Analysis of the State of Practice and Best Practices for Alternative Project Delivery Methods in the Transportation Design and Construction Industry

by

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ABSTRACT

Alternative Project Delivery Methods (APDMs), namely Design Build (DB) and Construction Manager at Risk (CMAR), grew out of the need to find a more efficient project delivery approach than the traditional Design Bid Build (DBB) form of delivery. After decades of extensive APDM use, there have been many studies focused on the use of APDMs and project outcomes. Few of these studies have reached a level of statistical significance to make conclusive observations about APDMs. This research effort completes a comprehensive study for use in the horizontal transportation construction market, providing a better basis for decisions on project delivery method selection, improving understanding of best practices for APDM use, and reporting outcomes from the largest collection of APDM project data to date. The study is the result of an online survey of project owners and design teams from 17 states representing 83 projects nationally. Project data collected represents almost six billion US dollars. The study performs an analysis of the transportation APDM market and answers questions dealing with national APDM usage, motivators for APDM selection, the relation of APDM to pre-construction services, and the use of industry best practices. Top motivators for delivery method selection: the project schedule or the urgency of the project, the ability to predict and control cost, and finding the best method to allocate risk, as well as other factors were identified and analyzed. Analysis of project data was used to compare to commonly held assumptions about the project delivery methods, confirming some assumptions and refuting others. Project data showed that APDM projects had the lowest overall cost growth. DB projects had higher schedule growth. CMAR projects had low design schedule growth but high construction schedule growth. DBB showed very little schedule growth and the highest cost growth of the delivery methods studied. Best practices in project delivery were studied: team alignment, front end planning, and risk assessment were identified as practices most critical to project success. The study contributes and improves on existing research on APDM project selection and outcomes and fills many of the gaps in research identified by previous research efforts and industry leaders.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

CHAPTER Page

APPENDIX Page

LIST OF TABLES

Table Page

Table Page

Table Page

Table | Page

LIST OF FIGURES

Figure Page

Figure Page

1 INTRODUCTION

Alternative Project Delivery Methods (APDMs), such as Design Build (DB) and Construction Manager at Risk (CMAR), grew out of the need to find a more productive project delivery approach than the traditional Design Bid Build (DBB) form of delivery. Over the past decades, these different delivery methods have matured. With this maturity, it has become important to understand what practices lead to success within these project delivery methods. This research study seeks to provide greater understanding of alternative project delivery projects, as well as their relationship to the best practices used in the industry.

One objective of this research effort is to complete a comprehensive study focused on the horizontal transportation construction market that is comparable to those performed on vertical APDM projects. Additional objectives include providing a better basis for decisions on which project delivery method should be chosen and how best to use each method, as well as providing a new foundation for decisions in regards to future project delivery use, both nationally and locally. This research effort seeks to provide data for educational purposes to improve the industry by performing an analysis of team alignment, pre-construction services, industry best practices, and the impacts these processes have on the project delivery processes and project outcomes. An in-depth literature review establishes a baseline for the study of transportation projects and identifies gaps in the research. This report seeks to answer questions surrounding ADPM use, as well as adding to an existing pool of data that documents the financial (cost), schedule, and quality results of APDM projects.

1.1 Research Sponsor

The Alliance for Construction Excellence (ACE) is a member organization of industry professionals with a common goal to identify, define, and resolve industry problems (ACE 2014). The mission of ACE is simply to Advance, Collaborate and Enrich the construction industry. To accomplish this goal, members of ACE are involved in promoting research; collecting, analyzing, managing, and disseminating information; and providing continuing education and training that firms and practitioners do not have the capacity to do on their own (ACE 2014). The research effort reported in this work was sponsored as a part of this objective.

1.2 Dissertation Organization

This is a report of the findings of a research effort focused on the best practices for delivering transportation projects. The dissertation first outlines the problem statement motivating the study in Chapter Two. Research objectives and hypotheses are also detailed in Chapter Two and provide an outline for the flow of the report. Chapter Three provides a background for each of the research study topics and performs a review of previous research investigation that has been performed in each topic of study. Chapter Four is a summary of the methodology used during the study and explains the statistical tools used for data analysis. Chapter Five provides sample descriptives and performance results. In Chapter Six findings regarding preconstruction services, best practices, and team alignment are given. Chapter Seven is a synthesis that combines the topics of the dissertation in a direct summary. The author has organized the report to mirror the flow of hypotheses provided in Chapter Two. The final chapter outlines conclusions of the study and summarizes the contributions made by the research effort, as well as limitations and recommendations of the study. Documents found to have relevance to the study, as well as supporting works, are referenced throughout the report and are found in the appendices.

2 PROBLEM STATEMENT/RESEARCH HYPOTHESES

This study of the nation's transportation projects provides owner or contractor organizations with important insight into delivery method selection and project comparisons at a national level. Research studies evaluating Design Build, Design Bid Build and Construction Manager at Risk have been numerous and increasing over the past two decades. None of these studies have focused on the empirical evaluation of a large sample of transportation projects. The benefit of this study to the construction industry as a whole is to have a collaborative effort from multiple owner organizations to provide extensive data on the selection and application of APDMs in transportation projects, providing the positives and negatives associated with each specific delivery method.

2.1 Problem Statement

Owner organizations have multiple delivery methods available to them, from the traditionally accepted Design Bid Build approach to the once considered "alternative" (but increasingly more traditional) delivery methods, such as Design Build and Construction Manager at Risk. Organizations must weigh the costs and benefits of each delivery method and find a method most fitting for use on a specific project. This selection process can be daunting when faced with economic, political, and public pressures. The best delivery method can be selected when the specific project requirements are understood and an effective comparison made to historical data and other similar national projects. Unfortunately, a national collaborative research investigation of significant size has not been performed and national benchmarking data has not been available to agencies or interested parties. By making this data available and organizing it for an agency or project specific use, a costly delivery method selection process may be effectively shortened and made more efficient. In addition to needing guidance in the selection of a delivery method, project owners seek to understand the best practices to use once a delivery method has been selected. This study provides the industry with the best practices within each delivery method that can lead to successful projects.

2.2 Research Objectives

This research study covers a range of topics that deal with successful project delivery. Contributions from research participants have been collected in the form of case studies and individual interviews, as well as survey data. The objectives of this research effort are to:

1. Complete a comprehensive and comparable study to those performed on vertical APDM projects for use in the horizontal transportation construction market.
2. Provide a better basis for decisions on which project delivery methods should be used and how best to use them.
3. Provide a better foundation for decisions in regards to future project delivery use, both nationally and locally.
4. Provide data to improve the industry by performing an analysis of team alignment, pre-construction services, industry best practices, and the impacts these processes have on the project delivery processes and project outcomes.

To accomplish these objectives, the research study focused on these main categories: projects outcomes, project delivery method selection, pre-construction services, and team alignment. Through each of these topics, the theme of industry best practices is also analyzed and reported. A list of the subtopics studied as a part of each of these categories follows.

1. Project Outcomes
    - Greatest challenges to transportation projects for all delivery methods, as well as for individual delivery methods
    - Greatest improvement factor for transportation projects for all delivery methods, as well as for individual delivery methods
    - Cost performance for transportation projects for all delivery methods, as well as for individual delivery methods
    - Schedule performance for transportation projects for all delivery methods, as well as for individual delivery methods
    - Pricing method for transportation projects for all delivery methods, as well as for individual delivery methods
    - Change order cost performance and delivery method
    - Change order schedule changes and delivery method
    - Reducing project changes
2. Project Delivery Method Selection
    - APDM selection criteria
    - APDM cost, schedule, and change order implications

- Perception of APDM usage among owners
- Unique characteristics of project delivery methods
- Satisfaction among delivery methods

3. Pre-Construction Services
    - Implementation of pre-construction services by delivery method
    - Use of “best practice” techniques in performing pre-construction services
    - Pre-construction services cost data
    - Estimating pre-construction services

4. Team Alignment
    - Factors motivating the selection of team members
    - Factors motivating the selection of team members by delivery method
    - Team alignment by delivery methods and project success
    - Factors contributing to team alignment
    - Factors disrupting team alignment

2.3 Research Hypotheses

The research hypotheses were developed on the theory that historical data of transportation projects is the best predictor of project outcomes when selecting a method of project delivery. The author feels that data of transportation projects across the nation will show statistical trends in cost, schedule, change orders, and other significant indicators of success, and will be specific to the delivery method used. These data can act as a lessons learned database that can be instrumental in risk mitigation and provide answers to specific questions that pertain to project objectives. A background for the creation of these hypotheses can be found in Chapter Four, which deals with the research methodology. The findings that relate to each of these hypotheses are discussed in detail in Chapters Five and Six dealing with the results of the study.

2.3.1 Project Outcomes

Hypothesis: *Project outcomes using alternative project delivery methods are different than using traditional design bid build. Each delivery method has results that are specific to that method.*

To test this hypothesis, the following assumptions will be analyzed:

- There are elements of each project that present the greatest challenge; these elements can be identified and ranked. The elements differ by delivery method.
- There are specific management practices that can improve project outcomes; these practices can be identified and ranked. Their importance varies by delivery method.
- Cost and schedule performance for transportation projects can be analyzed and performance will change based on delivery method.
- The primary pricing method used by each delivery method can be determined.
- Pricing method is a predictor of cost or schedule growth.
- Use of different delivery methods has an influence on the number and dollar amount of change orders.
- Use of different delivery methods is an indicator of the schedule impacts of change orders.

- Specific practices can be used to reduce change orders; these practices can be ranked by efficiency and change by delivery method.

2.3.2 Project Delivery Method Selection

Hypothesis: *There are a number of project delivery methods available to use on transportation projects; each delivery method has unique characteristics. Owners primarily select a delivery method because it will result in reduced project schedules and costs, mitigated risks, and successful completion of project goals based on the project scope and its management capabilities.*

To test this hypothesis, the following assumptions will be analyzed:

- The primary motivating factors for the selection of a project delivery method are the delivery method's ability to affect the project cost and the project schedule.
- Motivating factors for the section of a delivery method are not limited to cost and schedule; these factors can be ranked according to importance and differ between project delivery methods.
- There is a preference among national project owners as to what delivery methods are most effective at reducing costs, controlling schedule, mitigating risk, and reaching other project goals. This preference can be measured and compared.
- Project data can be used to find, support, or repudiate the trends in preference for a delivery method.
- Satisfaction for each delivery method can be measured.

2.3.3 Pre-Construction Services

Hypothesis: *Alternative project delivery methods (Design Build and CM at Risk) are better equipped to perform pre-construction services than the traditional Design Bid Build method.*

To test this hypothesis, the following assumptions will be analyzed:

- Pre-construction services are often performed on transportation projects. Alternative Project Delivery Methods are better equipped to perform these services.
- Pre-construction services can be accomplished through the use of industry best practices. The most beneficial practices to accomplish specific pre-construction services can be ranked.
- Project participants use best practices to achieve pre-construction service goals; these project participants can provide information as to the most effective practices to achieve these goals.
- Historical data can provide the costs of pre-construction services for transportation projects; this project data can be used as a guide to estimate pre-construction service costs.

2.3.4 Team Alignment

Hypothesis: *Each delivery method uses specific criteria for selecting and aligning the project team, which will differ among the delivery methods; team alignment will affect the success of projects.*

To test this hypothesis, the following assumptions will be analyzed:

- Project teams are selected based on a number of criteria. These selection criteria vary by delivery method.
- The alignment of team members will affect the success of a project. The importance team alignment plays in the success of a project differs by delivery method.
- There are practices that affect how a team is aligned. The relative importance of these practices can be ranked; these rankings change by delivery method.
- There are aspects of a project that will create challenges for a project team. These challenges can be identified and ranked; their rankings differ by delivery method.

2.4 Summary

This dissertation will provide analysis of actual project data, as well as feedback from industry professionals, to validate the research hypotheses. Research objectives will be realized by this in-depth analysis. Chapter Three provides a background in the use of APDMs and practices widely used in the transportation industry. A literature review provides details of previous works performed in the interest areas of this study. The findings of these studies are summarized and later used as a reference for discussion throughout the study. In Chapter Four, the research methodology guiding the dissertation is explained. Chapters Five and Six provide survey data, project performance data, and in-depth analysis of the survey results. A synthesis of valuable contributions made to the industry is given in Chapter Seven. Finally, Chapter Eight gives conclusions regarding testing of the research hypotheses and the accomplishment of study objectives.

3 BACKGROUND

This chapter provides a background and literature review focusing on project delivery methods such as Design Build (DB), Construction Manager at Risk (CMAR), also referred to as Construction Manager/General Contractor (CMGC), and Design Bid Build (DBB). Extra focus was given to finding research and studies that specifically addressed highway and other transportation uses of the delivery methods being studied.

3.1 Terms and Definitions

Throughout this work, various terms will be used. These terms will often be defined as they are reported in the research; however, the following terms with definitions will be helpful to understand throughout this work. These definitions have been adapted from the Construction Industry Institute (CII) glossary of terms (CII Glossary 2014).

Project delivery system: The process by which a construction project is designed and constructed for an owner.

Design Bid Build (DBB): A project delivery method defined in which design and construction are separate contracts. The criterion for final selection is [typically] lowest total construction cost.

Design Build (DB): A delivery system that has a single point of responsibility for both design and construction.

Procurement method: The process of choosing designers, constructors, and specialty consultants for a project based on qualifications, price, or best value.

Qualifications Based Selection: Procurement method involving a selection based on qualifications.

Construction Manager at Risk (CMAR, CM at-risk, or CMR): Design and construction are separate contracts. Criteria for final selection include factors other than just lowest total construction cost.

Construction Manager General Contractor (CMGC or CM/GC): A project delivery system where the design professional and the CM/GC are retained under separate contracts to the owner. The CM/GC is typically retained at the start of the design phase to provide pre-construction services including: estimating, budgeting, scheduling, constructability reviews, and other construction input. The CM/GC is then typically retained to construct the project as designed based on a Guaranteed Maximum Price (GMP). The CM/GC often self-performs a specified percent of the project.

Front end planning (FEP): The process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project. This planning happens early within the project life cycle before design and construction.

Total Design Cost: The Engineer's total fees, which include feasibility, concept, and detailed scope, along with design costs; this is sometimes known as plan, specifications and estimates (PS&E).

3.2 Alternative Project Delivery

Until the early 1990's, the primary, if not the only, method of delivery in the United States for construction of public highway projects was Design Bid Build (DBB). Beginning in 1990, the Federal Highway Administration (FHWA) began a program to allow for the use of alternative project delivery methods on public projects in an attempt to test the success of these methods as compared to the traditional DBB (FHWA 2013).

Design Bid Build, as the name implies, is a process in which an owner selects an architectural or design firm to design the project. After design is complete, a bidding process is used to select the general contractor. This selection process is often based on the lowest bidder. The contractor then builds the facility. There exists at least two contractual relationships; one between the owner and designer and a separate contractual agreement between the owner and the contractor. In Figure 3-1, a visual representation of the relationship between parties is shown. Solid lines represent a contractual relationship, whereas dashed lines represent communication or coordination relationships.

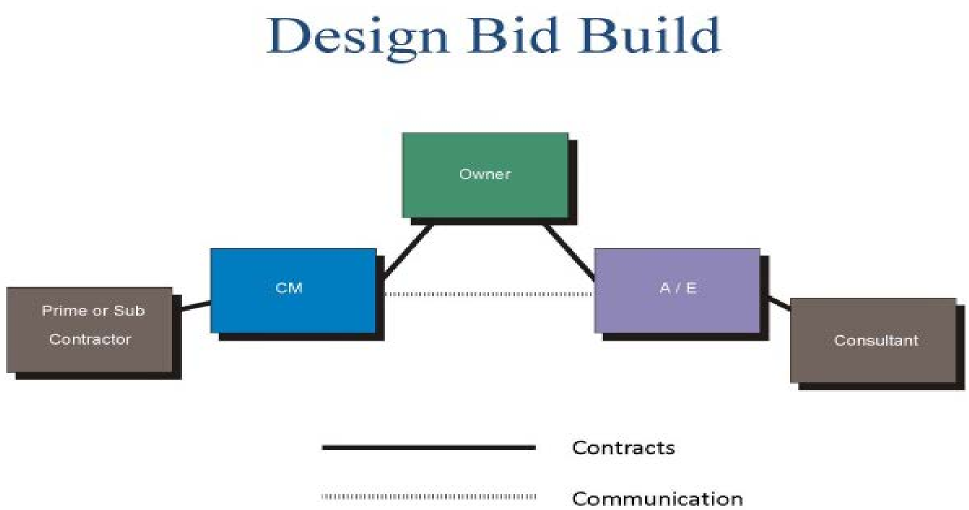


Figure 3-1 Design Bid Build

Over the last two decades in the United States, new delivery methods have emerged, allowing for flexibility in the way projects are designed, bid, and ultimately built. Mostly due to the existing legislation requiring the selection of the lowest bidder in public projects, highway construction projects were limited to the DBB method of project delivery. Over time, legislative changes have allowed for a shift to a more qualification based selection process in highway construction. The delivery methods called Design Build (DB) and Construction Manager at Risk (CMAR) are the two primary methods of project delivery that have emerged from this shift. Figure 3-2 and Figure 3-3 give a visual representation of the alternative delivery methods: CMAR and DB. In the Figures, solid lines represent a contractual relationship, whereas dashed lines represent communication or coordination relationships. It should be noted that under DB, the architect, engineer, and consultant sometimes fall under one firm.

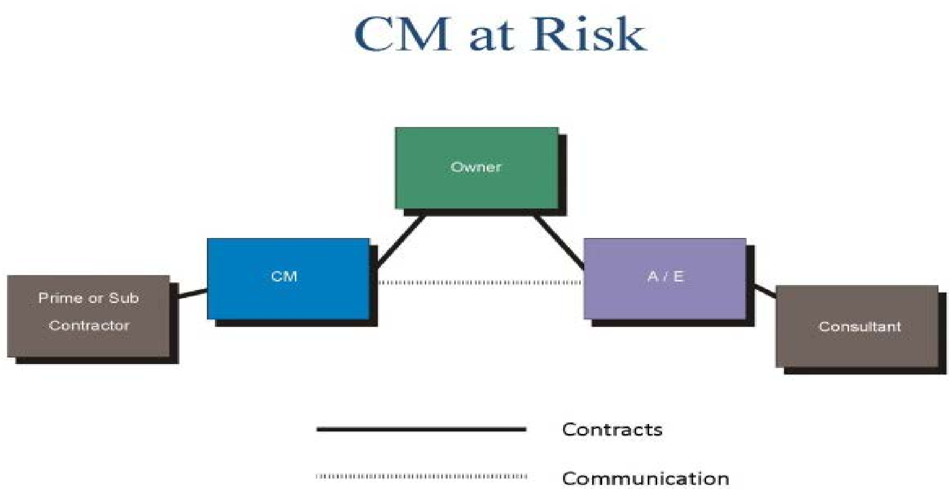


Figure 3-2 Construction Manager at Risk

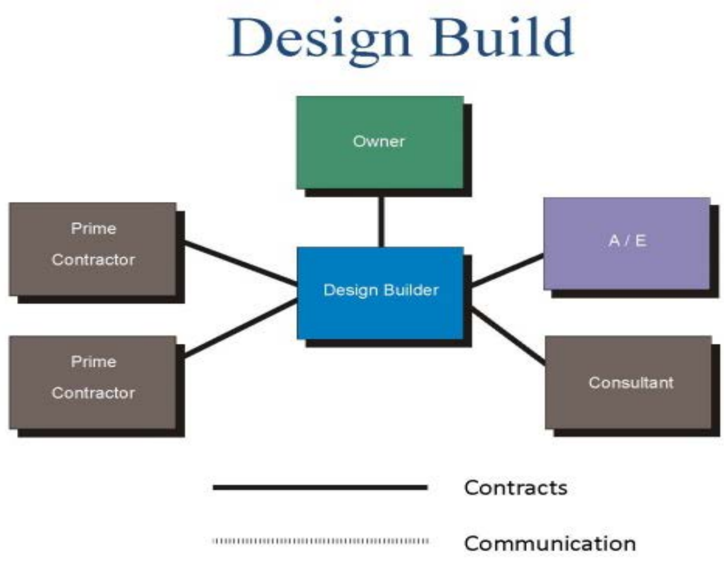


Figure 3-3 Design Build

All delivery methods were not analyzed in this study. APDMs such as Job Order Contracting (JOC) and Integrated Project Delivery (IPD) are a few of the APDMs used in the industry that are not a part of this research effort.

One of the main changes in the way highway projects are delivered using the alternative delivery methods deals with the design process. For a traditional project, the design of the project is complete before the selection of a contractor. With alternative project delivery, the design does not need to be completed before a contractor is selected. This allows for earlier construction participation in the design phase, as well as construction and design phase overlap. This relationship is illustrated in Figure 3-4.

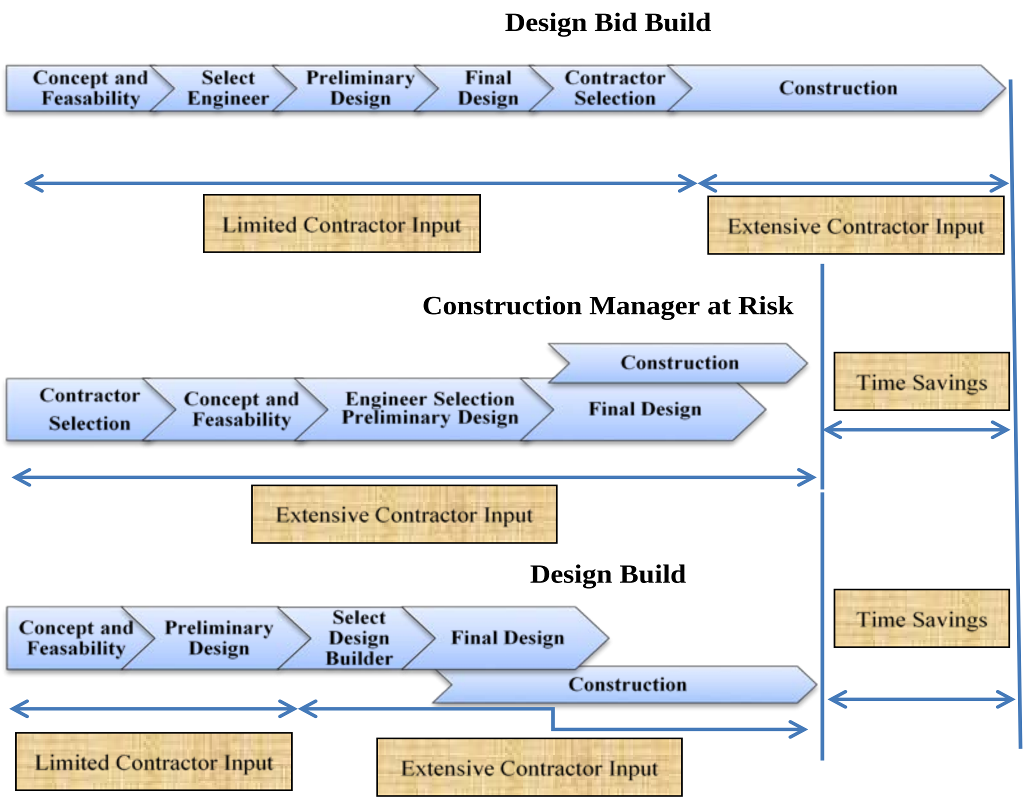


Figure 3-4 Project Life Cycle

Using APDMs, construction input can begin early in the design phase, allowing the design to be based on actual conditions found in the field. This gives a great advantage to the design team in that the data they normally use to design a roadway is generally based on very limited information about the site. Additionally, the use of APDM may eliminate the need for additional procurement cycles by combining the design and construction contracts. With some APDM, warranty and maintenance contracts can also be incorporated into the primary contract. The amount of design changes can also be reduced, as the design team can base the design on better constructability reviews. The main improvement seen in the literature is the speed of the design and construction phases (FHWA 2006).

One of the most significant differences between the project delivery methods are the criteria used to select the design and construction firms. Owners of highway projects can now select a contractor based on the contractor's ability to achieve success on a project rather than based on the lowest initial cost. This has caused many in the industry to question whether the use of DB and CMAR will lead to higher costs, delayed or accelerated projects, or changes in quality and performance. Many research efforts have been completed to answer these questions (Nikuu Goftar et al. 2014).

3.3 Literature Review

The following sections review the literature most relevant to this research effort. The literature outlined deals with APDM usage on buildings and then on transportation projects, pre-construction services, and best practices.

3.3.1 APDM and Buildings

Quite arguably, the most cited work in the literature dealing with alternative project delivery methods (APDMs) is a study completed in March 1998 by Victor Sanvido and Mark Konchar. The research report entitled: "Project Delivery Systems: Construction Manager at Risk, Design Build, Design Bid Build" has become a benchmark study for the industry and is widely used as a basis for further research, as well as a convincing support for the use of Design Build and CMAR delivery methods (Sanvido 1998). This work was sponsored by The Construction Industry Institute under the guidance of the Design Build Research Team Number 133. This research presents an empirical comparison of the cost, schedule, and quality attributes of the DBB, CMAR, DB project delivery systems using data from 351 U.S. building projects. The study provided quantitative data to support the selection of a specific delivery system. Specific study results showed that DB *unit cost* was at least 4.5 percent less than CMAR and 6.0 percent less than DBB. Design Build *construction speed* was at least 7 percent faster than CMAR and 12 percent faster than DBB. CMAR construction speed was at least 6 percent faster than DBB. Design Build *delivery speed* was at least 23 percent faster than CMAR and 33 percent faster than DBB. In addition, CMAR *delivery speed* was at least 13 percent faster than DBB.

3.3.2 APDM and Transportation Projects

In 2005, a report prepared for the American Association of State Highway and Transportation Officials (AASHTO) was completed as part of a project of the National Cooperative Highway Research Program, Transportation Research Board (AASHTO 2005). The purpose of this study was to highlight eight case studies that best provided geographical diversity and exemplified a variety of measures and techniques for which there were identifiable lessons learned and which could be applicable for other states nationwide. As a result of this study, a *Best Practices Decision Tree* was developed. The tool was meant to maximize efficiency, minimize project costs, and streamline the environmental permitting and design processes through the Design Build project delivery method. In this study, the authors outline key decision-making points and illustrate a general approach for decision makers when choosing the Design Build method of project delivery.

Utah has been at the forefront of public transportation projects using APDMs as a method of project delivery. Because of this, there have been multiple small case studies focused on projects performed by the Utah Department of Transportation. One such study was completed in 2003. This study is one of many case studies that have been performed on DB or CMAR projects nationwide (Leontiadis 2003). This study, like many of its sister studies, highlights the successes and failures of specific transportation projects as they use alternative project delivery methods.

A study was performed by the Utah Department of Transportation itself and released as an annual report in 2009. As part of an agreement with the FHWA in its Special Experimental Project Number 14 – Innovative Contracting (SEP 14) initiative, UDOT prepared this report to demonstrate their use of the Construction Manager at Risk alternative contracting process. In summary, the report claims to be the most "comprehensive analysis of [CMAR] available anywhere" (UDOT 2009). The analysis was completed by obtaining subjective information regarding the benefits and challenges of CMAR and validating this information. Interviews with the project teams were performed to discover trends that emerged from the interview responses. The trends showed that most members of the project teams believed:

- Total project costs were held down by CMAR.
- CMAR facilitated innovations that minimized construction time.
- CMAR enabled teams to work in a way that maximized productivity.
- CMAR gave them an advantage by optimizing risk analysis and mitigation.

Comparing the cost of CMAR projects to state average prices showed that the CMAR projects were 15 percent more cost-effective. This result was derived by comparing bid prices, and factoring in the reduced change orders and overruns. Direct savings attributed to the contractor's input during design on recent projects showed a six to nine percent savings on project costs (Utah 2009).

In a joint effort, the American Institute of Architects and the Associated General Contractors of America sought to align industry professionals in their definitions and understanding of delivery systems. In 2004, they released a "Primer on Project Delivery" (AGC 2004). This report had the goals of developing a set of definitions for the three primary delivery methods—Design Bid Build, Design Build, and Construction Management at Risk. The report goals led to creating definitions broad enough that all hybrids fall within the three primary delivery methods, encouraging consensus on a set of defining characteristics for each delivery method, and providing the industry with a set of definitions that others can use as a baseline.

An investigation in 2005 studied 21 Design Build projects from across the country with the intent of capturing their attributes and understanding their performance characteristics. The highway projects ranged from $83 Million to $1.3 Billion and results were summarized into two major sections of the report: Design Build Performance and Design Build Process. In Design Build Performance, it was found that 76 percent of the projects were completed ahead of the schedule established by the owner and cost growth rates were less than four percent, as opposed to an average of five to 10 percent, which was considered characteristic of Design Bid Build efforts (Warne 2005).

Multiple studies have been performed by the National Cooperative Highway Research Program. Two studies, the most recent one completed in 2006, dealt with best value contracting and gave direct comparison of transportation project performance between DB and DBB methods (Scott et al. 2006). The study found that DB projects had 4.7 percent less cost growth and 9.3 percent less time growth than DBB projects. Best value projects had 2.0 percent less cost growth and 18.5 percent less time growth than DBB.

Another study, completed more recently in 2010, dealt with CMAR projects. In this study, seven highway case studies from across the nation were used to compare how different departments of transportation (DOTs) were managing CMAR projects. In addition to these case studies, 47 state DOTs were surveyed regarding their CMAR experience. Survey results showed that a major benefit of CMAR is contractor input for pre-construction services, resulting in an average cost of 0.8 percent of construction costs. Contractor input during design of CMAR projects appeared to have no impact on design quality. CMAR services during the pre-construction phase reduce design costs an average of 40 percent. The use of a progressive rather than a lump sum GMP added value to CMAR projects by reducing the amount of contingency carried. The past project experience of CMAR personnel was perceived to have the greatest impact on project quality. Survey respondents reported that including a shared savings clause did not appear to create a significant incentive for CMAR participants. CMAR project delivery was seen as a more moderate shift than Design Build because the owner retains control of the design contract. Owners reported preference for this contracting method because they receive early contractor involvement and keep control over design. Perhaps the most emphasized finding from this report was that one of CMAR project delivery's major benefits is contractor input to the pre-construction design process (NCHRP 2010).

The findings of the studies that have been discussed in the previous section can be divided into four categories: unit costs, cost growth, delivery time, and schedule growth.

Table 3-1, Table 3-2, Table 3-3, and Table 3-4 give a summary of the findings reported previously in regards to APDM results. For each criterion, a sample size, the statistical test used, as well as a "p" or "R^2" value is given to provide statistical relevance for each study.

Table 3-1 Unit Cost Findings by Study

Reference	Project Type	Project Location	Unit Cost Major Finding	Statistical Significance	Statistical Method Used	Sample Size
Roth 1995	Navy child care facility	USA	DB 10% less than DBB	p-value= 0.083	t-test	6
Bennett et al 1996	General/not mentioned	UK	DB 13% less than DBB	R^2=0.51	multivariate	332
Konchar and Sanvido 1998	Industrial	USA	DB 6% less than DBB and 4.5% less than CMAR	R^2 = 0.99	multivariate	351
Ernzen and Schexnayder 2000	Highway	USA	DB showed 2% decrease in cost, while 1.2% increase in DBB	N/A	N/A	2
FHWA 2006	Highways	USA	DB 3% less than DBB	N/A	N/A	22
Hale et al 2009	Military buildings	USA	DB 4.5% less than DBB	p-value= 0.756	ANOVA	77
UDOT 2009	Highways	Utah	DBB 6% less than DB	N/A	N/A	19
Shrestha et al 2011	Highway	Texas	DB $5.1M Vs DBB $4.3M per lane mile	p-value= 0.458	ANOVA and t-test	22

Table 3-2 Cost Growth Findings by Study

Reference	Project Type	Project Location	Cost Growth Major Finding	Statistical Significance	Statistical Method Used	Sample Size
Ellis et al 1991	Highway	Florida	DB 2% less than DBB	N/A	N/A	N/A
Roth 1995	Navy child care facility	USA	6.51% in DB Vs 11.36% in DBB	p-value= 0.304	t-test	6
Pocock et al 1996	Public-sector	USA	DBB 12.8% cost growth, while DB showed 6.7%	p-value= 0.286	T test	25
Konchar and Sanvido 1998	Industrial	USA	5.2% less in DB compared to DBB	R^2=0.24	multivariate	351
Molenaar et al 1999	Public sector	USA	59% of DB projects showed less than 2% cost growth	N/A	N/A	104
Allen 2001	Horizontal military construction	USA	24.6% growth in DBB vs. 4.2% in DB	N/A	N/A	21
Allen 2001	Vertical military construction	USA	17.1% cost growth in DBB vs. 2.5% in DB	N/A	N/A	89
Warne 2005	Highways	USA	4% growth for DB, 5-10% growth for DBB	N/A	N/A	21
FHWA 2006	Highways	USA	DB showed 3% less cost growth than DBB	N/A	N/A	22
Shrestha et al 2007	Highways	USA	5.5% decrease in DB,4.1% increase in DBB	p-value= 0.03	ANOVA	15
Hale et al. 2009	NAVY buildings	USA	2% in DB, 4% in DBB	p-value= 0.011	ANOVA	77
UDOT 2009	Highways	Utah	CMAR 15% more cost effective than DBB	N/A	N/A	19
Shrestha et al 2011	Highways	Texas	7.8% in DB, 6.3% in DBB	p-value= 0.751	ANOVA and t-test	22
Minchin et al 2013	Highways	Florida	20.42% in DBB, 45% in DB	p-value= 0.105	ANOVA	51

Table 3-3 Delivery Time Findings by Study

Reference	Project Type	Project Location	Delivery Time Major Finding	Statistical Significance	Statistical Method Used	Sample Size
Bennett et al 1996	General/not mentioned	UK	DB 30% faster	R^2=0.80	multivariate	
Konchar and Sanvido 1998	Industrial	USA	DB 33% faster than DBB and 23% faster than CMAR, CMAR 13% faster than DBB	R^2=0.87	multivariate	351
Shrestha et al 2011	Highway	Texas	0.5 month/lane mile for DB, 2.0 month/lane mile for DBB	$P < 0.001$	ANOVA and t-test	22
FHWA 2006	Highways	USA	DB 14% faster than DBB	N/A	N/A	22

Table 3-4 Schedule Growth Findings by Study

Reference	Project Type	Project Location	Schedule Growth Major Finding	Statistical Significance	Statistical Method Used	Sample Size
Konchar and Sanvido 1998	Industrial	USA	11.4% less in DB than DBB	R^2=0.24	multivariate	351
Molenaar et al 1999	Public sector	USA	77% of projects showed less than 2% schedule growth	N/A	N/A	104
Ibbs et al 2003	General/not mentioned	CII database	7.7% increase in DB Vs. 8.4% growth in DBB	N/A	N/A	67
Shrestha et al 2007	Highways	USA	DB had 5.2% higher growth than DBB	p-value= 0.03	ANOVA	15
Shrestha et al 2011	Highway	Texas	20.5% DB Vs 5.1% DBB	p-value= 0.1665	ANOVA and t-test	22
Minchin et al 2013	Highways	Florida,	23% in DBB, 20.2% in DB	p-value= 0.105	ANOVA	51

The review of APDM literature showed that there are a large number of studies done on this topic. A few studies had sample sizes large enough to make statistical comparisons significant. Literature findings for APDM outcomes motivated the focus and methodology discussed in the next chapter, which increased in scope to capture more aspects of APDM usage. The additional scope focused on pre-construction services and industry best practices, such as team alignment. These topics are discussed in the next sections.

