81 NV	DBB	5	2	November-05
82 NV	DBB	2	12	May-06
83 NV	DBB	1	4	February-07
84 CA	DBB	2	13	May-01

Serial Number and Location	Project Delivery Method	Final Design Duration (months)	Estimated Construction Duration (months)	NTP Construction Duration (months)
01 CA	DB	9	32	42
02 AZ	DB	8	13	13
03 AZ	DB	12	18	18
04 AZ	DB	6	14	14
05 ND	DB	15	18	18
06 OK	DB	4	10	16
07 OK	DB	3	11	11
08 OK	DB	2	2	2
09 NV	DB	12	18	18
10 CA	DB	24	24	24
11 CA	DB	2	24	24
12 CA	DB	3	26	26
13 CA	DB	2	21	21
14 FL	DB	9	13	13
15 CA	DB	21	24	24
16 MI	DB	10	12	12
17 CA	DB	10	12	11
18 CA	DB	6	24	24
19 CA	DB	10	28	32
20 CA	DB	9	34	30
21 CA	DB	9	30	28
22CA	DB	8	20	20
23 CA	DB	14	31	31
24 CA	DB	9	31	30
25 MI	DB	7	7	7
26 AZ	DB	27	36	36
27 AZ	DB	5	12	12
28 WY	DB	6	don't have	don't have
29 WY	DB	4	don't have	don't have
30 CO	DB	11	15	15
31 AZ	DB	5	21	21
32 AZ	DB	7	16	16
33 AZ	DB	6	13	13
34 AZ	DB	4	8	8
35 AZ	DB	3	9	9
36 ND	DB	6	10	15
37	DB	4	13	13
38 CA	DB	7	32	32
39 CA	DB	6	24	24
40 CA	DB	6	20	15
41 CA	DB	7	15	15
42 CA	DB	11	30	30
43 WI	DBB	7	12	12
44 WI	DBB	4	9	9
45 WI	DBB	17	18	18
46 AZ	DBB	9	11	11

Serial Number and Location	Project Delivery Method	Final Design Duration (months)	Estimated Construction Duration (months)	NTP Construction Duration (months)
47 AZ	DBB	9	7	7
48 AZ	DBB	11	10	10
49 AZ	DBB	11	12	12
50 WY	DBB	12	7	7
51 NV	DBB	6	12	12
52 NV	DBB	28	20	20
53 CA	DBB	13	28	28
54 NV	DBB	3	3	3
55 WI	DBB	13	18	18
56 WI	DBB	8	18	18
57 WI	DBB	44	24	24
58 WI	DBB	30	28	28
59 WI	DBB	25	20	20
60 WI	DBB	12	19	19
61 CA	DBB	11	20	20
62 WI	DBB	27	18	18
63 CA	DBB	22	30	30
64 CA	DBB	15	26	26
65 CA	DBB	23	18	18
66 WI	DBB	12	6	6
67 CA	DBB	8	16	16
68 WI	DBB	18	20	20
69 WI	DBB	12	4	4
70 NV	DBB	14	16	16
71 NV	DBB	5	11	11
72 NV	DBB	10	3	3
73 CA	DBB	15	30	30
74 CA	DBB	12	15	15
75 CA	DBB	12	28	28
76 MI	DBB	16	12	12
77 MI	DBB	6	13	13
78 FL	DBB	15	15	15
79 CA	DBB	12	24	24
80 NV	DBB	4	5	5
81 NV	DBB	22	4	4
82 NV	DBB	11	12	12
83 NV	DBB	5	3	3
84 CA	DBB	17	28	28
Serial Number and Location	Project Delivery Method	Final Construction Duration (months)	Estimated Design and Construction Duration (months)	NTP Design and Construction Duration (months)
01 CA	DB	32	42	42
02 AZ	DB	12	18	18
03 AZ	DB	16	24	24
04 AZ	DB	12	20	20
05 ND	DB	20	30	30

