12-1-2013

Performance Comparison of Design-Build and Construction Manager/General Contractor Highway Projects

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PERFORMANCE COMPARISON OF DESIGN-BUILD AND CONSTRUCTION

MANAGER/GENERAL CONTRACTOR HIGHWAY PROJECTS

By

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Bachelor's Degree in Civil Engineering

Tribhuvan University, Nepal

2009

A thesis submitted in partial fulfillment

of the requirements for the

Master of Science in Civil Engineering

Department of Civil and Environmental Engineering and Construction

Howard R. Hughes College of Engineering

The Graduate College

University of Nevada, Las Vegas

December 2013

THE GRADUATE COLLEGE

We recommend the thesis prepared under our supervision by

Binita Shakya

entitled

Performance Comparison of Design-Build and Construction Manager/General Contractor Highway Projects

is approved in partial fulfillment of the requirements for the degree of

Master of Science in Engineering -- Civil and Environmental Engineering

Department of Civil and Environmental Engineering and Construction

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December 2013

Abstract

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Researchers have conducted numerous studies comparing project performance of design-bid-build (DBB) and design-build (DB) highway projects. However, little research has been done to compare the performance of DB and construction manager/general contractor (CM/GC) highway projects. Therefore, an exploratory study was conducted to compare the performance of 55 DB and 34 CM/GC highway projects from various States Departments of Transportation (DOTs) in terms of cost, change orders, and construction intensity. The results showed that contract award cost growth was significantly lower in DB projects than in CM/GC projects. In contrast to this, the total cost growth of DB projects was higher than that of CM/GC projects. In terms of change order cost factor and construction intensity, DB projects were found to be superior to CM/GC projects. However, no statistical difference was found.

Acknowledgements

I would like to express my sincere gratitude to my advisor, Dr. Pramen P. Shrestha, for his continuous guidance and support throughout my thesis research and study at University of Nevada, Las Vegas (UNLV). Dr. Shrestha provided me with valuable comments and remarks during the research. Without his guidance and persistent help, this thesis would not have been possible.

I would like to express deepest gratitude to my advisory committee, Dr. David R. Shields and Professor Neil D. Opfer. I would like to express my sincere gratitude to Dr. Nancy N. Menzel for being a part of my committee as the Graduate College Representative. I would also like to thank the Writing Center of UNLV for assisting me to edit this thesis.

I would like to express appreciation to members of the Federal Highway Administration (FHWA) Every Day Counts (EDC) and various States Departments of Transportation (DOTs), who have willingly shared their precious time in providing the detail information about DB and CM/GC highway projects. My special thanks to members of California DOT, Colorado DOT, Connecticut DOT, Florida DOT, Idaho DOT, Kentucky DOT, Louisiana DOT, Maine DOT, Michigan DOT, Minnesota DOT, Montana DOT, Nevada DOT, Ohio DOT, Oregon DOT, South Carolina DOT, and Utah DOT. Without the data provided by them, it would not have been possible to conduct this study.

My special thanks are extended to all my loved ones, who have supported me throughout the entire process. I will be grateful forever for your guidance.

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Chapter 1

Introduction

The project delivery method is defined as "the process by which a construction project is comprehensively designed and constructed for an owner - including project scope definition; organization of designers, constructors, and various consultants; sequencing of design and construction operations; execution of design and construction; and closeout and start-up" (Touran et al. 2009). Typically, there are three project delivery methods used in highway projects. They are design-bid-build (DBB), design-build (DB), and construction manager/general contractor (CM/GC).

For many decades, DBB was a major delivery method used to design and construct buildings, highways, and infrastructure projects. However, cost and schedule overruns, increased change orders, and disputes led State Departments of Transportation (DOTs) to slowly transition from the traditional method, DBB, to alternative project delivery (APD) methods. DB and CM/GC are major APD methods. In 2010, the Federal Highway Administration (FHWA) initiated Every Day Counts (EDC) to reduce the project delivery time using accelerated project delivery methods. EDC encourages the use of DB and CM/GC project delivery methods for the better and faster delivery of projects to the public (FHWA 2013a). The most-used APD method in highway construction is DB. However, recently State DOTs have started using CM/GC to construct highways.

Various studies have been conducted to determine the effect of DB and DBB project delivery methods on highway project performance. However, the performance comparison between DB and CM/GC has not been conducted yet. This exploratory study compares the performance of highway projects constructed using DB and CM/GC project delivery methods.

1.1. Design-Build (DB) in Highway Projects

FHWA defines DB as "a project delivery method that combines two, usually separate services into a single contract. With design-build procurements, owners execute a single, fixed-fee contract for both architectural/engineering services and construction" (FHWA 2013b). Therefore, DB is an integrated approach in which design and construction services are performed under a single contract. DB offers many benefits to the owner. The single point responsibility, low cost, accelerated schedule, and shifting risk to contractors are the major advantages of using DB. The designer and builder work together under the same contract in DB (Fig. 1). Because the designer and contractor work as a single team, the team develops innovative design and construction plans, ensuring quality and economy along with minimized risk and elimination of change orders.

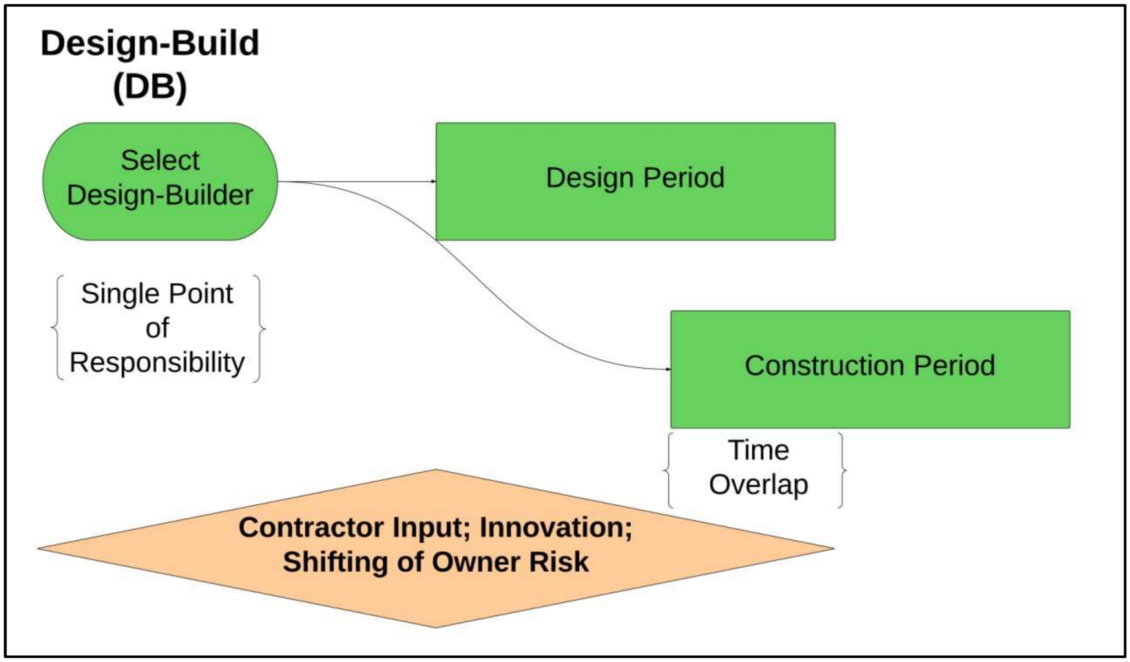

Figure 1. Design-Build (DB) Process

Most DB projects use a two-phase selection process. The two-phase selection involves pre-qualification of firms in the first step and issuance of the Request for Proposal (RFP) and evaluation of technical and price proposals in the second step. The scope of work should be well defined in the RFP document for the success of DB projects (FHWA 2009). Though the small highway projects use fixed-price sealed bidding as well as one-step, two-step, and sole-source selection methods to select the DB contractor, more states are transitioning from fixed-price and one-step low-bid methods to two-step best-value methods (Molenaar & Gransberg 2001).The best value selection process uses weighting method incorporating technical proposal and bid price while selecting DB contractor.

The study has found that DB is suitable for projects that require accelerated schedule and have well-defined design and construction scope (FHWA 2009). DB method is best suitable for projects, such as major and minor bridges, interstate and rural widening, buildings, and overpasses. However, the study has found that it is not appropriate for rehab/repair of major bridges, movable bridges, and urban construction/reconstruction works that have major problems related with utilities, subgrade, or other significant unknowns.

Currently, in most of the states, DB is allowed for the construction of transportation projects. Until the end of 2006, 13 states were not authorized to use DB in transportation projects (Ghavamifar and Touran 2008). On the basis of a 2013 Report of the Design Build Institute of America (DBIA), DB is "not specifically authorized" for transportation procurement in six states (DBIA 2013). In contrast to this, the Survey Report of FHWA Division Office showed that eight states were not authorized to use DB in transportation projects (Fig. 2) (Blanding 2012).