3.3.3 Pre-Construction Services and Project Delivery

A significant finding throughout the literature review, which was identified as a gap in the research by multiple other research efforts, was a lack of analysis of pre-construction practices by delivery method (FHWA 2006). A study by the Utah Department of Transportation found that the average fee for pre-construction services on highway projects was 0.80 percent of estimated construction costs (UDOT 2010). However an analysis of pre-construction service costs by delivery type was not performed and a small sample size of ten projects was used. No other research efforts that analyzed pre-construction services and their use within different delivery methods were found. A list of the pre-construction services included in this study, along with their definitions, is given in Appendix J.

3.3.4 Best Practices and Project Delivery

As underscored in the title of this work, the use of best practices for project delivery is highly relevant. Therefore, a literature review of best practices was performed. The group of research efforts done in the area of best practices that are of most relevance are the result of years of research by the Construction Industry Institute (CII). A CII Best Practice is “a process or method that, when executed effectively, leads to enhanced project performance” (CII 2014). Best practices have been proven as the result of extensive research efforts by the CII and others, as well as through industry collaboration and testing. A list of practices and/or tools to improve project delivery has been developed. These practices were used as a basis for understanding the delivery of projects in this research effort. The best practices as defined by the CII are given in Appendix K.

In addition to the best practices identified by the CII, additional practices were identified through the literature. These include sustainable design and construction, value engineering, and life cycle costing (SECBE 2004). Furthermore, this report more specifically reviews the practices of team alignment and pre-construction services.

3.3.5 Team Alignment and Project Delivery

While team building or team alignment has had a number of quality publications and research, one gap in the literature is an analysis of how team alignment is achieved within the different delivery methods. Team alignment practices have been shown to improve project outcomes and facilitate better working environments with less conflict and disputes (Griffith and Gibson, 1997). However, no literature was found that analyzed team alignment practices within different delivery methods.

3.4 Literature Review Summary

Although there have been significant amounts of research into alternative project delivery methods as they relate to transportation projects, there are further needs in terms of research as demonstrated by the literature review. Since the 1998 Sanvido study of

APDM on 351 building projects, there has not been a research effort of that scope and significance. With over 20 years of APDM projects completed since that benchmark study, there are most likely significant lessons to be learned. Additionally, no study of similar size and scope has ever been performed that is specific to transportation projects. The literature review was used early in the research effort to identify gaps in the available literature. This information was used to identify the objectives of this study into alternative project delivery methods of transportation projects.

It was the general observation of the author that the literature is lacking an in-depth analysis dealing with an adequate sample size to make conclusions supported by statistical significance. A few of the studies do reach a level of statistical significance based on their sample sizes, but most commonly, those studies have been performed in the style of a survey response of opinions rather than gathered project data. A large and in-depth quantitative analysis of APDM in the transportation market is needed.

The most recent and perhaps most closely related study in the literature would be the 2010 CMAR study for NCHRP by the Transportation Research Board. This study is notable because it uses multiple research methods to make its observations; a survey of 47 DOT employees, case studies of ten projects, as well as multiple project manager interviews. The study also identifies gaps within the research that the author's research effort seeks to fill. The gaps identified include: development of agency understanding and knowledge of CMAR versus DBB and DB, development of a guide for CMAR pre-construction cost modeling, and estimating CMAR pre-construction services fees (TRB

2010). These gaps in research are an example of the industry's recognition that more needs to be done in this area.

This research effort required the collaboration of industry professionals, as well as academia, in the collection of data and also the interpretation and implementation of the findings. The result is a research effort that examines the effectiveness of APDM in the transportation construction market, and provides a basis for decisions on which project delivery method should be used. This effort can provide a better foundation for decisions in regards to future project delivery decisions and will be instrumental to educate and improve the industry.

4 RESEARCH METHODOLOGY

The research methodology for this study was developed through the coordination of a dissertation committee, research steering team, and inputs of colleagues throughout the research effort.

4.1 Development Methodology

The research effort was sponsored by the Alliance for Construction Excellence (ACE). ACE was especially interested in research dealing with the use of alternative project delivery methods and the practices that surround them. Through the creation and coordination of a research steering team, an in-depth study of literature, and a series of team meetings, a set of objectives for the research project was solidified. This section on research methodology describes the research steering team, research sponsor, the development of survey documents used in data collection, the data collection and data analysis used, and limitations to the research.

4.2 Research Steering Team

As an organization of industry professionals, ACE was able to bring together a research steering committee with many years of experience to guide the proposed research in a desirable direction. The role of the team was to make decisions as to the direction the research would take given information gathered by the main researcher. Early in research team development, a proposed research topic was determined. The initial focus of the research team was limited to studying the use of alternative project delivery methods project outcomes. The research steering team wanted to mirror the

Sanvido study, but with application to the transportation industry. The original ACE research objectives were to:

1. Update the CII study and improve the analysis approach.
2. Establish a baseline study of transportation projects.
3. Document cost, schedule, and quality results of different methods in the sample
4. Publish the findings in a manner that advances and enriches the industry.

4.3 Methodology Flowchart

To reach these objectives, a plan for the research methodology was developed. A visual representation in the form of a flowchart is given in Figure 4-1 showing the key steps and milestones of the research effort.

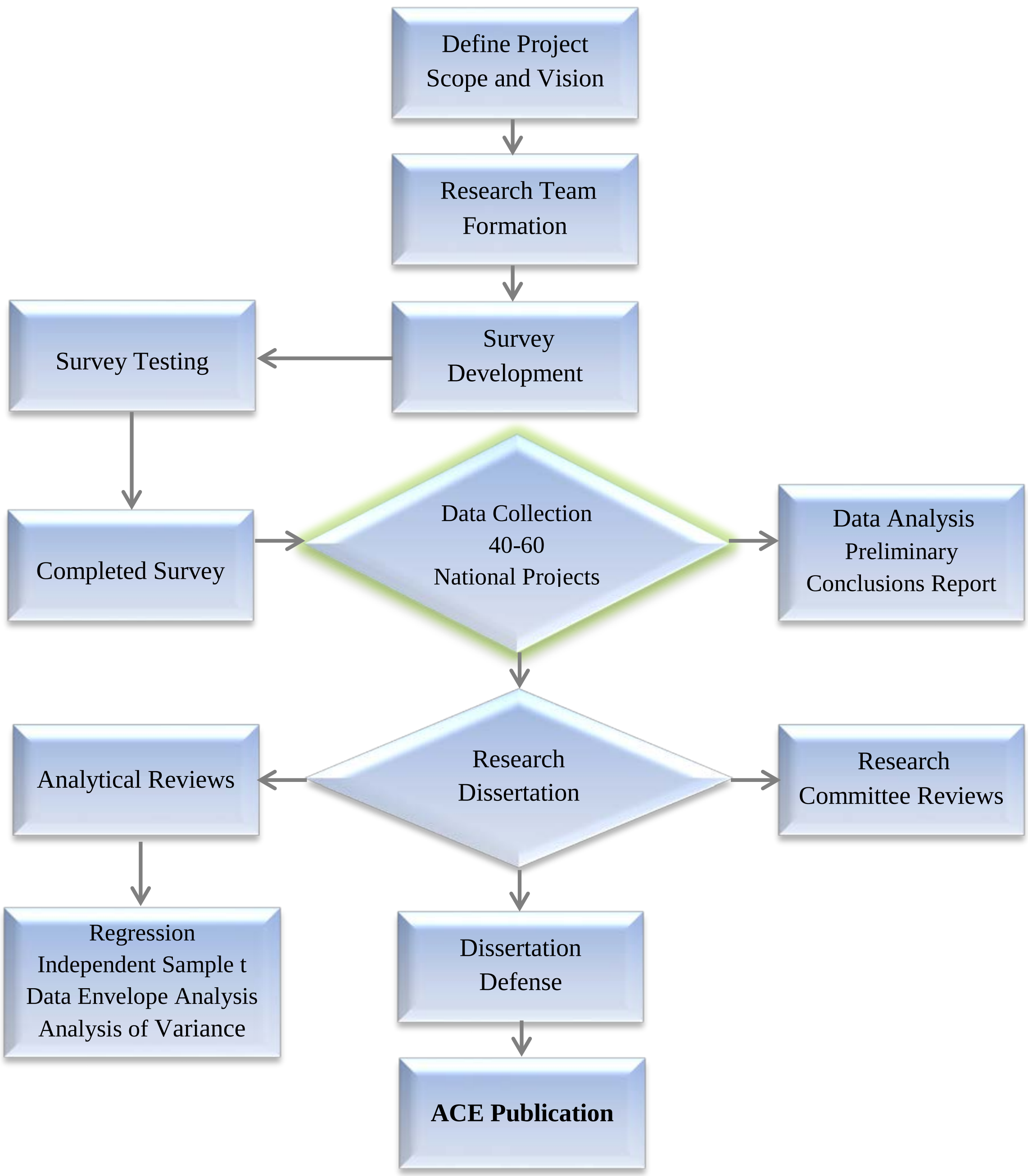


Figure 4-1 Methodology Flowchart

Detailed in Chapter Three, an in-depth literature review was performed showing that there had been a large amount of research done dealing with the use of alternative project delivery methods in transportation construction. The review identified gaps in the research and noted suggestions made for further research. The topics of these proposals for future research became an additional focus of the research steering team. The team decided that the research effort could add to the body of knowledge dealing with alternative project delivery by providing a robust analysis of project data. In addition, it would provide the industry with research into the areas identified as lacking in the research.

The following additional topics of interest were identified for the research effort:

1. Complete a comprehensive and comparable study of variance for use in the transportation infrastructure market among several delivery methods, including DB and CMAR.

2. Provide a better basis for decisions on the selection of project delivery method.

3. Identify tested best management practices within each project delivery method.

4. Increase owner agency understanding and knowledge of APDM.

5. Development of a guide for pre-construction services.

6. Develop a guide for CMAR use.

7. Publish the findings in a manner that advances and enriches the industry (ACE Publication).

8. Provide data for educational purposes to improve the industry.

4.4 Survey Development

Survey development began with understanding what kinds of data could be collected and from whom. Through research steering team meetings, sets of potential questions were reviewed for their relevance in the research. An important source for possible survey questions came from lessons learned sessions of actual projects performed through the city of Phoenix. Documentation of one of these lessons learned sessions is provided in Appendix F. After multiple reviews by research steering committee members, advisors, and fellow ASU students, a draft survey was finalized. This survey can be found in Appendix H.

Original efforts were made to collect data by means of a paper survey that would be emailed or faxed to potential survey takers. It was soon determined that to reach the number of respondents desired and for ease of data collection and analysis, the survey would be converted into an online survey. The online survey was created and went through rounds of adjustments and modifications to fit an online format. An outside consultant was also used to improve the survey, introducing a higher level of reliability in the responses.

The final version of this online survey is found in Appendix I. Subsequent surveys were developed after a short round of testing on actual projects in order to get feedback on how to improve the survey. This survey testing was done by members of the steering team or close associates. One criticism of the survey was its length as it was taking respondents over an hour to complete, resulting in incomplete data. New versions of the survey reorganized the most pertinent questions and placed these near the beginning of the survey to get a higher response rate. The survey was also shortened, removing questions that the research steering team felt did not provide the greatest return of desired data for the time commitment required. Regardless, the final survey was still long and required an in-depth knowledge of specific project details, making answering all the questions difficult for some.

Over 1000 targeted survey solicitations were made. These solicitations came from national project information like the SEP 14 projects, national and state departments of transportation, municipalities, previous research participants, managers of targeted projects, and contacts made through research steering team members. Projects were also found through an online survey: “Call for Participation” (Appendix B), which was sent to many state and local organizations that may have wanted to participate in the research effort.

Due to the nature of the data needed, it is difficult to get a truly random sample, as participation in research efforts often vary from state to state or within organizations. By collecting a large number of projects, statistical assumptions representing a true population can be achieved. The number of projects becomes important when performing tests of statistical significance, as sample data is less robust at less than 30 data points.

Project data was desired for specific project constraints. The survey outlined these constraints through an introductory statement that read:

> *Thank you for participating in this important research effort. This survey has been designed for horizontal construction projects that have been COMPLETED OR ARE NEAR COMPLETION. If your current project does not meet these specifications, then please use a past project to answer the questions. Ideally these projects will have a total cost over $5 million; however, this is not a necessary condition. It is desirable for the survey to be completed in one sitting; however, if it is necessary for you to leave the survey, you can do so at any time and continue where you left off by clicking on the link that was provided to you. Please note that if you follow the link from a new computer, the survey will think*

you have begun a new survey. To continue on previous work, please return to the survey on the same device. The survey ENDS AT QUESTION 37, questions 38-40 are feedback on the survey. If you have any questions please contact: Evan Bingham at evan.bingham@asu.edu or call any time (602) 541-1580. Again, thank you for your participation!

Collected project data was verified through email contact with the provider, and clarification of unclear responses was provided. The resulting raw data was then analyzed using a wide range of statistical tools described in the following section.

4.5 Analytical Approach

Project data was analyzed using a sophisticated set of tools. Analysis ranged from the basic reporting of descriptive data to regression analysis and analysis of variance. This section gives an overview of the tools used and analysis performed in the study.

4.5.1 Summary of Research Analysis

The collected data was analyzed using proven statistical tools and approaches which are detailed briefly in this section. This section does not provide the specific findings of the research as it relates to the analysis performed, but rather provides the reader with an understanding of the tools and language used to describe the data. Findings and results of analysis can found in the section "Research Findings." The statistical reviews and analyses were performed using three programs: Stat graphics, Excel, and Minitab.

4.5.2 Survey Collection Summaries

Data will be reported by responder description, project type, and other project related descriptives to show the sources and variation in data. This, along with basic inferential statistics, provides the reader with a ground level understanding of the data. This basic data will provide univariate analysis results such as mean, median, and mode, as well as descriptive statistics which simply summarize the sample. Sample data will also be analyzed using more sophisticated methods of investigation.

4.5.3 Univariate Inferential and Descriptive Data

Univariate inferential and descriptive data supplies a statistical representation of the mean of the population. If the sample size is significantly large and randomized, one can say that the sample mean is the same as the population mean. If the sampled number is sufficiently large, the Central Limit Theorem supports this conclusion. The confidence interval of the mean provides a range of the sample mean in which the population mean can be found. A confidence interval of 95 percent, for example, would give an interval for which it could be assumed that the population mean can be found with 95 percent confidence. The greater the sample size, the more confidence that can be placed in the mean (Babbie 2008).

A visual representation of a set of data can be seen in Figure 4-2 in the form of a boxplot. Boxplots provide information such as the median, interquartile range, outliers, and extremes. The median is demonstrated using a straight horizontal line. The box around the median gives the interquartile range with the bottom end showing the 25th percentile and the upper end depicting the 75th percentile. Fifty percent of responses are found within this interquartile. The median demonstrates the central tendency, while the box around it shows variability. If the line is not in the middle of the box, then the distribution is skewed. Vertical lines extend past the box, both above and below, demonstrating the largest and smallest values that are not considered outliers or extremes. In the example in Figure 4-2, outliers are notated using small circles and extremes are notated using asterisks.

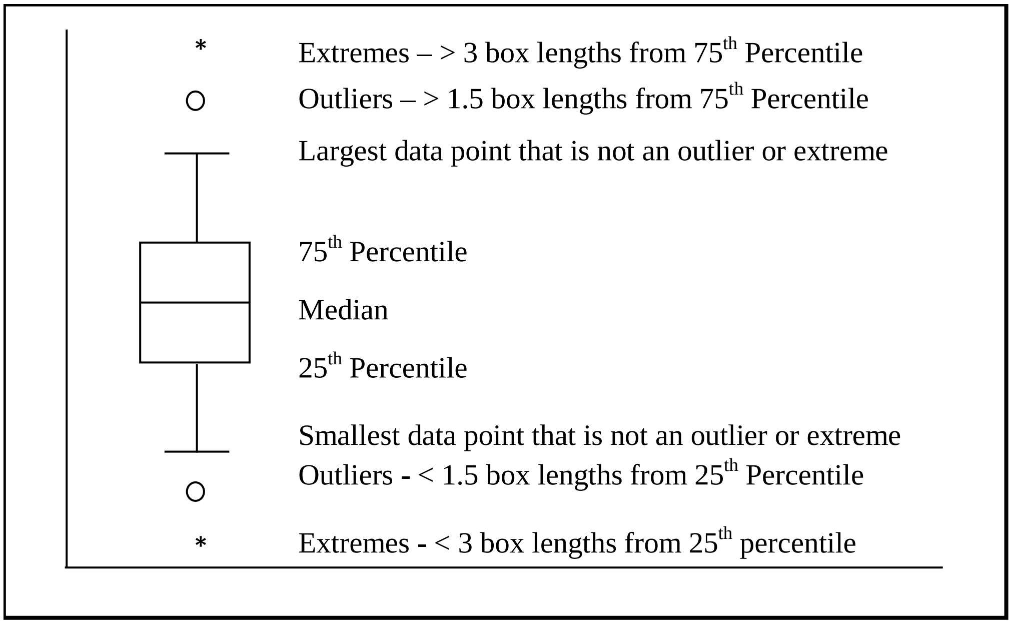


Figure 4-2 Boxplots

4.5.4 ANOVA, Regression, Sample T

ANOVA, or analysis of variance, is a statistical test that allows for an identification and measurement of variation between sample sets. This allows for a comparison of sample means.

Regression analysis is used to predict one variable from another by using an estimated line to summarize the relationship between variables (Siegel 2003). When data is obtained and compiled into data sets, the information can be graphed using a scatterplot. The independent variable or X is the data that is assumed to predict behavior in the independent variable Y. Using the data sets obtained, a researcher can graph the data that is independent along the X-axis and the corresponding dependent data on the Y-axis.

Using regression analysis and statistical programs, a trendline like the one shown in **Error! Reference source not found.** can be fitted to best match the data. In linear bivariate regression analysis, the trendline will follow the equation:

$$Y = b_1X + b_0,$$

where:

b_0 = Y- intercept

b_1 = slope or regression coefficient

The slope b_1 also shows how much Y will change given a one unit change in X. A positive slope indicates that as X changes by one unit, Y increases by b_1 and a negative slope indicates that as X changes by one unit, Y decreases by b_1.

Generally, not all of the variability in Y is explained by X. The coefficient of determination, or R^2, indicates how much of the variability of Y is explained by X. R^2 is used to measure if the model's independent variables are significant predictors of the dependent variables. R^2 is calculated by squaring the correlation *r*. R^2 values range from zero to one, with one indicating that X perfectly predicts Y and a zero indicating that X does not predict Y at all. In other words, an $R^2 = 0$ .75 indicates that 75 percent of the variation in Y can be explained by X. Our *r* value shows if there is a positive or negative relationship, *r* values range from negative one to one and a negative *r* value indicates that as X increases, Y decreases. If *r* is positive, then the reverse is true (Babbie 2008).

In order to determine the quality of models and their predictability, the author will calculate the *r* and R^2 value as well an F-statistic with its corresponding P-value using a statistical software package. A P-value of less than .05 would imply that our R^2 is statistically significant at the 95 percent confidence level.

4.5.5 Independent Samples t-test

The t-test measures whether the means of two groups are statistically different from one another. The author used an independent samples t-test, which evaluates whether means for two independent groups are significantly different from each other (Green et al. 1997). The independent samples t-test makes three assumptions.

1) The data being measured is collected from a random sample
2) Each sample average is assumed to be approximately normally distributed
3) Variance of the two samples are equal

4.6 Sample Size

Respondents were not always able to answer every question on the survey. When analyses are performed, the sample size of usable data is reported for each test run. Data collected on project cost and schedules, for example, may not have been available to respondents. All data was analyzed for use, and only valid data was considered; therefore, the sample sizes used for analysis changed throughout.

4.7 Limitations of Analysis

Some limitations to the data analysis procedures should be noted. Normally distributed populations are assumed throughout the analysis, unless noted otherwise. Samples are not from a truly random sample in that specific projects were targeted based on specific project parameters. Some sample data sets may not have high numbers of responses and may lead to weak arguments for correlation. These will be generally noted or will be evident based on the statistical indicators defined previously in this section.

4.8 Summary

This section has described the research steering team, the research sponsor, the development of survey documents used in data collection, the proposed data collection and data analysis to be used, and limitations to the research. Further understanding of statistical tools used throughout the research is explained in detail as the tests are reported in the data analysis sections.

The next chapter gives the findings of the study. The results of analysis using the tools described in this chapter are discussed in detail in the next chapter. The chapter is organized in order of the research objectives and hypotheses outlined in Chapter Two.

5 RESEARCH SURVEY DESCRIPTIVES AND PROJECT PERFORMANCE

Chapter Five gives the results of the survey and a detailed report of the findings of the study. In-depth statistical analyses were performed on survey data; the results of these analyses are found in the sections of this chapter. The chapter is organized in order of the research hypotheses explained previously in Chapter Two.

5.1 Survey Data

As described earlier, survey data was collected by soliciting responses via email from national and state department of transportation offices, as well as municipalities, previous research participants, managers of targeted projects, and FHWA listed SEP 14 projects. Over 1,000 emails were sent out, with 105 respondents participating in the survey. Of the 105 responses, 83 were considered to have usable data. The other 22 responses were deemed unusable due to a variety of reasons, such as insufficient data, inadequate project size, or data not relevant to the study. The final survey used to collect project data is found in Appendix I.

5.1.1 Role on the project

Owner organizations, such as departments of transportation and municipalities, were targeted for responses to the survey. After question one of the survey dealing with the contact information of the respondents, question two asked respondents for their role on the projects. Due to the targeted approach, 84 percent or 72 respondents were from owner organizations and 16 percent or 11 respondents were part of a design team, as shown in Figure 5-1. Contractors were not solicited to complete surveys. The high participation from owners makes the interpretation of results more applicable to owner organizations.

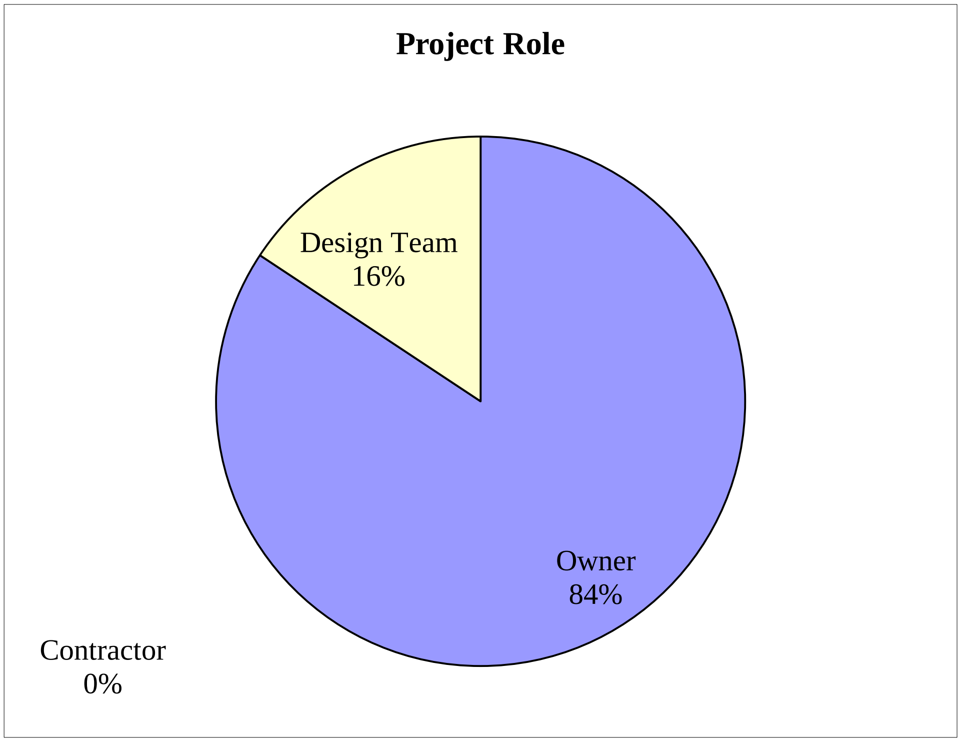


Figure 5-1 Role on Project
(N = 88)

5.1.2 Project Locations

Question three asked specifics about the project, including project name, location, and scope of work. Respondents to the survey answered questions regarding a specific project location. All projects were located across the continental US and Alaska. The project locations can be seen on Figure 5-2 and Figure 5-3, as well as Table 5-1 Project Locations by State.

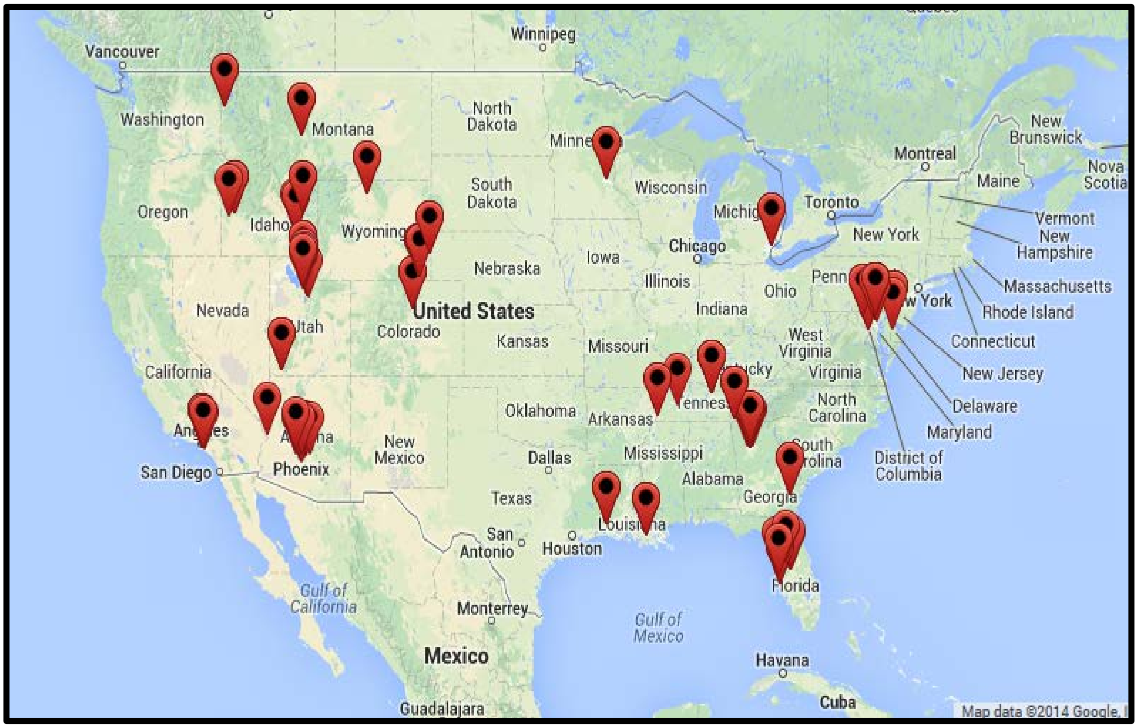


Figure 5-2 Project Locations (Google Maps)

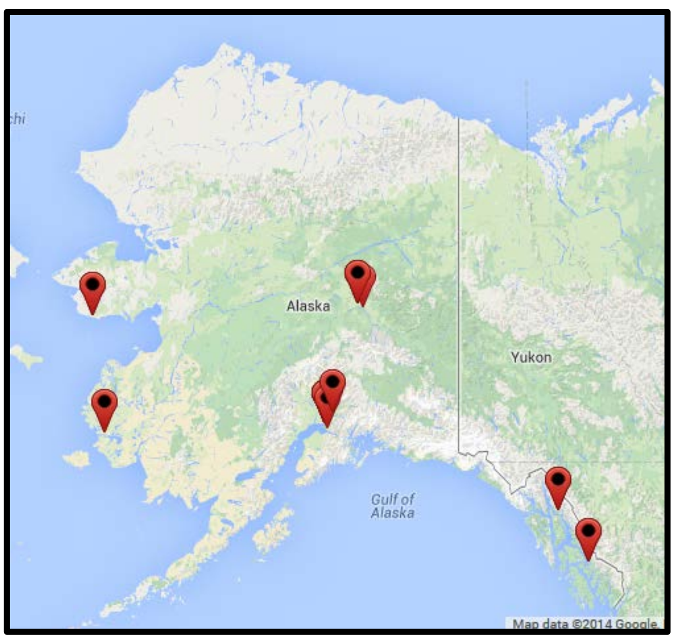


Figure 5-3 Projects in Alaska (Google Maps)

Table 5-1 Project Locations by State/Federal District

State/Federal District	Number of Projects
Alaska	11
Arizona	13
California	3
Colorado	1
Delaware	2
Florida	7
Georgia	9
Idaho	6
Louisiana	2
Maryland	8
Michigan	1
Minnesota	1
Montana	1
Tennessee	4
Utah	9
Washington, DC	1
Wyoming	4

As can be seen from the Figures and Table, there was a wide dispersion of projects, though not uniform. All projects included in the study were horizontal projects dealing with the transportation of people and/or freight. The project descriptions are found in Appendix C.

Survey respondents were asked in question five which delivery method was used for the project. Projects used in the study fell mostly into three categories: Design Build, Design Bid Build, and Construction Manager at Risk (CMAR). Design Bid Build was the dominant project delivery method, with 40 of the projects in the study using this delivery method; this represented 48.2 percent of the total projects. Design Build was used on 21 projects in the study, representing 25.3 percent of the projects. This was followed closely by 18 CMAR projects, representing 21.7 percent of the total projects. Four other projects in the study used different delivery methods, such as Job Order Contracting (JOC), representing 4.82 percent of the total projects used in the study. Figure 5-4 shows the breakdown of the number of projects by delivery method.

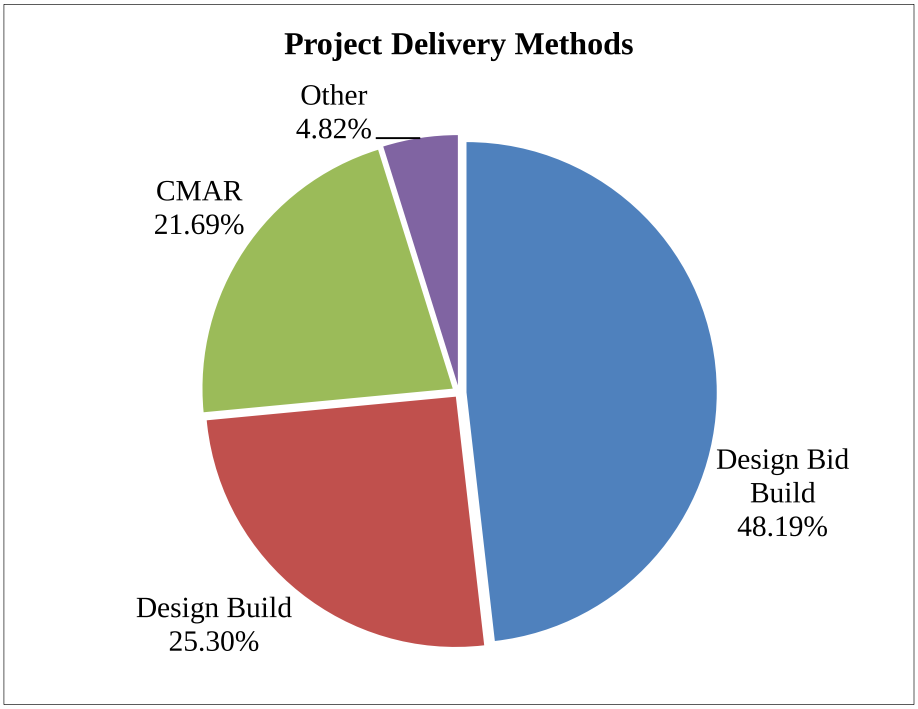
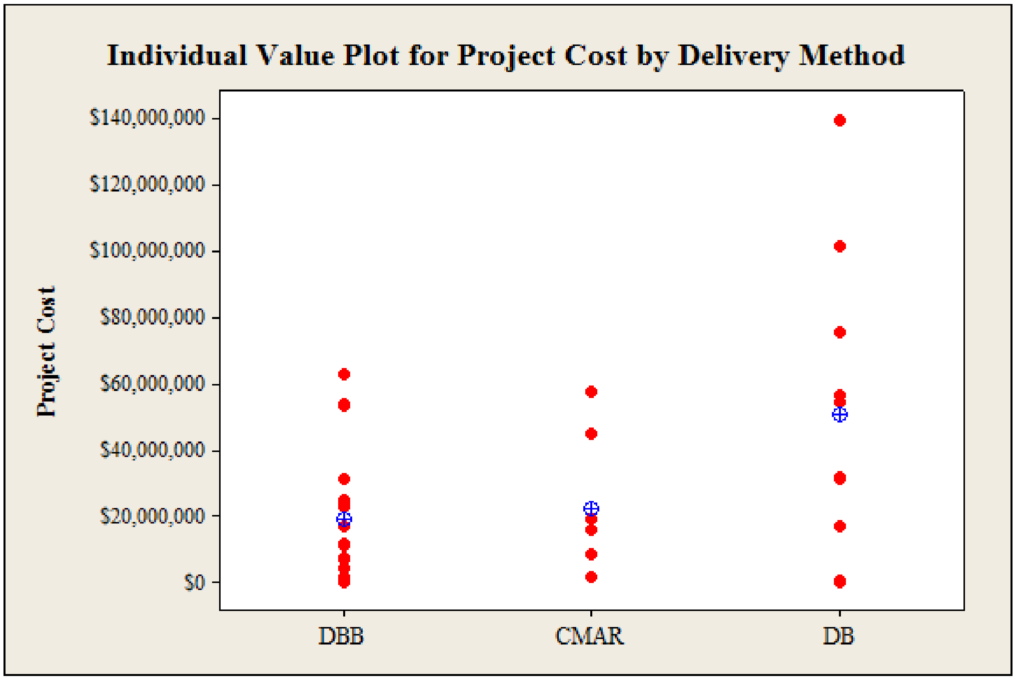


Figure 5-4 Project Delivery Methods
(N=83)

5.2 Project Size

The 83 projects surveyed ranged in cost from one million to over 900 million US dollars. They represent a total capital project value of almost six billion US dollars. Cost for each project is given in Appendix C. A breakdown of the cost per delivery method is given in Figure 5-5.



Mean (ø)

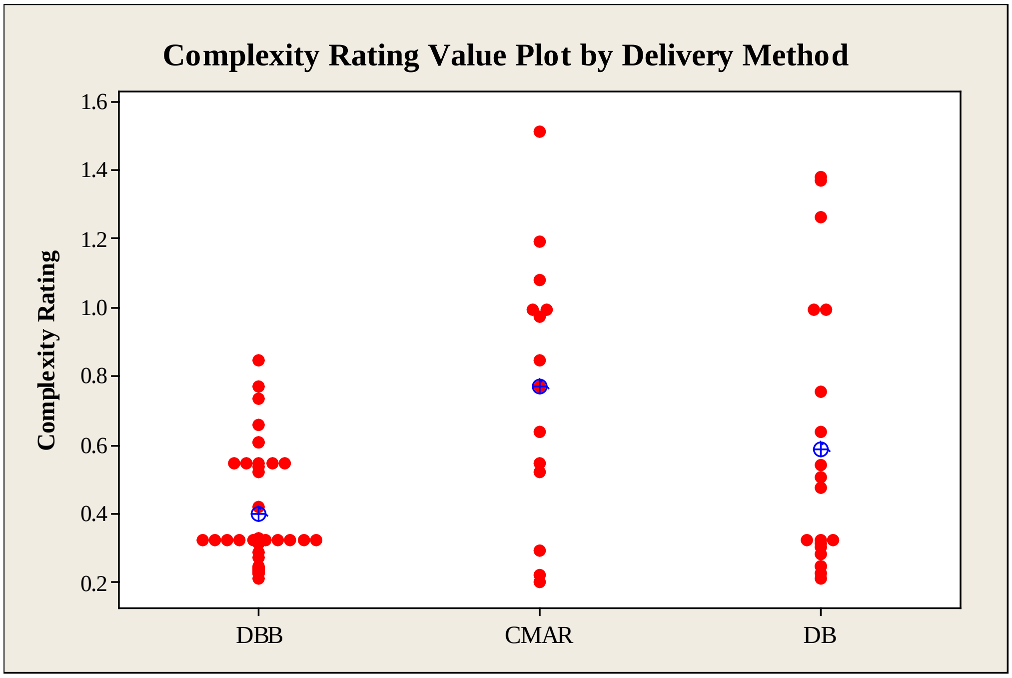
Figure 5-5 Individual Value Plot for Project Cost by Delivery Method

DBB project had the lowest average cost at just over 19 million US dollars. CMAR project had an average cost of over 22 million US dollars. DB project had the highest average cost at just over 51 million US dollars. DB project also showed the largest range of project costs.