Serial Number and Location	Project Delivery Method	Final Construction Duration (months)	Estimated Design and Construction Duration (months)	NTP Design and Construction Duration (months)
06 OK	DB	14	16	16
07 OK	DB	10	14	14
08 OK	DB	4	3	3
09 NV	DB	17	18	18
10 CA	DB	27	30	30
11 CA	DB	25	28	28
12 CA	DB	28	31	31
13 CA	DB	23	25	25
14 FL	DB	18	23	23
15 CA	DB	26	36	60
16 MI	DB	15	22	22
17 CA	DB	10	36	36
18 CA	DB	23	25	25
19 CA	DB	25	41	41
20 CA	DB	24	45	45
21 CA	DB	23	42	42
22CA	DB	17	23	23
23 CA	DB	28	38	38
24 CA	DB	28	40	40
25 MI	DB	10	13	13
26 AZ	DB	41	36	36
27 AZ	DB	13	26	26
28 WY	DB	12	12	12
29 WY	DB	7	8	8
30 CO	DB	14	24	24
31 AZ	DB	18	28	28
32 AZ	DB	13	24	24
33 AZ	DB	10	19	19
34 AZ	DB	5	12	12
35 AZ	DB	8	12	12
36 ND	DB	13	15	15
37	DB	13	20	20
38 CA	DB	31	38	38
39 CA	DB	24	28	28
40 CA	DB	15	20	20
41 CA	DB	12	22	22
42 CA	DB	26	28	28
43 WI	DBB	11	20	19
44 WI	DBB	11	13	13
45 WI	DBB	21	34	35
46 AZ	DBB	15	17	20
47 AZ	DBB	11	12	16
48 AZ	DBB	12	19	21
49 AZ	DBB	12	15	23
50 WY	DBB	8	19	19
51 NV	DBB	12	18	18
52 NV	DBB	29	35	48
53 CA	DBB	30	38	41

Serial Number and Location	Project Delivery Method	Final Construction Duration (months)	Estimated Design and Construction Duration (months)	NTP Design and Construction Duration (months)
54 NV	DBB	3	6	6
55 WI	DBB	20	28	31
56 WI	DBB	18	26	26
57 WI	DBB	26	60	68
58 WI	DBB	32	53	58
59 WI	DBB	24	44	45
60 WI	DBB	21	29	31
61 CA	DBB	24	30	31
62 WI	DBB	20	42	45
63 CA	DBB	29	50	52
64 CA	DBB	28	41	41
65 CA	DBB	17	38	41
66 WI	DBB	8	15	18
67 CA	DBB	17	22	24
68 WI	DBB	24	26	38
69 WI	DBB	5	12	16
70 NV	DBB	23	27	30
71 NV	DBB	11	16	16
72 NV	DBB	6	7	13
73 CA	DBB	29	46	45
74 CA	DBB	17	25	27
75 CA	DBB	30	39	40
76 MI	DBB	12	28	28
77 MI	DBB	13	19	19
78 FL	DBB	21	23	30
79 CA	DBB	26	36	36
80 NV	DBB	5	9	9
81 NV	DBB	5	6	26
82 NV	DBB	18	24	23
83 NV	DBB	3	7	8
84 CA	DBB	33	41	45

Serial Number and Location	Project Delivery Method	Final Design and Construction Duration (months)	Design and Construction Schedule Growth (months)	Total Schedule Growth (Months)	Schedule Intensity (SF/Day)
01 CA	DB	38	-0.0952381	-9.52381	173.44
02 AZ	DB	16	-0.1111111	-11.11111	298.30
03 AZ	DB	20	-0.1666667	-16.66667	196.64
04 AZ	DB	14	-0.3000000	-30.00000	588.91
05 ND	DB	25	-0.1666667	-16.66667	136.36
06 OK	DB	14	-0.1250000	-12.50000	68.18