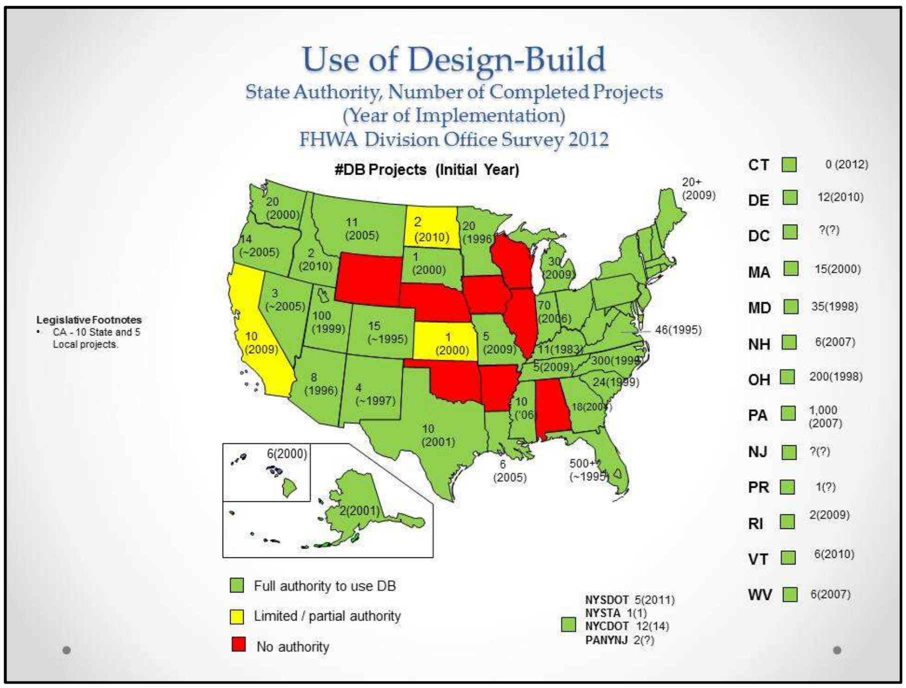

Figure 2. Design-Build (DB) Authority in Various States in 2012

Source: FHWA EDC (Blanding 2012)

1.2. Construction Manager/General Contractor (CM/GC) in Highway Projects

The CM/GC project delivery method is "an integrated team approach to the planning, design, and construction of a highway project, to control schedule and budget, and to ensure quality for the project owner" (Gransberg and Shane 2010). The federal aid transportation projects should get approval from Special Experimental Projects No. 14 (SEP-14) to use CM/GC. Though CM/GC is relatively new in highway projects, it has been used for a long time in vertical construction. According to FHWA, some differences in transportation projects from vertical construction include "self-performance requirements are typical, subcontractor procurement process is different, and CMGC relies on best-value selection" (FHWA 2013c). The variation in use of terms for CM/GC also depends on States codes. For example, it is referred to as CM/GC in Oregon but as general contractor/construction manager (GC/CM) in Washington (Rojas and Kell 2008).

There are two contract phases in CM/GC: the preconstruction or design phase and the construction phase (Fig. 3). The contractor's input in the preconstruction phase has been rated as the major advantage of using CM/GC (Gransberg and Shane 2010; Schierholz 2012). Similarly, the schedule-accelerating ability of the CM/GC contractor is recognized as the top benefit of using this project delivery method (Schierholz 2012). Furthermore, in addition to the cost advantage in the design phase, the teamwork between the construction manager and the designer are significant benefits of using CM/GC. However, it is suggested that in order to develop the co-ordination between construction manager and designer, the clause regarding teamwork should be clearly mentioned in the design and preconstruction services contract (Shane and Gransberg 2010).

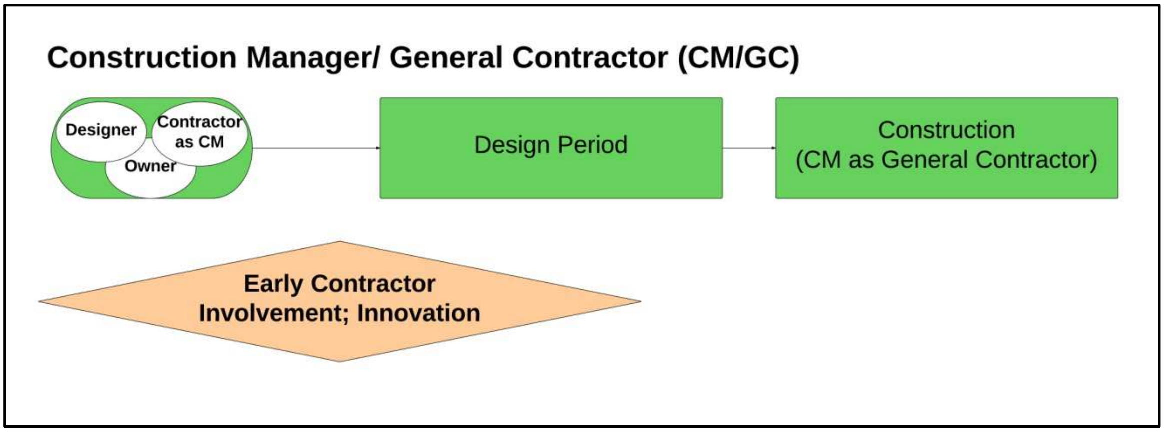

Figure 3. Construction Manager/General Contractor (CM/GC) Process

The FHWA Division Office Survey found that 12 states have full authority and six states have limited/partial authority to use the CM/GC project delivery method (Fig. 4) (Haynes 2012). The other study has found that thirteen states have legislative authorization to use the CM/GC method (Gransberg 2012).

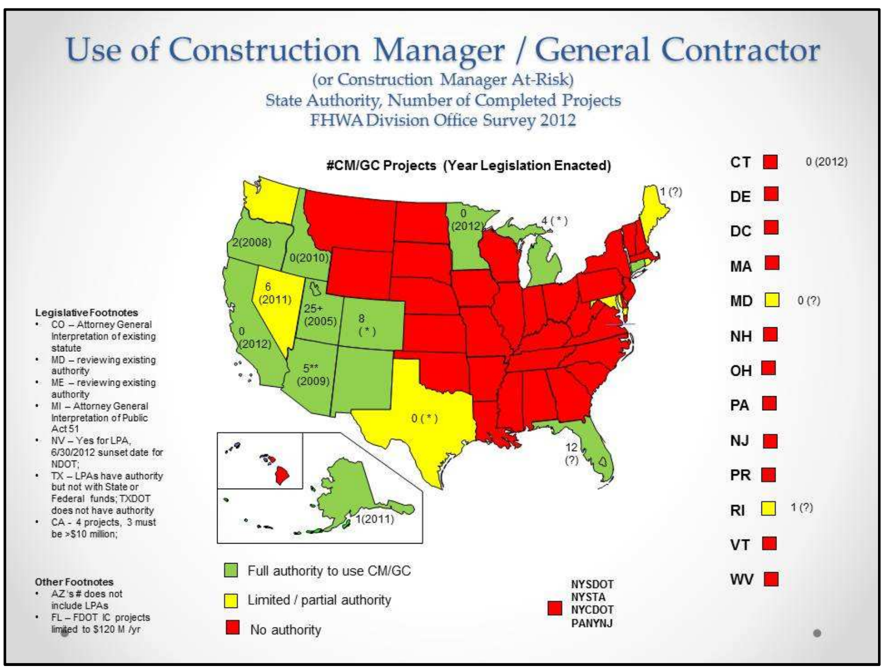

Figure 4. Construction Manager/General Contractor (CM/GC) Authority in Various States in 2012

Source: FHWA EDC (Haynes 2012)

CMGC method is used recently by State DOTs because owner has some control over the construction cost in this method compared to DB method. DB and CM/GC methods are similar in terms of contractor's input during design phase. However, there are some differences in these two methods. Table 1 shows the similarities and the differences in these two types of project delivery method.

Table 1. Comparison of Design-Build (DB) and Construction Manager/General Contractor (CM/GC) Project Delivery Methods

Design-Build (DB)	Construction Manager/General Contractor (CM/GC)
Similarities:	
♦ Innovative project delivery method.	♦ Innovative project delivery method.
♦ Compress schedule.	♦ Compress schedule.
♦ Contractor involvement in design.	♦ Contractor involvement in design.
♦ Reduced risk and omission.	♦ Reduced risk and omission.
Differences:	
♦ Single point of responsibility.	♦ Owner contracts with designer and contractor separately.
♦ Owner does not control design.	♦ Owner control design.
♦ Good for projects with well-defined scope and for projects that need accelerated schedule (FHWA 2013c).	♦ Good for complex projects that need third party inputs (FHWA 2013c).
♦ Owner must clearly define functions and responsibilities required by DB firm in Request for Proposal (RFP).	♦ Collaboration very important in CM/GC. It is better to clearly mention about collaborative work in contract (Shane and Gransberg 2010).
♦ DB firm selected by one-step RFP or two-step RFP method.	♦ Contractor selected by best value selection method along with price (FHWA 2013c).
♦ Single DB firm responsible for both design and construction.	♦ Contractor first selected as Construction Manager in pre-construction phase and selected as General Contractor in construction phase.
♦ Owner cannot change the contractor after the DB contract is awarded	♦ If the owner is not satisfied with the CM/GC firm's construction cost during negotiation, the owner can opt out for opening the bid to all the construction contractors similar to DBB method.

1.3. Research Needs and Objectives:

This exploratory study measured the performance of DB and CM/GC project delivery methods in highway projects. The main objectives of this research are:

- To compare the cost, change orders, and construction intensity of DB and CM/GC project delivery methods in highway projects;
- To determine whether these performance metrics are significantly different in these two types of delivery methods.

Chapter 2

Literature Review

Various literature related to DBB, DB, and CM/GC was reviewed. The literature review was primarily focused on the selection criteria for these three types of project delivery methods and performance comparisons of projects built using these methods. The performance comparison section is divided into two sections: the first section includes the project performance comparison of building and infrastructure projects built using these methods; and the second section covers the comparison in highway projects.