5.3 Project Complexity

Within the construction industry project outcomes typically focus on time, cost and quality as factors used in project or delivery method comparisons. Unfortunately these factors do not always adequately describe the details of a project. Project complexity can play a large part in the outcomes of a project. Transportation projects especially, can range from very basic to very complex. This section uses the analytical hierarchy process to address project complexity among the survey projects. This process is based off a study reported in the International Journal of Project Management which seeks to establish an index to measure project complexity (Vidal et. al.2010). The complexity index identifies four main complexity categories. Project size deals with the number of stakeholders and overall costs of the project. Project system variety deals with the number of components going into the project. Project system interdependence deals with issues including right of way, environmental controls and other interactions within the project. Lastly project system context-dependence deals with issues that arise in the network environment of the project. Each of these categories was given a weight relative to the others indicating the categories that were the greatest contributors to project risk. These weights were derived from input given by experienced project managers.

Projects were compared within each index topic and a ranking or percentage score was given to each project based on the parameters of the individual project. Complexity scores consisted of weighted averages of several components including number of stakeholders, overall costs, number of construction components, ROW, utility adjustments, environmental controls, or other contributors to the before mentioned categories. Through the analytical hierarchy process, the project weights were multiplied with the category weights and added to give a final score for each project. Category weights were derived from the research performed by Vidal based on input from project managers. The final calculated project score is an indicator of the complexity of the project in relation to the other surveyed projects and allows for a hierarchical ordering. The total relative score for each project is given in Appendix L. Figure 5-6 shows the complexity score for each project compared based on project delivery method. DBB projects tended to be less complex with an average score of 0.40; CMAR projects showed the highest average relative score of 0.77; and DB projects had an average score of 0.59.



Mean (ø)

Figure 5-6 Complexity Rating Value Plot by Delivery Method

The project scores were used for a better comparison of projects that have similar complexity. This factor should be considered to understand possible causes for difference in project outcomes.

5.4 Project Outcomes

This section provides the results and findings of survey data dealing with the project outcomes. These project outcomes include factors leading to project success, cost and schedule performance, pricing method analysis, and change order data.

5.4.1 Cost Analysis

Various factors affecting cost were analyzed and are discussed in this section. A regression analysis was done to determine the effects of delivery method on cost growth.

The average cost of design, pre-construction, and right of way/utilities adjustments were examined as a percentage of the total cost. These averages were calculated for all the projects together, as well as by delivery method, and can be seen in Table 5-2.

Table 5-2 Cost for Design, Pre-con, and ROW as Percentage of Total Cost

	Design	Pre-Construction	ROW/Utilties Adj.
DBB (N = 11)	17.12%	0.22%	20.46%
CMAR (N = 7)	11.89%	6.17%	30.58%
DB (N = 9)	7.09%	8.60%	12.52%
All Projects (N = 27)	12.42%	7.03%	19.23%

The results in the table show that, on average, pre-construction services represent a greater percentage of the total cost for CMAR and DB projects at 6.17 percent and 8.60 percent, respectively. This should not come as a surprise, as there is more contractor and design influence in pre-construction services for CMAR and DB projects. Conversely, one can see that the design phase for DBB projects have a higher overall percentage of total cost when compared to the APDMs. These average costs for design and pre-construction services can be used as a guide for estimating these services. The table also shows right of way (ROW) and utility adjustments as a percentage of total costs per delivery method. The author advises that caution should be used with the ROW percentages, as there were outliers in the data under this topic and the data may not represent a true population mean.

Although survey questions were asked that could have resulted in a cost per lane mile analysis, it was found that due to factors such as project complexity, adequate data was not available in the projects surveyed to make a responsible analysis. The variation in transportation projects makes a cost per lane mile analysis impractical without strict controls over the type of project analyzed.

5.4.1.1 Cost Growth and Delivery Method

Respondents of the survey answered questions in regards to costs of the project, both budgeted and actual. They were asked to list specific project cost such as design, pre-construction services, right of way and utility adjustment, owner's contingency, and total project cost. Growth of design costs and total project costs were calculated in order to analyze the data further.

Total Project Cost Growth was calculated as:

$$\frac{(Actual\ Total\ Project\ Cost - Budgeted\ Total\ Project\ Cost)}{Budgeted\ Total\ Project\ Cost}$$

A negative number indicates a reduction in cost from the original budgeted costs. The average cost for each category requested (design, pre-construction services, right of way adjustment, owner's contingency, other costs, and total project cost) is given in Table 5-3.

Table 5-3 Cost Growth Measures

	Design cost growth	Pre-Construction Service Costs growth	Right of Way and Utility Adjustment Costs growth	Total Owner's Contingency growth	Other Cost growth	Total Project Cost growth
Average cost growth for DBB (N = 19)	4.67%	-16.67%	14.44%	-9.78%	-17.53%	-2.59%
Average cost growth for CMAR (N = 8)	3.26%	21.84%	0.11%	-62.67%	13.61%	4.04%
Average cost growth for DB (N = 11)	-2.74%	-12.51%	-31.08%	-35.57%	-16.36%	-5.37%
Average cost growth for total sample (N = 41)	2.05%	-2.76%	-6.66%	-33.96%	-13.71%	-2.98%

A one-way ANOVA test was run for both design cost growth and total project growth using all delivery methods. No statistically significant difference was found between the means for the three variables at the 95 percent confidence level with P-values of 0.6246 and 0.3268, respectively. The ANOVA tables for each are shown in Table 5-4 and Table 5-5.

Table 5-4 ANOVA Table for Design Cost Growth

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.03	2	0.02	0.48	0.625
Within groups	1.04	29	0.04		
Total (Corr.)	1.07	31			

(N = 37)

Table 5-5 ANOVA Table for Total Project Cost Growth

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.07	2	0.04	1.15	0.327
Within groups	1.09	36	0.03		
Total (Corr.)	1.17	38			

(N = 37)

A histogram of the total project cost growth for each of the delivery methods can be seen in Figure 5-7 . The distribution for each can be seen, with DB projects having the greatest variability and CMAR the least. CMAR may have a smaller standard deviation due to the smaller sample size available for those projects. This could be an indicator that CMAR projects have more predictable cost growth.

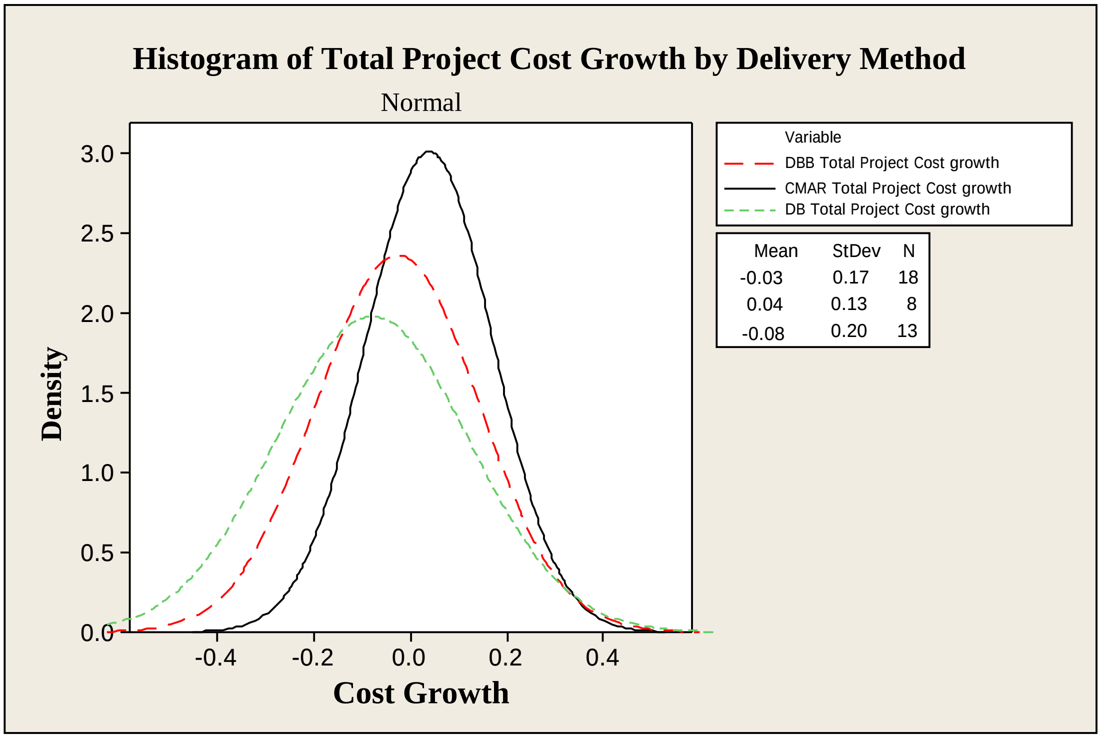


Figure 5-7 Histogram for Total Project Cost Growth

The author could find no indication that the use of delivery method was an indicator for either design or total cost growth. Although differences were found between the sub-samples, they were not statistically significant. Owners should not use cost growth as a basis for delivery method selection.

5.4.1.2 Cost Growth Performance and Regression Analysis

A multivariate regression was run to determine the impact of delivery method on cost growth performance. The dummy variables of CMAR and DB were used with DBB being the omitted variable. The regression results are provided in Figure 5-8. Looking at the results shows that the coefficients for DB and CMAR would imply a 3.2 percent reduction in cost growth for DB projects compared to the more traditional DBB method and a 5.9 percent increase in cost growth for CMAR projects when compared to DBB method; however, the P-value for each of the coefficients was extremely high, indicating that there is no statistically significant difference between the delivery methods that would affect the cost growth of a project. Our R-squared value was low as well, indicating the selection of delivery method would only explain 3.5 percent of the variability in cost growth had the P-values been statistically significant.

Regression Statistics	
Multiple R	0.19
R Square	0.04
Adjusted R Square	-0.03
Standard Error	0.17
Observations	35

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.04	0.02	0.59	0.56
Residual	32	0.99	0.03		
Total	34	1			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.02	0.04	-0.52	0.61	-0.11	0.06	-0.11	0.06
CMAR	0.06	0.08	0.76	0.45	-0.1	0.22	-0.1	0.22
DB	-0.03	0.07	-0.47	0.64	-0.17	0.11	-0.17	0.11

Figure 5-8 Regression Output for Cost Growth and Delivery Method

5.4.2 Schedule Analysis

Survey respondents were asked to answer questions regarding the project schedule. The survey asked for budgeted and actual dates for detailed design, construction, and completion. This information was used to analyze the projects' schedule performance.

Information on the duration of the project was requested for both budgeted and actual lengths. Days per lane mile were examined between the three delivery methods to see if there were any large differences between the groups. As with cost per lane mile, a days per lane mile analysis showed that insufficient data about the projects made the analysis impractical. Without more information on project size, components, stakeholders, and other contributing factors it would be difficult to analyze transportation project data responsibly.

5.4.2.1 Design Schedule Growth

Respondents were asked to answer questions about the length of the design phase, namely the planned and actual start and end dates for detailed design. A measurement of how much the schedule for design grew or shrank was calculated using the difference in start and end dates for both planned and actual schedules and the Detailed Design Growth was calculated.

Detailed Design Growth =

$$\frac{(Actual\ Detailed\ Design\ Duration - Planned\ Detailed\ Design\ Duration)}{Planned\ Detailed\ Design\ Duration}$$

Detailed design growth was then used to calculate the means and standard deviation, and Levene's test was used to determine if there was a statistically significant difference between the standard deviation within the three variables (Table 5-6 and Table 5-7). This test is used to check variability between the groups and can be important in order to determine if one delivery method had more variability in Detailed Design Growth. This would indicate that there is less uniformity in the detailed design phase for a particular delivery method. The P-value of 0.16 indicated that there was not a significant difference in the standard deviations.

Table 5-6 Mean, Standard Deviation, Minimum, and Maximum for Detailed Design Schedule Growth

Detailed Design Schedule Growth	Mean	St. Dev	Min	Max
DBB Detailed Design growth % (N = 20)	18.10%	0.77	-0.92	2.96
CMAR Detailed Design growth % (N = 7)	0.01%	0.13	-0.25	0.24
DB Design growth % (N = 9)	29.55%	0.51	-0.18	1.32

Table 5-7 Levene's test for Detailed Design Growth

	Test	*P-Value*
Levene's	1.92	0.16

(N = 36)

Levene’s test compares the standard deviation with the three groups and compares the standard deviations between only two groups at a time. It may be interesting to note that although the test showed a lack of statistically significant differences between standard deviations when compared across the three groups, the comparison given in Table 5-8 shows significant differences between each of the groups when compared to only one other delivery method.

Table 5-8 Comparison of Standard Deviation for Detailed Design Growth

Comparison	*Sigma1*	*Sigma2*	*F-Ratio*	*P-Value*
CMAR Detailed Design growth % / DBB Detailed Design growth % (N = 7)	0.13	147.79	8.116E-7	0.00
CMAR Detailed Design growth % / DB Design growth % (N = 20)	0.13	1.18	0.01	0.00
DBB Detailed Design growth % / DB Design growth % (N = 9)	147.79	1.18	15652.3	0.00

5.4.2.2 Construction Schedule Growth

The duration of the projects in the study were further examined by calculating the schedule growth for the construction phase of the project. Respondents were asked to report on the planned beginning and end date for construction, as well as the actual beginning and end date for construction. The author then calculated the Construction Schedule Growth.

Construction Schedule Growth was calculated as:

$$\frac{(Actual\ Project\ Duration - Planned\ Project\ Duration)}{Planned\ Project\ Duration}$$

The growth for each delivery method was evaluated by comparing means, standard deviation, minimums, and maximums. These are given in Table 5-9.

Table 5-9 Construction Growth Mean, Standard Deviation, Minimum, and Maximum

Schedule Growth by Delivery Method	Mean	St. Dev	Min	Max
DBB Construction growth (N = 18)	-8.06%	0.27	-0.7	0.42
CMAR Construction growth (N = 8)	25.41%	0.56	-0.24	1.51
DB Construction growth (N = 15)	18.56%	0.71	-0.08	2.44

A one-way ANOVA test was run to determine if there were statistically significant differences between the means at the 95 percent confidence level. The ANOVA results in Table 5-10 show the F-Ratio for the between groups estimate compared to the within groups estimate. The corresponding P-value of 0.195 tells one there was not statistical significance when comparing the three variables.

Table 5-10 ANOVA Table for Construction Growth by Delivery Method

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.86	2	0.43	1.71	0.195
Within groups	9.07	36	0.25		
Total (Corr.)	9.93	38			

(N = 41)

Looking at Figure 5-9 one can visually see the means are not statistically significant at the 95 percent confidence level due to the overlap in intervals.

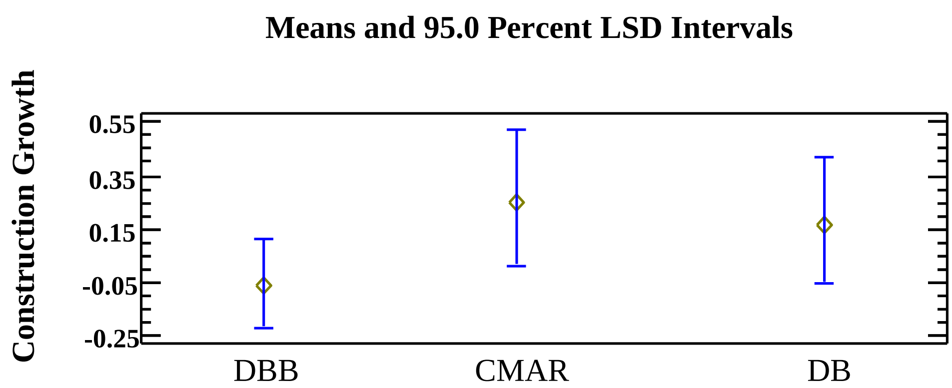


Figure 5-9 Means and 95 percent LSD Interval for Construction Growth

5.4.2.3 Total Schedule Growth

In addition to answering questions about the detailed design dates for the project, respondents were also asked to give start and end dates for the total schedule. These were used to calculate the Overall Schedule Growth.

Overall Schedule Growth =

$$\frac{(Actual\ Project\ Duration - Planned\ Project\ Duration)}{Planned\ Project\ Duration}$$

The Overall Schedule Growth was then examined by looking at the mean, standard deviation, minimum, and maximum as given in Table 5-11. A one-way ANOVA test was also run to compare the three means to determine if there were statistically significant differences between them at the 95 percent confidence level. As can be seen in Table 5-12, the P-value was 0.512, indicating that they were not significantly different.

Table 5-11 Mean, Standard Deviation, Minimum, and Maximum for Overall Schedule Growth

Schedule Growth by Delivery Method	Mean	St. Dev	Min	Max
DBB Overall Schedule Growth (N = 21)	4.65%	0.19	-0.45	0.54
CMAR Overall Schedule Growth (N = 7)	13.27%	0.35	-0.2	0.88
DB Overall Schedule Growth (N = 13)	20.24%	0.55	-0.003	1.94

Table 5-12 ANOVA Table for Overall Schedule Growth

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.18	2	0.09	0.68	0.512
Within groups	4.8	36	0.13		
Total (Corr.)	5.01	38			

(N = 41)

The means and 95 percent LSD Intervals chart in Figure 5-10 also shows that the means do not have statistically significant differences between them. The area of overlap between the intervals indicates that there is no significant difference between the means.

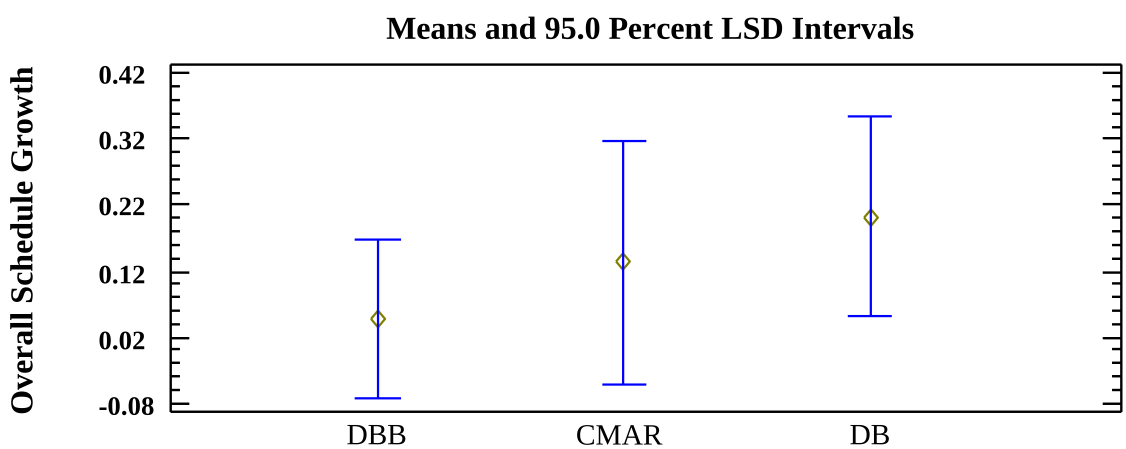


Figure 5-10 Means and 95 percent LSD Intervals for Overall Schedule Growth

Due to the lack of statistical significance between the means, the nonparametric Kruskal-Wallis test was run to determine if there was a significant difference between the medians. Table 5-13 shows the results of the test returning a P-value of 0.94101, indicating that there was not any statistically significant difference between the medians of the delivery methods at the 95 percent confidence level.

Table 5-13 Kruskal-Wallis Test for Overall Schedule Growth

	Sample Size	*Average Rank*
DBB Overall Schedule Growth (N = 21)	19	19.37
CMAR Overall Schedule Growth (N = 7)	8	20.5
DB Overall Schedule Growth (N = 13)	12	20.67

Test statistic = 0.12   P-Value = 0.941

The author did not find significant evidence that delivery method was a predictor of schedule growth. Schedule growth should not be used by owners in selecting a delivery method.

5.4.2.4 Total Schedule Growth and Regression Analysis

A multivariate regression was run using Total Schedule Growth and delivery method in order to determine the impact that delivery method might have on the schedule growth of a project. The dummy variables of DB and CMAR were used with DBB being the omitted variable. The regression results are shown in Figure 5-11. The output indicated that selecting a DB method over DBB method could result in a 32.67 percent increase in Total Schedule Growth and selecting CMAR over DBB could result in a 20.90 percent increase in Total Schedule Growth; however, the P-values for both of these coefficients were above 0.05. The P-value for DB projects did come close to statistical significance though with a value of 0.066. The R-squared value was low as well and had the output indicated statistical significance, then the selection of delivery method would have explained 9.2 percent of the variability in Total Schedule Growth.

Regression Statistics	
Multiple R	0.30
R Square	0.09
Adjusted R Square	0.04
Standard Error	0.49
Observations	40.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2.00	0.89	0.45	1.86	0.17
Residual	37.00	8.86	0.24		
Total	39.00	9.75			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.17	0.11	-1.57	0.12	-0.38	0.05	-0.38	0.05
CMAR	0.21	0.23	0.92	0.36	-0.25	0.67	-0.25	0.67
DB	0.33	0.17	1.89	0.07	-0.02	0.68	-0.02	0.68

Figure 5-11 Regression Output for Total Schedule Growth and Delivery Method

5.4.3 Pricing Method

Question ten on the survey asked respondents to answer questions in regards to which pricing method was used. The three options given to them were Guaranteed Maximum Price (GMP), Unit Price, and Fixed Price. The definitions for these pricing methods follow (Means 2010).

> *Guaranteed Maximum Price (GMP) or Guaranteed Maximum cost contract:* A contract for construction wherein the contractor's compensation is stated as a combination of accountable cost plus a fee, with a guarantee by the contractor that the total compensation will be limited to a specific amount.
>
> *Unit Price or Unit Cost Contract:* A contract for construction with a stipulated cost per unit of measure for the volume of work produced.

Fixed Price Contract: A type of contract in which the contractor agrees to construct a project for an established price, agreed in advance.

5.4.3.1 Pricing Method by Delivery Method

Table 5-14 lists the total count of projects for each pricing method grouped by delivery method. One can see that the most common pricing method used for DBB projects was Unit Price, with 27 out of 32 projects using the unit price method. GMP was the most common method used for CMAR projects, with 10 out of 14 projects utilizing that pricing method. Fixed Price was the most common method used for DB projects, with 12 out of 14 projects using it.

Table 5-14 Number of Projects Using Pricing Method by Delivery Method

DBB			CMAR			DB		
Fixed Price	GMP	Unit Price	Fixed Price	GMP	Unit Price	Fixed Price	GMP	Unit Price
5	0	27	1	10	3	12	1	2

Project owners can use this pricing method information as a guide in the selection of a pricing method for chosen delivery method. There are exceptions to each, but typically each delivery method has a preferred pricing method. DBB uses Unit Price, CMAR uses GMP, and DB typically uses a Fixed Price method.

5.4.3.2 Pricing Method and Schedule Growth

The three pricing methods were evaluated to see the effects the pricing method had on schedule growth. As mentioned previously, schedule growth was calculated as:

Schedule Growth =

$$\frac{(Actual\ Project\ Duration - Planned\ Project\ Duration)}{Planned\ Project\ Duration}$$

The mean schedule growth for each of the pricing methods, as well as the standard deviations, is given in Table 5-15. GMP had the highest schedule growth, with a mean of 25.44 percent. It is worth noting that the sample size for the GMP projects was rather small, with data for only six projects. Additionally, the range of responses for schedule growth was large for those six projects. The boxplots showing the medians and interquartiles can be seen in Figure 5-12.

Table 5-15 Means and Standard Deviations for Schedule Growth by Pricing Method

	Mean	St. Dev.	Count
Fixed Price	5.65%	0.83	11
GMP	25.44%	0.64	6
Unit Price	18.33%	0.37	16

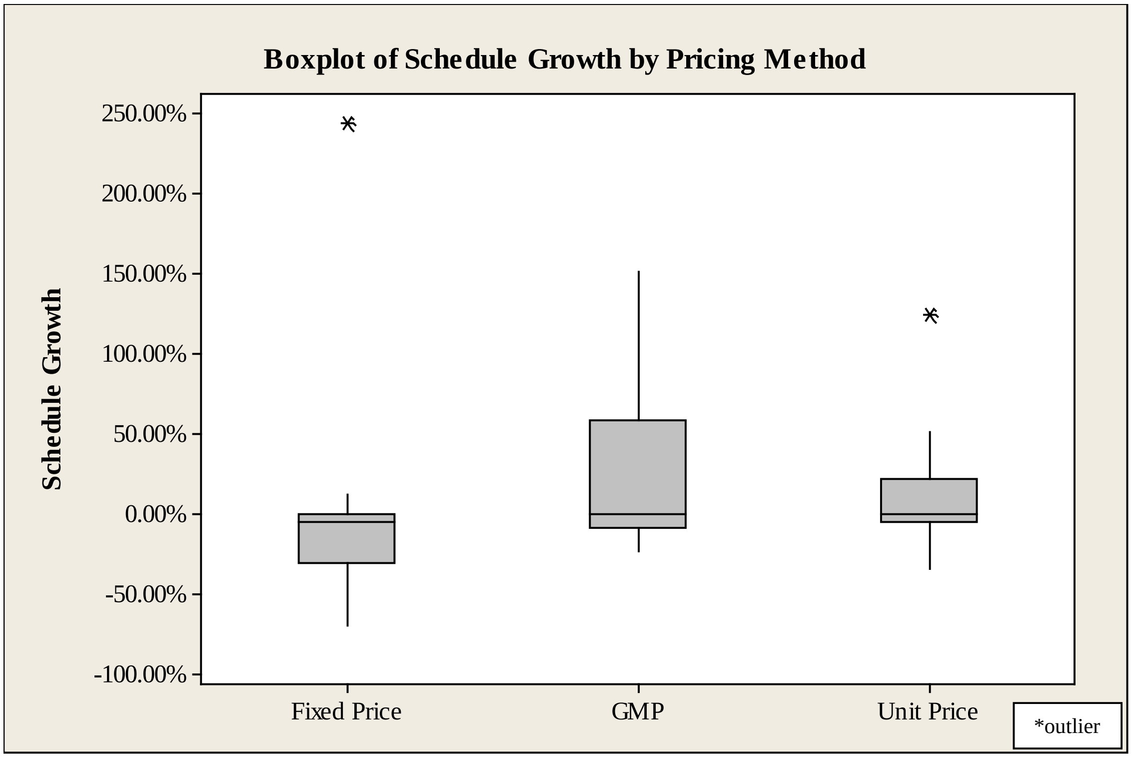


Figure 5-12 Boxplot of Schedule Growth by Pricing Method

A one-way ANOVA test was run, as well as a multivariate regression analysis, to see the effects the pricing method chosen had on schedule growth. The three pricing methods were used as the independent variables, with schedule growth being the dependent variable. Dummy variables were used for GMP and Unit Price, with Fixed Price being the omitted variable. The equation was in the form of:

$$Y = b_2x + b_1x + b_0$$

The regression was run using Excel and the resulting output can be seen in Figure 5-13. The results indicated a 19.8 percent increase in schedule growth for GMP projects over Fixed Price projects and a 5.8 percent increase in schedule growth for Unit Price projects compared to Fixed Price projects. The resulting R-squared value was low at

0.0136, indicating that only 1.4 percent of the variability in schedule growth could be explained by the pricing method selected. Also, the P-values for each of the dummy variables did not indicate statistical significance. The ANOVA portion of the output resulted in a P-value of 0.8135, indicating that there was not a statistically significant difference between the three means at the 95 percent confidence level. These means schedule growth is not related to the pricing method, for this sample.

Regression Statistics	
Multiple R	0.12
R Square	0.01
Adjusted R Square	-0.05
Standard Error	0.61
Observations	33.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2.00	0.15	0.08	0.21	0.81
Residual	30.00	11.06	0.37		
Total	32.00	11.21			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.06	0.18	0.31	0.76	-0.32	0.43	-0.32	0.43
Unit Price	0.06	0.24	0.25	0.81	-0.43	0.54	-0.43	0.54
GMP	0.20	0.31	0.64	0.53	-0.43	0.83	-0.43	0.83

Figure 5-13 Regression Output for Pricing Method and Schedule Growth

5.4.3.3 Pricing Method and Cost Growth

The three pricing methods were evaluated to see the effects the pricing method had on cost growth. As mentioned previously, cost growth was calculated as:

Cost Growth =

$$\frac{(Actual\ Total\ Project\ Cost - Budgeted\ Total\ Project\ Cost)}{Budgeted\ Total\ Project\ Cost}$$

The mean cost growth figures were calculated for each of the pricing methods; the results are found in Table 5-16, along with the standard deviations and number of projects that had sufficient information to be evaluated using pricing method and cost growth measures. It can be seen that the Fixed Price and Unit Price methods both had an average cost reduction of 6.32 percent and 7.32 percent, respectively. GMP projects had, on average, a 4.29 percent increase in cost growth.

Table 5-16 Cost Growth by Pricing Method

	Mean	St. Dev.	Count
Fixed Price	-6.32%	0.15	12
GMP	4.29%	0.11	5
Unit Price	-7.32%	0.23	12

The boxplots of the various pricing methods shown in Figure 5-14 allows one to see the medians and interquartile ranges for each of the pricing methods. The author noticed that the range of responses for Fixed Price and Unit Price were mostly in the negative direction, indicating a reduction in costs; however, the amount of reduction for Unit Price projects appears to have greater variability, as can be seen by the interquartile. Most of the cost growth for GMP projects was in a positive direction, indicating that most of the responses regarding cost growth for this pricing method showed an increase in costs.

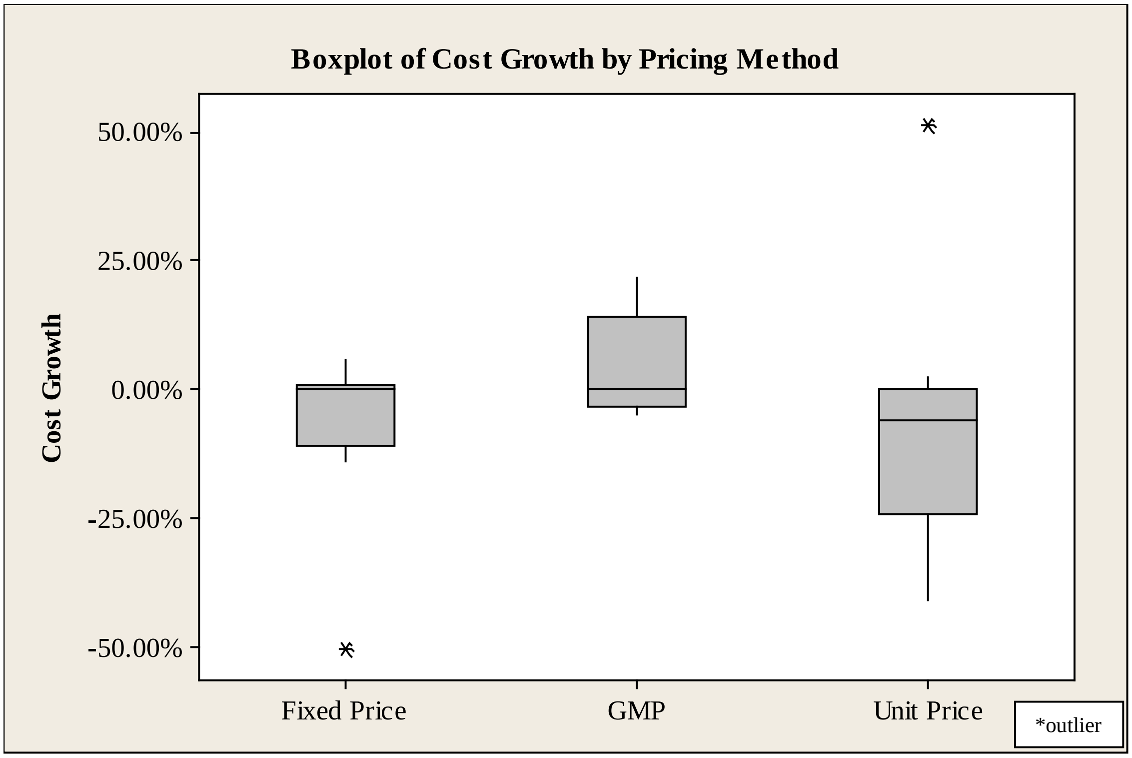


Figure 5-14 Boxplot of Cost Growth by Pricing Method

A one-way ANOVA test was run, as well as a multivariate regression analysis, to see the effects the pricing method chosen had on cost growth. The three pricing methods were used as the independent variables, with cost growth being the dependent variable. Dummy variables were used for GMP and Unit Price, with Fixed Price being the omitted variable. The equation was in the form of:

$$Y = b_2x + b_1x + b_0$$

The regression was run, and the resulting output can be seen in Figure 5-15. It can be seen from the figure that the unit price method indicated a one percent reduction in cost growth over the fixed price method, and that the GMP method indicated a 10.6 percent increase in cost growth over the fixed price method. The R-squared value tells one that 5.5 percent of the variability in cost growth can be explained by the pricing method selected; however, the P-values for the independent variables were high, indicating that there was not statistical significance. From the output given in Figure 5-15, one can also see the ANOVA table, which shows that there was not a statistically significant difference between the means of the variables at the 95 percent confidence level given the P-value of 0.4768.

Regression Statistics	
Multiple R	0.24
R Square	0.06
Adjusted R Square	-0.02
Standard Error	0.18
Observations	29.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2.00	0.05	0.03	0.76	0.48
Residual	26.00	0.88	0.03		
Total	28.00	0.93			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.06	0.05	-1.19	0.24	-0.17	0.05	-0.17	0.05
Unit Price	-0.01	0.08	-0.13	0.90	-0.16	0.14	-0.16	0.14
GMP	0.11	0.10	1.08	0.29	-0.10	0.31	-0.10	0.31

Figure 5-15 Regression Output for Pricing Method and Cost Growth

5.4.4 Change Orders

Questions 27 through 30 asked respondents to answer questions about change orders issued on the project. The questions asked for information such as the number of change orders, total dollar value of the change orders, the effects change orders had on cost and schedule, and what could have been done to avoid the changes.

5.4.4.1 Number of Change Orders

The average number of change orders for all delivery methods was calculated and found to be 14.04. The average was then calculated for each of the delivery methods and the results can be seen in Table 5-17. One project's change orders were found to be an extreme outlier and left out of the calculations due to the large scope of the project. (There were 797 change orders on the one project that entailed 248 lane miles, as well as reconstruction of several bridges and overpasses). By looking at the results in Table 5-17, one can see that DB projects had the highest number of change orders, with an average of 23.31 per project, followed by CMAR projects, with an average of 13.11 change orders per project.

Table 5-17 Average Number of Change Orders by Delivery Method

	Average Number of Change Orders
DBB (N = 24)	8.21
CMAR (N = 9)	13.11
DB (N = 16)	23.31

A one-way ANOVA test was run in order to compare if there was a statistically significant difference between the means of the three delivery methods at the 95 percent confidence level. Table 5-18 gives results showing that no significant difference between the means was found, with a P-value of 0.46.