Serial Number and Location	Project Delivery Method	Final Design and Construction Duration (months)	Design and Construction Schedule Growth (months)	Total Schedule Growth (Months)	Schedule Intensity (SF/Day)
07 OK	DB	12	-0.1428571	-14.28571	30.30
08 OK	DB	5	0.6666667	66.66667	12.27
09 NV	DB	17	-0.0555556	-5.55556	117.65
10 CA	DB	27	-0.1000000	-10.00000	336.70
11 CA	DB	27	-0.0357143	-3.57143	195.53
12 CA	DB	31	0.0000000	0.00000	179.57
13 CA	DB	25	0.0000000	0.00000	136.22
14 FL	DB	26	0.1304348	13.04348	76.92
15 CA	DB	60	0.0000000	66.66667	39.39
16 MI	DB	26	0.1818182	18.18182	203.56
17 CA	DB	35	-0.0277778	-2.77778	145.22
18 CA	DB	26	0.0400000	4.00000	93.88
19 CA	DB	40	-0.0243902	-2.43902	101.65
20 CA	DB	41	-0.0888889	-8.88889	116.00
21 CA	DB	37	-0.1190476	-11.90476	161.03
22CA	DB	22	-0.0434783	-4.34783	21.88
23 CA	DB	33	-0.1315789	-13.15789	89.14
24 CA	DB	32	-0.2000000	-20.00000	70.98
25 MI	DB	16	0.2307692	23.07692	51.14
26 AZ	DB	41	0.1388889	13.88889	449.00
27 AZ	DB	26	0.0000000	0.00000	156.16
28 WY	DB	12	0.0000000	0.00000	303.03
29 WY	DB	9	0.1250000	12.50000	40.10
30 CO	DB	23	-0.0416667	-4.16667	116.60
31 AZ	DB	23	-0.1785714	-17.85714	474.31
32 AZ	DB	20	-0.1666667	-16.66667	195.45
33 AZ	DB	14	-0.2631579	-26.31579	157.18
34 AZ	DB	8	-0.3333333	-33.33333	2218.39
35 AZ	DB	11	-0.0833333	-8.33333	175.80
36 ND	DB	13	-0.1333333	-13.33333	80.42
37	DB	17	-0.1500000	-15.00000	58.82
38 CA	DB	34	-0.1052632	-10.52632	118.04
39 CA	DB	27	-0.0357143	-3.57143	144.44
40 CA	DB	18	-0.1000000	-10.00000	61.87
41 CA	DB	19	-0.1363636	-13.63636	30.38
42 CA	DB	26	-0.0714286	-7.14286	107.96
43 WI	DBB	18	-0.0526316	-10.00000	160.61
44 WI	DBB	15	0.1538462	15.38462	93.94
45 WI	DBB	38	0.0857143	11.76471	162.42
46 AZ	DBB	24	0.2000000	41.17647	9.85
47 AZ	DBB	20	0.2500000	66.66667	37.30
48 AZ	DBB	23	0.0952381	21.05263	60.36
49 AZ	DBB	23	0.0000000	53.33333	100.42
50 WY	DBB	20	0.0526316	5.26316	7.68
51 NV	DBB	18	0.0000000	0.00000	20.96
52 NV	DBB	57	0.1875000	62.85714	19.38
53 CA	DBB	43	0.0487805	13.15789	116.28

Serial Number and Location	Project Delivery Method	Final Design and Construction Duration (months)	Design and Construction Schedule Growth (months)	Total Schedule Growth (Months)	Schedule Intensity (SF/Day)
54 NV	DBB	6	0.0000000	0.00000	5.91
55 WI	DBB	33	0.0645161	17.85714	215.95
56 WI	DBB	26	0.0000000	0.00000	172.69
57 WI	DBB	70	0.0294118	16.66667	31.49
58 WI	DBB	62	0.0689655	16.98113	142.46
59 WI	DBB	49	0.0888889	11.36364	166.98
60 WI	DBB	33	0.0645161	13.79310	110.19
61 CA	DBB	35	0.1290323	16.66667	59.21
62 WI	DBB	47	0.0444444	11.90476	58.03
63 CA	DBB	51	-0.0192308	2.00000	141.35
64 CA	DBB	43	0.0487805	4.87805	104.12
65 CA	DBB	40	-0.0243902	5.26316	79.55
66 WI	DBB	20	0.1111111	33.33333	19.59
67 CA	DBB	25	0.0416667	13.63636	81.82
68 WI	DBB	42	0.1052632	61.53846	104.00
69 WI	DBB	17	0.0625000	41.66667	10.70
70 NV	DBB	37	0.2333333	37.03704	8.65
71 NV	DBB	16	0.0000000	0.00000	102.27
72 NV	DBB	16	0.2307692	128.57143	7.39
73 CA	DBB	44	-0.0222222	-4.34783	71.23
74 CA	DBB	29	0.0740741	16.00000	33.82
75 CA	DBB	42	0.0500000	7.69231	50.05
76 MI	DBB	28	0.0000000	0.00000	104.39
77 MI	DBB	19	0.0000000	0.00000	175.11
78 FL	DBB	36	0.2000000	56.52174	27.78
79 CA	DBB	38	0.0555556	5.55556	50.96
80 NV	DBB	9	0.0000000	0.00000	181.82
81 NV	DBB	27	0.0384615	350.00000	1.20
82 NV	DBB	29	0.2608696	20.83333	25.08
83 NV	DBB	8	0.0000000	14.28571	1.79
84 CA	DBB	50	0.1111111	21.95122	7.27