*2.1. **Factors in Selecting a Project Delivery Method***

Selection of an appropriate project delivery method is an important decision to maintain balanced cost, schedule, and quality. Various factors affect the selection of the project delivery method (Tran and Molenaar 2012, 2013; Ghavamifar and Touran 2008; Touran et al. 2011; Schierholz 2012; Touran et al. 2009). The study by Tran and Molenaar (2012) determined eight, twelve, and eight critical risk factors that influence the decision of the selection of DBB, DB, and CM/GC methods, respectively, in highway projects. Among the three project delivery methods, the study found four common critical risk factors: "unexpected utility encounter;" “third-party delays during construction;” “geotechnical investigation;” and “delays in reviewing and obtaining environmental approvals." The authors also conducted research on the risk factors that should be considered while selecting the DB project delivery method in highway projects. They found seven risk factors: (1) “scope risk;” (2) “third-party and complexity risk;” (3) “construction risk;” (4) “utility and right-of-way (ROW) risk;” (5) “level of design and contract risk;” (6) “management risk;” and (7) “regulation and railroad risk."

The laws and regulations of the state also affect the selection of the project delivery method (Ghavamifar and Touran 2008). This study categorized the authority of using project delivery into four groups on the basis of statutory permission for DOT projects: (1) fully authorized, (2) authorized but needs extra approvals, (3) authorized for a pilot program and/or with some limitations, (4) not authorized. This study found DB was fully authorized to use in state-funded transportation projects only in 17 states and CM/GC in 14 states on the basis of state code as of December 2006. On the other hand, 13 states were not authorized to use DB, and 31 states were not authorized to use CM/GC in transportation projects before the end of December 2006. Though the use of an APD was allowed in other project types, the study found that it was not allowed in transportation projects in some states.

A single project delivery method is not suitable for all types of projects (Touran et al. 2011). There are different legal, environmental, and technical requirements of the projects that determine the type of project delivery method to be used. The study identified 24 factors that affect the decision of selecting a project delivery method in transit projects. Furthermore, the study categorized the factors into five groups on the basis of whether the factor was related to a project, policy, agency, life-cycle issues or other issues. According to transit agencies that were interviewed, the top reasons behind the selection of APD methods were schedule reduction, implementing innovations, cost certainty, and early involvement of the contractor in the design process. The authors studied nine transit projects with a total cost of more than $3.0 billion built using DB and construction-management-at-risk (CMAR). The quantitative analysis of project schedule and cost performance showed that the DB projects and the CMAR projects were completed ahead of schedule, and the average cost growth of DB and CMAR projects were less than the estimates.

The proper use of a project delivery method is most important to successfully deliver a project (Schierholz 2012). This study observed the increasing use of the CM/GC project delivery method. Analyzing case studies for 12 highway and 15 non-highway projects related to transportation, the study found that the issues related to schedule were the highest-rated project factors contributing to the selection of CM/GC in both highway and non-highway projects. Similarly, the content analysis revealed the accelerated schedule advantage and the early involvement of contractor as the top reasons for selection of CM/GC. Furthermore, the study ranked the quality of design, cost, and schedule as first, second, and third-ranked benefits of the CM/GC process in highway projects. However, in the case of non-highway projects, cost, schedule, and the quality of design were first, second, and third benefits of the CM/GC process. As CM/GC is relatively new, education and training about the CM/GC method is required for all the involved personnel to overcome their lack of experience. This training requirement has been the most challenging issue in CM/GC. The study also found that collaboration among owner, designer, and contractor is a vital part of CM/GC method.

Recently, DB and CM/GC have become viable methods because of the need to accelerate the project schedule, use of innovative ideas, cost certainty, contractor involvement in design, and flexibility during construction (Touran et al. 2009).

2.2. Comparison of Project Delivery Methods

Various studies have been conducted to compare the performance between DBB and DB methods. However, there have not been any studies performed yet to compare the performance of DB and CM/GC project delivery methods in highway projects. Therefore, the literature review regarding the performance comparison is focused on the DB, DBB, and CM/GC project delivery methods in building, infrastructure, and highway projects.

2.2.1. Building and Infrastructure Projects

The analysis of existing studies reveals that the DB method is superior to the DBB method in building and infrastructure projects (Konchar and Sanvido 1998; Ling et al. 2004; Hyun et al. 2008; Moon et al. 2011; Hale et al. 2009; Rosner et al. 2009; Water Design Build Council (WDBC) 2009; West Valley Construction 2011). Konchar and Sanvido (1998) compared the performance of DB, DBB, and CMAR project delivery methods in building projects with respect to cost, schedule, and quality metrics. The study used 351 building projects from the United States. The metrics of cost were unit cost, project cost growth, and intensity. The metrics of schedule were construction speed, delivery speed, and schedule growth. The metrics of quality were turnover, system, and process equipment. The multivariate analysis revealed that the cost growth and schedule growth of the DB projects was less than the DBB projects by 5.2% and 11.37% respectively. Similarly, the cost growth and schedule growth of DB projects were less than the CMAR projects by 12.6% and 21.8% respectively. Likewise, the study showed that DB and CMAR outperformed DBB in terms of unit cost, construction speed, and delivery speed.

Ling et al. (2004) analyzed 54 DBB and 33 DB building projects from Singapore and identified 11 performance metrics segregated from 59 potential factors. The 11 metrics included unit cost, project cost growth, intensity, construction speed, delivery speed, schedule growth, turnover quality, system quality, process equipment quality, owner's satisfaction, and owner's administrative burden. The study found that the project size affected the schedule performance. Similarly, the study concluded that the technical expertise of the contractor impacted the "owner's satisfaction." The study also found that the past experience of the contractor in quality performance impacted the "owner's administrative burden."

Hyun et al. (2008) used 10 DB and 14 DBB public multifamily housing projects and evaluated the effect of the project delivery method on the design performance of these projects. This study concluded that the design performance of DB outperformed DBB in eight categories: "consideration on the path of flow," "sunshine and ventilation," "flexible space," "specialization of unit-household," "utility," "analysis on the level of finishing material," "maintenance and repair," and "ecological floor space ratio."

Moon et al. (2011) evaluated the cost, schedule, and construction intensity and delivery intensity of 21 DB and 79 DBB multifamily-housing construction projects. The metrics of schedule were construction schedule growth, delivery growth, design speed, and construction speed. The metrics of cost were award rate, final cost to budget, cost growth, and unit cost. The study found that the DB method was superior to the DBB method in all of the metrics of schedule and intensity; however, in the metrics of cost, DB was only superior in terms of cost growth.

In 2009, Hale et al. statistically compared 39 DBB and 38 DB projects for the Naval Facilities Engineering Command (NAVFAC) in terms of cost and schedule performance, and concluded that DB projects performed superior to DBB projects. The study analyzed cost-related performance metrics, such as cost per bed with other costs, cost per bed, and total project cost growth. The metrics for duration-related performance were project duration, fiscal-year duration, construction-start duration, project duration per bed, fiscal-year duration per bed, construction-start duration per bed, and time growth. The results showed that the metrics for schedule-related performance for DB projects were superior to DBB projects. In contrast, only cost-growth of DB projects was significantly less than DBB projects; however, the results relating to other cost-related metrics were not statistically different.

Rosner et al. (2009) investigated the performance of 278 DB and 557 DBB projects for the Air Force military construction (MILCON) and found the DB method was superior to the DBB method. The performance metrics used for the study were unit cost, cost growth, schedule growth, modifications per million dollars (Mods/$M), current working estimate/programmed amount ratio (CWE/PA), and total project time. The findings showed that DB performed better than DBB with respect to cost growth and Mods/$M. In contrast, DBB outperformed DB with respect to the total project time. However, the historical analysis showed that DB is superior to DBB with respect to cost growth, Mods/$M, and total project time. The facility type analysis also showed that DB performed better in most of the facility types.

The questionnaire survey conducted by Water Design Build Council (WDBC) (2009) showed that DB projects had lower design and construction schedule growth than DBB projects. The study found that the median duration for the completion of design and construction of a project was 23 months for DB and 40 months for DBB. Also, the study found that the project intensity of DB projects were $1.5 million/month, whereas project intensity of DBB projects was $0.6 million/month.

West Valley Construction (2011), a design-build firm, estimated that DB projects resulted in about 6% cost advantage, 33% schedule advantage, and 60% reduction in claims and litigation in comparison to DBB. In addition, the firm also stated that the designer and the contractor needed to work together in a single company and under a single point of contact for a project in an integrated DB method.

Rojas and Kell (2008) compared 273 DBB and 24 CMAR Pacific Northwest Public schools in Oregon and Washington, and found that bid and cost growth varies depending on the size of the project. The study evaluated the cost effectiveness of the CMAR project delivery method in terms of change order, guaranteed maximum price (GMP), and project cost. The researchers inferred that GMP does not guarantee cost control. The overall statistical comparison indicated CMAR (4.74%) had less change order than DBB (6.29%); however, when a comparison was made on the large projects (greater than $5 million), no significant difference was found in change order growth between DBB (5.3%) and CMAR (6.13%).

2.2.2. Highway Projects

Shrestha et al. (2007) statistically compared project performance of four DB ($126 million to $1.4 billion) and 11 DBB highway projects ($50 to $100 million) in terms of cost, schedule, and change order metrics. The DBB projects were selected from the database of the Texas Department of Transportation (TxDOT), whereas the DB projects were selected from a list of FHWA SEP-14 projects. The DB projects were in the states Arizona, New Mexico, Utah, and Virginia. The findings showed that an average cost growth of the DB (-5.47%) was lower than that of DBB (4.12%). Similarly, the schedule growth of the DB (7.59%) was lower than that of the DBB (12.88%). However, the schedule growth was not statistically significant. Likewise, the change-order cost factor was not statistically significant, though the change order cost factor of the DB (5.28%) was higher than that of the DBB (3.94%). The study observed that the type of input impacted the performance of the projects. For example, the study found that delays during project construction directly impacted the cost growth, delivery speed, and schedule growth, consequently affecting the change order.