Table 5-18 ANOVA table for Number of Change Orders by Delivery Method

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	2.67E11	2	1.33	0.79	0.460
Within groups	7.08E12	42	1.69		
Total (Corr.)	7.36E12	44			

5.4.4.2 Cost per Change Order

The average cost per change order was calculated by dividing the total dollar amount of all change orders by the number of change orders for each project. These numbers were then averaged for each delivery method, as well as all delivery methods together. The average for all projects, regardless of delivery method, was found to be $204,602 and the average cost per change order for each delivery method can be seen in Table 5-19. It can be seen that although CMAR projects did not have the highest average number of change orders, they did have the highest average cost per change order, with an average of $348,777.

Table 5-19 Average Cost per Change Order by Delivery Method

	Average Cost per Change Order
DBB (N = 21)	$ 189,441
CMAR (N = 9)	$ 348,777
DB (N = 15)	$ 123,416

5.4.4.3 Change Orders as Percent of Total Cost

The dollar value of the change orders was evaluated based on a percentage of the total project cost. This was calculated by taking the total dollar value of change orders and dividing by the total cost of the project. The average percentage for each delivery method is given in Table 5-20. Design Bid Build projects had the highest cost as a percentage of their total cost at 5.81 percent, followed by DB projects with 2.03 percent. Interesting to note, CMAR projects had the highest average cost per change order, but their total change order cost as a percentage of total project cost was the lowest at one percent.

Table 5-20 Dollar Value of Change Orders as Percentage of Total Cost

	Dollar Value of Change Orders as Percentage of Total Cost
DBB (N = 15)	5.81%
CMAR (N = 9)	1.00%
DB (N = 10)	2.03%

5.4.4.4 Change Orders as Percent of Total Schedule

Question 29 on the survey asked respondents to give the number of months the project was delayed or accelerated due to change orders. This information was then used to determine the schedule growth due to change orders. This was calculated by dividing the time of the delay or acceleration due to change orders by the total planned schedule. CMAR had the largest delays, with an average increase in schedule growth of 7.56 percent. Design Bid Build and Design Build projects were very close, with 3.88 percent and 3.40 percent increases, respectively. These numbers can be seen in Table 5-21.

Table 5-21 Average Change Order Delay as Percentage of Total Planned Schedule

	Average Change Order Delay as a Percentage of Total Planned Schedule
DBB (N = 13)	3.88%
CMAR (N = 8)	7.56%
DB (N = 9)	3.40%

5.4.4.5 Change Orders as Percent of Construction Schedule

Similarly, the average change order delay as a percentage of the planned construction schedule was calculated. This was done by dividing the length of time the project was delayed or accelerated due to change orders by the planned construction duration. Looking at Table 5-22, one can see that DBB and CMAR projects had similar delays, with an average of 6.27 percent and 6.65 percent increases in schedule growth due to change orders. DB projects had a 2.80 percent increase in schedule growth due to change orders.

Table 5-22 Average Change Order Delay as a Percentage of Construction Schedule

	Average Change Order Delay as a Percentage of Construction Schedule
DBB (N = 13)	6.27%
CMAR (N = 8)	6.65%
DB (N = 11)	2.80%

5.4.4.6 Improvements to Avoid Changes

Question 30 on the survey asked respondents to "indicate what could have been done during the phases of front end planning, design, or pre-construction to avoid these changes?" They were asked to select an option for "most important factor" that could have assisted in avoiding the change orders. Their rankings by frequency of factor selected for avoiding change orders are given in Table 5-23.

Table 5-23 Services that Could Help Avoid Change Orders (All Delivery Methods)

Services that Could Help Avoid Change Orders	Frequency
Constructability/bidability analysis	7
Risk identification and assessment	7
Design management	5
Agency coordination and estimating	3
Identification of project objectives	2
Risk mitigation	2
Site logistics planning	2
Stakeholder management	2
Value analysis/engineering	2
Construction phase sequencing	1
Cost estimating	1
Disruption avoidance planning	1
Multiple bid package planning	1
Schedule development	1

(N = 38)

The rankings for each of the delivery methods were calculated in similar fashion and can be seen in Table 5-24. The author noted that, "constructability/bidability analysis" ranked high for both DBB and DB projects, but was never selected for CMAR projects. "Budget management," "building information modeling," and "small, women, and minority owned business enterprise participation" all ranked low in importance across all three delivery methods and were never selected.

Table 5-24 Services that Could Help Avoid Change Orders (By Delivery Method)

DBB	
Constructability/bidability analysis	4
Design management	2
Identification of project objectives	2
Risk mitigation	2
Agency coordination and estimating	1
Construction phase sequencing	1
Disruption avoidance planning	1
Real-time cost feedback	1
Risk identification and assessment	1
Site logistics planning	1
Stakeholder management	1
Value analysis/engineering	1

(N = 18)

CMAR	
Agency coordination and estimating	1
Cost estimating	1
Design management	1
Multiple bid package planning	1
Risk identification and assessment	1
Site logistics planning	1
Value analysis/engineering	1

(N = 7)

DB	
Risk identification and assessment	5
Constructability/bidability analysis	3
Design management	2
Agency coordination and estimating	1
Schedule development	1
Stakeholder management	1

(N = 13)

5.5 Project Delivery Method Selection

The following sections deal with the motivation for the selection of delivery methods. The owners' perceptions of project delivery methods are also analyzed.

5.5.1 Factors Influencing Selection of Delivery Method

Question six in the survey used a seven point Likert scale and asked the respondents to rate each factor given by the importance it held for the selection of the delivery method used on the project. The scale was from one to seven, with one indicating "least importance" and seven indicating "greatest importance." The factors they were asked to rate are given in Table 5-25 and a sample of the online survey can be seen in Appendix I.

Table 5-25 Question Six - Factors Rated for Importance in Delivery Method Selection

Cost of project
Urgency of project
Opportunity for innovation
Best method for risk allocation
Required by owner or regulatory agency
Regulatory initiatives
Lack of in-house resources
Quality concerns
Multiple stakeholder coordination
Other

The factors affecting the selection of delivery method were evaluated as a whole, meaning all delivery methods together, as well as separately (i.e., by Design Bid Build, CMAR, Design Build).

5.5.1.1 All Project Delivery Methods

When all delivery methods were analyzed together, the mean, standard deviation, median, and mode were computed. Table 5-26 shows that the factor with the highest mean, median, and mode was “urgency of project”, followed closely by “cost of project” and “best method for risk allocation”. This suggests that when looking at all the projects together, these factors had the most influence on the delivery method selected.

Table 5-26 Factors Influencing Delivery Method Selection

	Mean	St. Dev.	Median	Mode
Urgency of project	5.06	1.61	5.00	7.00
Cost of project	4.96	1.68	5.00	5.00
Best method for risk allocation	4.69	1.63	5.00	6.00
Quality concerns	4.38	1.94	5.00	6.00
Multiple stakeholder coordination	4.15	2.01	4.00	6.00
Opportunity for innovation	4.15	1.82	4.00	5.00
Required by owner or regulatory agency	3.65	2.30	4.00	1.00
Lack of in-house resources	3.43	1.97	3.00	1.00
Regulatory initiatives	3.11	2.00	2.00	1.00

(N = 63)

A boxplot of all the factors can be seen in Figure 5-16 with the medians and interquartile range. This gives one some idea as to where the majority of respondents rated each factor when considering its influence on the selection of delivery method. For example, one can see that 50 percent of respondents rated “urgency of project” between a four and seven, with the median response being a five. It can be seen when looking at “regulatory initiatives” that many respondents gave it a low score, resulting in a low median; however, the range of responses is larger, with 50 percent of responses between one and five.

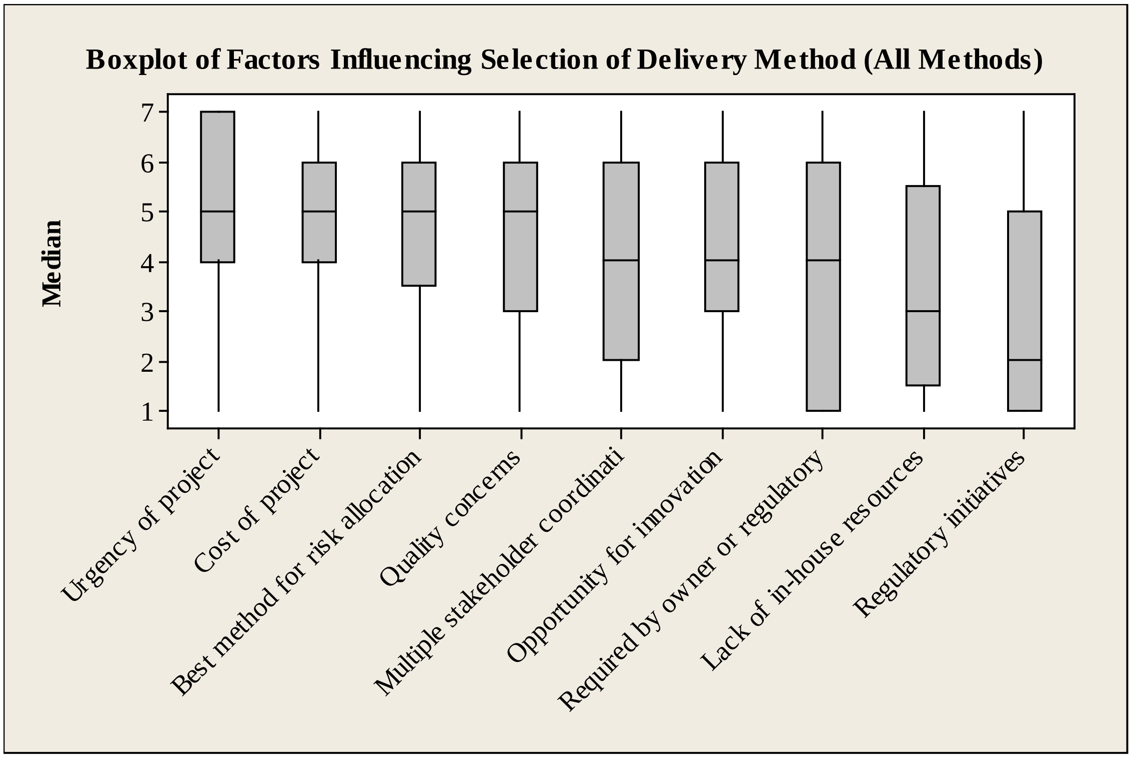


Figure 5-16 Boxplot of Factors Influencing Selection of Delivery Method
(N = 63)

A one-way ANOVA test was computed to compare the means between the factors affecting the selection of delivery method. Table 5-27 provides a summary of results for the ANOVA test. A low P-value of 0.00 was found, implying that there is a statistically significant difference between the means of the nine variables at the 95 percent confidence level. In other words, at least one factor influencing the selection of delivery method was statistically different from at least one of the others.

Table 5-27 ANOVA Table for Factors Influencing Delivery Method Selection

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	242.23	8	30.28	7.89	0.00
Within groups	2248.17	586	3.84		
Total (Corr.)	2490.4	594			

(N = 63)

The graph of means and 95 percent Least Significant Difference (LSD) in Figure 5-17 helps one to see which factors were significantly different from one another. The graph gives the means with the upper and lower limit calculated by Fisher's least significant difference. Two factors that are significantly different from one another will not have overlapping intervals. From this, one can see that "urgency of project", "cost of project", and "best method for risk allocation" are significantly different from "required by owner", "lack of in-house resources", and "regulatory initiatives". It also can be seen that "quality concerns" and "multiple stakeholder coordination" are significantly different from "lack of in-house resources" and "regulatory initiatives" and so forth. A statistical difference means that decisions to choose a specific delivery method are much more heavily based on factors such as project schedule, cost, and risk allocation than any other factors. Many of the means were statistically significant from one another for factors influencing the selection of delivery method. By learning what influences project owners to select a delivery method, an owner can align specific project goals with the delivery method most likely to help achieve those goals. Project participants can also understand better what factors they should be considering and the priority of each factor in selecting a delivery method.

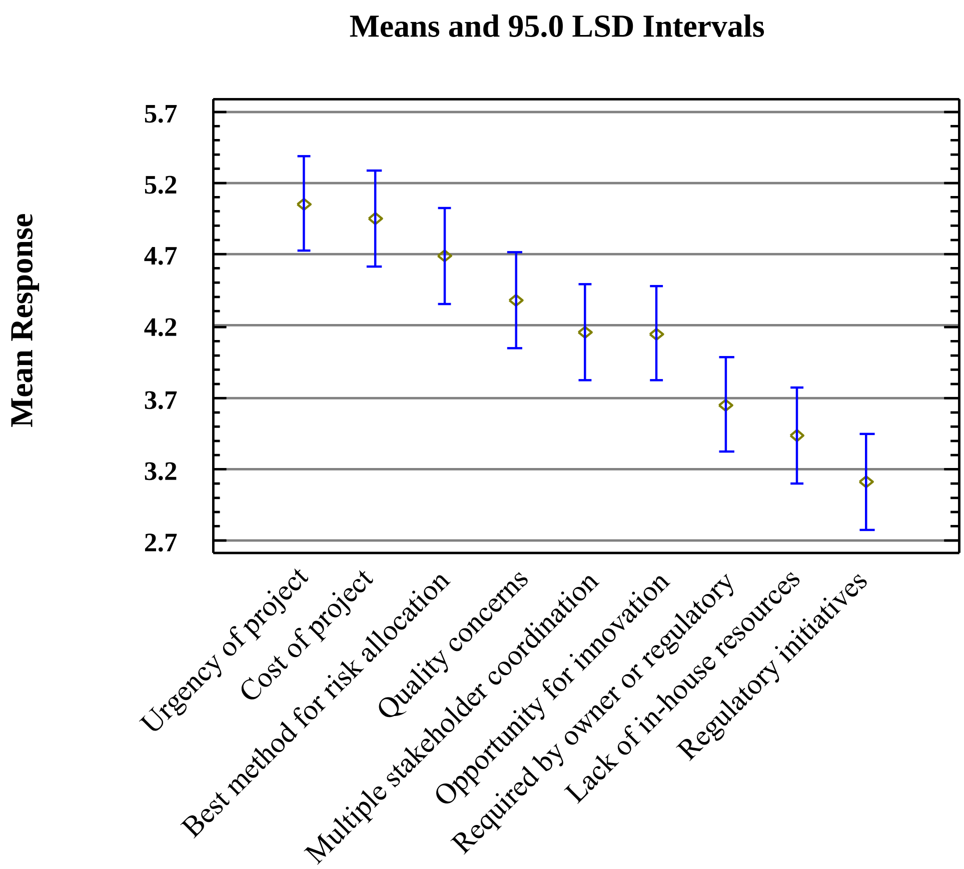


Figure 5-17 Means and 95 percent LSD Intervals for All Delivery Methods
(N = 63)

5.5.1.2 Design Bid Build Project Delivery Method

Delivery method selection analyses were performed for each of the delivery methods (i.e., CMAR, DBB, and DB). The highest rated factors for Design Bid Build were “cost of project”, “urgency of project”, and “required by owner”. The means, standard deviation, median, and mode are given in Table 5-28. The highest mean of 4.97 was for “cost of project” which was not surprising in this case, as the nature of DBB projects lends itself to producing a lower cost project due to low cost bidding. It was expected that this would be an important factor for those selecting DBB. In addition, the author saw that "required by owner" or "regulatory agency" was rated high for DBB projects, with a mean of 4.73. This was also expected, since many state DOTs and regulatory agencies require the use of this delivery method.

Table 5-28 Means, Standard Deviation, Median, and Mode for DBB Projects

	Mean	St. Dev	Median	Mode
Cost of project	4.97	1.87	5.00	6.00
Urgency of project	4.87	1.65	5.00	4.00
Required by owner or regulatory agency	4.73	2.18	5.00	7.00
Multiple stakeholder coordination	4.50	2.01	5.00	6.00
Best method for risk allocation	4.37	1.61	4.00	4.00
Quality concerns	4.37	1.96	5.00	6.00
Regulatory initiatives	3.83	1.89	4.00	4.00
Opportunity for innovation	3.73	1.64	4.00	3.00
Lack of in-house resources	3.52	2.11	3.00	1.00

(N = 31)

The boxplot in Figure 5-18 shows the medians and interquartile ranges for the factors influencing DBB projects. One can see that "lack of in-house resources" had a large range for the interquartile, with 50 percent of respondents answering between two and six.

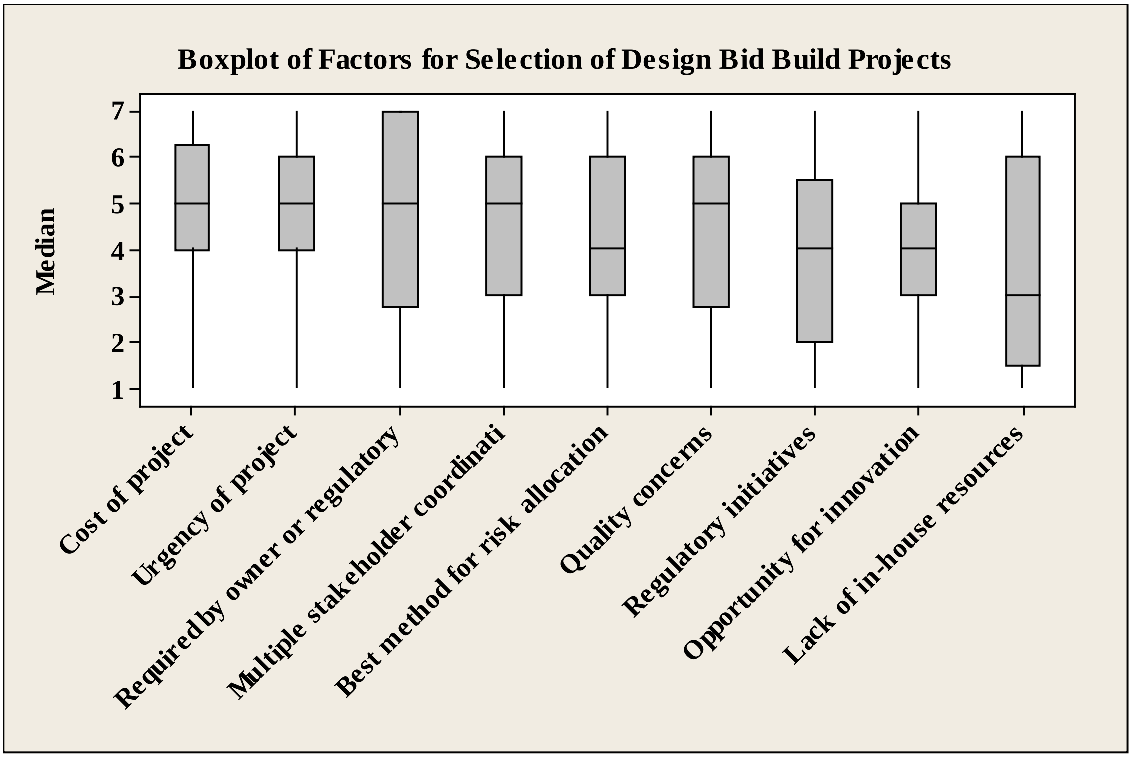


Figure 5-18 Factors for DBB Projects
(N = 31)

An ANOVA test was conducted for the DBB sub-sample. Table 5-29 shows that the P-value of 0.024 was less than 0.05, indicating that at least one of the means of the factors was significantly different from another at the 95.0 percent confidence level.

Table 5-29 ANOVA Table for Factors Influencing DBB Projects

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	64.22	8	8.03	2.25	0.024
Within groups	927.0	260	3.56		
Total (Corr.)	991.21	268			

(N = 31)

The means and 95.0 percent LSD Intervals demonstrated in Figure 5-19 shows which factors had means that were statistically different. There was slightly more overlap between the intervals than there was for the CMAR projects; however, one can still see that the top four factors (cost of project, urgency of project, required by owner or regulatory, and multiple stakeholder coordination) were statistically different from lack of in-house resources. Additionally, one can see that "cost of project" and "urgency of project" were statistically different from "regulatory initiatives", "opportunity for innovation", and "lack of in-house resources".

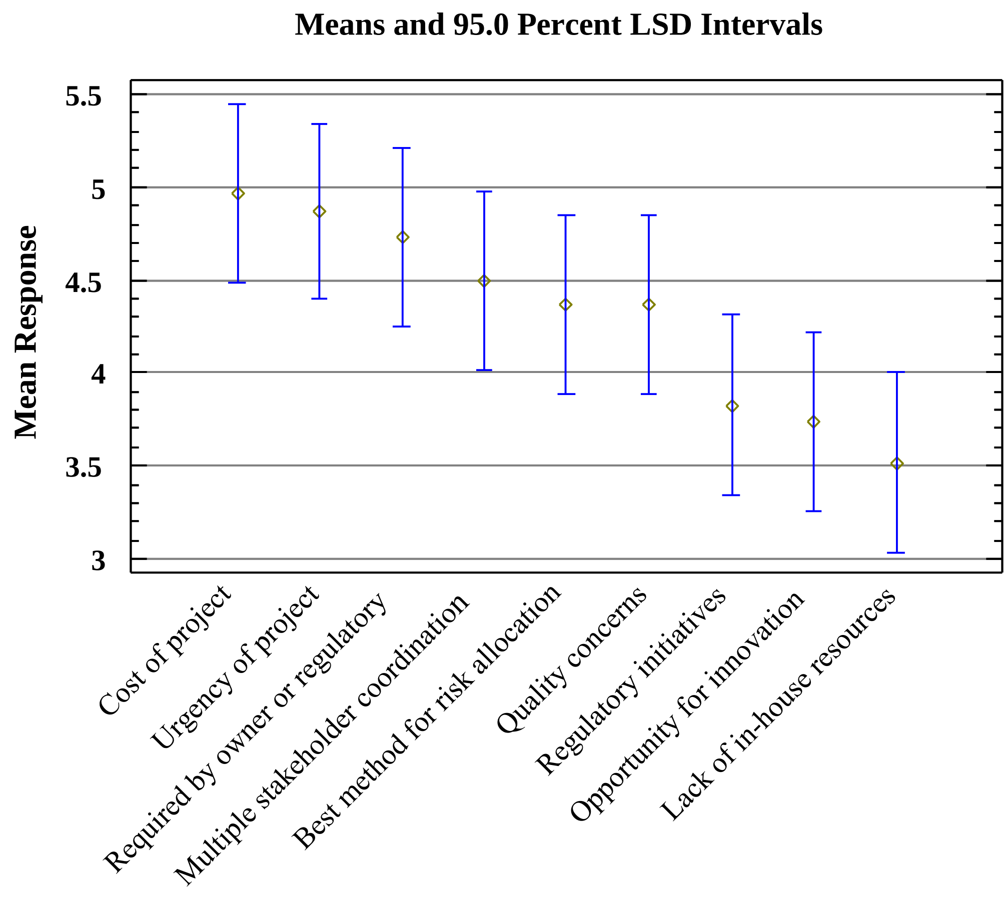


Figure 5-19 Means and 95 percent LSD Intervals for DBB Factors
(N = 31)

Selection of DBB for project delivery is highly motivated by the objective of controlling costs. The urgency of the project is also a large contributor to the selection of DBB. DBB is often still required to be used on public projects; therefore, it is not surprising that one of the top three contributors to selecting DBB to deliver a project is a requirement by the owner or regulatory agency.

5.5.1.3 CMAR Project Delivery Method

The means, standard deviation, median, and mode for each of the factors affecting the selection of delivery method for only CMAR projects is shown in Table 5-30. The factors with the highest mean, median, and mode were "best method for risk allocation", "cost of project", and "quality concerns". When comparing these factors to those that were rated highest for all the projects, one can see that "best method for risk allocation" has an increased mean. This is something one may expect to see for CMAR projects due to their ability to spread risks across multiple stakeholders. The most frequent selection mode for this factor was a seven, indicating the "greatest importance" for selecting the delivery method chosen.

Table 5-30 Mean, Standard Deviation, Median, and Mode for CMAR Projects

	Mean	St. Dev.	Median	Mode
Best method for risk allocation	5.21	2.08	6.00	7.00
Cost of project	5.00	1.60	5.00	5.00
Quality concerns	4.80	2.01	6.00	6.00
Opportunity for innovation	4.07	2.43	5.00	1.00
Multiple stakeholder coordination	4.07	2.25	4.00	6.00
Urgency of project	3.93	2.05	4.00	4.00
Lack of in-house resources	2.60	1.80	2.00	1.00
Required by owner or regulatory agency	2.20	1.74	1.00	1.00
Regulatory initiatives	2.00	1.77	1.00	1.00

(N = 15)

When looking at the boxplot of factors for CMAR projects, one can see that although many respondents gave "best method for risk allocation" a high rating (median of six), there was a large range of responses, with 50 percent of responses between three and seven. Also, when one looks at “regulatory initiatives”, it can be seen that almost all responses within the CMAR group gave this a low importance rating of between one and two. There were, however, two respondents that gave this a high rating for importance in the selection process. The medians and boxplots for each of the factors are shown in Figure 5-20.

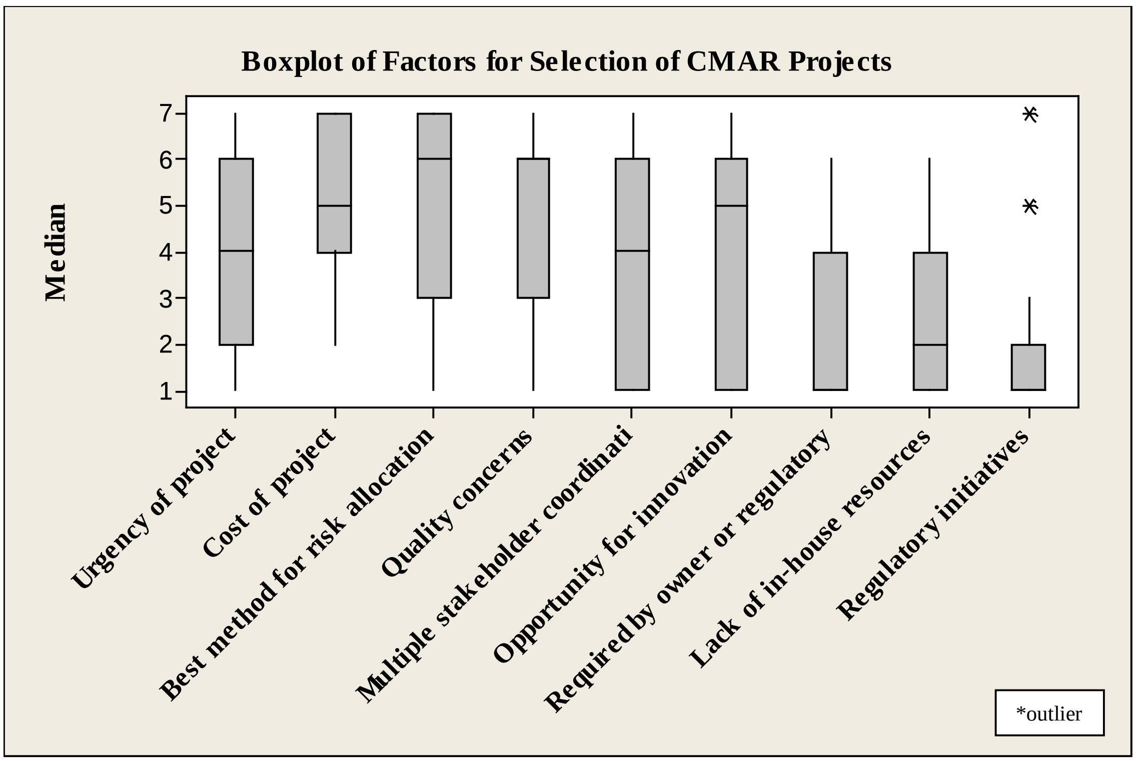


Figure 5-20 Boxplot Factors for Selection of CMAR Projects
(N = 15)

An ANOVA test for the CMAR projects sub-sample was performed, and statistical significance was again found between the means for the factors influencing the selection of delivery method. Table 5-31 shows the P-value from the test was 0.00, implying that there are statistically significant differences between the means of the nine variables at the 95.0 percent confidence level.

Table 5-31 ANOVA Table for Factors Influencing CMAR Projects

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	175.32	8	21.91	5.55	0.00
Within groups	493.56	125	3.95		
Total (Corr.)	668.87	133			

(N = 15)

The means and 95 percent LSD Intervals allow one to see that there were several statistically significant differences when comparing two factors to one another. Namely, the top six factors were significantly different from the lower three factors shown on Figure 5-21.

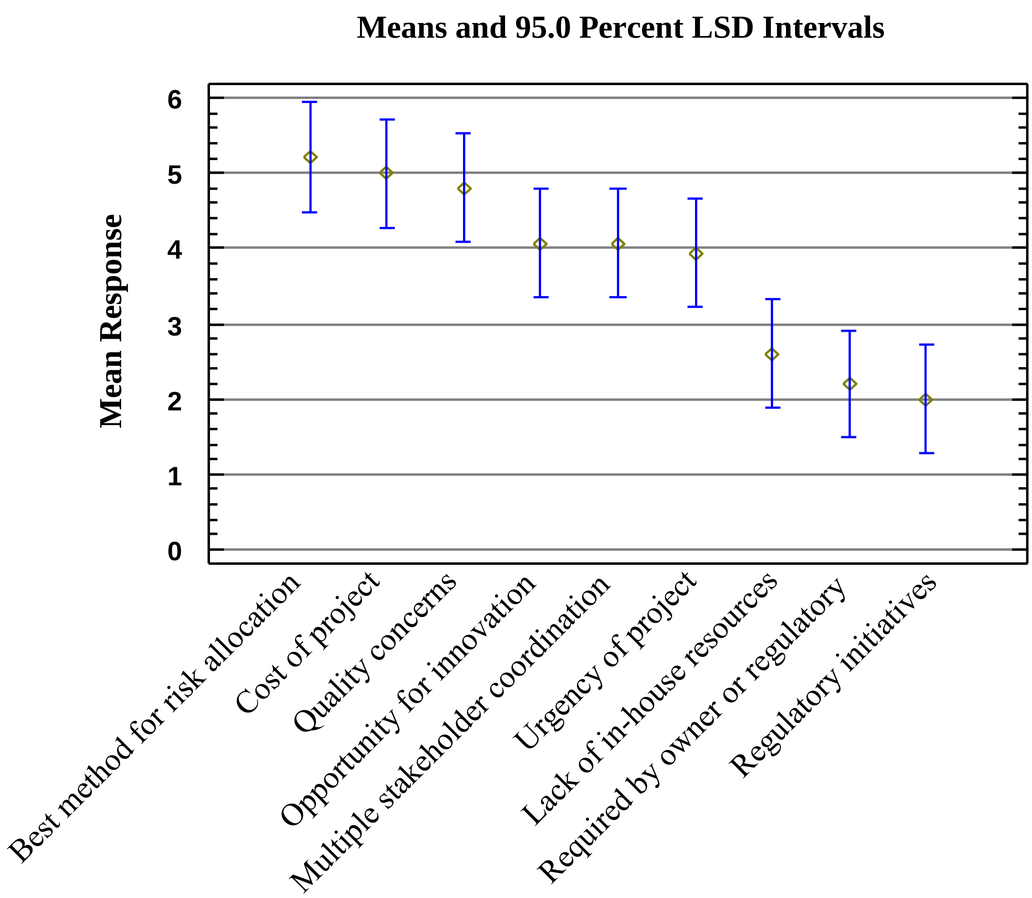


Figure 5-21 Means and 95 percent LSD Intervals for CMAR Projects
(N = 15)

The factors influencing the selection of CMAR as a delivery method help owners to understand more about using CMAR to deliver a project. CMAR can be used when risk allocation is a high priority. The selection of CMAR is also motivated highly by the objectives of controlling costs and quality. The project urgency or schedule does not seem to be a large contributor to the selection of CMAR.

5.5.1.4 Design Build Projects Delivery Method

When looking at DB projects, the author noticed that "urgency of project" had a high mean of 6.12. This could be expected for DB projects, since they are able to overlap construction and design on the project. Also, "best method for risk allocation" seemed to have a lot of influence over the selection of DB, which could also be expected because of the ability to transfer some of the risk to the DB contractor as compared to traditional DBB projects. The mean for "best method for risk allocation" was 4.71. "Cost of project" seemed to have a high importance for all three delivery method selection processes. The resulting means can be seen in Table 5-32.

Table 5-32 Means, Standard Deviation, Median, and Mode for DB Projects

	Mean	St. Dev	Median	Mode
Urgency of project	6.12	0.99	4.00	7.00
Cost of project	4.76	1.64	5.00	5.00
Best method for risk allocation	4.71	1.69	6.00	6.00
Opportunity for innovation	4.35	1.90	5.00	6.00
Quality concerns	3.82	2.01	4.00	4.00
Lack of in-house resources	3.65	1.97	5.00	1.00
Multiple stakeholder coordination	3.47	2.15	4.00	1.00
Required by owner or regulatory agency	2.76	2.14	1.00	1.00
Regulatory initiatives	2.53	1.84	1.00	1.00

(N = 17)

Figure 5-22 shows the medians for each of the factors, as well as the interquartile range. “Required by owner” had a large range for the interquartile, with a low median of one. This factor seemed to be either of no importance for selecting the delivery method or of high importance. This is not entirely unexpected due to the nature of the question. Either the owner organization requires the method and it is important or they do not and it would likely not hold sway in the selection process.

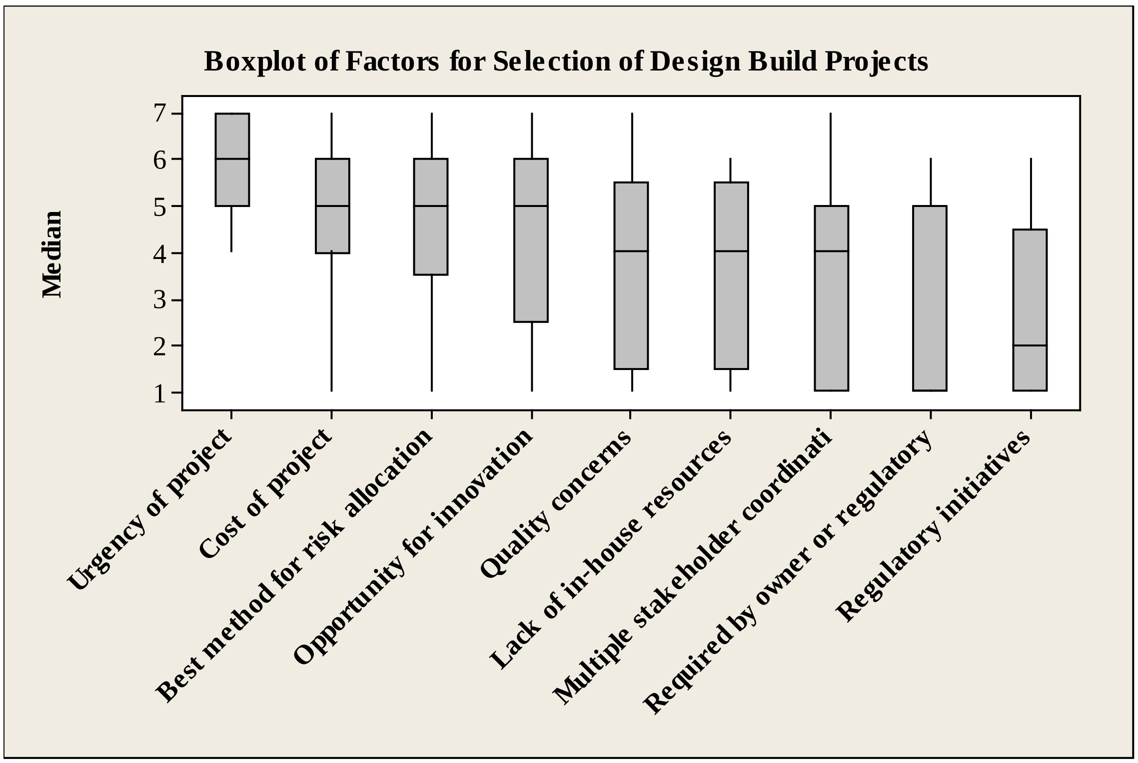


Figure 5-22 Boxplot of Factors for DB Projects
(N = 17)

The same ANOVA test was run for the DB projects sub-sample and the results showed that there was statistical significance between the nine means at the 95 percent confidence level with a P-value of 0.00 as given in Table 5-33.