APPENDIX E

Change-Order Data for DB and DBB Projects

Serial Number and Location	Project Delivery Method	Number of Design Change Orders	Cost of Design Change Orders	Number of Construction Change Orders
01 CA	DB	5	96,452	8
02 AZ	DB	0	0	0
03 AZ	DB	0	0	0
04 AZ	DB	1	(373,350)	0
05 ND	DB	0	0	0
06 OK	DB	16	0	17
07 OK	DB	5	0	11
08 OK	DB	0	0	0
09 NV	DB	8	389,000	0
10 CA	DB	15	200,000	91
11 CA	DB	7	3,718,656	7
12 CA	DB	18	567,210	24
13 CA	DB	6	128,952	25
14 FL	DB	0	0	0
15 CA	DB	0	0	0
16 MI	DB	0	0	43
17 CA	DB	20	0	19
18 CA	DB	65	242,630	42
19 CA	DB	45	145,904	92
20 CA	DB	60	2,514,620	102
21 CA	DB	6	(1,571,166)	0
22CA	DB	0	0	0
23 CA	DB	31	652,123	92
24 CA	DB	90	409,193	105
25 MI	DB	39	0	39
26 AZ	DB	0	0	20
27 AZ	DB	1	4,000	6
28 WY	DB	6	365,955	0
29 WY	DB	3	33,008	0
30 CO	DB	unknown	0	unknown
31 AZ	DB	0	0	0
32 AZ	DB	5	1,800,000	0
33 AZ	DB	2	822,000	0
34 AZ	DB	0	0	0
35 AZ	DB	6	726,850	2
36 ND	DB	0	0	0
37	DB	1	800	45
38 CA	DB	18	974,840	26
39 CA	DB	18	632,519	10
40 CA	DB	23	191,676	24
41 CA	DB	0	0	0
42 CA	DB	6	1,314,923	0

Serial Number and Location	Project Delivery Method	Number of Design Change Orders	Cost of Design Change Orders	Number of Construction Change Orders
43 WI	DBB	6	59,872	14
44 WI	DBB	5	64,521	33
45 WI	DBB	8	239,838	41
46 AZ	DBB	9	129,693	35
47 AZ	DBB	3	96,345	17
48 AZ	DBB	4	88,621	22
49 AZ	DBB	5	152,966	2
50 WY	DBB	0	0	4
51 NV	DBB	20	101,000	20
52 NV	DBB	9	82,338	20
53 CA	DBB	155	2,151,312	30
54 NV	DBB	0	0	2
55 WI	DBB	23	401,783	42
56 WI	DBB	16	823,641	71
57 WI	DBB	13	321,578	22
58 WI	DBB	41	1,584,267	73
59 WI	DBB	59	3,542,879	122
60 WI	DBB	13	168,492	29
61 CA	DBB	86	538,121	240
62 WI	DBB	11	211,384	86
63 CA	DBB	134	487,695	79
64 CA	DBB	84	667,078	111
65 CA	DBB	32	172,686	26
66 WI	DBB	6	67,522	11
67 CA	DBB	87	253,687	76
68 WI	DBB	9	961,567	36
69 WI	DBB	3	5,286	9
70 NV	DBB	5	62,323	12
71 NV	DBB	4	300,000	4
72 NV	DBB	6	13,151	13
73 CA	DBB	8	17,811	117
74 CA	DBB	25	58,683	22
75 CA	DBB	59	465,491	128
76 MI	DBB	84	535,971	103
77 MI	DBB	0	0	106
78 FL	DBB	not available	not available	not available
79 CA	DBB	66	550,317	120
80 NV	DBB	5	522,000	5
81 NV	DBB	1	3,520	4
82 NV	DBB	8	518,000	8
83 NV	DBB	0	0	2
84 CA	DBB	7	11,576	40
Serial Number and Location	Project Delivery Method	Cost of Construction Change Orders	Total Number of Change Orders	Total Cost of Design and Construction Change Orders
01 CA	DB	536,121	13	632,573