Shrestha et al. (2012) conducted the comparison of 16 DBB and six DB large highway projects (greater than $50 million) with respect to cost, schedule, and change order metrics. They also investigated the project characteristics associated with the performance. The DB projects were selected from the list of FHWA SEP-14 projects, whereas, the DBB projects were selected from Texas only. The study found that the DB projects outperformed the DBB projects in terms of delivery speed and construction speed. However, the study found that cost-related metrics, schedule growth, and cost per change order were not significantly different between DB and DBB project delivery methods. The study also found that there is an association among the cost, schedule, and change order metrics with various input factors, such as project characteristics, and contract clauses.

Based on the literature review, though various comparisons have been done between the DB and the DBB methods in highway and non-highway projects, no comparisons have been conducted between the DB and the CM/GC method in highway projects. Thus, this study fulfills the need of performance comparisons between the DB and the CM/GC highway projects.

Chapter 3

Research Methodology

The study collected the DB and CM/GC highway projects' performance related data from various States DOTs. Next, statistical analysis was conducted to determine the significant difference in performance of these two project delivery methods. The scope, objectives, and the literature reviewed for this study have been described in the previous chapters. The rest of the steps involved in this methodology are described below.

3.1. ***Data Collection***

The study collected data for this research from various State DOTs. The States' DOT members were contacted in order to collect the information related to DB and CM/GC highway projects. The data that was not received from the State DOTs was collected from the FHWA and State DOT websites. The study collected data related to project-specific information such as project name, project identity, and project location. Additionally, the study collected data related to size of the project in lane miles and then collected the data related to project description: project type, construction type, project-delivery approach, contractor-selection method, notice to proceed (NTP), cost, schedule, and change order metrics. The cost data collected were estimated project cost (design and construction cost), bid project cost, final project cost, and total change orders. Similarly, schedule data were estimated project duration, bid project duration, and final project duration.

The selection criteria set to select DB and CM/GC highway projects were: (1) the projects should be related to highway only, (2) the projects should be completed at the time of the study, and (3) data should be collected from the states using both DB and

CM/GC project delivery methods for more reliable comparison. The data was collected from January to August 2013. The collected data include 68 DB projects and 40 CM/GC projects. However, as the study used completed projects only, 13 DB projects and six CM/GC projects under construction were eliminated from data analysis. Therefore, the study used 55 DB highway projects and 34 CM/GC highway projects. Data from DB projects were received from 10 DOTs: Florida, Kentucky, Louisiana, Michigan, Maine, Montana, Nevada, Oregon, Ohio, and South Carolina. Data from CM/GC projects were received from three states: Utah, Colorado, and Nevada.

Figure 5 shows the number of DB and CM/GC highway projects data used in the study from various State DOTs. The 55 DB highway projects include five from Louisiana, 11 from Florida, nine from Michigan, nine from Kentucky, seven from Maine, four from Ohio, three from Oregon, three from South Carolina, three from Montana, and one from Nevada. Similarly, 34 CM/GC highway projects used for the study include one from Colorado, one from Nevada, and 32 from Utah. Although data from seven CM/GC projects was collected from Colorado, only one project was used for the study as the remaining six projects were under construction. The response from Idaho indicated that Idaho DOT received authorization to use DB and CM/GC in the 2010 legislative session and contracted a DB pilot project in September 2012. Also, the responses showed that Idaho DOT and Minnesota DOT had not contracted any CM/GC projects until the time of this study. Similarly, the response from Connecticut showed that it received authority to use DB in two pilot projects in May 2012, and it is in initial state of DB. According to the response from California DOT, DB highways in California were under construction at the time of the study.

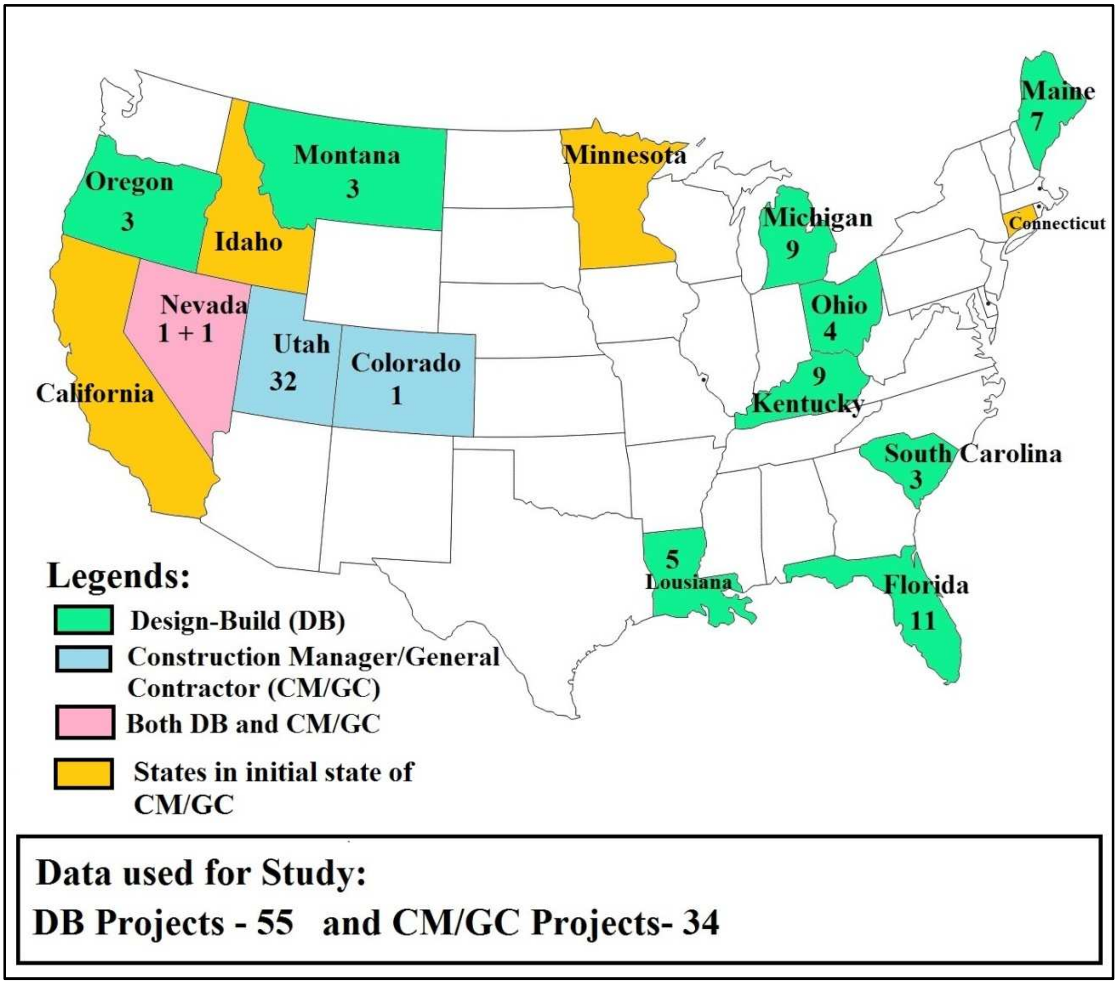

Figure 5. Map Showing the States Participated in the Study and Number of Projects

As the CM/GC delivery method is relatively new in highway projects, few states have completed highway projects using CM/GC. Utah DOT (UDOT) is the only DOT with a large number of CM/GC projects. According to UDOT 2011 CM/GC annual report, UDOT has 22 Federal and State CM/GC projects that are in progress or completed (Alder 2011). Therefore, for the study, CM/GC data was collected from those 22 Federal and State CM/GC projects. The 22 CM/GC projects had several phases. This study considered each phase as an individual project because each phase has its own construction NTP, final acceptance date, original bid amount and so on. Therefore, 22 CM/GC projects became 46 projects by counting each phase as single project. Among those 46 projects, the study considered completed projects and projects having detailed information on cost and schedule. Thus, the data of 32 completed projects was used for this study.

The study considered only cost, change order, and construction intensity performance to compare DB and CM/GC highway projects. The study used such metrics as contract-award cost growth, total cost growth, change order cost growth, and construction intensity for the performance comparison between DB and CM/GC highway projects. In the beginning, the research set out to determine some additional metrics, such as schedule growth, actual-cost per lane distance, project-delivery speed per lane distance, and construction speed per lane distance. However, the study could not collect the project size in lane miles and the schedule data. Thus, due to lack of complete data of schedule and project size of CM/GC projects, the metrics related to schedule, cost per lane mile, and construction speed were eliminated during the comparison. The performance metrics used in the study are defined as follows:

❖ Cost-related outputs

1. Contract award cost growth. It is defined as the difference between the design and construction bid cost and the estimated design and construction cost divided by the estimated design and construction cost. Contract award cost growth is expressed in percentages and is given in Equation 1.

$$\text{Contract Award Cost Growth (\%)} = \frac{\text{Design and construction bid cost} - \text{Estimated design and construction cost}}{\text{Estimated design and construction cost}} \times 100 \quad \ldots\ldots\ldots\ldots(1)$$

2. Total cost growth. It is defined as the difference between the final design and construction cost and the estimated design and construction cost divided by the estimated

design and construction cost. Total cost growth is expressed in percentages and is given in Equation 2.

$$\text{Total cost growth (\%)} = \frac{\text{(Final design and construction cost-design and construction bid cost)}}{\text{design and construction bid cost}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

❖ Change order-related output

3. Change order cost factor. It is defined as the ratio of the total change order and the total project cost. Change order cost factor is expressed in percentages and is given in Equation 3.

$$\text{Change order cost factor (\%)} = \frac{\text{Total change order}}{\text{Total project cost}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

❖ Construction intensity. It is defined as the unit cost of design and construction per unit time. Construction intensity is expressed in \$/day and is given in Equation 4.

$$\text{Construction intensity} \left(\frac{\$}{\text{day}}\right) = \frac{\text{final design and construction cost}}{\text{total project duration}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3.2. Statistical Analysis

The study used descriptive statistics and the one-way ANOVA (Analysis of Variance) Test for the data analysis. The one-way ANOVA Test compared the means of performance metrics and determined whether those means were significantly different from each other. The null hypothesis (H_0) for ANOVA was that the means of performance metrics related to cost, change order, and construction intensity in highways built using these two project delivery methods were equal ($\mu_1=\mu_2$). If p-value was equal to or less than 0.05, then reject H_0 at $\alpha=0.05$. The advantage of using ANOVA was that the number of observations in each group was not necessarily equal. For the validity of the results of ANOVA, four assumptions must be fulfilled: (1) the dependent variables should be in ratio scale, (2) the dependent variables for all the groups are normally distributed, (3) the samples are independent, and (4) the variances of the population distributions for all the groups are equal.