Table 5-33 ANOVA Table for Factors Influencing DB Projects

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	166.82	8	20.85	6.13	0.000
Within groups	490.12	144	3.40		
Total (Corr.)	656.94	152			

(N = 17)

The means and 95 percent LSD Intervals in Figure 5-23 show that "urgency of project" had a high mean and was statistically different from all other means. In addition, "cost of project", "risk allocation", and "opportunity for innovation" were significantly different from the two factors with the lowest means ("required by owner" and "regulatory initiatives").

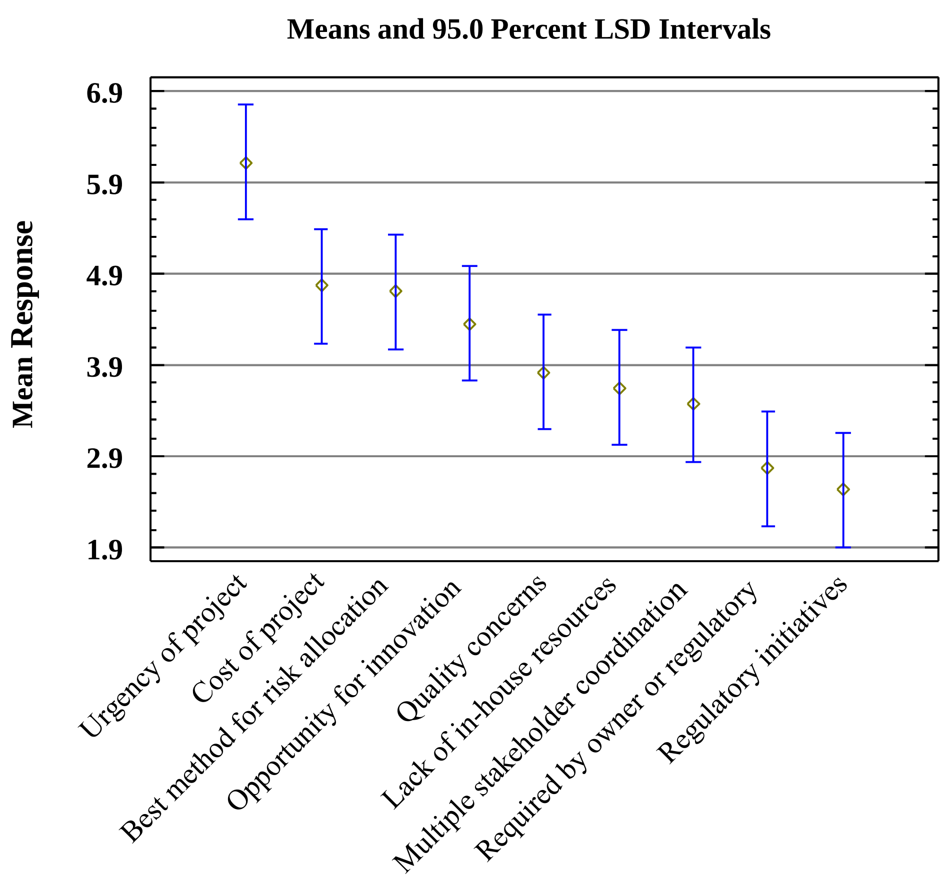


Figure 5-23 Means and 95 percent LSD Intervals for DB Projects
(N = 17)

The selection of the DB delivery method is highly motivated by the objective to deliver the project in a shorter period of time. The cost of project is also a large contributor to the selection of this delivery method. This indicates that owners using DB to deliver projects feel that they are not sacrificing cost for an accelerated schedule. Similarly to CMAR projects, DB projects are seen to be a better mechanism of allocating risks.

5.5.2 Delivery Method Selection by Cost and Schedule

Part of the hypothesis for project delivery selection asserted that there is a preference among national project owners as to what delivery methods are most effective at reducing costs and controlling schedule. This preference was measured and a comparison is made in this section.

An ANOVA test was performed for the criteria "cost of project" and "urgency of project". The variance of means for each delivery method within the criteria was analyzed. The analysis of "cost of project" by delivery method resulted in the summary statistics found in Table 5-34.

Table 5-34 Method Selection on Cost of Project: Summary Statistics

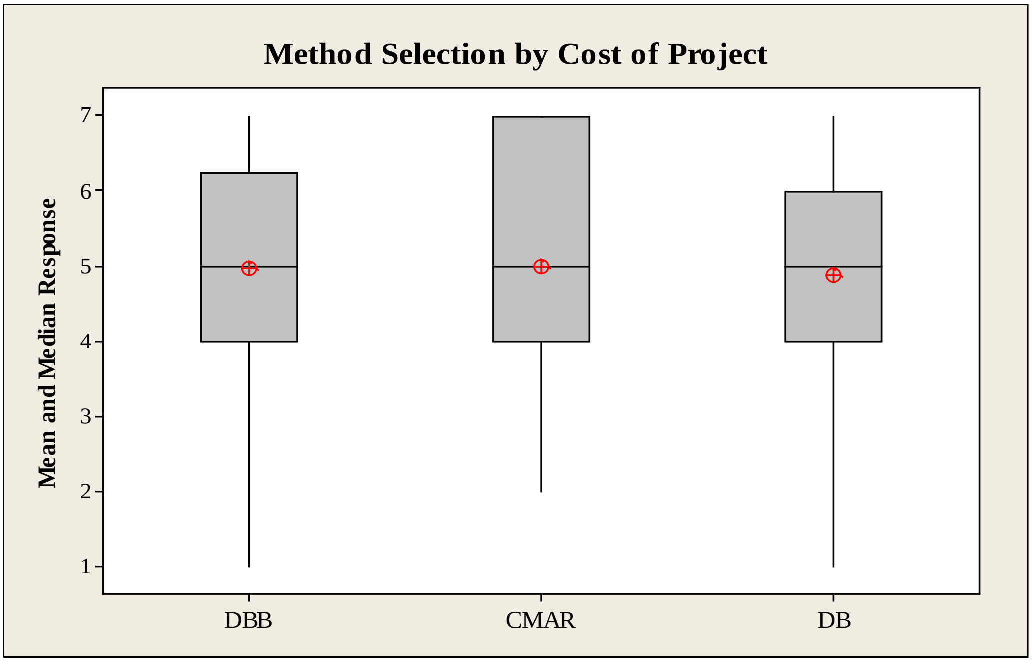
	Count	*Mean*	*Standard deviation*	*Coeff. of variation*	*Minimum*	*Maximum*	*Range*
DBB	31	5.03	1.87	37.17%	1.0	7.0	6.0
CMAR	15	5.0	1.60	32.07%	2.0	7.0	5.0
DB	17	4.76	1.64	34.43%	1.0	7.0	6.0
Total	63	4.95	1.73	34.87%	1.0	7.0	6.0

In addition to the summary statistics, Table 5-35 provides the LSD intervals that would indicate if there is a significant difference in the means. The observation that the LSD intervals for "cost of project" are overlapping, and the closeness of the means for each delivery type, show that the overall perception is that there is not a significant difference between the cost implementations of the delivery methods. The delivery methods of DBB and CMAR particularly show no difference, where DB projects were perceived to cost more. This observation does not reach a level of significance at the 95 percent confidence interval, as it can be observed that the LSD Intervals overlap.

Table 5-35 Method Selection Cost of Project: Table of Means with 95 percent LSD Intervals

			Stnd. error		
	Count	*Mean*	*(pooled s)*	*Lower limit*	*Upper limit*
DBB	31	5.03	0.31	4.59	5.48
CMAR	15	5.0	0.45	4.36	5.64
DB	17	4.76	0.42	4.16	5.37
Total	63	4.95			

Table 5-35 also shows the mean for each column of data. It shows the standard error of each mean, which is a measure of its sampling variability. The standard error is formed by dividing the pooled standard deviation by the square root of the number of observations at each level. Table 5-35 also displays an interval around each mean. The intervals currently displayed are based on Fisher's least significant difference (LSD) procedure. They are constructed in such a way that if two means are the same, their intervals will overlap 95.0 percent of the time. The means, medians, and standard deviations for the “cost of project” by delivery method are shown graphically in the box and whisker plot in Figure 5-24.



Mean (ø) and Median (|) Response

Figure 5-24 Method Selection by Cost of Project

“Urgency of project” by delivery method was also analyzed through an analysis of variance test to determine if there was a perception as to what delivery method would result in a project being completed faster. The summary of the ANOVA test, as well as a multiple range test, is provided in Table 5-36 and Table 5-37. The multiple range test is a comparison procedure to determine which means are significantly different from the others. The bottom half of the output shows the estimated difference between each pair of means. An asterisk has been placed next to the sub-sample pairs CMAR-DB and DBB-DB, indicating that these sub-samples show statistically significant differences at the 95.0 percent confidence level. The two homogenous groups (CMAR and DBB) are identified using columns of X's. This indicated that there are no statistically significant differences between the means of these two sub-samples.

Table 5-36 Method Selection for Urgency of Project: Summary Statistics

	Count	*Average*	*Standard deviation*	*Coeff. of variation*	*Minimum*	*Maximum*	*Range*
DBB	32	4.94	1.66	33.71%	1.0	7.0	6.0
CMAR	15	3.93	2.05	52.16%	1.0	7.0	6.0
DB	17	6.12	0.99	16.23%	4.0	7.0	3.0
Total	64	5.02	1.78	35.43%	1.0	7.0	6.0

Table 5-37 Method Selection for Urgency of Project: Multiple Range Tests

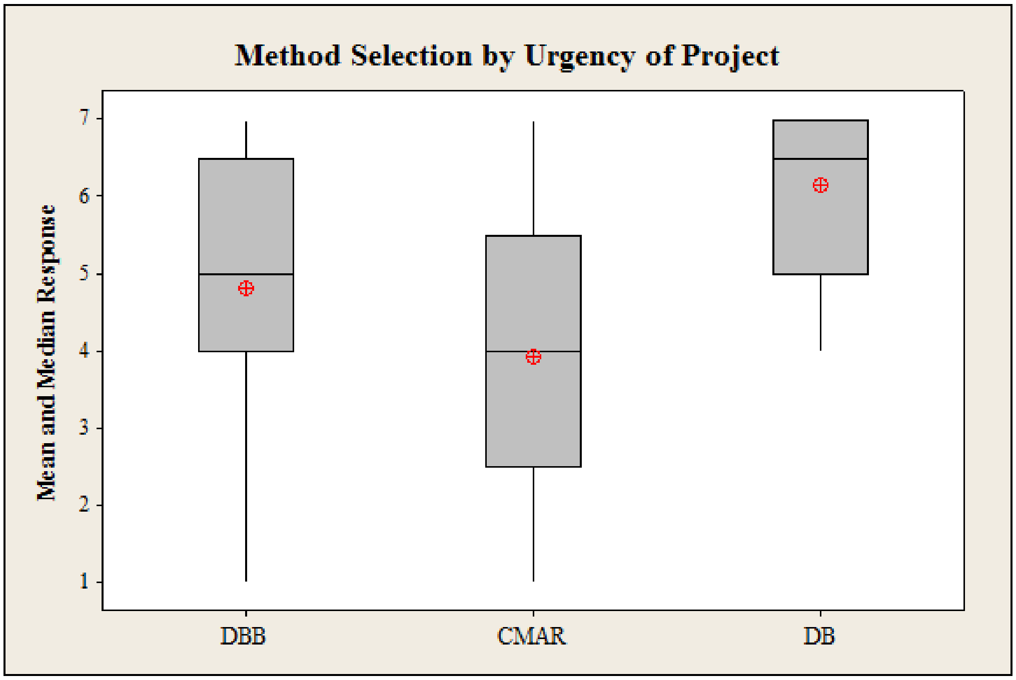
	Count	*Mean*	*Homogeneous Groups*
DBB	32	4.94	X
CMAR	15	3.93	X
DB	17	6.12	X

Method: 95.0 percent LSD

Contrast	*Sig.*	*Difference*	*+/- Limits*
CMAR - DBB		-1.00	1.02
CMAR - DB	*	-2.18	1.15
DBB - DB	*	-1.18	0.97

* denotes a statistically significant difference.

The boxplot in Figure 5-25 provides a visual representation of the means, medians, and standard deviations observed for the delivery methods analyzed in terms of the selection criteria: “urgency of project”.



Mean (ø) and Median (|) Response

Figure 5-25 Method Selection by Urgency of Project

The analysis of "urgency of project" indicates a perception that CMAR and DBB projects deliver projects slower than DB projects. The author notes that previous works have indicated that both CMAR and DB projects deliver projects faster than DBB projects. This analysis simply reports some of the primary motivations for selecting each delivery method and may not consider other motivating factors, as was highlighted previously for CMAR projects. Regardless, these are the perceptions that were observed through the analysis. In future sections, the projects are examined in terms of actual outcomes.

5.5.3 Project Delivery Method Satisfaction

Question seven of the survey asked respondents “Do you think that the chosen delivery method was the best fit for this project?” Out of the 15 CMAR projects that answered this question, 100 percent reported that the chosen delivery method was the best fit for the project. Out of the 33 DBB projects that answered, 90.91 percent reported this method was the best fit and 9.09 percent reported that another delivery method would have been a better fit. Of those who reported that another delivery method would have been better, 66.67 percent reported that CMAR would have been the best option and 33.33 percent reported that DB would have been a better choice for the project. Out of the 17 DB projects that answered this question, 88.24 percent reported that DB was the best delivery method for the project and 11.76 percent reported that it was not. Of those who stated that another delivery method would have been the best fit, 100 percent selected DBB as the best fit for the project. These results are shown in Table 5-38.

Table 5-38 Delivery Method Satisfaction

Delivery Method	N	Yes, best fit	No, not best fit	Selected Alternative
DBB	33	90.91%	9.09%	CMAR - 66.67%, DB - 33.33%
CMAR	15	100%	0%	N/A
DB	17	88.24%	11.76%	DBB - 100%

Overall, there is a high satisfaction rating for all the delivery methods. Project owners using CMAR seem to be especially satisfied with all survey participants, indicating that CMAR was the best fit. DB projects had the most project owners that felt that DB was not the best method to use, with all indicating that DBB would have been a better fit. Satisfaction can be gained using any delivery method, but the survey results indicate that the selected delivery method may not always be the best fit for the project.

6 PRE-CONSTRUCTION SERVICES AND BEST PRACTICES

Chapter Six details the results of analysis performed on survey data dealing with pre-construction, the use of industry best practices, as well as project team selection and alignment.

6.1 Pre-construction Service Activities

One objective of this research was to better understand how agencies might better perform pre-construction services. Part of the survey was dedicated to the discovery of the management practices used in the pre-construction phases and how they led to success. Twenty-one pre-construction services were identified; they are given in Table 6-1. Details of each are provided in Appendix J.

Table 6-1 Pre-Construction Service Activities

Identification of project objectives
Risk identification and assessment
Risk mitigation
Design management
Agency coordination and estimating
Constructability/bidability analysis
Value analysis/engineering
Bid packaging
Schedule development
Site logistics planning
Disruption avoidance planning
Small, women, and minority owned business enterprise participation
Construction phase sequencing
Subcontractor prequalification
Multiple bid package planning
Real-time cost feedback
Building information modeling
Total cost of ownership analysis
Cost estimating
Budget management
Stakeholder management

6.1.1 Pre-construction Elements and Delivery Method

The pre-construction elements were rated for each project based on the perception by the respondent of how well the project team performed each service. Survey responses were in Likert scale format, with "1" indicating poor and "7" indicating well. The mean response for all the projects, as well as the mean response per delivery method, is summarized in Table 6-2. Variance from the sample mean is given in Table 6-3. Positive variance shows an improvement in the objective.

Because the means were very close, a statistically significant variance of means was not obtained at the 95 percent confidence level. However, an analysis of these means and there variations from the total mean gives an indication of how well the different delivery methods are able to perform the pre-construction services.

Table 6-2 Pre-Construction Services Means

Means	Identification of project objectives	Risk identification and assessment	Risk mitigation	Design management	Agency coordination and estimating	Constructability/ bidability analysis	Value analysis/ engineering
Sample	5.94	5.31	5.13	5.26	5.24	5.37	4.98
DBB	5.92	5.08	4.84	5.35	5.54	5.36	4.81
CMAR	5.89	6.00	6.11	5.33	4.50	5.89	5.67
DB	6.00	5.29	5.00	5.00	5.15	5.00	4.77
Means	Bid packaging	Schedule development	Site logistics planning	Disruption avoidance planning	Small, women, and minority owned business enterprise participation	Construction phase sequencing	Subcontractor prequalification
Sample	5.98	5.34	5.20	5.21	5.25	5.40	5.08
DBB	6.04	5.20	5.00	5.33	5.63	5.39	5.00
CMAR	6.12	5.67	5.85	5.09	4.42	5.39	4.94
DB	5.79	5.43	5.21	5.07	5.00	5.42	5.29
Means	Multiple bid package planning	Real-time cost feedback	Building information modeling	Total cost of ownership analysis	Cost estimating	Budget management	Stakeholder management
Sample	6.01	5.39	5.24	5.15	5.15	5.38	5.13
DBB	6.00	5.12	4.88	5.17	5.38	5.21	5.00
CMAR	5.94	5.38	5.21	5.22	5.19	5.40	5.08
DB	6.08	5.92	5.92	5.08	4.67	5.73	5.38

Table 6-2 gives an indication of a delivery method's ability to influence specific pre-construction services. There is a lot of information that can be gained from this table; a few notable observations are mentioned here. Firstly, it did not seem to make a large difference as to which delivery method was used; the project means were very close in all cases. In fact, no significant difference for means was found for any group. This could show that the delivery method selected does not play a significant role in the effectiveness of a pre-construction service. Some minor observations about the table include DB and CMAR's ability to mitigate risk more effectively when compared to DBB projects. CMAR showed higher means for value analysis and engineering, and a lower means for subcontractor prequalification. Building information modeling was also more practical for DB and CMAR projects. DB projects showed a lower mean for cost estimating. Table 6-3 gives the variance from the mean for each of the pre-construction services. This table makes it easy to see the delivery methods that may perform the pre-construction services better (positive deviation from the mean) and those that may not (negative deviation from the mean).

Table 6-3 Pre-Construction Services Variance

Variance	Identification of project objectives	Risk identification and assessment	Risk mitigation	Design management	Agency coordination and estimating	Constructability/ bidability analysis	Value analysis/ engineering
DBB	-0.02	-0.23	-0.29	0.09	0.30	-0.01	-0.17
CMAR	-0.05	0.69	0.98	0.08	-0.74	0.52	0.67
DB	0.06	-0.03	-0.13	-0.26	-0.09	-0.37	-0.21

Variance	Bid packaging	Schedule development	Site logistics planning	Disruption avoidance planning	Small, women, and minority owned business enterprise participation	Construction phase sequencing	Subcontractor prequalification
DBB	0.14	-0.11	0.00	0.07	0.08	0.17	0.07
CMAR	-0.31	0.71	0.62	0.52	-0.18	0.43	0.39
DB	-0.08	-0.27	-0.50	-0.48	-0.01	-0.61	-0.59

Variance	Multiple bid package planning	Real-time cost feedback	Building information modeling	Total cost of ownership analysis	Cost estimating	Budget management	Stakeholder management
DBB	-0.49	-0.06	-0.28	0.07	0.05	0.07	-0.19
CMAR	0.89	0.47	1.05	0.47	0.25	-0.12	0.34
DB	-0.24	-0.58	-0.55	-0.33	-0.26	-0.07	0.15

Again, it should be noted that the means were not found to have a high level of statistical difference. Caution should be taken when making assumptions about results reported. This information is nonetheless valuable to at least show trends in preference.

6.1.2 Best Practices in Pre-construction Services

Survey respondents were asked to consider each of the elements of pre-construction services that were offered during the duration of the project. Participants were then asked to provide the management tools that could be best used to accomplish their pre-construction service goals.

Some pre-construction services had obvious management practices that were used to accomplish an objective. For example, in order to accomplish an effective risk identification and assessment, the most widely used practice was found to be performing a formal project risk assessment. What is important to note are the other significant contributors to successful risk identification and assessment, such as front end planning or a constructability review process. This section provides a breakdown of the best practices to accomplish common pre-construction services.

Important to note in the information in this section is the reporting of “other” management techniques used to accomplish the service. A large percentage of “other” responses represent a gap in the best practices. For example, the service of building information modeling (BIM) had most of the respondents referring to the use of computer aided software as the most used practice for achieving successful BIM programs. The definitions of most of the best practices were given earlier in Chapter Two. Each has a unique set of tools and supporting literature that have earned them the status of best practice.

Twenty-one pre-construction services were analyzed. Table 6-4 is a matrix that provides the responses of respondents. Participants were asked to report the practice that was the most effective at accomplishing the pre-construction services listed across the top of the matrix. The responses were totaled and the numbers seen in the matrix cells are the percent of respondents who felt that the best practice was the most effective to achieve the pre-construction service. Highlighted cells show that a larger percentage of respondents (over 10 percent) favored the best practice to achieve the pre-construction service. Seventeen best practices were tested. The numbers in the matrix show the effectiveness of each best practice.

Table 6-4 Best Practices for Pre-Construction Services

Best Practice \ Pre-construction Service	Identification of project objectives	Risk identification and assessment	Risk mitigation	Design management	Agency coordination and estimating	Constructability/bidability analysis	Value analysis/engineering	Bid packaging	Schedule development	Site logistics planning	Disruption avoidance planning	Small, women, and minority business participation	Construction phase sequencing	Subcontractor prequalification	Multiple bid package planning	Real-time cost feedback	Building information modeling	Total cost of ownership analysis	Cost estimating	Budget management	Stakeholder management	AVERAGE
Alignment of project participants	18	6	9	18	24	3	0	8	4	0	4	14	0	5	6	5	13	4	4	4	28	8.43
Benchmarking of other projects	9	3	0	3	3	3	0	0	11	0	4	5	4	10	0	0	0	4	4	4	0	3.19
Change management process	3	3	6	3	3	0	0	0	7	0	28	0	0	0	0	0	0	0	4	17	3	3.67
Constructability	3	10	3	9	0	53	7	8	7	12	8	5	42	0	12	0	7	0	15	0	0	9.57
Disputes prevention and resolution	3	3	6	6	3	7	0	0	0	4	24	0	4	5	0	10	0	0	0	4	0	3.76
Front end planning	33	6	6	15	14	10	4	24	25	32	8	0	12	0	12	5	13	8	11	4	14	12.19
Use of lessons learned system	3	6	12	6	0	3	4	8	14	16	4	0	4	14	18	5	7	0	7	8	3	6.76
Materials management	0	0	0	0	0	0	0	4	0	0	0	0	8	0	0	5	0	0	0	0	0	0.81
Partnering	9	3	6	6	17	3	4	0	0	4	4	24	4	14	6	5	0	0	0	0	24	6.33
Planning for startup	0	0	0	0	7	3	7	16	21	16	8	10	4	10	24	5	20	8	4	4	0	7.95
Project risk assessment	3	55	38	0	0	3	4	8	0	8	4	0	0	5	0	5	0	0	0	0	0	6.33
Quality management techniques	6	0	0	9	7	3	0	8	7	0	0	5	4	5	12	20	13	0	15	17	7	6.57
Team building	3	3	3	9	7	0	0	8	0	0	0	24	0	14	0	5	0	0	4	4	17	4.81
Zero accidents techniques	0	0	0	0	0	0	0	0	0	4	4	0	0	5	0	0	0	0	0	0	0	0.62
Sustainable design and construction	6	0	3	3	3	0	11	0	4	4	0	0	12	0	0	5	0	13	4	13	0	3.86
Value engineering	0	0	3	9	7	3	59	4	0	0	0	0	0	0	0	10	0	8	11	4	0	5.62
Life cycle costing	0	0	0	3	3	0	0	0	0	0	0	0	4	0	0	5	20	54	15	13	0	5.57
Other	0	0	3	0	0	3	0	4	0	0	0	14	0	14	12	10	7	0	4	4	3	3.71

Scale from least to most beneficial

Each of the pre-construction services given is not discussed in detail. Only some of the findings are discussed here. One example of pre-construction services discussed further is the identification of project objectives. Transportation projects, like all projects, need to identify specific scope or project objectives. Early in the feasibility and concept stages of the project life cycle, these objectives may be very vague. As a project progresses through the life cycle, the scope should become more defined. A pre-construction service is of great importance in helping an owner identify these objectives. Figure 6-1 shows the management practices used on the sample projects to deliver this pre-construction service.

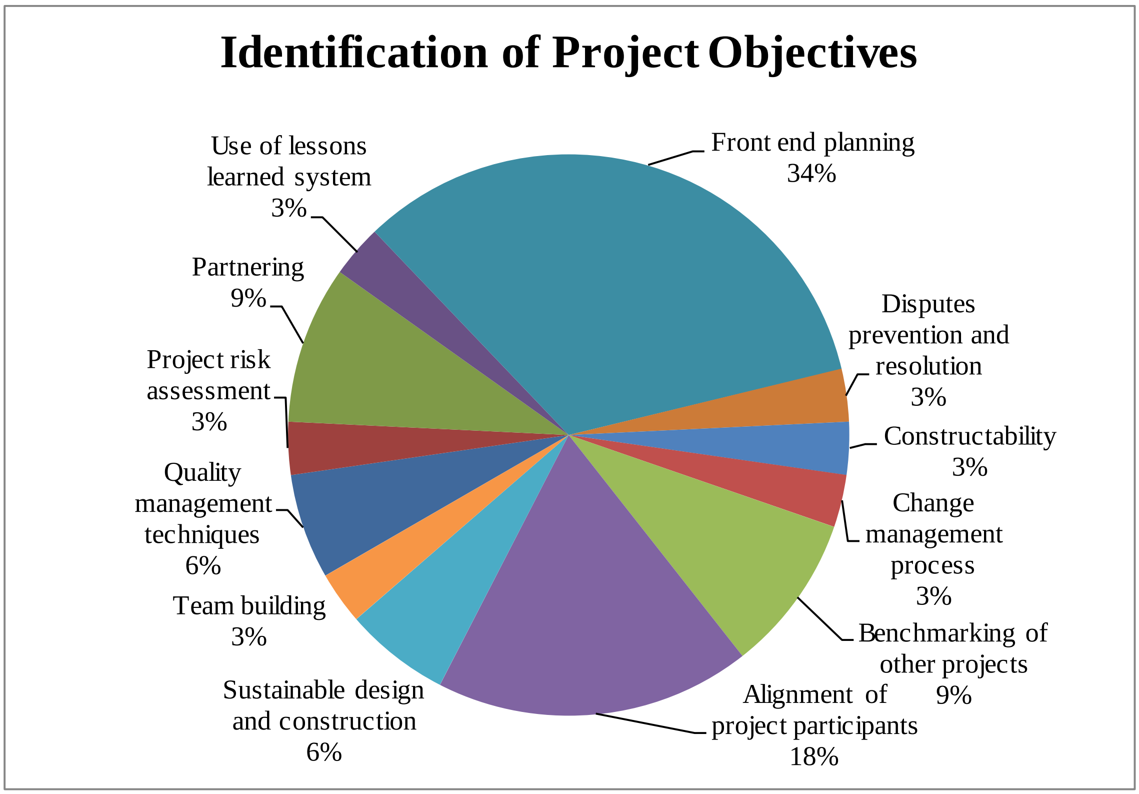


Figure 6-1 Identification of Project Objectives by Project

One practice that stands out as especially effective is the use of front end planning. A formal front end planning program defines the project scope early in the project. Additionally, alignment of project participants can get everyone "on the same page" so each project objective can be identified.

Inherent in any project is the element of risk. Project owners often make big decisions based on little information. To minimize risk, one pre-construction service that can be obtained is a risk identification and assessment. In Figure 6-2, a pie chart shows the reported management practices that could best identify and assess risk.

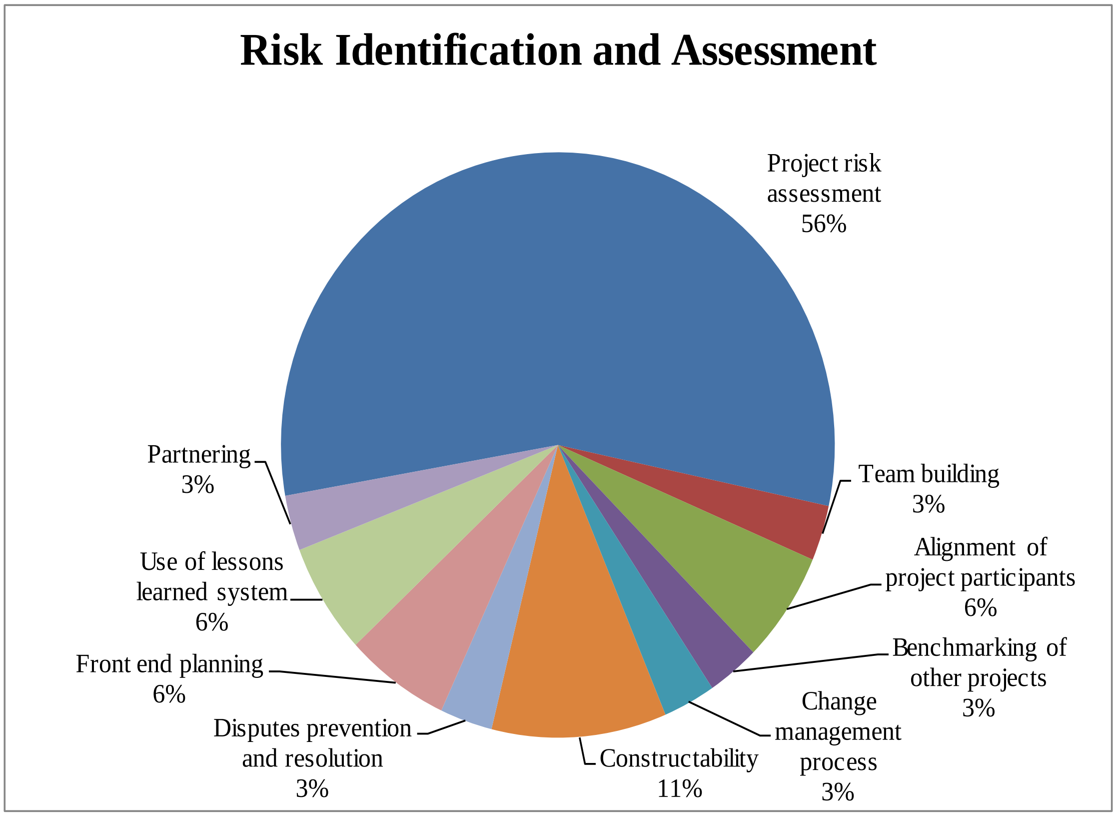


Figure 6-2 Risk Identification and Assessment

An obvious tool that was used was a formal project risk assessment program. The tools used in the project risk assessment can act as a checklist to help identify what the unknowns in a project are. Alignment of project participants, constructability, and a front end planning process was also widely used to identify risk.

Closely related to risk identification and assessment is risk mitigation. Risk mitigation is the next step in a project risk assessment. This is the action that comes after identification of possible risks. Figure 6-3 shows the practices used to mitigate risk.

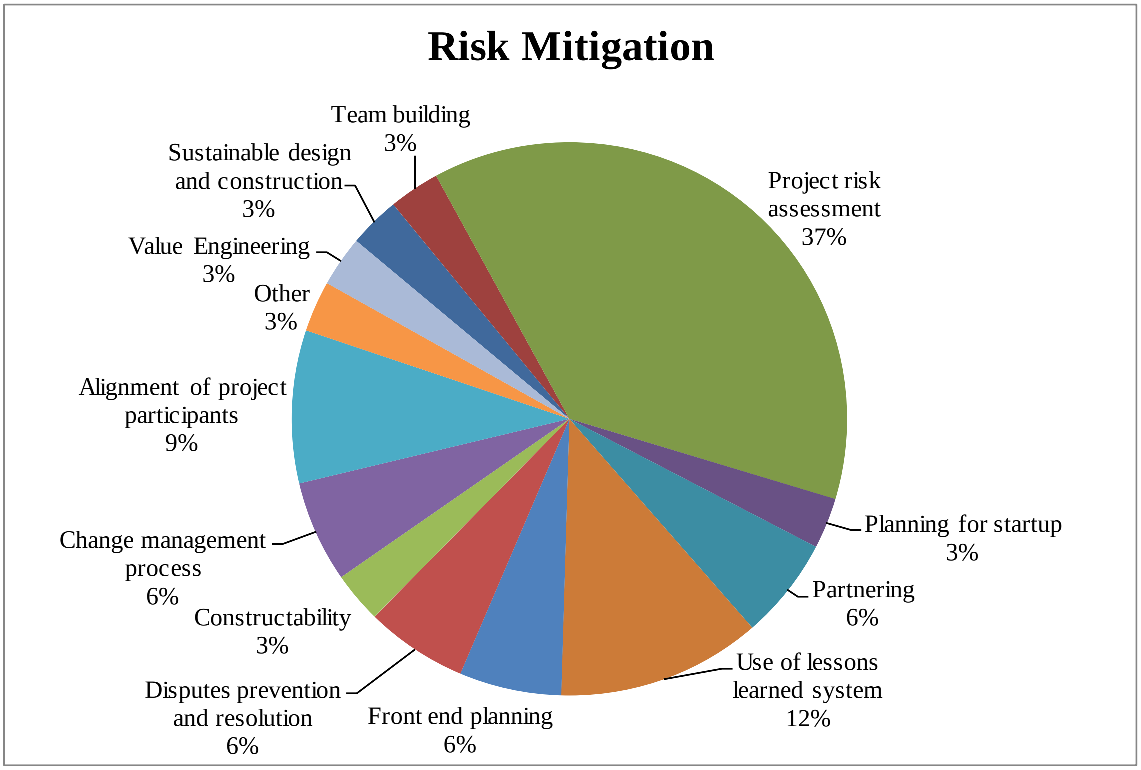


Figure 6-3 Risk Mitigation

The project risk assessment and front end planning practices were again identified, but a use of a lessons learned system is also helpful to understand how risks similar to the ones identified have been mitigated in the past.

Design management is a process in which many project stakeholders need to coordinate to define the scope in great detail. It takes a well-managed team to bring together a completed design. Figure 6-4 provides the best practices for achieving the management of the design.