Serial Number and Location	Project Delivery Method	Cost of Construction Change Orders	Total Number of Change Orders	Total Cost of Design and Construction Change Orders
02 AZ	DB	-	0	-
03 AZ	DB	-	0	-
04 AZ	DB	-	1	(373,350)
05 ND	DB	-	0	-
06 OK	DB	-	33	-
07 OK	DB	-	16	-
08 OK	DB	-	0	-
09 NV	DB	-	8	389,000
10 CA	DB	2,340,032	106	2,540,032
11 CA	DB	3,718,655	14	7,437,311
12 CA	DB	1,400,297	42	1,967,507
13 CA	DB	856,274	31	985,226
14 FL	DB	-	0	-
15 CA	DB	-	0	-
16 MI	DB	562,000	43	562,000
17 CA	DB	-	39	-
18 CA	DB	69,880	107	312,510
19 CA	DB	397,571	137	543,475
20 CA	DB	1,300,087	162	3,814,707
21 CA	DB	-	6	(1,571,166)
22CA	DB	-	0	-
23 CA	DB	1,139,939	123	1,792,062
24 CA	DB	667,078	195	1,076,271
25 MI	DB	340,028	78	340,028
26 AZ	DB	206,902	20	206,902

Serial Number and Location	Project Delivery Method	Cost of Construction Change Orders	Total Number of Change Orders	Total Cost of Design and Construction Change Orders
27 AZ	DB	726,498	7	730,498
28 WY	DB	-	6	365,955
29 WY	DB	-	3	33,008
30 CO	DB	173,250	0	173,250
31 AZ	DB	-	0	-
32 AZ	DB	-	5	1,800,000
33 AZ	DB	-	2	822,000
34 AZ	DB	-	0	-
35 AZ	DB	338,150	8	1,065,000
36 ND	DB	-	0	-
37	DB	259,060	46	259,860
38 CA	DB	700,500	44	1,675,341
39 CA	DB	187,410	28	819,929
40 CA	DB	731,179	47	922,855
41 CA	DB	-	0	-
42 CA	DB	-	6	1,314,923
43 WI	DBB	828,226	20	888,098
44 WI	DBB	288,280	38	352,801
45 WI	DBB	920,662	49	1,160,500
46 AZ	DBB	579,710	44	709,403
47 AZ	DBB	414,005	20	510,350
48 AZ	DBB	202,879	26	291,500
49 AZ	DBB	125,151	7	278,117
50 WY	DBB	120,365	4	120,365