In this study, the performance metrics measured were all in ratio scale. To check whether the dependent variables were normally distributed or not, the Anderson Darling Test was conducted. Similarly, the samples taken in this study were independent of each other. To test whether the population variances of these two groups were equal, Levene's Test was conducted.

The Anderson-Darling Test was conducted to determine whether the dependent variables for all the groups were normally distributed. The null hypothesis of this Test was that the dependent variable was normally distributed. If the p-value was less than 0.05, then the null hypothesis was rejected. The results showed that the p-value was less than 0.05 for all the four variables, indicating that the population distribution was not normal (Table 2). Generally, if the population is not normal, the Kruskal Wallis Test must be conducted. However, ANOVA is a better test than the Kruskal Wallis Test for small sample sizes (Khan and Ryner 2003). Therefore, the study used ANOVA Test.

The number of samples used in the study was not equal for all the metrics. Though 55 DB and 34 CM/GC projects data were used for the study, the CM/GC projects did not have all the required information. Therefore, there was variation in number of samples in the four different metrics used for the study. As shown in Table 2, CM/GC projects used in contract award cost growth was 34, whereas only 24 CM/GC projects were used in total cost growth. Similarly, 15 CM/GC projects were used for change order cost factor, and 24 CM/GC projects used for construction intensity.

Table 2. Anderson-Darling Test Results

S. No.	Outputs	Project delivery methods	Number of samples	Anderson-Darling Test statistics	p-value
1	Contract award cost growth	DB	55	1.9	<0.01*
		CM/GC	34	3.5	<0.01*
2	Total cost growth	DB	55	2.8	<0.01*
		CM/GC	24	0.8	0.04*
3	Change order cost factor	DB	55	3.0	<0.01*
		CM/GC	15	1.7	<0.01*
4	Construction intensity	DB	55	3.1	<0.01*
		CM/GC	24	2.0	<0.01*

* Significant at alpha level 0.05

Levene 's Test was used to determine if the samples had equal variances. The null hypothesis of this Test was that the samples had equal variances. The null hypothesis was rejected if the p-value of this Test was less than 0.05. The results presented in Table 3 show that all four metrics have equal variances.

Table 3. Test Results of Homogeneity of Variance

S. No.	Metrics	Levene statistic	p-value
1	Contract award cost growth	0.01	0.92
2	Total cost growth	2.99	0.09
3	Change order cost factor	1.26	0.27
4	Construction intensity	0.50	0.48

Significance at alpha level 0.05

3.3. Adjustments for Time and Location

The cost data should be adjusted to a same-year and same-location index in order to establish a more direct comparison of the projects. Therefore, the construction intensity ($/day) was adjusted to the 2013 values by using published conversion factors of Engineering News Records (ENR 2013a). Then the construction intensity was adjusted to Denver location values by using Metro Area Multiplier of Engineering News Records (ENR 2013b). The construction intensities were multiplied by the August, 2013 Base ENR index and divided by the Construction NTP ENR Index to adjust to 2013 values. Likewise, the converted construction intensities were multiplied by the Metro Area Multiplier of Denver and divided by the Metro Area Multiplier of their respective cities to adjust for location. However, the contract award cost growth, total cost growth, and change order cost factor were not adjusted to 2013 values as these metrics were calculated in percentage. As construction intensity was the only metric that compared unit cost per unit time, this cost was only adjusted to find more valid comparison in reference to time and location. Therefore, bid cost, final cost, change order, contract award cost growth, total cost growth, and change order cost factor were not adjusted according to time and location.

Chapter 4

Findings

The data was analyzed using the Statistical Package for the Social Sciences (SPSS) software. The results are presented in two sections. The first section reports the results based on the descriptive statistics and the second section summarizes the results of the one-way ANOVA test.

4.1. Descriptive Statistic

Figure 6 shows the range of cost of the DB and CM/GC projects used in the study. The study used 55 DB and 34 CM/GC projects. However, all CM/GC projects did not have the cost information. Therefore, only 26 CM/GC projects having cost information were used for the calculation of cost related metrics. Out of 55 DB and 26 CM/GC projects, 25 DB projects and 19 CM/GC projects had the cost range of $1 to $20 million. Similarly, 18 DB projects and only three CM/GC projects had the cost range of $20 to $50 million. In addition, nine DB projects had the cost range of $50 to $100 million, but in contrast, there were no CM/GC projects in the range of $50 to $100 million. Similarly, three DB projects cost greater than $100 million, and one CM/GC project cost greater than $100 million. The cost of DB projects were greater than $1 million. However, three CM/GC projects cost less than $1 million.

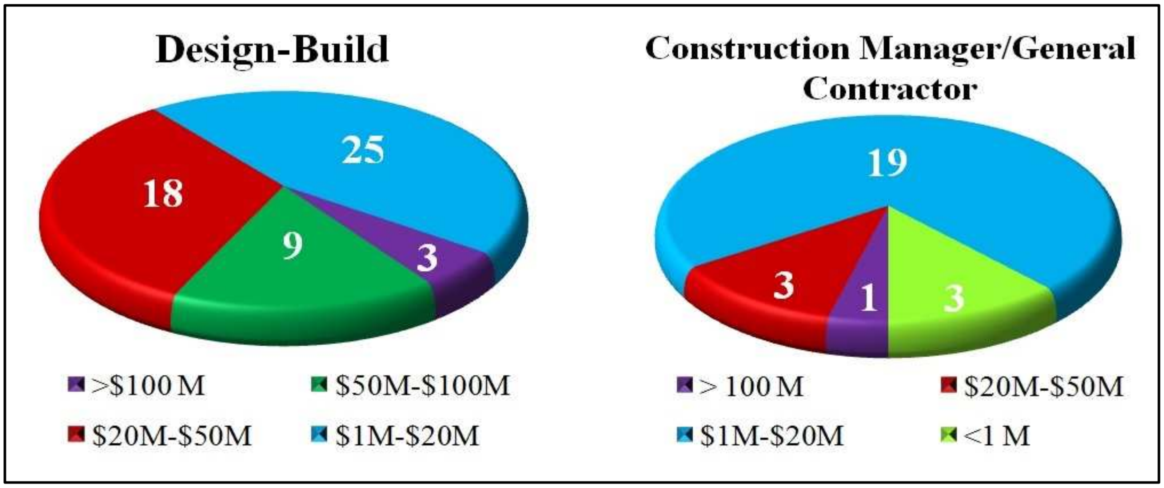

Figure 6. Number of Projects with Various Range of "Final Completion Design and Construction Cost"

Figure 7 shows the range of duration of the DB and CM/GC projects used in the study. The duration used in the study was the working days. Out of 55 DB and 34 CM/GC projects, only 27 CM/GC projects had the project duration related information. Therefore, 55 DB and 27 CM/GC projects were used to calculate the final design and construction duration. The duration of DB projects were greater than 100 days, whereas one CM/GC project had a duration of less than 100 days. Sixteen DB projects and 10 CM/GC projects had a final design and construction duration range of 100 to 500 days. Similarly, 31 DB projects and 16 CM/GC projects had a final design and construction duration range of 500 to 1000 days. In addition, six DB projects had a final design and construction duration range of 1000 to 1500 days and two DB projects had a final design and construction duration greater than 1500 days. In contrast, all the CM/GC projects used for the study had a final design and construction duration of less than 1000 days.

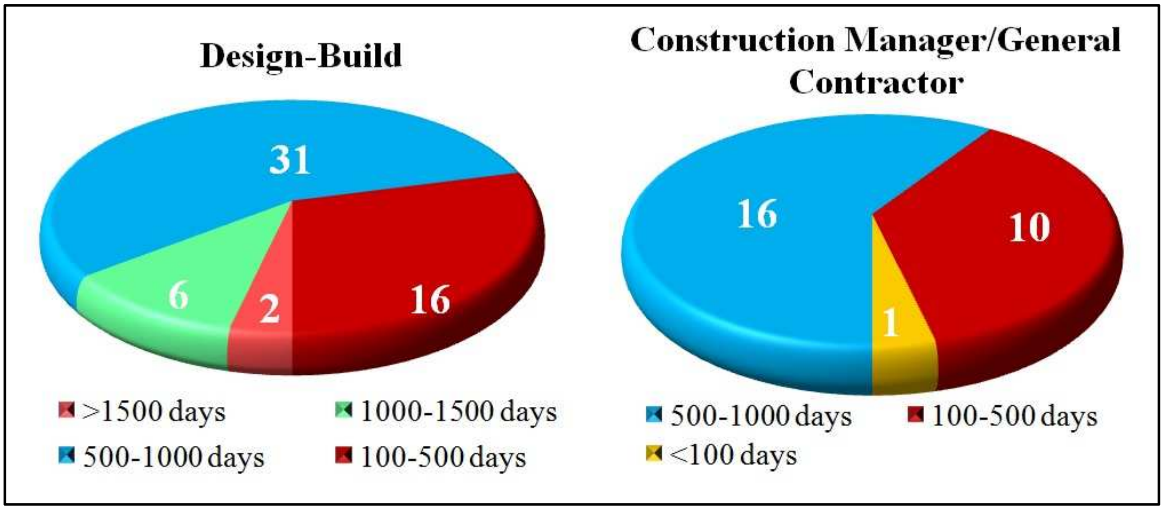

Figure 7. Number of Projects with Various Range of "Final Completion Design and Construction Duration"

Table 4 shows the range of project cost and duration of DB and CM/GC projects collected for this study. It shows that the DB projects (maximum $358 million) were bigger than the CM/GC projects ($105 million). Similarly, the average size of DB projects was greater than that of CM/GC projects. The range of the project duration in working days was 114 days to 1827 days in DB projects. The project duration in working days was 70 days to 954 days in CM/GC projects. The number of CM/GC projects that had final project cost data were only 26 and that had final project duration were only 27.