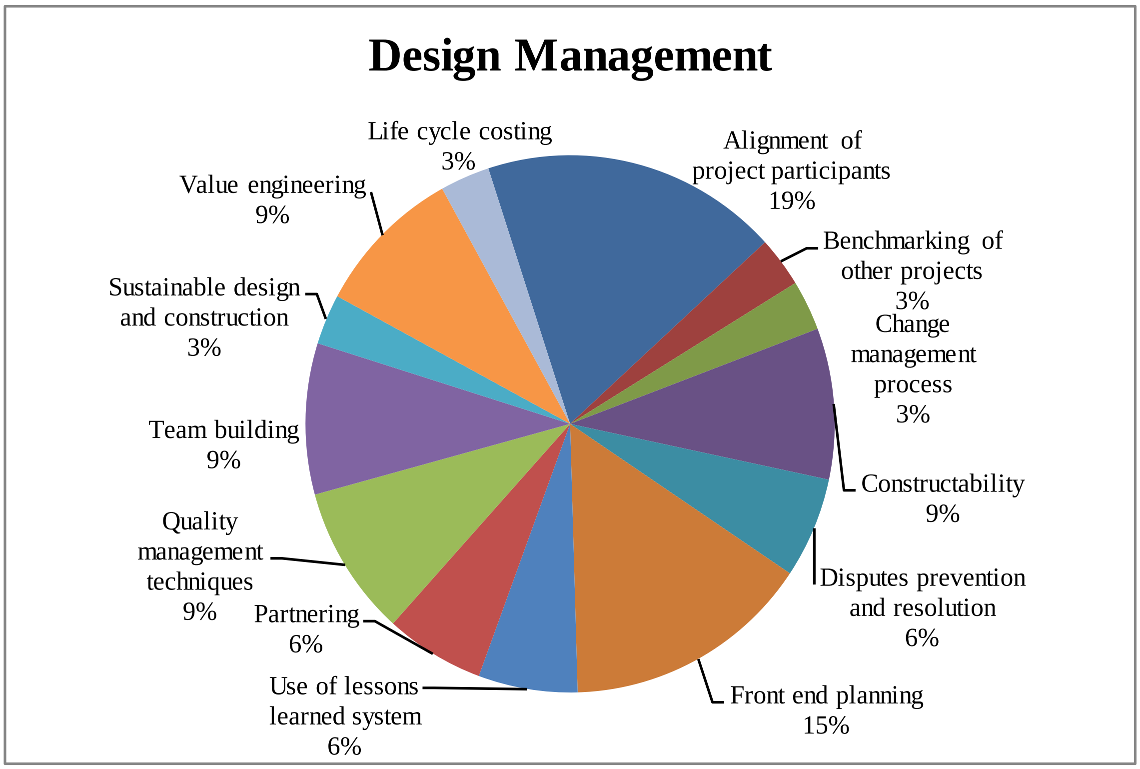


Figure 6-4 Design Management

Design management is more complex than just the use of one specific tool or practice. As shown in Figure 6-4, practices that bring stakeholders together, like “alignment of project participants” as well as using “quality management techniques”, are ideal for design management. Once again, front end planning makes the top two as a most used practice, along with alignment.

6.2 Industry Best Practices

The information in the last section has given information for the best practices needed to achieve pre-construction services. Some of these services were discussed in more detail, while others were only summarized in Table 6-4. This table can be used as an informative reference to understand how to effectively use industry best practices. In this section, best practices, as well project challenges, are discussed in further detail. Figure 6-5 depicts the practices perceived to be the best for overall project success.

Figure 6-5 Best Overall Practice

The best overall practice to accomplish a project's pre-construction service goals was front end planning. Following behind front end planning are constructability reviews and alignment of project participants. All the best practices can and should be used to achieve goals during the pre-construction phase. The next section will discuss project outcomes.

6.2.1 Most Challenging Aspects to Successful Project Completion

Question 21 on the survey asked respondents to select which "aspects of the project posed the greatest challenges to successful completion of the project itself". The results from respondents were ranked according to frequency and the results for all delivery methods considered together can be seen in Table 6-5. “Environmental impacts,” “public involvement,” and “project schedule” were the greatest challenges for successfully completing a project for all delivery methods taken as a whole.

Table 6-5 Most Challenging Aspects for Successful Project Completion (All Projects)

Most Challenging Aspects for Successful Project completion	Frequency
Environmental Impacts	9
Public Involvement	7
Project Schedule	6
Differing Site Conditions	4
Constructability Procedure	3
Construction Site Access	3
Decision Complexity	3
Existing Conditions	3
Schedule Acceleration	3
Cumulative Impact of Change Orders	2
Owner Changes/Approvals	2
Right of Way	2
Equipment Complications/Availability	1
Long Lead Items/Procurement	1
Owner-Mandated Subcontract	1
Project Delivery Method	1
Project Funding	1
Safety Hazards	1
Team Member Coordination	1
Unclear Project Purpose	1
New or Unfamiliar Technology	0
Project Cost Controls	0

(N = 56)

Table 6-6 breaks down the most challenging aspects for project completion by the three delivery methods in order of frequency selected. “Environmental impacts” was the most frequently chosen as the most challenging aspect for successfully completing a DBB project. “Environmental impacts” also showed up as a concern for CMAR and DB projects, albeit with less frequency. “Public involvement” and “construction site access” were the most frequent selections for CMAR and DB projects, respectively.

Table 6-6 Most Challenging Aspects for Successful Project Completion by Delivery Method

DBB	
Environmental Impacts	6
Existing Conditions	3
Project Schedule	3
Public Involvement	3
Constructability Procedure	2
Differing Site Conditions	2
Schedule Acceleration	2
Decision Complexity	1
Long Lead Items/Procurement	1
Owner Changes/Approvals	1
Project Schedule	1
Right of Way	1
Safety Hazards	1
Unclear Project Purpose	1

(N = 30)

CMAR	
Public Involvement	2
Cumulative Impact of Change Orders	1
Decision Complexity	1
Environmental Impacts	1
Owner Changes/Approvals	1
Project Funding	1
Project Schedule	1

(N = 8)

DB	
Construction Site Access	3
Differing Site Conditions	2
Environmental Impacts	2
Project Schedule	2
Constructability Procedure	1
Cumulative Impact of Change Orders	1
Decision Complexity	1
Equipment Complications/Availability	1
Owner-Mandated Subcontract	1
Public Involvement	1
Right of Way	1
Schedule Acceleration	1
Team Member Coordination	1

(N = 18)

6.2.1.1 Management Practice that Could Have Improved Project Outcomes

Question 23 on the survey asked respondents to select “which one management practice could have improved project outcomes the most”. The management practice options were analyzed by looking at the frequency of responses. The options and their frequencies were recorded and examined by all delivery methods together, as well as each delivery method individually. Table 6-7 lists the options that respondents were given ranked by the frequency of their selection. By looking at the table, one can see that “front end planning” was most frequently listed as the one management practice that could have improved the outcome of the project.

Table 6-7 Practices that Could Have Improved Project Outcomes (All Delivery Methods)

Practice that Could Have Improved Project Outcomes	Frequency
Front end planning	12
Project risk assessment	7
Alignment of project participants	6
Disputes prevention and resolution	5
Constructability	4
Partnering	4
Team building	4
Change management process	3
Use of lessons learned system	3
Materials management	3
Planning for startup	2
Quality management techniques	2
Other from the previous question	2
Benchmarking of other projects	1
Value engineering	1
Life cycle costing	1
Zero accidents techniques	0
Sustainable design and construction	0

(N =56)

The pie chart in Figure 6-6 shows the management practices that could have improved the project outcomes based on the frequency selected. One can see that 20 percent of the projects could have improved their outcomes by implementing better front end planning. "Project risk assessment" was also a management practice that was frequently selected, with 12 percent of respondents stating that this could have improved the outcomes. "Alignment of project participants" was the next most frequent selection, with 10 percent of respondents claiming this could have improved outcomes.

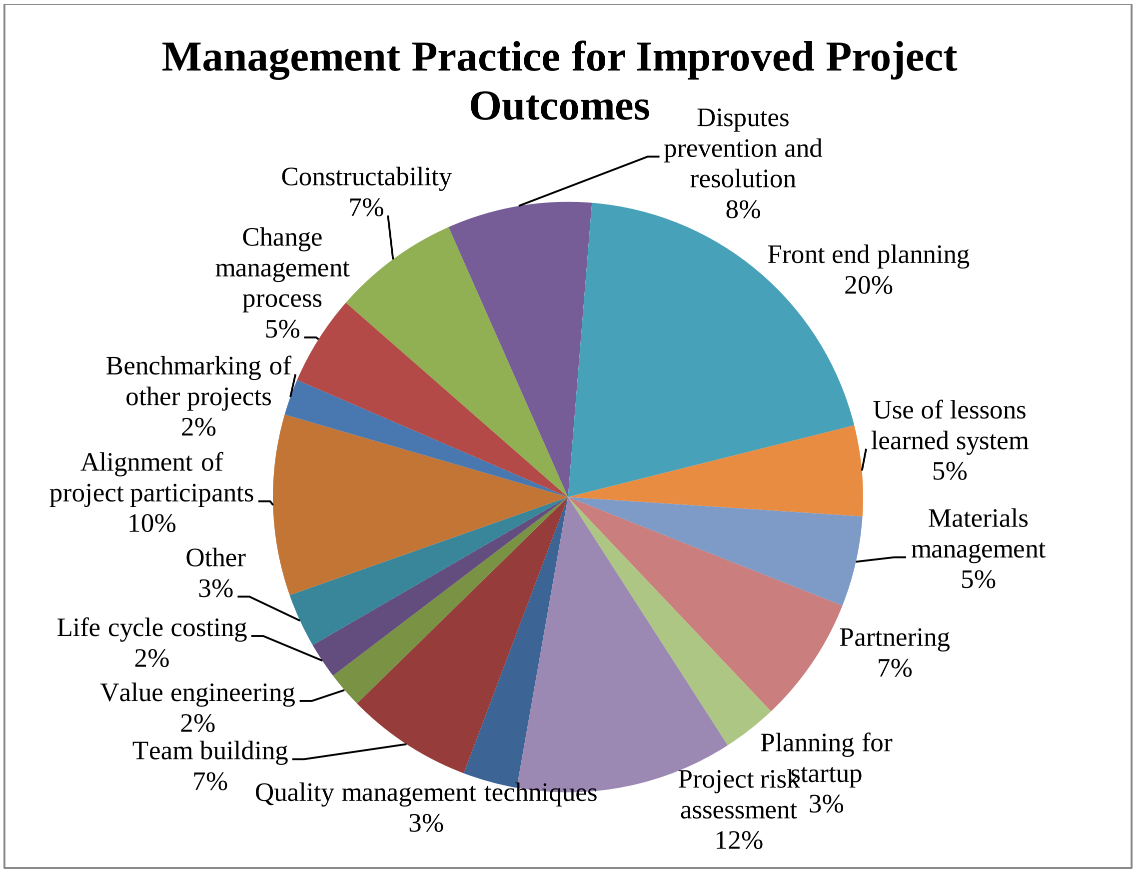


Figure 6-6 Management Practice for Improved Project Outcomes (All Delivery Methods)

The management practice options were broken down and analyzed by delivery method. It can be seen in Table 6-8 that the top selection of "front end planning" from above was also frequently selected for each delivery method, with a large portion of respondents in the DBB grouping selecting this as the management practice that would best improve project outcomes.

Table 6-8 Practice that Could Have Improved Project Outcome (by Delivery Method)

DBB	
Front end planning	8
Alignment of project participants	3
Project risk assessment	4
Disputes prevention and resolution	3
Materials management	2
Team building	2
Change management process	1
Constructability	1
Partnering	1
Value engineering	1
Life cycle costing	1
Other from the previous question	1

(N = 28)

CMAR	
Alignment of project participants	2
Front end planning	2
Planning for startup	2
Change management process	1
Constructability	1
Use of lessons learned system	1
Partnering	1
Team building	1

(N = 11)

DB	
Constructability	2
Disputes prevention and resolution	2
Front end planning	2
Partnering	2
Project risk assessment	2
Quality management techniques	2
Change management process	1
Use of lessons learned system	1
Materials management	1
Team building	1

(N = 17)

6.3 Team Alignment

Survey respondents were asked to answer questions in regards to team alignment. These questions ranged from topics such as how the team was selected to what aspects of the project created the most challenges for the project team. The various alignment questions were evaluated for all delivery methods together as well as individually.

6.3.1 Team Selection for All Delivery Methods

Question 13 on the survey gave the respondents a list of factors that may have influenced team selection for the project. They were asked to rate these factors based upon how influential they were using a seven point Likert scale, where one indicated “no influence” and seven indicated “a primary motivating factor”. The factors listed were “location of team member, licensure and professional registrations, history with company, project experience, experience in selected delivery method, budget compliance, legal obligation, safety record, team training/apprenticeship, experience with local conditions/regulatory officials, workload, and contractual obligation”. The influence these factors placed upon team selection was analyzed collectively with all delivery methods together, as well as individually by delivery method.

Table 6-9 shows the means and standard deviations for each of the factors listed from greatest to smallest mean. The top three factors, when measured by largest mean, were "project experience", "schedule compliance", and "licensure and professional registrations" with means of 5.65, 5.24, and 5.03, respectively. Schedule compliance refers to the availability of a team member to work on a given project.

Table 6-9 Means and Standard Deviation for Factors Influencing Team Selection

Factor	Mean	St. Dev.
Project experience	5.65	1.54
Schedule compliance	5.24	1.31
Licensure and professional registrations	5.03	1.67
Experience in selected delivery	4.74	1.69
Budget compliance	4.70	1.41
Experience with local conditions	4.55	1.88
History with company	4.44	1.78
Workload	4.44	1.86
Safety record	4.30	1.62
Location of team member	3.94	2.00
Contractual obligation	3.84	2.04
Team training/apprenticeship	3.74	1.78
Legal obligation	3.72	2.03

(N = 59)

A one-way ANOVA test was performed to determine if there was a statistically significant difference between the means of the 13 factors at the 95 percent confidence level. The ANOVA results shown in Table 6-10 returned a P-value of 0.00, indicating that there was indeed a significant difference between the means.

Table 6-10 ANOVA Table for Factors Influencing Team Selection

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	259.29	12	21.61	7.04	0.000
Within groups	2403.65	783	3.07		
Total (Corr.)	2662.94	795			

(N = 59)

A multiple range test (MRT) was conducted and a means and 95 percent LSD interval chart was produced to determine exactly which means had significant differences from one another. Looking at the means and 95 percent LSD interval chart in Figure 6-7, one can see that those that are significantly different from one another do not have intervals that overlap. Thus, the "project experience" mean has a statistically significant difference from almost all other factors, with the exception of "licensure and professional registration" and "schedule compliance".

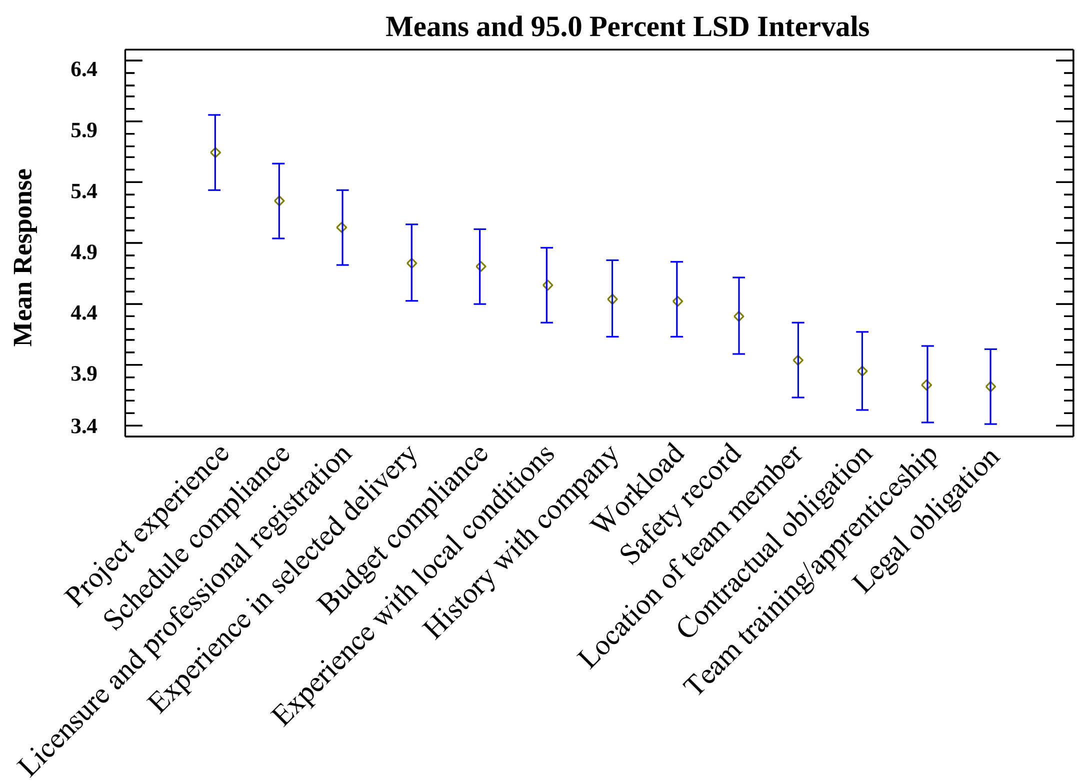


Figure 6-7 Means and 95 percent LSD Intervals for Factors for Team Selection
(N = 59)

The various boxplots for factors influencing team selection are given in Figure 6-8. One can see that some of them, such as "location of team member" and "contractual obligation", had a large range with the interquartile stretching from two to six on the Likert scale. This shows some variability in how important these factors were for team selection.

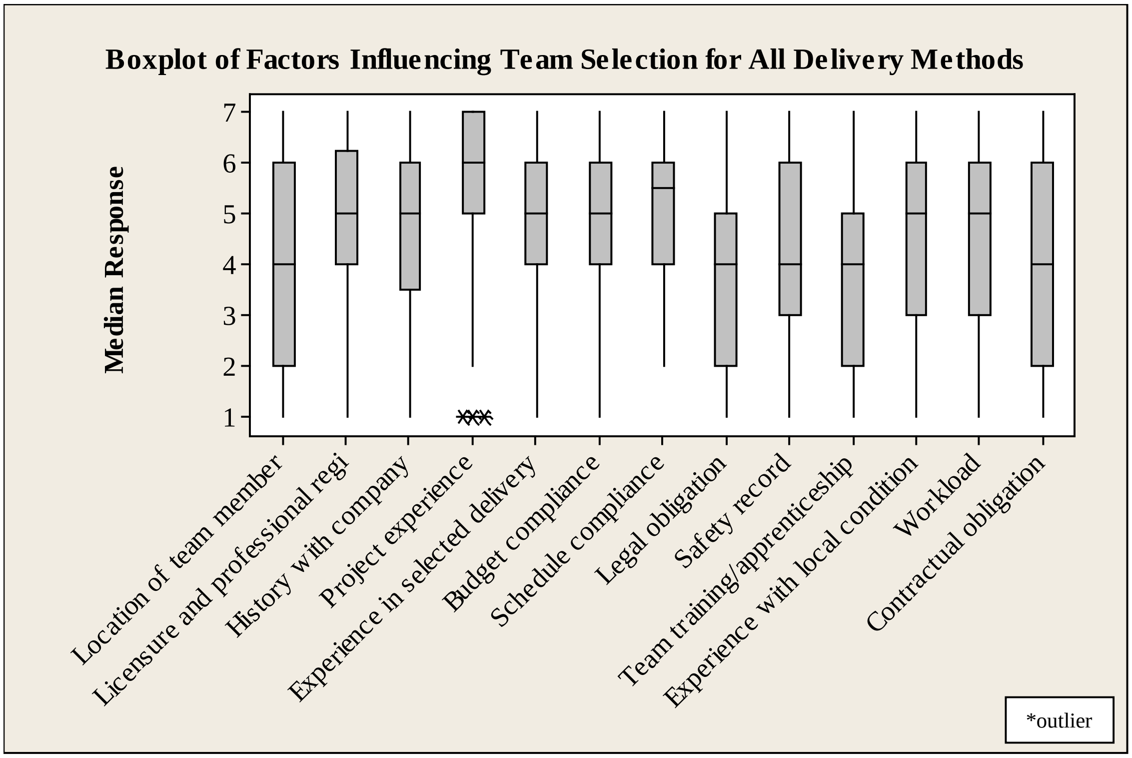


Figure 6-8 Boxplot of Factors Influencing Team Selection (All Delivery Methods)
(N = 59)

6.3.2 Team Selection for DBB Project Delivery Method

ANOVA and Multiple Range tests were run for each of the delivery methods separately in order to analyze the most important factors to each method. The means and standard deviations can be seen in Table 6-11, ranked from largest mean to smallest mean. "Project experience" had the highest means and also the lowest standard deviation.

Table 6-11 Means and Standard Deviations for Factors Influencing Team Selection (DBB)

Factors	Mean	St. Dev.
Project experience	5.62	1.37
Licensure and professional regis	5.24	1.77
Schedule compliance	5.17	1.42
Budget compliance	4.96	1.14
Workload	4.90	1.65
Experience with local conditions	4.76	1.84
Location of team member	4.57	1.87
Experience in selected delivery	4.43	1.81
History with company	4.29	1.70
Contractual obligation	4.15	2.11
Safety record	3.96	1.58
Legal obligation	3.93	2.21
Team training/apprenticeship	3.79	1.77

(N = 30)

The 13 factors for team selection were examined using the one-way ANOVA test. The output results are given in Table 6-12, with a P-value of 0.0004, indicating that there was a statistically significant difference between the 13 means at the 95 percent confidence level.

Table 6-12 ANOVA Table for Factors Influencing Team Selection (DBB)

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	109.56	12	9.13	3.05	0.0004
Within groups	1064.1	355	3.0		
Total (Corr.)	1173.65	367			

(N = 30)

The means and 95 percent LSD Intervals in Figure 6-9 show which variables are significantly different from one another when using the Multiple Range test. The factors with intervals that do not overlap had statistically significant differences between their means.

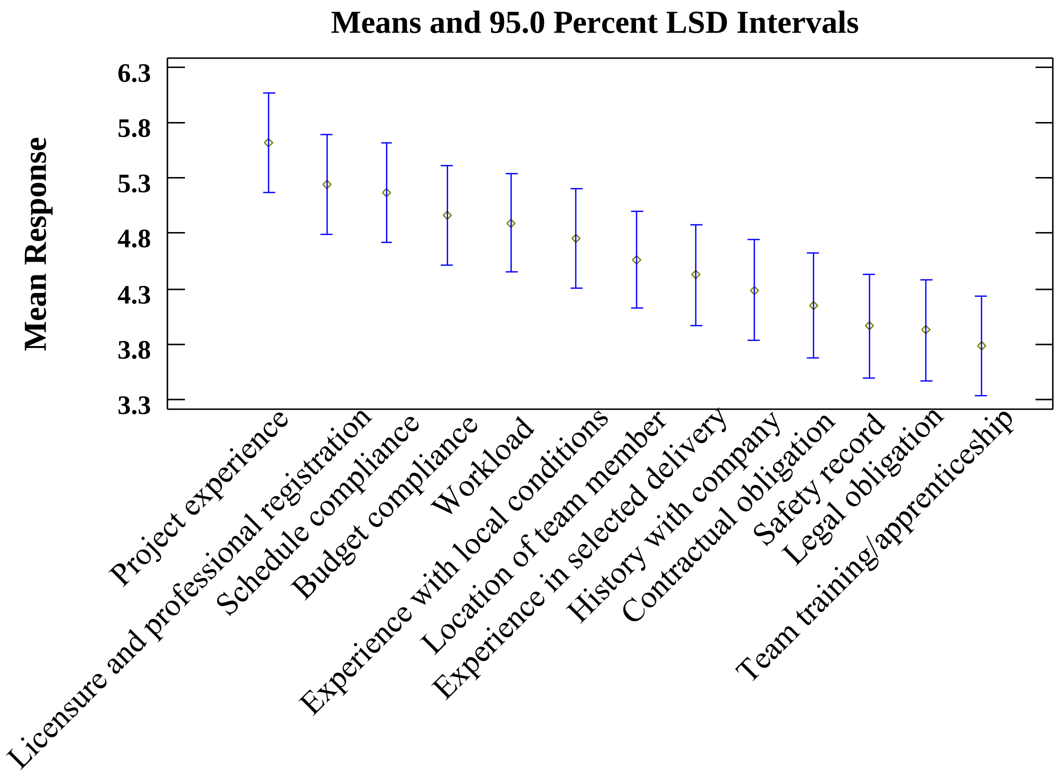


Figure 6-9 Means and 95 percent LSD Intervals for Factors Influencing Team Selection (DBB)
(N = 30)

The boxplots of each factor were studied to see patterns in responses. Figure 6-10 shows the boxplots. The author noticed that "project experience" had a high median and low range, with the exception of one outlier. Respondents ranked this factor high in importance for team selection, with a median of 6.0 and more than 50 percent of respondents rating "project experience" between five and seven.

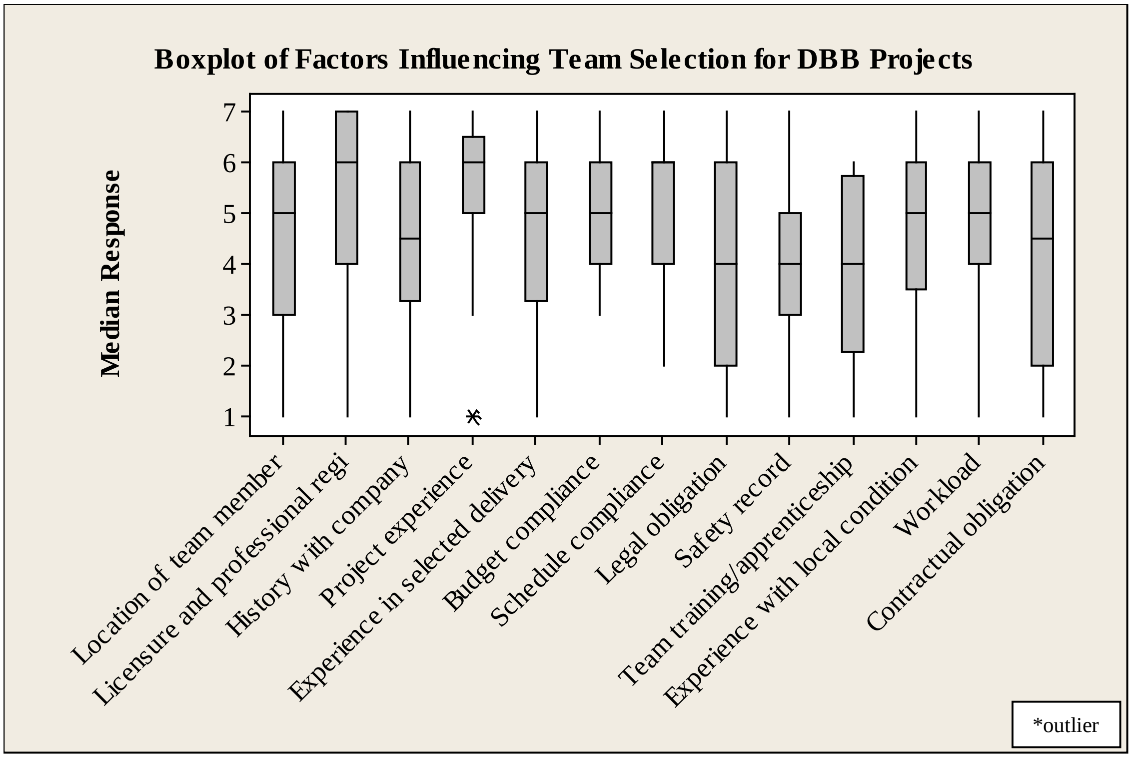


Figure 6-10 Boxplot of Factors Influencing Team Selection (DBB)
(N = 30)

6.3.3 Team Selection for CMAR Project Delivery Method

Again, a similar process was used to analyze the CMAR projects. The means and standard deviations for the factors influencing CMAR projects ranked from highest mean to lowest mean can be seen in Table 6-13.

Table 6-13 Means and Standard Deviation for Factors Influencing Team Selection (CMAR)

Factors	Mean	St. Dev.
History with company	5.55	0.93
Schedule compliance	5.36	1.36
Project experience	5.18	2.27
Safety record	4.82	1.60
Licensure and professional regis	4.45	2.11
Experience in selected delivery	4.45	2.02
Experience with local conditions	4.36	1.69
Location of team member	4.18	1.89
Budget compliance	4.18	1.89
Workload	4.00	2.00
Contractual obligation	3.91	2.21
Team training/apprenticeship	3.55	1.69
Legal obligation	3.36	2.11

(N = 11)

When the ANOVA test was run for this group, the P-value of 0.171, as seen in Table 6-14, indicated that there was not a statistically significant difference between the 13 means at the 95 percent confidence level; however, the multiple range test showed that there was a significant difference between a few of the means when comparing the means of two variables at a time. "History with company" was found to be significantly different from "legal obligation", "team training/apprenticeship", and "contractual obligation". Also, "project experience" and "schedule compliance" were found to be different from "legal obligation" and "team training/apprenticeship". By looking at the means and 95 percent LSD intervals in Figure 6-11, one can see that these have a statistically significant difference between them with the intervals not overlapping.

Table 6-14 ANOVA Table for Factors Influencing Team Selection (CMAR)

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	58.656	12	4.89	1.41	0.171
Within groups	452.0	130	3.48		
Total (Corr.)	510.66	142			

(N = 11)

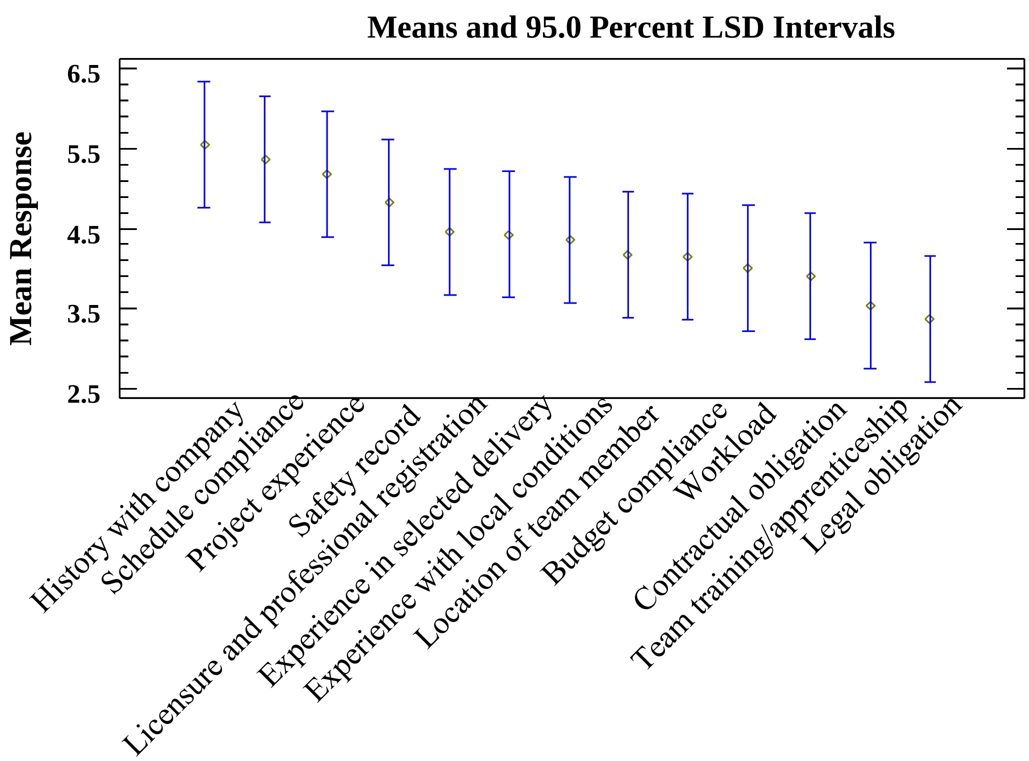


Figure 6-11 Means and 95 percent LSD Intervals for Factors Influencing Team Selection (CMAR)
(N = 11)

The boxplot in Figure 6-12 shows the medians and interquartile for each of the factors influencing team selection for CMAR projects. It is interesting to note that for “history with company”, there was a small range of responses and 50 percent of respondents answered with either a five or a six for level of importance in selection of team members. The author also noticed there was a tight grouping of responses for “safety record”, with 50 percent of respondents rating it between a four and a six. For factors “contractual obligation” and “licensure and professional registrations”, the ranges were noticeably larger.

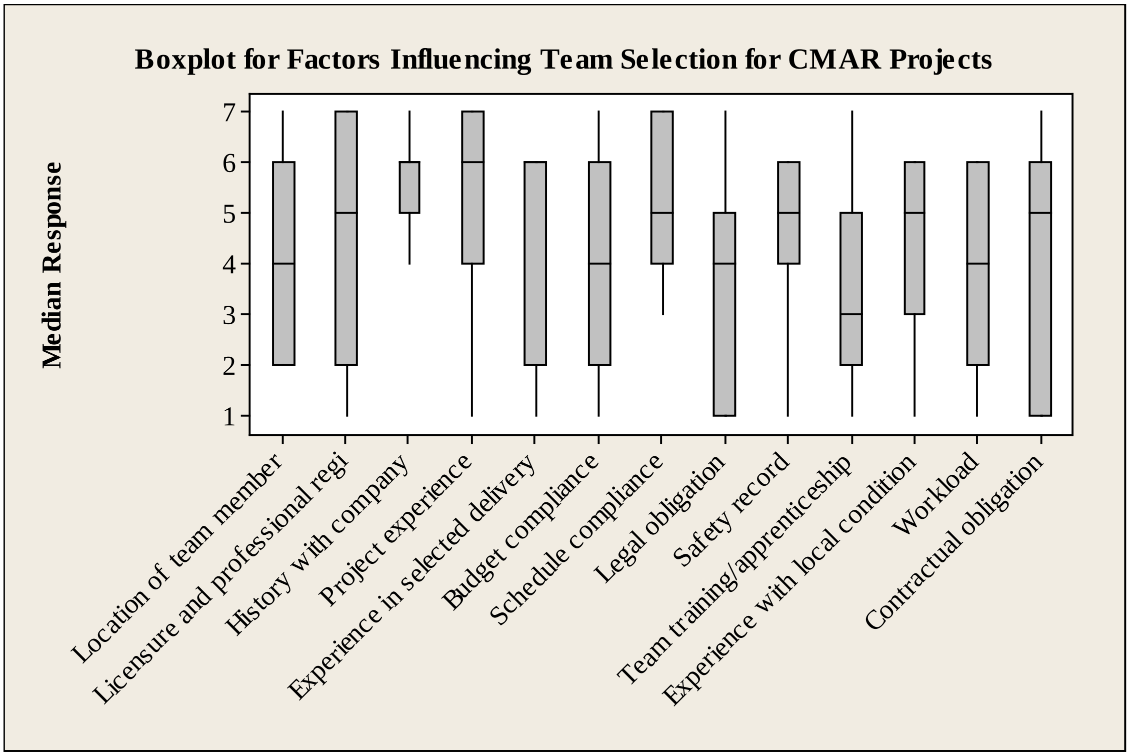


Figure 6-12 Boxplot for Factors Influencing Team Selection (CMAR)
(N=11)

CMAR project team members are selected based on their own specific criteria. They favor team members with a history with the company with specific project experience. As with all projects, the availability of team members often depends on when other projects are finishing; this leads to team selection based on availability and schedule constraints.

6.3.4 Team Selection for DB Project Delivery Method

Analysis was run for Design Build projects using the same methods as the other delivery methods. The means and standard deviations of the factors influencing team selection for DB projects are given in Table 6-15. They are listed by factor in order from highest mean to lowest mean. "Project experience" was once again among the factors with the highest means, with a value of 5.91 and a standard deviation of 1.31. An interesting difference between this and the other delivery methods was that the mean for "experience in selected delivery method" jumped quite a bit when looking only at DB projects. The mean for this factor under CMAR and DBB projects was 4.45 and 4.43, respectively. When looking only at DB projects, this factor had a higher mean of 5.27. The standard deviation for this factor also fell under DB projects when compared to CMAR (st. dev. = 2.02) and DBB (st. dev. = 1.81) projects.

Table 6-15 Means and Standard Deviations for Factors Influencing Team Selection (DB)

Factors	Mean	St. Dev.
Project Experience	5.91	1.31
Experience in Selected Delivery	5.27	1.24
Schedule Compliance	5.27	1.20
Licensure and Professional Regis	5.05	1.25
Budget Compliance	4.64	1.43
Safety Record	4.45	1.65
Experience with Local Conditions	4.36	2.06
History with Company	4.09	2.02
Workload	4.05	1.99
Team Training/Apprenticeship	3.77	1.90
Legal Obligation	3.64	1.81
Contractual Obligation	3.43	1.89
Location of Team Member	2.95	1.91

(N = 18)

The one-way ANOVA test summarized in Table 6-16 resulted in a P-value of 0.00, indicating that there was a statistically significant difference between the means of the 13 variables at the 95 percent confidence level. The means and 95 percent LSD intervals chart in Figure 6-13 shows which factors had significant differences from other factors by the lack of overlap in interval lines.