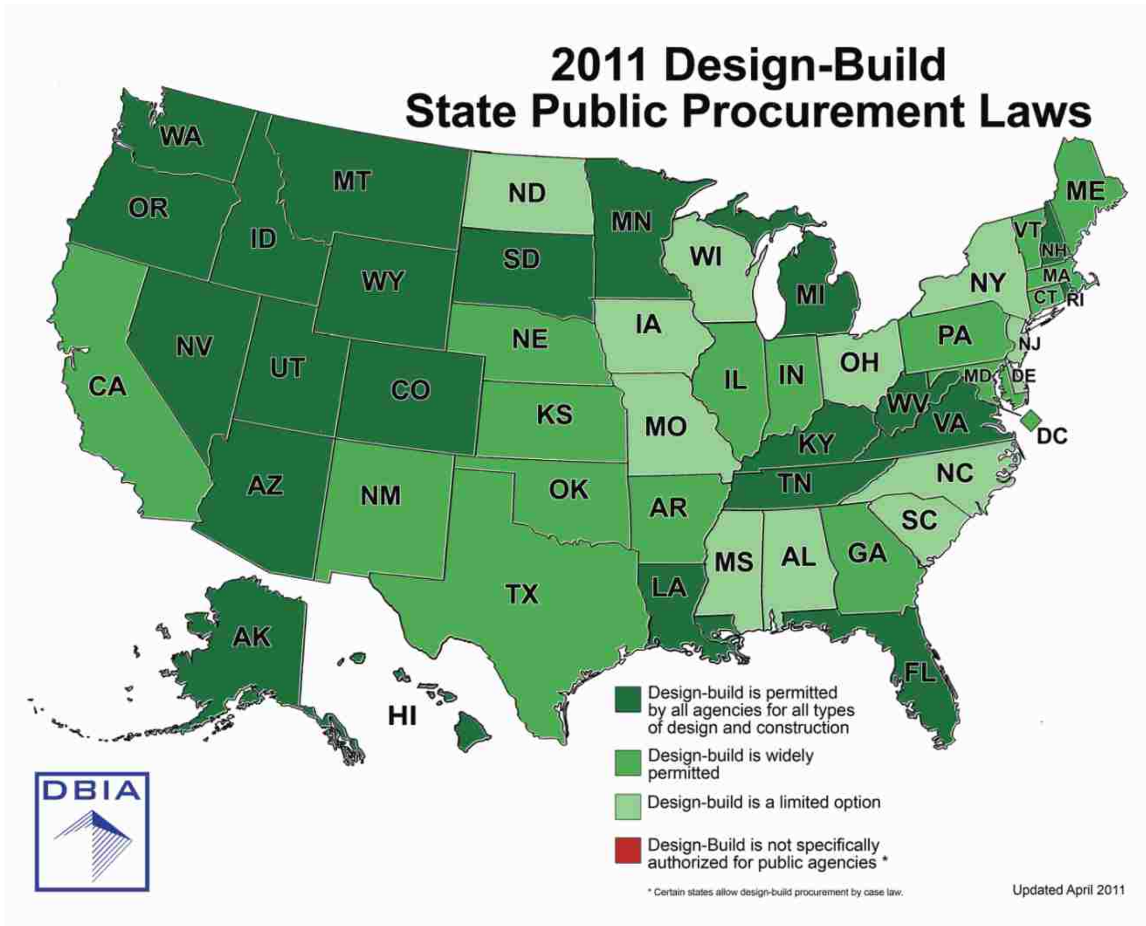
Serial Number and Location	Project Delivery Method	Cost of Construction Change Orders	Total Number of Change Orders	Total Cost of Design and Construction Change Orders
51 NV	DBB	101,000	40	202,000
52 NV	DBB	248,634	29	330,972
53 CA	DBB	803,365	185	2,954,677
54 NV	DBB	5,400	2	5,400
55 WI	DBB	1,104,217	65	1,506,000
56 WI	DBB	2,138,990	87	2,962,631
57 WI	DBB	740,422	35	1,062,000
58 WI	DBB	2,808,689	114	4,392,956
59 WI	DBB	30,519,171	181	34,062,050
60 WI	DBB	948,289	42	1,116,781
61 CA	DBB	2,520,401	326	3,058,522
62 WI	DBB	2,423,935	97	2,635,319
63 CA	DBB	1,253,716	213	1,741,411
64 CA	DBB	409,013	195	1,076,091
65 CA	DBB	177,394	58	350,080
66 WI	DBB	93,478	17	161,000
67 CA	DBB	570,913	163	824,600
68 WI	DBB	1,338,433	45	2,300,000
69 WI	DBB	24,664	12	29,950
70 NV	DBB	25,667	17	87,990
71 NV	DBB	300,000	8	600,000
72 NV	DBB	28,614	19	41,765
73 CA	DBB	823,994	125	841,804
74 CA	DBB	27,399	47	86,083
75 CA	DBB	632,769	187	1,098,260

Serial Number and Location	Project Delivery Method	Cost of Construction Change Orders	Total Number of Change Orders	Total Cost of Design and Construction Change Orders
76 MI	DBB	408,886	187	944,857
77 MI	DBB	1,140,065	106	1,140,065
78 FL	DBB	not available	0	-
79 CA	DBB	580,914	186	1,131,231
80 NV	DBB	522,000	10	1,044,000
81 NV	DBB	16,136	5	19,656
82 NV	DBB	518,000	16	1,036,000
83 NV	DBB	1,336	2	1,336
84 CA	DBB	391,313	47	402,889

APPENDIX F

DESIGN-BUILD INSTITUTE OF AMERICA

STATE PUBLIC PROCUREMENT LAWS



Number of states where public agencies are permitted to use DB

20 states use DB for all types of design and construction projects

18 states DB is widely permitted but not all agencies are permitted to use DB

12 states DB is a limited option.

DBIA (2011) "Design-Build State Procurement Map" <http://www.dbia.org/NR/rdonlyres/91BB442E-DC31-4493-954D-248540B54D30/0/proc2011_0526b.pdf (May 2011)

VITA

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