Table 4. Project Cost and Duration Data

S. No.	Data attributes	Statistics	Design-Build	Construction Manager/General Contractor
1	Final project cost	Minimum	$2,317,220	$297,601
		Maximum	$358,700,948	$105,598,495
		Mean	$37,111,852	$13,356,736
		Median	$23,713,153	$7,580,460
		Standard Deviation	$7,038,352	$21,421,772
		Number of Samples (N)	55	26
2	Final project duration	Minimum	114 days	70 days
		Maximum	1827 days	954 days
		Mean	697 days	570 days
		Median	665 days	554 days
		Standard Deviation	350 days	272 days
		Number of Samples (N)	55	27

The analysis of the data shows that DB projects had negative cost growth for contract awards, whereas CM/GC projects had positive cost growth (Table 5). The results showed that the mean cost growth for contract awards of DB projects (-3.65%) was lower than that of CM/GC projects (3.50%). Similarly, the median cost growth for contract awards of DB projects (-0.3%) was lower than that of CM/GC projects (2.28%). However, in the case of total cost growth, the mean of DB projects was more than that of CM/GC, whereas the median for both DB and CM/GC projects were similar. The data shows that the standard deviation for CM/GC projects was greater than that of DB projects. Therefore, the results showed that the DB projects were bid lower compared to the CM/GC projects.

The data analysis showed that the average change-order cost factor and standard deviation of DB were lower than CM/GC, whereas the median of the DB projects was higher than that of the CM/GC projects. On the other hand, the data showed that mean and median construction intensity of the DB projects were higher than that of the CM/GC projects. Despite this, there was not much difference in the standard deviation between the DB and the CM/GC projects.

Table 5. Descriptive Statistics

S. No.	Data attributes	Statistics	Design-Build (DB)	Construction Manager/General Contractor (CM/GC)
1	Contract award cost growth (%)	Mean	-3.65	3.50
		Median	-0.30	2.28
		Standard deviation	12.12	17.82
		Number of samples (N)	55	34
2	Total cost growth (%)	Mean	4.01	1.68
		Median	2.38	2.04
		Standard deviation	5.00	8.65
		Number samples (N)	55	24
3	Change-order cost factor (%)	Mean	3.25	4.29
		Median	2.07	1.75
		Standard deviation	4.15	5.43
		Number of samples (N)	55	15
4	Construction intensity ($/day)	Mean	53,684	46,499
		Median	39,965	29,978
		Standard deviation	47,131	50,501
		Number of samples (N)	55	24

4.2. One-way Analysis of Variance Results

A one-way ANOVA Test was conducted to determine whether the means of the performance metrics were significantly different between these two types of delivery methods. If the p-value is greater than 0.05, the samples' means are not statistically different. Table 7 shows the mean values of cost, change order, and intensity metrics for

DB and CM/GC projects. F-values and p-values of those metrics are also shown in Table 6.

The mean of the contract award cost growth for DB and CM/GC projects was significantly different. The p-values of this metric were less than 0.05. Therefore, this study has shown that the mean contract award cost growth was significantly higher in CM/GC projects in comparison to DB projects. In contrast, no statistical significance was found in other metrics, such as total cost growth, change-order cost factor, and construction intensity during the analysis. These findings suggest that, in general, DB contractors were bidding significantly lower than the estimated cost of the projects compared to CM/GC contractors. Although the data showed that the total project cost growth was higher in DB projects than in CM/GC projects, no significant difference was found.

Table 6. Results of One-way Analysis of Variance (ANOVA) Test

S. No.	Performance metrics	Unit	Design Build	Construction Manager/General Contractor	F-value	p-value
1	Contract award cost growth	%	-3.65	3.50	5.10	0.026
2	Total cost growth	%	4.01	1.68	2.23	0.140
3	Change-order cost factor	%	3.25	4.29	0.64	0.427
4	Construction intensity	$/day	53,684	46,499	0.37	0.544

* Significant at alpha level 0.05

Figure 8 shows the box plots of the median values of these four performance metrics in DB and CM/GC projects. The plots show that there are no large numbers of outliers in the data set. The smaller number of outliers in the data shows that the variances in the data set were not high.

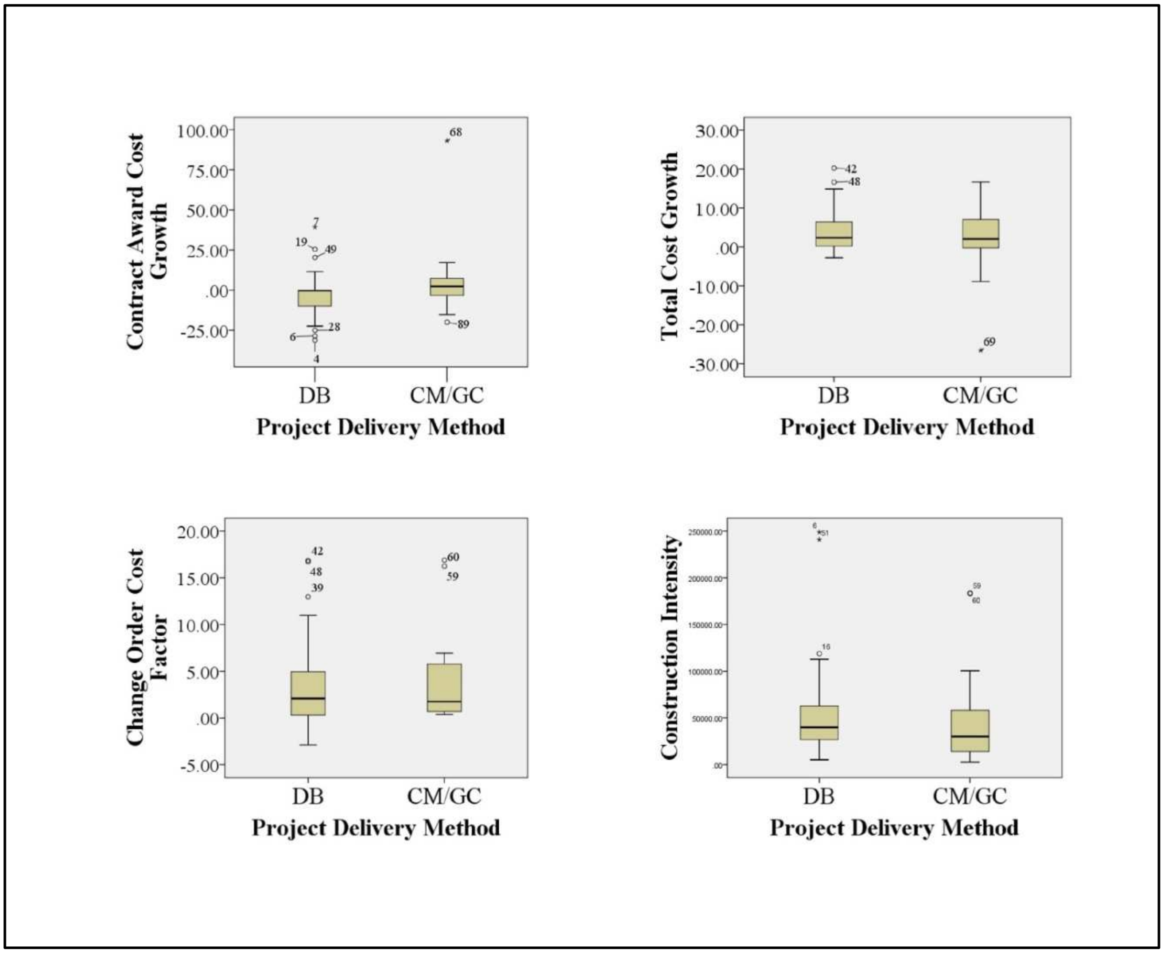

Figure 8. Box Plot of Performance Metrics of Design-Build (DB) and Construction Manager/ General Contractor (CM/GC) Projects

4.3. Limitations of the Study

The research was conducted with a small sample of CM/GC projects as few State DOTs had completed highway projects using the CM/GC project delivery method. The sample could not be collected from all states because CM/GC projects were not built all over the United States. The study could not collect the estimated and bid duration of most of the CM/GC projects. Therefore, the schedule-related metrics such as contract award schedule growth and total schedule growth could not be compared in these two types of projects. In addition, due to unavailability of lane mile data of CM/GC projects, the study could not compare metrics related to lane mile such as project delivery speed per lane mile, actual cost per lane mile, and construction speed per lane mile.

Chapter 5

Conclusions and Recommendations

The study investigated the performance of DB and CM/GC highway projects in terms of cost, change order, and construction intensity. The study collected data of completed DB and CM/GC highway projects from the states that have built DB and CM/GC highway projects. Contract-award cost growth, total cost growth, change order cost factor, and construction intensity were used as metrics for comparison of performance between DB and CM/GC highway projects. One of the significant findings of this study was that DB projects were bid significantly lower than that of CM/GC projects. In contrast to this, the study also found that DB projects have high total cost growth in comparison to CM/GC projects, but no significant difference was found. The negative cost growth for contract awards in DB and positive cost growth in CM/GC indicated that DB projects bid low in comparison to CM/GC projects. Similarly, the results also showed that the change order factor was higher in CM/GC projects than in DB projects. Despite this, there was no significant difference in these means. The construction intensity, which was the measure of the amount of cost spent every working day, was higher in DB projects than in CM/GC projects. However, there was no significant difference in these means.