Table 6-16 ANOVA Table for Factors Influencing Team Selection (DB)

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	186.11	12	15.51	5.39	0.000
Within groups	782.96	272	2.88		
Total (Corr.)	969.07	284			

(N = 18)

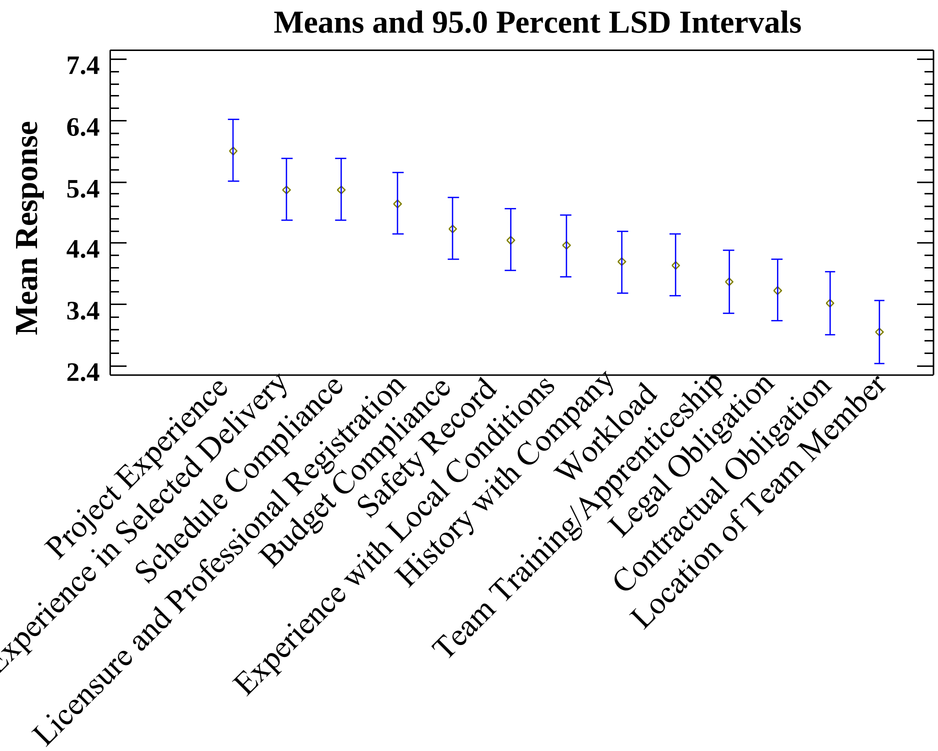


Figure 6-13 Means and 95 percent LSD Intervals for Factors Influencing Team Selection (DB)
(N = 18)

The boxplots for factors influencing team selection for DB projects are given in Figure 6-14. It can be seen in the figure that "experience in selected delivery method" was important for most respondents using the DB method, with nearly 50 percent of those surveyed giving it a six or a seven. It can also be seen that there was a high level of importance placed upon “project experience”, with 50 percent of respondents rating it a five or higher and 25 percent of those giving it either a six or a seven.

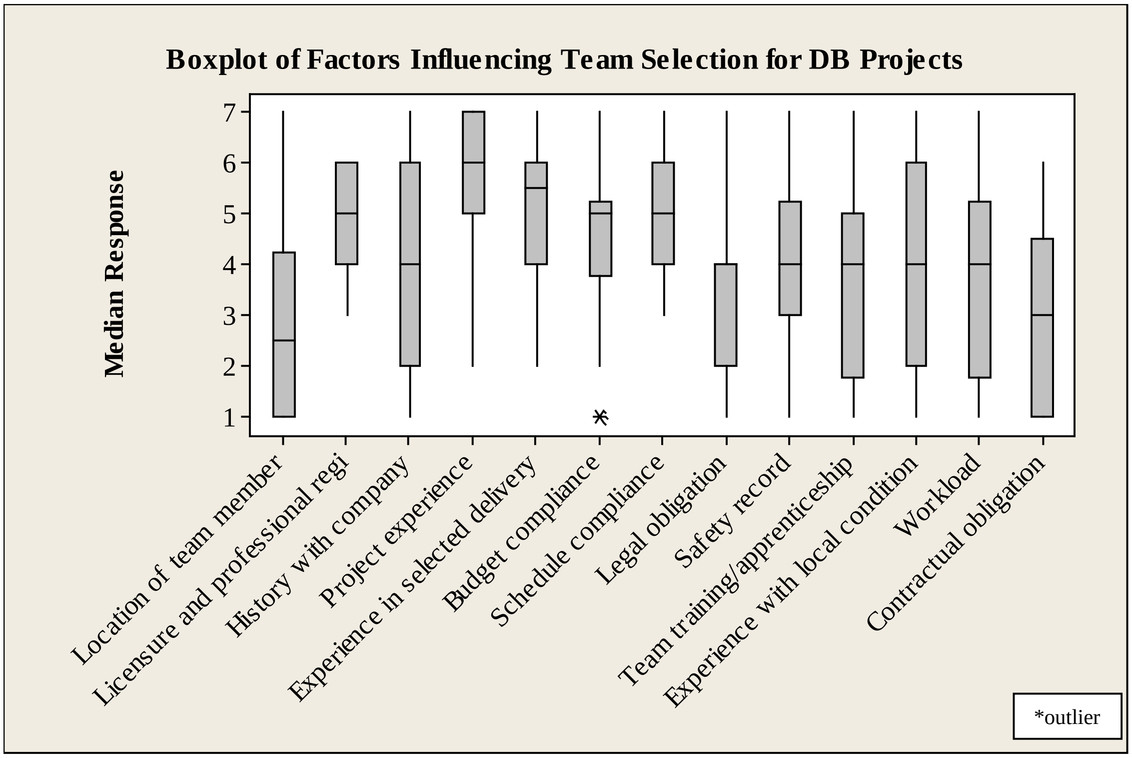


Figure 6-14 Boxplot of Factors Influencing Team Selection (DB)
(N = 18)

It was interesting to note that “project experience” and “schedule compliance” ranked high in importance for all three delivery methods, both when analyzed collectively and individually. “Experience in selected delivery method” ranked considerably higher in importance for DB projects than it did for CMAR and DBB projects. “History with the company” seemed to be a significant influence in team selection for CMAR projects, but not the other two delivery methods, and “location of team member” was noticeably lower in importance for DB projects, with a mean of 2.95. CMAR and DBB projects had means of 4.57 and 4.18, respectively.

6.3.5 Team Alignment and Project Delivery Method

Question 14 on the survey asked respondents to rate how influential team alignment was to the success of their project using a Likert scale from one to seven, with one indicating "not at all" and seven indicating "very influential". The means were calculated for the various project delivery methods (DBB, CMAR, and DB) to see if there was a difference between the methods as to how influential they saw team alignment as being to the success of the team. The means are shown in Table 6-17. There was no statistically significant difference between the means when a one-way ANOVA test was run, indicating that the influence of team alignment did not change based on the delivery method of the project. Table 6-18 shows the F-ratio and P-value of 0.70 and 0.0502, respectively. A Multiple Range test was conducted to determine if there was statistical significance between any two of the delivery methods' means; however, the author did not find any difference at the 95 percent confidence level. This can also be seen from Figure 6-15 with the overlap in intervals.

Table 6-17 Means of Importance of Team Alignment for Success of Project

DBB	5.60
CMAR	5.17
DB	5.61

(N = 62)

Table 6-18 ANOVA Table for Importance of Team Alignment

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	1.84	2	0.92	0.70	0.502
Within groups	75.14	57	1.32		
Total (Corr.)	76.98	59			

(N = 62)

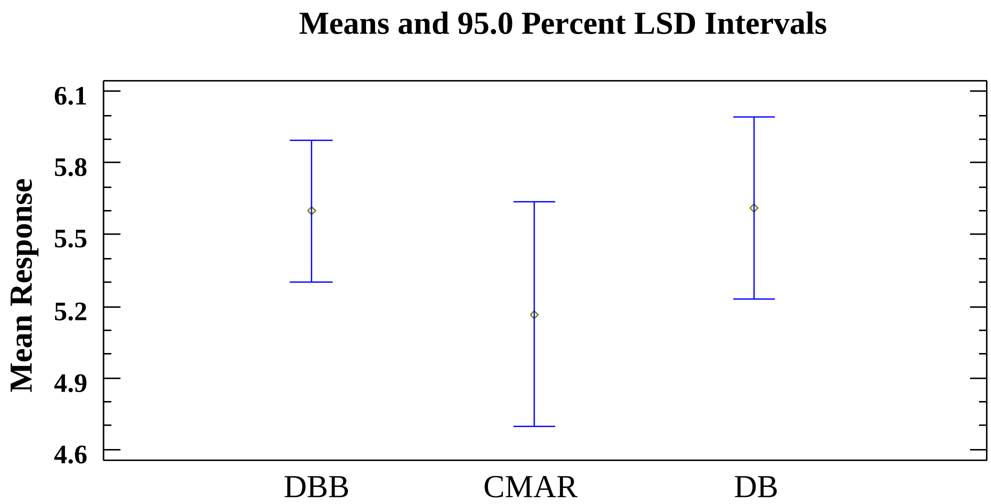


Figure 6-15 Means and 95 percent LSD Intervals for Team Alignment Importance
(N = 62)

The findings indicate that with each delivery method, team alignment is important. Delivery method selection will not be an indicator of better team alignment and no one delivery method can guarantee better team alignment. It is important for owners using all the delivery methods to focus on team alignment principles for success.

6.3.6 Most Beneficial Aspect to Team Alignment

Question 19 on the survey asked respondents to select, from a list, the one aspect of team alignment that was most beneficial to the team. The team alignment aspects were adapted from CII's team alignment tools (CII 1998). These aspects were analyzed by looking at what was frequently the most beneficial to the project. Frequency of responses were recorded for all delivery methods together, as well as separately, to see if certain aspects were more important to specific delivery methods. Table 6-19 lists the options that respondents were given and lists them in order of what was selected most frequently as being the most beneficial to team alignment. "Established expectations" was selected more often, with 12 different respondents selecting this option. This was followed closely by “established team trust, honesty, and shared values” with ten respondents selecting this option. Many of the top choices appear to deal with communication issues and understanding of team values.

Table 6-19 Most Beneficial Aspect to Team Alignment (All Delivery Methods)

Most Beneficial Aspect to Team Alignment	Frequency
Established expectations	12
Established team trust, honesty, and shared values	10
Communicated effectively with stakeholders	8
Developed individual and group roles and responsibilities	8
Conducted productive team meetings	4
Resolved conflicts appropriately	4
Defined project leadership and accountability	3
Defined project success	3
Established project priorities such as costs, schedule, public relations, etc.	3
Evaluated risk	3
Involved all project stakeholders appropriately	2
Addressed concerns	1
Effectively used planning tools	1
Measured team alignment	1
Conducted adequate pre-construction or front end planning practices	0
Documented project details, including shortcomings and successes	0
Instituted effective team building programs	0

(N = 60)

The pie chart in Figure 6-16 gives a breakdown of the aspects that were most beneficial for team alignment by the percent of respondents who selected that aspect. One can see that “established expectations” and “established team trust, honesty, and shared values” were selected the most, with 19 percent and 16 percent of respondents selecting those aspects as most important, respectively.

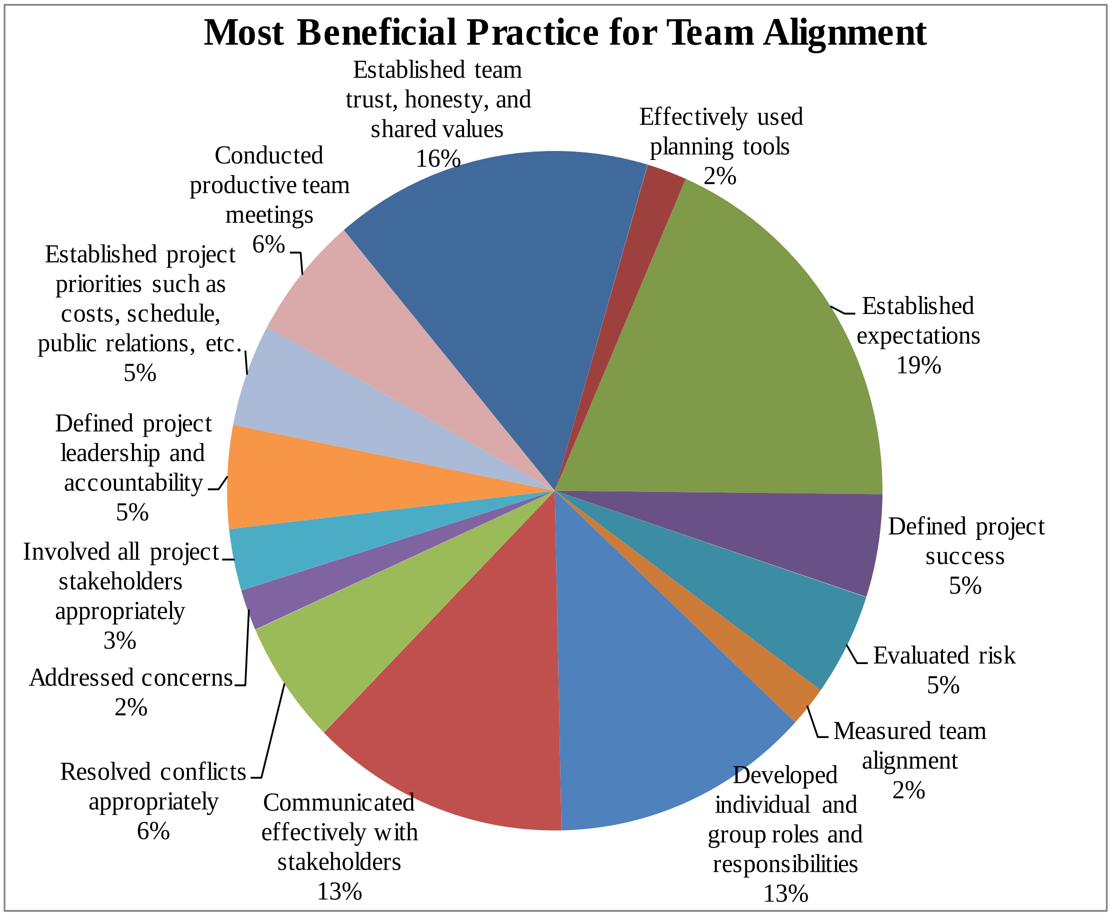


Figure 6-16 Most Beneficial Aspect for Team Alignment (All Delivery Methods)
(N = 60)

The same aspects were reviewed by delivery type to see if there was a difference in responses based upon the delivery method used for a particular project.

Table 6-20 Most Beneficial Aspects for Team Alignment (DBB)

Aspects for DBB	Frequency
Established expectations	6
Communicated effectively with stakeholders	5
Developed individual and group roles and responsibilities	4
Established team trust, honesty, and shared values	4
Conducted productive team meetings	2
Defined project leadership and accountability	2
Evaluated risk	2
Addressed concerns	1
Defined project success	1
Established project priorities such as costs, schedule, public relations, etc.	1
Involved all project stakeholders appropriately	1
Resolved conflicts appropriately	1

(N = 30)

Table 6-21, Table 6-20, and Table 6-22 list the aspects in order of most frequently selected for each delivery method. Interestingly, "established expectations" was fairly high for both DBB and DB projects, but was selected only once for CMAR projects. The author also noticed that "established team trust, honesty, and shared values" appeared to be high in importance for team alignment for all three delivery methods.

Table 6-20 Most Beneficial Aspects for Team Alignment (DBB)

Aspects for DBB	Frequency
Established expectations	6
Communicated effectively with stakeholders	5
Developed individual and group roles and responsibilities	4
Established team trust, honesty, and shared values	4
Conducted productive team meetings	2
Defined project leadership and accountability	2
Evaluated risk	2
Addressed concerns	1
Defined project success	1
Established project priorities such as costs, schedule, public relations, etc.	1
Involved all project stakeholders appropriately	1
Resolved conflicts appropriately	1

(N = 30)

Table 6-21 Most Beneficial Aspects for Team Alignment (CMAR)

Aspects for CMAR	Frequency
Established team trust, honesty, and shared values	3
Resolved conflicts appropriately	3
Communicated effectively with stakeholders	1
Conducted productive team meetings	1
Developed individual and group roles and responsibilities	1
Effectively used planning tools such as organizational charts and integrated daily schedules	1
Established expectations	1
Evaluated risk	1

(N = 12)

Table 6-22 Most Beneficial Aspect for Team Alignment (DB)

Aspects for DB	Frequency
Established expectations	4
Developed individual and group roles and responsibilities	3
Established team trust, honesty, and shared values	3
Communicated effectively with stakeholders	2
Defined project success	2
Conducted productive team meetings	1
Established project priorities such as costs, schedule, public relations, etc.	1
Involved all project stakeholders appropriately	1
Measured team alignment	1

(N = 18)

6.3.7 Most Challenging Aspect to Team Alignment

Question 20 on the survey asked respondents to select, from a list, the aspect "which challenged the project team the most during the execution of the project". The aspects the respondents were able to choose from were examined based upon highest frequency for all delivery methods together, as well as by individual delivery method. Responses for each aspect were totaled and all aspects were ranked according to their frequency. The rankings for all delivery methods can be seen in Table 6-23.

Table 6-23 Most Challenging Aspect for Team Alignment (All Projects)

Most Challenging Aspect for Project Team	Frequency
Constructability Procedure	7
Project Schedule	7
Public Involvement	7
Decision Complexity	6
Environmental Impacts	4
Construction Site Access	3
Differing Site Conditions	3
Existing Conditions	3
Team Member Coordination	3
Cumulative Impact of Change Orders	2
Owner Changes/Approvals	2
Project Funding	2
Equipment Complications/Availability	1
Owner-Mandated Subcontract	1
Project Cost Controls	1
Schedule Acceleration	1
Unclear Project Purpose	1

(N = 54)

The ranking was repeated for each delivery method separately. The rankings for the three methods are given in Table 6-24. “Constructability procedure”, “project schedule”, and “public involvement” had the highest ranking when all delivery methods were analyzed together; however, it can be noted that “constructability procedure” had a high frequency of occurrence for both DBB and DB projects, but not CMAR projects, which is understandable due to the high level of contractor influence early on in CMAR projects. The author also noted that “project schedule” was selected for DBB projects as the most challenging for the project team, but had a low occurrence for both CMAR and DB projects. DBB project delivery time is typically slower than DB and CMAR, and this challenge was confirmed by the rankings.

Table 6-24 Most Challenging Aspect for Project Team by Delivery Method

DBB	
Project Schedule	5
Public Involvement	5
Constructability Procedure	4
Environmental Impacts	3
Differing Site Conditions	2
Owner Changes/Approvals	2
Equipment Complications/Availability	1
Existing Conditions	1
Project Cost Controls	1
Project Funding	1
Schedule Acceleration	1
Team Member Coordination	1
Unclear Project Purpose	1

(N = 29)

CMAR	
Team Member Coordination	2
Cumulative Impact of Change Orders	1
Decision Complexity	1
Existing Conditions	1
Project Funding	1
Project Schedule	1
Public Involvement	1

(N = 8)

DB	
Decision Complexity	4
Constructability Procedure	3
Construction Site Access	3
Cumulative Impact of Change Orders	1
Differing Site Conditions	1
Environmental Impacts	1
Existing Conditions	1
Owner-Mandated Subcontract	1
Project Schedule	1
Public Involvement	1

(N = 17)

For a project to be successful, owners should focus on possible challenges to the project team. The selection of a delivery method can be an indication of the types of challenges that may occur and should be addressed early in the project life cycle. DBB projects should be concerned with the effect of the project schedule, as well as public involvement. CMAR projects should consider the coordination and communication between team members as a source of possible challenges. Complexity seemed to be the greatest challenge for DB project teams. This confirms the observation that the DB projects in the sample seemed to have greater complexity. Complexity is often a precursor to the selection of DB.

6.4 Summary of Research Findings

This chapter has been an in-depth analysis of survey data that has answered questions related to the research objectives and hypotheses. Analysis was performed on project delivery method selection, team alignment, and pre-construction services. Detailed analysis of project data gave the findings for project outcomes. The next chapter provides a concise synthesis of the research study.

7 RESEARCH SYNTHESIS

This chapter provides a synthesis of the research study. Most of the topics presented in this chapter have been covered in Chapters Five and Six. Here, the results have been summarized and condensed. Some discussions and conclusions are also made about the research results.

7.1 Project Outcomes

Cost and schedule performance for transportation projects was analyzed and performance change based on delivery method. Several tests were run to determine if there was any significant difference between the different delivery methods in regards to cost and schedule performance. The questions on the survey asking respondents to give information on the planned and actual cost and schedule were some of the least answered questions by respondents, and limited the sample size for these areas of review. Table 7-1 is a summary of the findings for cost, schedule, and changes by delivery method.

Table 7-1 Cost and Schedule Outcomes by Delivery Method

	DBB	CMAR	DB
Average Cost Growth	4.67%	3.26%	-2.74%
Average Design Schedule Growth	18.10%	0.01%	29.55%
Average Construction Schedule Growth	-8.06%	25.41%	18.56%
Average Total Schedule Growth	4.65%	13.27%	20.24%
Most Common Pricing Method	Unit Price	GMP	Fixed Price
Average Number of Change Orders	8.21	13.11	23.31
Average Cost per Change Order	$189,441.26	$348,777.66	$123,416.15
Average Dollar Value of Change Orders as Percentage of Total Cost	5.81%	1.00%	2.03%
Average Delay as Percent of Total Schedule due to Change Orders	3.88%	7.56%	3.40%

A detailed analysis of the cost, schedule, and change order findings can be found in Chapter Five. The data from this chapter was compiled in Table 7-1 for an inclusive view of cost, schedule, and change order performance by delivery method. As was identified in the literature review in Chapter Two, there have been a number of research studies that have reported this type of data about transportation projects. This study adds to those findings. A general conclusion of this study is that many of the assumptions about the project delivery methods were confirmed by this study. A weakness of all of the studies similar to this is the number of projects studied. Although this has been an analysis of the largest number of transportation projects in the literature, still more projects were needed to reach the desired level of significance for some analyses. This data improves confidence in the use of specific delivery methods to achieve project outcomes related to cost, schedule, and change orders.

Project data can be used to find, support, or repudiate the trends in preference for a delivery method. The study found that project owners felt that different project delivery methods had unique strengths, as discussed in the literature review and throughout the report. For example, owners often feel that CMAR and DB projects can deliver projects faster, but that DBB projects may be less costly. Actual project data was analyzed to validate these and other preferences. Some of the findings about these preferences were discussed in detail in Chapter Five and will be summarized later in this chapter; brief conclusions regarding the costs of design, pre-construction services, and ROW are discussed in this section. This section also makes conclusions about cost and schedule growth, as well as days and cost per lane mile.

The average cost of design, pre-construction, and right of way/utilities adjustments were examined as a percentage of the total cost. These averages were calculated for all the projects together, as well as by delivery method, and can be seen in Table 7-2.

Table 7-2 Average Cost as a Percentage of Total Cost

	Design	Pre-Construction	ROW/Utilties Adj.
DBB (N = 11)	17.12%	0.22%	20.46%
CMAR (N = 7)	11.89%	6.17%	30.58%
DB (N = 9)	7.09%	8.60%	12.52%
All Projects (N = 27)	12.42%	7.03%	19.23%

Table 7-2 shows that DBB and CMAR projects have, on average, a higher cost for design phase, as well as ROW and utilities adjustments. CMAR and DB projects have a higher cost for pre-construction services at 6.17 percent and 8.6 percent, respectively.

Cost growth was also reported; the average cost for each category requested (design, pre-construction services, right of way adjustment, owner's contingency, other costs, and total project cost) can be seen in Table 7-3 .

Table 7-3 Cost Growth Measures

	Design cost growth	Pre-Construction Service Costs growth	Right of Way and Utility Adjustment Costs growth	Total Owner's Contingency growth	Other Cost growth	Total Project Cost growth
Average cost growth for DBB (N = 19)	4.67%	-16.67%	14.44%	-9.78%	-17.53%	-2.59%
Average cost growth for CMAR (N = 8)	3.26%	21.84%	0.11%	-62.67%	13.61%	4.04%
Average cost growth for DB (N = 11)	-2.74%	-12.51%	-31.08%	-35.57%	-16.36%	-5.37%
Average cost growth for total sample (N = 41)	2.05%	-2.76%	-6.66%	-33.96%	-13.71%	-2.98%

The overall schedule growth was examined and found that there was no significant difference in schedule growth for each of the delivery methods. There was, however, a statically significant difference in the detailed design schedule growth. Table

7-4 shows that DB projects were more susceptible to detailed design schedule growth at 29.55 percent and DBB projects followed closely behind at 18.10 percent. CMAR projects showed little to no design schedule growth.

Table 7-4 Means for Detailed Design Schedule Growth

Detailed Design Schedule Growth	Mean
DBB Detailed Design growth % (N = 20)	18.10%
CMAR Detailed Design growth % (N = 7)	0.01%
DB Design growth % (N = 9)	29.55%

Construction schedule growth showed a different scenario, with more growth for CMAR and DB projects. Table 7-5 provides the mean construction schedule growth by delivery method.

Table 7-5 Means for Construction Schedule Growth

Schedule Growth by Delivery Method	Mean
DBB Construction growth % (N = 18)	-8.06%
CMAR Construction growth % (N = 8)	25.41%
DB Construction growth % (N = 15)	18.56%

7.1.1 Pricing Method

The primary pricing method used by each delivery method can be determined. DBB, CMAR, and DB projects were analyzed and the study concluded that there was a clear preference for pricing method within each delivery method. CMAR projects tended to use a GMP pricing method, while DB projects preferred a fixed price method and DBB projects overwhelmingly used a unit price method. Table 7-6 gives a summary of the projects by delivery type and the pricing method used on the project.

Table 7-6 Pricing Method by Delivery Method

DBB			CMAR			DB		
Fixed Price	GMP	Unit Price	Fixed Price	GMP	Unit Price	Fixed Price	GMP	Unit Price
5	0	27	1	10	3	12	1	2

Pricing method is a predictor of cost or schedule growth. Survey data was analyzed and the study found that the average schedule and cost growth differed by pricing method. Table 7-7 provides a conclusion, showing GMP and unit price contracts experiencing an increased schedule growth when compared to fixed price contracts. GMP showed an increase for cost growth as well, when both fixed price and unit price pricing methods had an average reduction in costs.

Table 7-7 Cost and Schedule Growth by Pricing Method

	Average Schedule Growth	St. Dev.	N	Average Cost Growth	St. Dev.	N
Fixed Price	5.65%	0.83	11	-6.32%	0.15	12
GMP	25.44%	0.64	6	4.29%	0.11	5
Unit Price	18.33%	0.37	16	-7.32%	0.23	12

Although a good number of projects reported data to provide these statistics, analysis did not reach a level of statistical significance at the 95 percent confidence level. In spite of this, these numbers show a trend for GMP projects with a growth of both schedule and cost.

7.1.2 Change Orders

Use of different delivery methods has an influence on the number and dollar amount of change orders. The analysis showed that DB projects had on average more change orders, but that the costs per change order were less than both CMAR and DBB projects. DBB projects showed the highest percent of total costs due to change orders. DBB also had the lowest average number of change orders per project. The number, cost, and dollar value of change orders can be seen in Table 7-8.

Table 7-8 Change Order Data by Delivery Method

	Average Number of Change Orders	Average Cost per Change Order	Dollar Value of Change Orders as Percentage of Total Cost
DBB (N = 24)	8.21	$ 189,441.26	5.81%
CMAR (N = 9)	13.11	$ 348,777.66	1.00%
DB (N = 16)	23.31	$ 123,416.15	2.03%

A high level of statistical significance was not reached with this data. Additionally, the author notes that project complexity and size could have played a role in the number and value of change orders. With a sample size of this number, normalizing the data for comparison was not practical.

Use of different delivery methods is an indicator of the schedule impacts of change orders. Change order analysis confirmed the theory that the different delivery methods would have an impact on change orders. Although DB had the most change orders, the average delay caused in both the construction phase, as well as overall, was less than delays caused by CMAR and DBB projects. Table 7-9 provides the schedule impacts of change orders by delivery type.

Table 7-9 Change Orders and Schedule Delays by Delivery Method

	Average Number of Change Orders	Average Change Order Delay as a Percentage of Total Schedule	Average Change Order Delay as a Percentage of Construction Schedule
DBB (N = 13)	8.21	3.88%	6.27%
CMAR (N = 8)	13.11	7.56%	6.65%
DB (N = 11)	23.31	3.40%	2.80%

Specific practices can be used to reduce change orders; these practices can be ranked by efficiency and change by delivery method. Many practices were found to decrease the number and cost of change orders for a project. When survey data was compiled, it was concluded that the services that could help reduce change orders the most were "constructability/bidability analysis", "risk identification assessment", and "good design management". The data was then divided by delivery method to determine the best services to avoid changes by delivery method. The responses were ranked by frequency of selection for each method and can be seen in Table 7-10.

Table 7-10 Services that Could Help Avoid Change Orders by Delivery Method

DBB	
Constructability/bidability analysis	4
Design management	2
Identification of project objectives	2
Risk mitigation	2
Agency coordination and estimating	1
Construction phase sequencing	1
Disruption avoidance planning	1
Real-time cost feedback	1
Risk identification and assessment	1
Site logistics planning	1
Stakeholder management	1
Value analysis engineering	1

(N = 18)

CMAR	
Agency coordination and estimating	1
Cost estimating	1
Design management	1
Multiple bid package planning	1
Risk identification and assessment	1
Site logistics planning	1
Value analysis engineering	1

(N = 7)

DB	
Risk identification and assessment	5
Constructability/bidability analysis	3
Design management	2
Agency coordination and estimating	1
Schedule development	1
Stakeholder management	1

(N = 13)

7.1.3 Delivery Method Satisfaction

Satisfaction for each delivery method can be measured. The results of the survey showed that for each of the delivery methods used, the majority of owners believed that the delivery method used was the best fit for the project. DB projects had the lowest level of satisfaction, with 11.76 percent feeling a different delivery method would have been a better fit. Project owners that showed dissatisfaction with the DB delivery method showed a preference for the use of DBB as a better fit for the project. Table 7-11 shows the owner satisfaction for each delivery method, as well the preferred alternative.

Table 7-11 Delivery Method Satisfaction

Delivery Method	N	Yes, best fit	No, not best fit	Selected Alternative
DBB	33	90.91%	9.09%	CMAR - 66.67%, DB - 33.33%
CMAR	15	100%	0%	N/A
DB	17	88.24%	11.76%	DBB - 100%

7.2 Project Delivery Method Selection

The motivating factors for the selection of a delivery method were analyzed for projects of all delivery methods. It was found that the overwhelming motivation for the selection of a delivery method was the method’s ability to affect the cost and schedule. There was a high level of statistical significance showing that there was a significant weight given to cost and schedule, as compared to other factors motivating project delivery selection. The rankings for selection of delivery methods in order of greatest influence to least influence are provided in Table 7-12.

Table 7-12 Factors Rated for Importance in Delivery Method Selection (All Delivery Methods)

Factor influencing delivery method selection	Rank
Cost of project	1
Urgency of project	2
Opportunity for innovation	3
Best method for risk allocation	4
Required by owner or regulatory agency	5
Regulatory initiatives	6
Lack of in-house resources	7
Quality concerns	8
Multiple stakeholder coordination	9
Other	10

Multiple motivating factors for the selection of a delivery method were analyzed and the study showed that they were not limited to cost and schedule implications. Additionally, when the factors were identified for each delivery method, the motivation behind the selection of each delivery method varied.

Design Bid Build projects also showed a unique ranking of motivating factors for selection of this delivery method. The highest ranking items for this delivery method were the importance of cost and schedule as motivating factors. Not surprisingly, these two motivating factor were followed closely by a requirement of the owner or regulatory agency to use Design Bid Build. This shows that there are still a large number of transportation projects that require the use of DBB as the primary delivery method. The rankings of factors influencing the selection of DBB are found in Table 7-13.

Table 7-13 Motivating Factors for Selection of DBB Projects with Means

Cost of project	4.97
Urgency of project	4.87
Required by owner or regulatory agency	4.73
Multiple stakeholder coordination	4.50
Best method for risk allocation	4.37
Quality concerns	4.37
Regulatory initiatives	3.83
Opportunity for innovation	3.73
Lack of in-house resources	3.52

(N = 31)

For CMAR projects, the main motivator for selection of this delivery method was that it was perceived to be the "best method for risk allocation". Still highly ranked was CMAR's ability to affect cost, as well as "quality concerns". The ranking of motivating factors for CMAR projects are given again in Table 7-14 in order of greatest to least influence.

Table 7-14 Motivating Factors for Selection of CMAR Projects with Means

	Mean
Best method for risk allocation	5.21
Cost of project	5.00
Quality concerns	4.80
Opportunity for innovation	4.07
Multiple stakeholder coordination	4.07
Urgency of project	3.93
Lack of in-house resources	2.60
Required by owner or regulatory agency	2.20

(N = 15)

Design Build projects were selected based on a unique set of factors. This project delivery method was found through the literature to be selected based on the project team's desire to accelerate the schedule. The study similarly found that schedule was the overwhelming motivator for the selection of DB to deliver that project. Other influencing factors can be seen in Table 7-15.

Table 7-15 Motivating Factors for Selection of DB Projects with Means

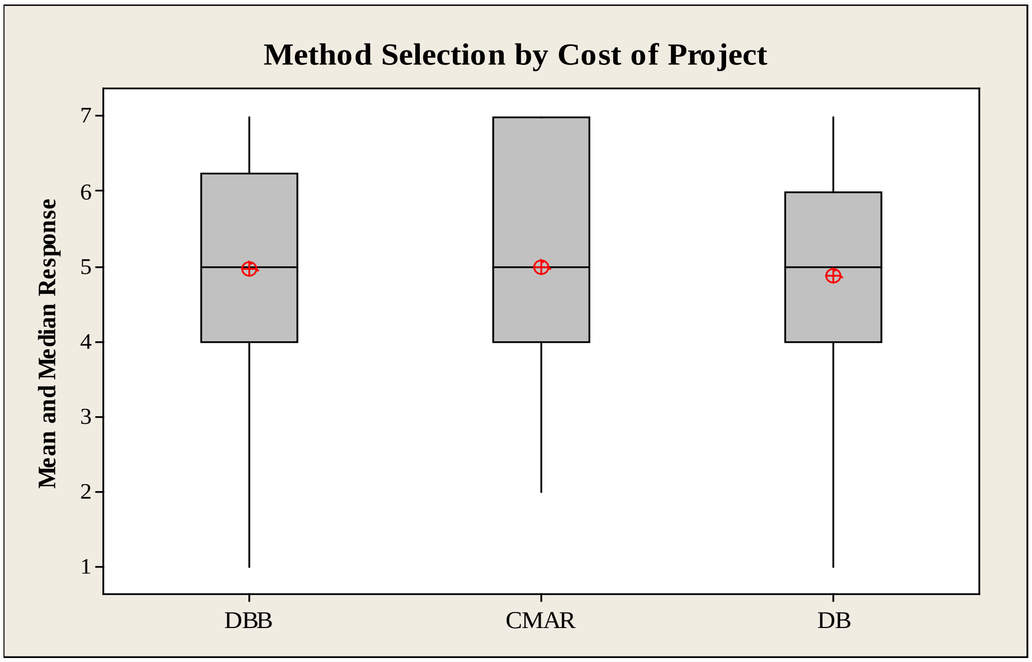
Urgency of project	6.12
Cost of project	4.76
Best method for risk allocation	4.71
Opportunity for innovation	4.35
Quality concerns	3.82
Lack of in-house resources	3.65
Multiple stakeholder coordination	3.47
Required by owner or regulatory agency	2.76
Regulatory initiatives	2.53

(N = 17)

The testing of the research hypothesis did show that there are specific motivating factors for the section of a delivery method; that they are not limited to cost and schedule; and these factors can be ranked according to importance and differ between project delivery methods.