The number of DB projects used in the study were large in comparison to the number of CM/GC projects. With the limited data available for CM/GC projects, the results of this study determined that DB highway projects were bid significantly lower than CM/GC highway projects. However, due to unavailability of complete schedule data, it can be determined whether DB outperformed CM/GC highway projects in terms of schedule. In order to determine which delivery method provides superior performance, further studies should be conducted with complete sets of cost, schedule, and change order data after many states have completed CM/GC highway projects. Indeed, some of the results are not statistically significant; nevertheless, this study shed some light on the performance comparison between DB and CM/GC highway projects. Because there have been no studies conducted in the past regarding performance comparison between DB and CM/GC in highway projects, this exploratory study's results are useful for the future researchers working toward comparison of these two project delivery methods.

The sample size used in the study was small because few CM/GC highway projects were completed at the time of the study. Therefore, in order to find significant statistical results, further studies needs to be conducted using a larger sample size. In addition, this study has collected DB and CM/GC state highway projects from few states. Thus, this study can be broadly expanded in the future comparing a large number of DB and CM/GC highway projects from many states. Likewise, it is suggested that the data related to all the performance metrics should be collected in the future studies. The future research should also consider samples having costs of a similar range in order to achieve better results.

Appendix: Data Collection of Design-Build Highway Projects

Project Number	1	2	3	4	5	6	7	8
Project Location (State)	Oregon	Oregon	Oregon	Florida	Florida	Florida	Florida	Florida
Project Type	Bridge	Bridge	Bridge	Road	Bridge	Road	Road	Rest Area Construction
Project Size								
Total Road or Bridge Lenth (In Miles)	23	Bridge Approaches	Bridge Approaches	6.192	0.639	9.64	7.2	0.624
Total Number of Lanes	4	2						
Cost								
Estimated Design and Construction Cost ($)	$20,336,224	$47,921,948	$76,744,000	$38,078,810	$90,447,354	$170,005,760	$24,953,489	$29,453,572
Design and Construction Bid Cost ($)	$22,695,200	$42,670,500	$59,725,000	$26,205,000	$81,520,000	$121,526,930	$34,778,500	$29,453,572
Final Completion Design and Construction Cost ($)	$25,691,026	$44,148,189	$64,460,000	$28,104,518	$86,384,535	$132,443,843	$34,781,575	$29,453,572
Schedule								
NTP of Projects	Apr-04	Dec-08	May-06	7/22/2009	8/3/2000	1/31/2008	2/9/2010	8/22/2002
Estimated Design and Construction Duration (Days or Months)	462	484	660	695	1065	748	675	790
Bid Design and Construction Duration (Days or Months)	462	484	660	695	1065	748	771	789
Final Completion Design and Construction Durations (Days or Months)	462	484	660	1015	1444	947	771	789
Change Order								
Total Change Order	$1,144,397	$928,876	$3,521,735	$1,899,518	$4,864,535	$10,316,913	$3,075	$0

Project Number	9	10	11	12	13	14	15	16
Project Location (State)	Florida	Florida	Florida	Florida	Florida	Florida	Michigan	Michigan
Project Type	Road	Intelligent Transportation System	Road	Road	Road	Intelligent Transportatio n System	Bridge	Road
Project Size								
Total Road or Bridge Lenth (In Miles)	2.581	24.967	0.567	4.173	7.8	21.835	Single Bridge Replacement	6
Total Number of Lanes								
Cost								
Estimated Design and Construction Cost ($)	$65,764,000	$26,259,150	$39,994,935	$20,500,000	$81,401,950	$26,190,074	$7,072,074	$43,880,551
Design and Construction Bid Cost ($)	$67,303,000	$23,687,512	$39,525,385	$20,500,000	$81,401,950	$26,190,074	$7,285,000	$35,941,016
Final Completion Design and Construction Cost ($)	$68,478,717	$23,713,154	$39,645,385	$20,470,318	$79,124,002	$26,920,827	$7,376,696	$35,348,348
Schedule								
NTP of Projects	7/24/2002	4/17/2008	11/19/2009	10/1/2009	4/6/2005	11/15/2006	10/29/2008	9/4/2008
Estimated Design and Construction Duration (Days or Months)	1500	950	950	388	700	710	Award to 6/15/2010	Award to 6/15/2010
Bid Design and Construction Duration (Days or Months)	1598	1024	949	525	1074	665	Same as above date	Same as above date
Final Completion Design and Construction Durations (Days or Months)	1598	1024	949	525	1074	665	408	263
Change Order								
Total Change Order	$1,175,717	$25,641	$120,000	-$29,682	-$2,277,948	$730,753	$91,696	-$592,668

Project Number	17	18	19	20	21	22	23	24
Project Location (State)	Michigan	Michigan	Michigan	Michigan	Michigan	Michigan	Michigan	Ohio
Project Type	Road	Road	Bikepath	Road	Intelligence Transportation System	Bridge	Bridge	Road
Project Size								
Total Road or Bridge Lenth (In Miles)	6	9	7	4		1 Mile of Freeway Reconstruction and 1	2 Bridge Replacement	9.19
Total Number of Lanes								
Cost								
Estimated Design and Construction Cost ($)	$44,924,708	$52,103,662	$3,229,000	$21,019,500	$3,793,735	$11,165,200	$7,111,308	$17,843,111
Design and Construction Bid Cost ($)	$40,477,777	$43,892,297	$4,050,000	$17,423,830	$3,577,700	$11,801,450	$7,090,000	$13,838,853
Final Completion Design and Construction Cost ($)	$41,122,078	$46,502,152	$4,171,992	$17,554,504	$3,693,629	$11,826,954	$7,091,550	$14,801,828
Schedule								
NTP of Projects	10/1/2009	2/24/2010	12/7/2009	12/16/2009	10/27/2009	10/6/2009	11/15/2011	2/12/2001
Estimated Design and Construction Duration (Days or Months)	Award to 11/11/11	Award to 05/02/12	Award to 03/02/12	Award to 06/17/11	Award to 09/17/10	Award to 05/15/11	Award to 06/29/12	-
Bid Design and Construction Duration (Days or Months)	Same as above date	Same as above date	Same as above date	Same as above date	Same as above date	Same as above date	Same as above date	561
Final Completion Design and Construction Durations (Days or Months)	667	687	701	378	441	402	181	553
Change Order								
Total Change Order	$644,301	$2,609,855	$121,992	$130,674	$115,929	$25,504	$1,550	$962,975

Project Number	25	26	27	28	29	30	31	32
Project Location (State)	Ohio	Ohio	Ohio	Nevada	Maine	Maine	Maine	Maine
Project Type	Road	Road	Road	Interstate Interchange	Bridge	Bridge	Bridge	Road
Project Size								
Total Road or Bridge Lenth (In Miles)	0.47	12.56	5.00	<1	0.2	0.2	0.5	
Total Number of Lanes								
Cost								
Estimated Design and Construction Cost ($)	$16,968,440	$22,149,942	$25,762,841	$20,000,000	Est not given out	Est not given out	Est not given out	Est not given out
Design and Construction Bid Cost ($)	$15,444,670	$20,066,295	$23,444,848	$15,000,000	$5,400,000	$10,875,000	$63,122,000	$14,990,000
Final Completion Design and Construction Cost ($)	$16,099,824	$21,611,279	$25,158,533	$15,000,000	$5,361,075	$12,215,520	$64,460,023	$15,668,000
Schedule								
NTP of Projects	3/20/2001	3/8/2005	1/22/2010	Apr-10	6/23/2010	12/16/2009	5/7/2010	8/11/2010
Estimated Design and Construction Duration (Days or Months)	-	-	-	396	572	572	770	550
Bid Design and Construction Duration (Days or Months)	410	873	609	264	528	572	770	528
Final Completion Design and Construction Durations (Days or Months)	539	821	877	361	506	572	770	506
Change Order								
Total Change Order	$655,154	$1,544,984	$1,713,685	$350,000	$9,769	$1,340,520	$1,338,023	$375,732

Project Number	33	34	35	36	37	38	39	40
Project Location (State)	Maine	Maine	Maine	South Carolina	South Carolina	South Carolina	Kentucky	Kentucky
Project Type	Road	Bridge	Road	Intersection Safety	Road	Bridge	Road	Road
Project Size								
Total Road or Bridge Lenth (In Miles)	3	0.2	6	20.5	39	0.38	3.462	2.128
Total Number of Lanes								5
Cost								
Estimated Design and Construction Cost ($)	Est not given out	Est not given out	Est not given out	$16,500,000	$72,501,000	$2,681,326	$12,669,873	$14,178,451
Design and Construction Bid Cost ($)	$6,025,000	$7,820,000	$6,286,037	$17,000,000	$65,463,000	$2,947,544	$11,025,932	$14,178,451
Final Completion Design and Construction Cost ($)	$6,855,185	$7,866,069	$6,618,121	$17,719,751	$65,668,762	$2,947,544	$12,669,873	$14,178,451
Schedule								
NTP of Projects	10/4/2010	6/24/2010	8/24/2009	5/2/2011	10/11/2010	7/1/2011	10/6/2006	11/27/2006
Estimated Design and Construction Duration (Days or Months)	726	638	506	600	974	140		
Bid Design and Construction Duration (Days or Months)	726	528	506	486	745	140		
Final Completion Design and Construction Durations (Days or Months)	880	528	506	808	963	114	434	386
Change Order								
Total Change Order	$97,698	$46,069	$48,781	$719,751	$205,762	$0	$1,643,550	$0

Project Number	41	42	43	44	45	46	47	48
Project Location (State)	Kentucky	Kentucky	Kentucky	Kentucky	Kentucky	Kentucky	Kentucky	Montana
Project Type	Road	Road	Road	Road	Road	Road	Road	Road
Project Size								
Total Road or Bridge Lenth (In Miles)	2.29	<1	1.022	8.041	4.336	5.5	5	Varying length from as little
Total Number of Lanes	5			4	2	2	4	
Cost								
Estimated Design and Construction Cost ($)	$18,728,853	$8,177,867	$3,410,242	$51,481,965	$45,998,571	$55,086,242	$39,195,613	$3,396,099
Design and Construction Bid Cost ($)	$18,724,571	$6,799,019	$3,150,435	$50,283,913	$45,623,391	$53,167,078	$38,671,292	$3,510,490
Final Completion Design and Construction Cost ($)	$18,728,853	$8,177,867	$3,410,242	$51,481,965	$45,998,571	$55,086,242	$39,195,613	$4,095,330
Schedule								
NTP of Projects	3/22/2007	8/9/2007	5/21/2007	5/30/2007	9/15/2008	10/2/2007	8/18/2008	12/1/2011
Estimated Design and Construction Duration (Days or Months)								6/1/2012
Bid Design and Construction Duration (Days or Months)								5/25/2012
Final Completion Design and Construction Durations (Days or Months)	928	507	239	880	952	794	762	224
Change Order								
Total Change Order	$1,410	$1,378,848	$259,807	$1,198,052	$375,180	$1,919,164	$524,321	$684,840

Project Number	49	50	51	52	53	54	55
Project Location (State)	Montana	Montana	Louisiana	Louisiana	Louisiana	Louisiana	Louisiana
Project Type	Bridge	Road	Bridge	Road	Road	Road	Bridge
Project Size							
Total Road or Bridge Lenth (In Miles)	1	10.7	14.6	3	2.6	2.84	1.12
Total Number of Lanes			4	6	6	6	4
Cost							
Estimated Design and Construction Cost ($)	$1,916,691	$18,482,703	$375,000,000	$100,000,000	$36,000,000	$60,000,000	$24,000,000
Design and Construction Bid Cost ($)	$2,307,500	$16,600,000	$347,856,245	$100,000,000	$36,240,000	$60,000,000	$24,451,787
Final Completion Design and Construction Cost ($)	$2,317,220	$17,003,468	$358,700,948	$111,211,570	$36,720,147	$61,164,652	$24,451,787
Schedule							
NTP of Projects	6/1/2011	12/8/2009	4-May-06	30-Dec-08	28-Apr-10	12-Feb-10	25-Jan-10
Estimated Design and Construction Duration (Days or Months)	11/4/2011	8/31/2011					
Bid Design and Construction Duration (Days or Months)	11/4/2011	10/20/2011	1456	1058	604	1064	506
Final Completion Design and Construction Durations (Days or Months)	336	470	1827	1290	705	1279	506
Change Order							
Total Change Order	$13,263	$395,173	$10,844,703	$11,211,570	$480,147	$1,164,652	$0

Appendix: Data Collection of Construction Manager/General Contractor Highway Projects

Project Number	1	2	3	4	5	6	7	8
Project Location (State)	Utah	Utah	Utah	Utah	Utah	Utah	Utah	Utah
Project Type	Road	Road	Road	Road	Road	Road	Interchange	Road
Project Size								
Total Road or Bridge Lenth (In Miles)								
Total Number of Lanes								
Cost								
Total Design Cost ($)				$ 934,346	$ 5,769,325	$ 211,115		$ 794,412
Engineer's Estimated Cost ($)	$4,036,311	$2,326,172	$4,085,442	$ 5,706,332	$ 87,127,133	$4,469,904	$30,975,849	$11,538,617
Planned Change Order cost ($)				$10,602,046	$ 3,767,188	$ -	$ 5,789,539	
Original Bid Cost ($)	$3,995,048	$2,497,677	$4,402,052	$ 6,050,432	$ 92,830,570	$3,976,395	$36,293,459	$11,470,926
Actual Construction Cost ($)				$17,101,743	$105,598,496	$3,864,124	$44,732,080	$11,575,461
Unplanned Change Order				$ 2,888,601	$ 17,157,005	$ 57,010	$ 784,840	
Schedule								
Construction NTP	5/16/2007	6/6/2007	6/29/2007	8/24/2007	2/27/2008	3/13/2008	10/26/2007	9/17/2008
Final Acceptance	7/3/2008	10/7/2008	10/7/2008	1/25/2008	9/30/2010	9/30/2010	10/14/2010	9/24/2009
Total Project Duration (in days or months)	318	383	412	148	848	848	891	621
Construction Duration (in days or months)	300	353	336	111	680	668	775	269

Project Number	9	10	11	12	13	14	15	16
Project Location (State)	Utah	Utah	Utah	Utah	Utah	Utah	Utah	Utah
Project Type	Road	Road	Road	Road	Road	Road	Road	Road
Project Size								
Total Road or Bridge Lenth (In Miles)					3.7 miles			
Total Number of Lanes								
Cost								
Total Design Cost ($)	$ 175,824	$ 205,801	$ 88,699	$ 539,570	$ 359,232	$ 1,428,450	$ 3,903,013	
Engineer's Estimated Cost ($)	$3,012,322	$2,803,851	$1,343,530	$9,402,251	$1,320,313	$10,410,776	$24,880,997	$21,889,360
Planned Change Order cost ($)					$ -	$ 3,563,501	$ 5,293,446	$ 3,632,103
Original Bid Cost ($)	$2,553,247	$2,916,156	$1,292,448	$8,357,196	$2,549,341	$10,778,168	$26,273,979	$20,399,648
Actual Construction Cost ($)	$2,561,950	$2,998,744	$1,292,448	$7,862,130	$2,647,509	$10,527,558	$28,764,880	$28,047,779
Unplanned Change Order					$ -	$ 38,921	$ 450,877	$ 714,093
Schedule								
Construction NTP	2/10/2009	8/4/2009	8/4/2009	11/19/2009	1/2/2008	2/26/2008	6/11/2008	5/13/2009
Final Acceptance	11/9/2009	7/22/2010	7/1/2010	11/30/2010	5/13/2009	9/16/2009	9/17/2009	11/20/2010
Total Project Duration (in days or months)	654	835	821	928	434	524	525	831
Construction Duration (in days or months)	195	254	240	269	359	411	334	378

Project Number	17	18	19	20	21	22	23	24	25
Project Location (State)	Utah	Utah	Utah	Utah	Utah	Utah	Utah	Utah	Utah
Project Type	Bridge	Road	Road	Road	Road	Road	Road	Road	Bridge
Project Size									
Total Road or Bridge Lenth (In Miles)								1.46	4.5
Total Number of Lanes								6	
Cost									
Total Design Cost ($)	$ 770,622	$ 160,142	$ 1,173,664	$ 93,562	$ 1,178,824	$ 606,789	$ 66,916	$ 1,216,965	$ 431,474
Engineer's Estimated Cost ($)	$6,513,613	$1,780,786	$11,200,994	$830,783	$ 8,493,950	$5,105,058	$ 477,041	$10,106,546	$4,846,002
Planned Change Order cost ($)				$ -	$ 822,790	$ -	$ -	$ 93,625	$ 318,061
Original Bid Cost ($)	$6,542,197	$1,915,066	$12,032,465	$839,398	$ 8,834,794	$5,028,378	$ 532,809	$10,203,871	$5,294,135
Actual Construction Cost ($)		$1,772,342	$12,989,309	$835,756	$10,530,033	$5,420,233	$ 597,739	$10,814,854	$5,729,175
Unplanned Change Order				$ 6,245	$ 529,381	$ 354,713	$ 3,422	$ 271,115	$ 396,807
Schedule									
Construction NTP	8/5/2008	2/11/2009	6/15/2009	3/19/2009	6/25/2009	3/30/2010	9/14/2010	12/2/2009	9/3/2009
Final Acceptance	9/14/2009	7/28/2009	11/15/2010	11/3/2009	11/18/2011		9/8/2011	11/21/2011	6/25/2010
Total Project Duration (in days or months)	554	263	602	368	899		847	954	329
Construction Duration (in days or months)	289	97	373	165	629		259	516	214

Project Number	26	27	28	29	30	31	32	33	34
Project Location (State)	Utah	Utah	Utah	Utah	Utah	Utah	Utah	Colorado	Nevada
Project Type	Bridge	Bridge	Road	Road	Road	Road	Road	Bridges	Road
Project Size									
Total Road or Bridge Lenth (In Miles)								0.5 miles	<1
Total Number of Lanes									
Cost									
Total Design Cost ($)		$ 961,782	$ 116,543						
Engineer's Estimated Cost ($)	$1,257,200	$5,173,709	$338,495	$6,593,398	$ 29,940	$1,842,699	$ 75,608	$ 5,400,000	$ 10,000,000
Planned Change Order cost ($)									
Original Bid Cost ($)	$1,216,400	$5,459,703	$291,726	$6,647,500	$ 29,940	$1,714,730	$ 82,400	$ 5,700,000	$ 8,000,000
Actual Construction Cost ($)			$297,602					$ 5,800,000	$ 8,000,000
Unplanned Change Order								$ 37,000	$ -
Schedule									
Construction NTP	11/1/2010	3/14/2011	8/30/2011	8/1/2005	12/20/2006	4/11/2007	1/31/2007	29-Aug-12	Jun-12
Final Acceptance	9/13/2011			10/20/2008	11/8/2007	7/3/2008	3/7/2007		
Total Project Duration (in days or months)	327							162	70
Construction Duration (in days or months)	228			841					

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