There is a preference among national project owners as to what delivery methods are most effective at reducing costs and controlling schedule. This preference can be measured and compared. Project owners where asked to provide the motivation for selecting a specific delivery method. It was discovered that, for the most part, each method was perceived by the owner to be the most effective at influencing cost and schedule outcomes. To analyze their preferences further, an analysis of means between the delivery method groups was performed for “cost of project” and “urgency of project”. This could indicate if one project delivery method was perceived to be more effective than another at influencing the cost or schedule.

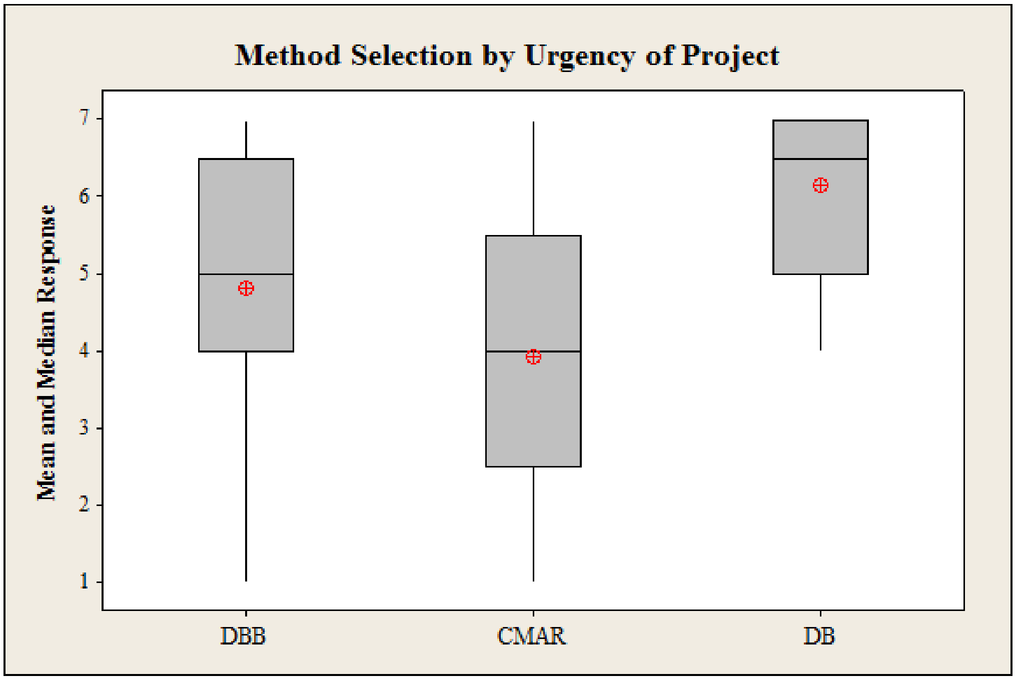
Cost was first analyzed; Figure 7-1 shows the close relationship between the means for “cost of project” by delivery method. The data indicated that owners did not believe that any one delivery method was the most effective at controlling project costs. A slight preference was shown for DBB projects for controlling cost, but not to any significant level.



Mean (ø) and Median (|) Response

Figure 7-1 Method Selection by Cost of Project

A similar analysis was used to examine project schedule and delivery method assumptions. Project owners showed a belief that the selection of Design Build to deliver a project had the greatest ability to affect the project schedule. There was not a statistically significant difference found between DBB and CMAR projects, but both were perceived to be less effective at influencing the project schedule. Figure 7-2 shows a boxplot of these findings.



Mean (ø) and Median (|) Response

Figure 7-2 Method Selection by Urgency for Project

This section is not intended to indicate that the selection of the delivery methods actually have an effect on project costs and schedule; it served to indicate the perception of project owners in regards to the different delivery methods and expectations. Actual project outcomes are summarized in the previous sections, as well as in the section titled project outcomes in Chapter Five.

7.3 Pre-Construction Services

Pre-construction services are often performed on transportation projects. Different project delivery methods are better equipped to perform these services. The study concluded that the different delivery methods had varying abilities to successfully complete the pre-construction services. For most pre-construction services identified in the survey, CMAR and DB projects were better equipped to provide those services. This is most likely due to the structure of CMAR and DB projects and the timing of contractor involvement. This is one of the advantages to APDM usage; however, DBB projects showed a greater ability to perform some of the pre-construction services. For example, they were rated higher for their control over “design management”, “agency coordination”, and use of “small, women, and minority businesses”. However, overall, DB and CMAR projects showed an increased ability to perform pre-construction services.

Pre-construction services can be accomplished through the use of industry best practices. The most beneficial best practices to accomplish specific pre-construction services can be ranked. The study showed that among the best practices, there were some that were considered to be the most beneficial. Figure 7-3 shows a pie chart depicting the resulting conclusion to the practices perceived to be the best for overall project success.

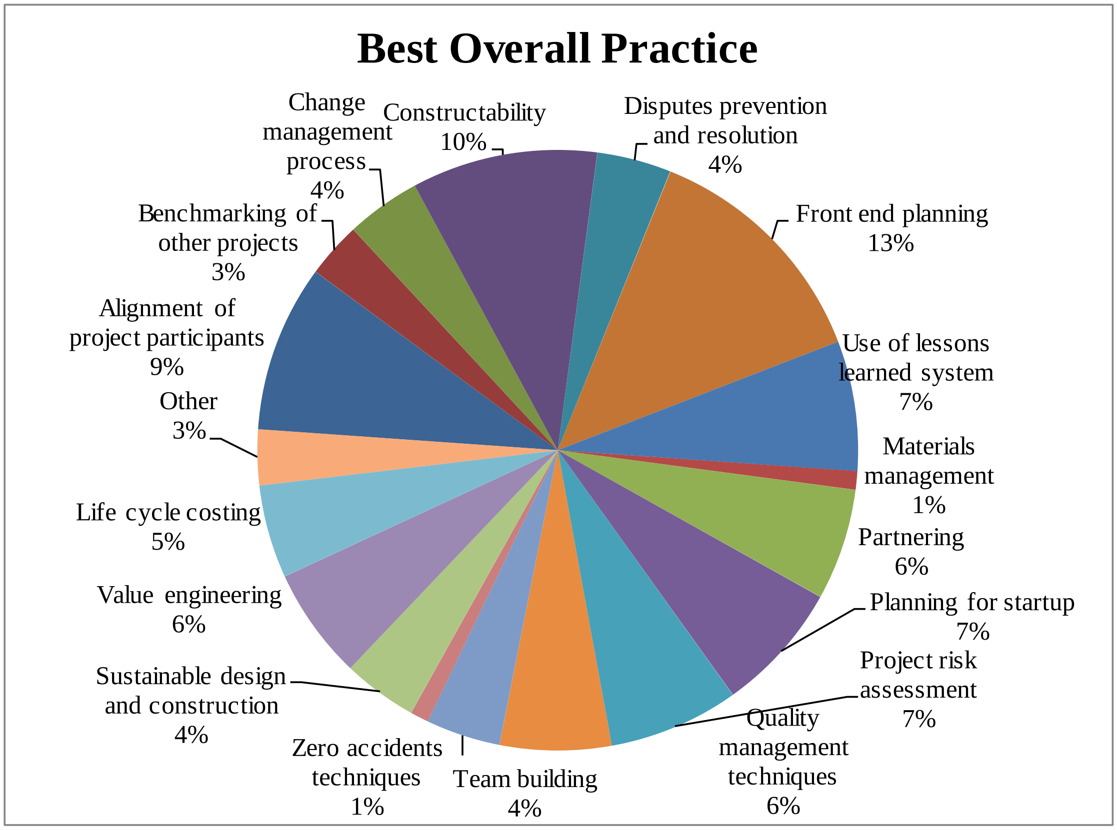


Figure 7-3 Most Beneficial Best Practices

The best overall practice to accomplish a project's pre-construction service goals was "front end planning". Following closely behind "front end planning" were "constructability reviews" and "project risk assessment".

Project participants use best practices to achieve pre-construction service goals; these project participants can provide information as to the most effective practices to achieve these goals. This study found that project teams use specific practices to successfully accomplish pre-construction services. Some of these practices are considered to be "best practices" by the industry because they have shown a great ability to affect the success of a project. As a project team seeks to perform a specific pre-construction service, they should use the practices that are most fitted for the success of each objective. The matrix provided in Table 7-16 is a breakdown of the services that are often performed by an organization and the practices that should be used to accomplish that service. The numbers in the boxes represent the percentage of responses that felt like the specific practice was the most beneficial to achieve the service objective above. Practices that were found to be most beneficial are highlighted on the table.

Table 7-16 Best Practices by Objective Matrix

Best Practice \ Pre-construction Service	Identification of project objectives	Risk identification and assessment	Risk mitigation	Design management	Agency coordination and estimating	Constructability/bidability analysis	Value analysis/engineering	Bid packaging	Schedule development	Site logistics planning	Disruption avoidance planning	Small, women, and minority business participation	Construction phase sequencing	Subcontractor prequalification	Multiple bid package planning	Real-time cost feedback	Building information modeling	Total cost of ownership analysis	Cost estimating	Budget management	Stakeholder management	AVERAGE
Alignment of project participants	18	6	9	18	24	3	0	8	4	0	4	14	0	5	6	5	13	4	4	4	28	8.43
Benchmarking of other projects	9	3	0	3	3	3	0	0	11	0	4	5	4	10	0	0	0	4	4	4	0	3.19
Change management process	3	3	6	3	3	0	0	0	7	0	28	0	0	0	0	0	0	0	4	17	3	3.67
Constructability	3	10	3	9	0	53	7	8	7	12	8	5	42	0	12	0	7	0	15	0	0	9.57
Disputes prevention and resolution	3	3	6	6	3	7	0	0	0	4	24	0	4	5	0	10	0	0	0	4	0	3.76
Front end planning	33	6	6	15	14	10	4	24	25	32	8	0	12	0	12	5	13	8	11	4	14	12.19
Use of lessons learned system	3	6	12	6	0	3	4	8	14	16	4	0	4	14	18	5	7	0	7	8	3	6.76
Materials management	0	0	0	0	0	0	0	4	0	0	0	0	8	0	0	5	0	0	0	0	0	0.81
Partnering	9	3	6	6	17	3	4	0	0	4	4	24	4	14	6	5	0	0	0	0	24	6.33
Planning for startup	0	0	0	0	7	3	7	16	21	16	8	10	4	10	24	5	20	8	4	4	0	7.95
Project risk assessment	3	55	38	0	0	3	4	8	0	8	4	0	0	5	0	5	0	0	0	0	0	6.33
Quality management techniques	6	0	0	9	7	3	0	8	7	0	0	5	4	5	12	20	13	0	15	17	7	6.57
Team building	3	3	3	9	7	0	0	8	0	0	0	24	0	14	0	5	0	0	4	4	17	4.81
Zero accidents techniques	0	0	0	0	0	0	0	0	0	4	4	0	0	5	0	0	0	0	0	0	0	0.62
Sustainable design and construction	6	0	3	3	3	0	11	0	4	4	0	0	12	0	0	5	0	13	4	13	0	3.86
Value engineering	0	0	3	9	7	3	59	4	0	0	0	0	0	0	0	10	0	8	11	4	0	5.62
Life cycle costing	0	0	0	3	3	0	0	0	0	0	0	0	4	0	0	5	20	54	15	13	0	5.57
Other	0	0	3	0	0	3	0	4	0	0	0	14	0	14	12	10	7	0	4	4	3	3.71

Scale from least to most beneficial

Historical data can provide the costs of pre-construction services for transportation projects; this project data can be used as a guide to estimate pre-construction services for future projects. Data from the surveyed projects showed that the different delivery methods were not equal in terms of the cost of pre-construction services. Table 7-17 provides the pre-construction service costs as a percentage of total costs for DBB, CMAR, and DB projects. Not surprisingly, CMAR and DB projects had a higher percentage of cost for pre-construction services. The percent of total cost for pre-construction services can be used as a guide to estimate pre-construction service costs for future projects.

Table 7-17 Pre-Construction Service Costs

	Pre-Construction Service Costs as a Percent of Total Cost
DBB (N = 11)	0.22%
CMAR (N = 7)	6.17%
DB (N = 9)	8.60%
All Projects (N =27)	7.03%

7.4 Best Practices and Project Challenges

There are elements of each project that present the greatest challenge; these elements can be identified and ranked. The elements differ by delivery method. Analysis of survey data concluded that the top three elements presenting the greatest challenge to transportation project completion for all delivery methods considered together was “environmental impacts”. “Public involvement” and “project schedule” were the next most challenging elements. When these projects were analyzed by delivery method, the analysis found that for DBB projects, the greatest challenges came from “environment impacts”, followed by “existing conditions”, “project schedule”, and “public involvement". DB projects were challenged by "construction site access", followed closely by "differing site conditions", "environmental impacts", and "project schedule". Lastly, CMAR projects reported "public involvement" as the most challenging. The other choices selected under CMAR each only had one project that selected the other factors as most challenging. More challenges were discussed in Chapter Five that give insight into elements that cause projects to be unsuccessful.

There are specific management practices that can improve project outcomes; these practices can be identified and ranked. Their importance varies by delivery method. Data from respondents showed that the project outcome could be improved by using effective management practices. The overwhelming majority of respondents felt that the most effective management practice to improve project outcome was the use of a front end planning process. Also ranking highly were performing "project risk assessments" and "alignment of project participants". When analyzed by delivery method, DBB and CMAR projects had the same top practices as all delivery methods considered together. DB projects cited "constructability reviews" and "dispute prevention and resolution" as the practices that could most improve project outcomes.

7.5 Team Alignment

Project teams are selected based on a number of criteria. These selection criteria vary by delivery method. The study concluded that there are specific factors that lead to the selection of team members, and that these factors can be ranked by importance. For all delivery methods used, "project experience" and "schedule compliance" ranked highly. CMAR projects ranked "history with company" as the most important criterion. All other delivery methods had a relatively low ranking for this criterion. Table 7-18 provides the responses of project participants, showing the criteria for selecting a team and the rank by frequency of selection for each delivery method.

Table 7-18 Factors Influencing Team Selection

Factor	All Projects (N = 78)		DBB (N = 31)		CMAR (N = 15)		DB (N = 17)	
	Rank	Average	Rank	Average	Rank	Average	Rank	Average
Project experience	1	5.65	1	5.62	3	5.18	1	5.91
Schedule compliance	2	5.24	3	5.17	2	5.36	3	5.27
Licensure and professional registrations	3	5.03	2	5.24	5	4.45	4	5.05
Experience in selected delivery	4	4.74	8	4.43	6	4.45	2	5.27
Budget compliance	5	4.70	4	4.96	9	4.18	5	4.64
Experience with local conditions	6	4.55	6	4.76	7	4.36	7	4.36
History with company	7	4.44	9	4.29	1	5.55	8	4.09
Workload	8	4.44	5	4.90	10	4.00	9	4.05
Safety record	9	4.30	11	3.96	4	4.82	6	4.45
Location of team member	10	3.94	7	4.57	8	4.18	13	2.95
Contractual obligation	11	3.84	10	4.15	11	3.91	12	3.43
Team training/apprenticeship	12	3.74	13	3.79	12	3.55	10	3.77
Legal obligation	13	3.72	12	3.93	13	3.36	11	3.64

Factors influencing the selection of the project team were analyzed collectively, as well as by delivery method. The means were compared to determine which had statistically significant differences between them. Using the one-way ANOVA test, the delivery methods, individually as well as collectively, had significant differences between the means of the 13 variables at the 95 percent confidence level, with the exception of the CMAR projects. The CMAR group had the smallest sample size, which may have contributed to the lack of a statistically significant difference between the means.

When the means for the different delivery methods were examined separately, there were a few things that were noticed. The factors "project experience" and "schedule compliance" had a high mean for each of the delivery methods and seemed to have high importance regardless of delivery method selected. Although there were some similarities between the methods, the author also noticed some large differences. The factor “history with the company” had a high mean for CMAR projects, but was low for both DBB and DB projects. As CMAR projects are increasing in use on transportation projects, the contribution of a team member with experience in CMAR is valuable. Also, the factor “location of the team member” did not have an exceptionally high mean for CMAR projects or DBB projects, but was noticeably low for DB projects, with a mean of 2.95. The factor “experience with selected delivery method” was also important for DB projects, with a mean of 5.27 versus a mean of 4.45 for CMAR projects and 4.43 for DBB projects. When ranking the factors according to the highest means, “experience with selected delivery method” was second for DB projects and sixth and eighth for CMAR and DBB projects, respectively.

There are practices that affect how a team is aligned. The relative importance of these practices can be ranked; these rankings change by delivery method. Study findings showed that team alignment was affected by the practices of a project team. It was also found that the different delivery methods showed unique sets of practices that seemed to improve team alignment. In Chapter Five, the practices that were most beneficial to improve team alignment were discussed in detail and by each delivery method. Table 7-19 shows the general conclusions of the analysis by providing the aspect most beneficial to team alignment and the number of times the aspect was reported as most beneficial. The table also reports by delivery method. The survey found that the most beneficial practice to achieve project success was to establish expectations, followed closely by establishing team trust, honesty, and shared values.

Table 7-19 Most Beneficial Aspects to Team Alignment

Most Beneficial Aspect to Team Alignment	Frequency			
	DBB (N = 30)	CMAR (N = 15)	DB (N = 18)	All Methods (N = 63)
Established expectations	6	1	4	12
Established team trust, honesty, and shared values	4	3	3	10
Communicated effectively with stakeholders	5	1	2	8
Developed individual and group roles and responsibilities	4	1	3	8
Conducted productive team meetings	2	1	1	4
Resolved conflicts appropriately	1	3	0	4
Defined project leadership and accountability	2	0	0	3
Defined project success	1	0	2	3
Established project priorities such as costs, schedule, public relations, etc.	1	0	1	3
Evaluated risk	2	1	0	3
Involved all project stakeholders appropriately	1	0	1	2
Addressed concerns	1	0	0	1
Effectively used planning tools such	0	1	0	1
Measured team alignment	0	0	1	1
Conducted adequate preconstruction or front end planning practices	0	0	0	0
Documented project details, including short comings and successes	0	0	0	0
Instituted effective team building programs	0	0	0	0

There are aspects of a project that will create challenges for a project team. These challenges can be identified and ranked; their rankings differ by delivery method. Project teams will have multiple challenges through the course of a project. The study concluded that there are aspects that will challenge the team more than others; a survey of all project participants showed that the greatest challenge to team alignment was the pressures caused by the project schedule. There were many challenges identified by respondents and each delivery method showed a unique set of challenges to team alignment; however, each individual delivery method cited project schedule as the most challenging to team alignment. This was followed closely behind by “team coordination” for CMAR projects, “constructability procedure” for DBB projects, and “environmental impacts” for DB projects.

7.6 Implications for Practitioners

The industry has been using alternative project delivery methods for many decades. Some of the misconceptions about the strengths and weaknesses of each method have continued to influence how a delivery method is selected and implemented. This section serves as advice to practitioners in selecting and using a delivery method. First practitioners should be aware of the preference given to specific delivery methods to accomplish specific project goals. Practitioner should be aware that although there may be a preference for a delivery method to accomplish a specific goal, the research may not support that assumption. For example, DBB may be selected based on its ability to control costs, the reality is that it has the highest cost growth measure of the sample of the delivery methods studied. While a practitioner might select DBB based on a low cost per lane mile, they should first consider the size and complexity of the project. It would not be wise to assume that DBB would be the most accurate cost predictor when all aspects of the project are considered. In general this study showed that the majority of the assumptions concerning cost growth, schedule growth, and other success indicators made about project outcomes by delivery method are not supported by data. Some however do reach a level of significance.

Although project size, complexity, number of stakeholders and other project characteristics play a role in project outcomes, some general observations can be made about delivery method outcomes. For example, DB project have greater design schedule growth followed by DBB projects. CMAR projects show very little design schedule growth. However, both CMAR and DB projects tend to have greater construction schedule growth. This results in very little difference in overall schedule growth between the delivery methods.

Selection of a delivery method therefore may come down to a few very basic preferences. CMAR projects should be selected when the owner prefers a greater amount of control over the project while still taking advantage of the transfer of risk. CMAR is well suited for more complex as well as basic projects. DB projects have been shown to be effective for large or complex transportation project where cost is the not the main motivating factor for section. DB projects show good cost control and may lead to a shorter overall schedule but may also lead to increased schedule growth. DBB project are well fit for non-complex projects. These are projects in which there are few unknowns and expectations should be consistent with previous projects.

After a method is selected, there are specific practices that should always be implemented to achieve a successful project. A formal and effective front end planning procedure is critical to project success and will improve any project. Practitioners should also give great emphasis on team alignment including the alignment of project participants. Alignment is a great indicator of project success and poor alignment is cited as a leading cause for challenges. Constructability reviews are also a key component regardless of delivery method selected. Constructability reviews should be given a high priority.

Many of the practices that lead to successful projects are accomplished in a pre-construction phase. The APDMs are well suited to incorporate these services. This may add additional costs to APDM projects but these services are essential. DBB projects can also perform preconstruction services, their costs are typically rolled into the cost of construction and may not be separated.

Practitioners should avail themselves of every tool or procedure that make projects run efficiently. An overall observation that could lead to a conflict free project is the practice of communicating expectations. This applies to participants at all levels. When expectation are understood and communicated participants are all pulling in the same direction. When the opposite is true, time, money, and energy are wasted.

8 CONCLUSIONS AND RECOMMENDATIONS

This chapter offers a summary of the research study. Conclusions are made in relation to the research hypotheses and objectives that were identified for the study. Limitations to the research are identified and recommendations for improvements to this and future studies are provided.

8.1 Research Summary

Organizations have the opportunity and challenge of finding a delivery method that is the best fit for a specific project. Additionally, once a delivery method has been selected, a project team is then faced with the challenge of finding the best way to achieve project objectives. This research effort was performed with a goal of improving the way projects are delivered. A background and in-depth literature review provided a foundation for analysis and an understanding of gaps in the research. The research methodology described in Chapter Four detailed the path to accomplish the research objectives.

To accomplish the research objectives, the research study focused on four main categories: project outcomes, delivery method selection, pre-construction services, and best practices, such as team alignment. Within each research objective, many topics were covered and based on those topics, specific research hypotheses were tested. The next section restates the hypotheses that were tested and concludes if the hypotheses were validated.

The research effort was able to accomplish study objectives by completing a comprehensive and comparable study to those performed on vertical APDM projects that can now be used in the horizontal transportation construction market. Through the collection of project data as well as input from industry leaders the research report provides a better basis for decisions on which project delivery methods should be used and how best to use them. Practitioners can use this research to provide a better foundation for decisions in regards to future project delivery use, both nationally and locally. Through the publication of the dissertation as well as future articles and papers, the findings of this effort can be used for educational purposes to improve the industry. By performing an analysis of team alignment, pre-construction services, industry best practices, and understanding the impacts these processes have on the project delivery processes and project outcomes, practitioners will be better prepared to make key management decisions to achieve successful projects.

The research topics were divided into four categories, each with specific goals for testing a hypothesis. The four categories and the conclusions for each hypothesis are given in this section.

8.1.1 Project Outcomes

Hypothesis: *Project outcomes using alternative project delivery methods are different than using traditional Design Bid Build. Each delivery method has results that are specific to that method.*

- CMAR and DB project have more variety in both size and complexity. They are more commonly used for larger or more complex projects.
- The greatest challenges to transportation project completion was environmental impacts, public involvement, and project schedule. For DBB projects, environmental

impacts, existing conditions, project schedule, and public involvement. For DB projects, construction site access, differing site conditions, environmental impacts, and project schedule. For CMAR projects, public involvement as the most challenging element.

- The most effective management practice to improve project outcome was the use of a front end planning process. Also ranking highly were performing project risk assessments and alignment of project participants.
- CMAR projects tended to use a GMP pricing method, while DB projects preferred a fixed price method and DBB projects overwhelmingly used a unit price method.
- Pricing method is a predictor of cost or schedule growth. GMP and unit price contracts had an increased schedule growth when compared to fixed price contracts. GMP showed an increase for cost growth as well, while both fixed price and unit price pricing methods had an average reduction in costs.
- GMP projects had more growth in both schedule and cost.
- DB projects had on average more change orders, cost per change order was less than both CMAR and DBB projects. DBB projects showed the highest percent of total costs due to change orders. DBB also had the least average number of change orders per project.
- Complexity and size play a role in the number and value of change orders.
- DB had the most change orders. The average delay caused in both the construction phase, as well as overall, was less than delays caused by DBB and CMAR projects.

- The services that could help reduce change orders the most were constructability/bidability analysis, risk identification assessment, and good design management.
- Owners feel that CMAR and DB projects can deliver projects faster
- DB projects have lower design and ROW/utilities costs, but a slightly higher pre-construction services cost. DBB projects have almost no pre-construction service costs, but a very high design cost. CMAR projects were found to be right in the middle of DBB and DB for pre-construction services and design costs, but had a high ROW/utility cost.
- No significant difference in overall schedule growth for each of the delivery methods.
- DB projects were more susceptible to design schedule growth at 29.55 percent and DBB projects followed closely behind at 18.10 percent. CMAR projects showed little to no design schedule growth.
- Construction schedule growth showed more growth for CMAR and DB projects.
- The majority of owners believed that the delivery method used was the best fit for the project.

8.1.2 Project Delivery Method Selection

Hypothesis: *There are a number of project delivery methods available to use on transportation projects; each delivery method has unique characteristics. Owners primarily select a delivery method because it will more likely result in reduced project schedules and costs, mitigated risks, and successful completion of project goals based on the project scope and its management capabilities.*

- The primary motivating factors for the selection of a project delivery method are the delivery method's ability to affect the project cost and the project schedule.
- For CMAR projects, the main motivator for selection of this delivery method was that it was perceived to be the "best method for risk allocation". Still highly ranked was CMAR's ability to affect cost, as well as "quality concerns".
- The highest motivating factors for DBB selection were the importance of cost and schedule as well as requirement of the owner or regulatory agency to use Design Bid Build
- Design Build was selected based on the project team's desire to accelerate the schedule. The study similarly found that schedule was the overwhelming motivator for the selection of DB to deliver that project.

8.1.3 Pre-Construction Services

Hypothesis: *Alternative project delivery methods (Design Build and CM at Risk) are better equipped to perform pre-construction services than the traditional Design Bid Build method.*

- CMAR and DB projects were better equipped to provide pre-construction services.
- DBB projects were rated higher for their control over "design management", "agency coordination", and use of "small, women, and minority businesses".
- The best overall practice to accomplish a project's pre-construction service goals was "front end planning". Following closely by "constructability reviews" and "project risk assessment".

- CMAR and DB projects had a higher percentage of cost for pre-construction services, at 6.17 percent and 8.60 percent, respectively. DBB projects perform very little pre-construction services, and therefore had almost no cost associated with these services.

8.1.4 Team Alignment

Hypothesis: *Each delivery method uses specific criteria for selecting and aligning the project team, which will differ among the delivery methods; team alignment will affect the success of projects.*

- Project teams are selected primarily on “project experience” and “schedule compliance”
- CMAR projects ranked “history with company” as the most important criterion.
- The greatest challenge to team alignment was the pressures caused by the project schedule: “team coordination” for CMAR projects, “constructability procedure” for DBB projects, and “environmental impacts” for DB projects.

The goals of testing specific research hypotheses were met successfully. The study has provided conclusions to the hypotheses, as summarized in this section. Not all hypotheses were found to be validated, or validation may not have reached a statistical significance. The findings, however, add to the body of knowledge and give valuable insight into the study topics.

8.2 Limitations/Recommendations

Although the research effort was quite successful, there were limitations to the research and lessons learned from the methodology that may be discussed. These limitations range from unclear survey wording to uncontrollable limitations in statistical analysis methods. This section is an attempt to address the limitations that may have had an effect on the research results.

Several questions asked on the survey relied upon a seven point Likert scale and collected data were not always normally distributed. There are significant arguments in academia that argue for or against using parametric tests, such as regression and ANOVA, while not meeting the assumptions for normality when using a Likert scale. Many of the arguments reason in favor of using parametric tests without meeting the normal distribution assumption and claim that robustness can be met without it. The later argument was used in favor of using parametric tests for this research; however, some might find reason to dispute this, while holding to the former argument against using parametric tests in this case.

Questions 31 through 34 in the survey asked respondents to give specific answers in regards to schedule (both planned and actual), as well as cost (both budgeted and actual). Due to the specific dates and dollar amounts required to answer this question, it was often times left blank, while the rest of the survey received quality responses. This limited the data in regards to cost and schedule performance. Many of the tests run in these areas did not have statistical significance and was likely due to the smaller sample sizes that were used for these areas. A possible remedy for this might have been to place these questions closer to the beginning of the survey, so respondents could answer these before survey fatigue set in.

Question three on the survey asked respondents to give specific information about details of the project they were using to answer the survey questions. One part of this question asked respondents to list the “scope of work” and “capacity of facility built” (i.e., lane miles). This question needed to be a little more specific and get precise information from them. It was unclear if some of the respondents were answering using total lane miles or miles of construction (i.e., several lanes per mile). This made some of the data unusable.

After reviewing the data for question six in the survey, which asked respondents to rate the factors that influenced their selection of delivery method using the seven point Likert scale, it was found that “regulatory initiatives” may have likely been misunderstood. It appears that some respondents referred to it in a similar manner as “required by owner or regulatory agency”. Some further clarification to ensure what was meant by “regulatory initiatives” would have been helpful.

8.2.1 Suggestions for Future Research

The author notes that literature dealing with alternative project delivery is extensive. However, the level of statistical significance for the majority of the studies performed is lacking based on small sample sizes. Although this has been the largest study of transportation projects to date, a good number of the analyses were still unable to show statistical significance. The author suggests that future research efforts focus on combining the results of research efforts through a Bayesian analysis in order to pool the significance of each study and make significant conclusions.

Additional research should focus on the long-term quality differences seen between the delivery methods. Quality studies have been completed based on qualitative data, but an analysis of quality by quantitative and measurable data, such as road condition tests, has not been performed.

8.3 Research Contributions

This successful research effort has resulted in very valuable information that will be beneficial to the construction industry. The Author has identified a number of contributions that follow.

- Largest APDM study for transportation construction market
- Documented cost, and schedule results for DB and CMAR
- Provided a better basis for delivery method selection and use
- Performed an analysis of
    - team alignment
    - pre-construction services
    - industry best practices
    - the impacts these processes have on project delivery

8.4 Conclusions Summary

Despite some limitations inherent in any research effort, this work proved successful in meeting the research objectives. Using a similar research approach to those used for analysis of delivery methods on vertical projects, this study was able to provide a baseline for transportation projects and add to the body of knowledge for APDM usage. By documenting the cost, schedule, and quality results of the survey, a better understanding of DBB, CMAR, and DB projects was realized. This research provides a better basis for decisions on which project delivery methods should be used and how best to use them. Additional useful contributions into understanding the best practices used in

APDM projects and transportation projects as a whole was also attained. Through the publication of this research, together with additional works that come from this study, this effort provides data for educational purposes to improve the industry. By performing an analysis of team alignment, pre-construction services, and industry best practices, the study has demonstrated the impacts these practices have on the project delivery processes and project outcomes. The author hopes that this work is found to advance and enrich the industry and provide beneficial insight into the best practices used in transportation projects.

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APPENDIX A

PARTICIPATION EMAIL

John Doe,

My name is Evan Bingham and I am a Graduate Research Associate at Arizona State University. As part of a national research study we are collecting data on infrastructure projects throughout the nation. This study is being done in collaboration with the Alliance for Construction Excellence (ACE) and the School of Sustainable Engineering and the Built Environment through Arizona State University. A necessary component of the study requires feedback by way of a survey from project leads/managers. We would greatly appreciate your help by participating in a survey. Feedback from individuals such as yourself is critical for the success of the study. I have listed below some of the benefits that your organization can hope to achieve by participating in this endeavor.

- Provide your organization with specific performance measures to benchmark your projects with other agencies
- Provide specific management techniques that could be used to improve the way your organization performs
- Increase your understanding of traditional and alternative project delivery methods
- Provide validation for the use of alternative project delivery methods at a state and national level
- Provide a guide for pre-construction services
- Provide a better basis for your organization's selection of project delivery methods
- Enrich and advance the industry through a beneficial research collaboration

I have attached a document giving a summary of our research objectives and a description of our study.

The following link is the survey for which we would like project leads/managers to take. This can be taken for past **completed projects or projects that are near completion**. If your current project does not meet the qualifications, then please use a past completed project.

https://www.surveymonkey.com/s/SR32HVD

As someone who has previously worked in the industry, I understand that your time is very valuable and we would sincerely appreciate your participation. We look forward to hearing back from you. Please feel free to contact me with any questions that you may have.

Kind Regards,

Evan Bingham

APPENDIX B

REQUEST FOR PARTICIPATION

The Alliance for Construction Excellence (ACE) in collaboration with Arizona State University Schools of Engineering is sponsoring a research effort aimed at improving the delivery of horizontal projects. As an essential component of the research we are collecting specific project information from agencies actively involved in using multiple project delivery methods. The goal of the research is to improve the delivery of horizontal projects through a better understanding of effective management techniques, targeted preconstruction services, and an improved basis for delivery method selection. We are collecting data using Design Build, Design Bid Build or Construction Manager at Risk. In order to gather data for analysis we are requesting your participation.

What can this research do for your agency?

- Provide your organization with specific performance measures to benchmark your projects with other agencies
- Provide specific management techniques that could be used to improve the way your organization performs
- Increase your understanding of traditional and alternative project delivery methods
- Provide validation for the use of alternative project delivery methods at a state and national level
- Provide a guide for preconstruction services
- Provide a better basis for your organization's selection of project delivery methods
- Enrich and advance the industry through a beneficial research collaboration

How can you help us?

We are trying to collect specific project data by way of an online survey. The survey needs to be completed by a member of either an owner or contracting organization that has a good knowledge of the completed project. The survey asks questions about cost and schedule performance as well as project team dynamics for the targeted project. Projects can implement any type of project delivery method but should have a total project cost over $5 million and been completed in the last five years.

We are trying to complete several surveys from each state to provide significant feedback. Your help would be greatly appreciated. We feel the benefits to your organization will be worth your participation efforts. To contribute to this endeavor or for any questions, please contact:

Evan Bingham
Graduate Research Associate
Arizona State University
evan.bingham@asu.edu
Phone: (602) 541-1580

Alliance for Construction Excellence

Ira A. Fulton Schools of Engineering
ARIZONA STATE UNIVERSITY

APPENDIX C

PROJECT DESCRIPTIVES

Survey ID	Role	State	Scope	Capacity	Delivery Method	Pricing Method	Calendar Days	Total Project Cost $	Complexity Rating 1 - low 5-high
3105296867	Owner	AZ	Underpass	Underpass	CMAR	GMP	858	$8,500,000	1
3105279948	Owner	AZ	Road reconstruction and improvement, restoration of historic street lights		CMAR	GMP	798	$665,500	1
3105255187	Owner	AZ	New city road	7.5 miles	CMAR	GMP	2218	$45,000,000	2
3084014844	Owner	MI	Terminal and connectors, bridges, roadways		CMAR		1199	$400,000,000	5
3083892838	Owner	AZ	Airport rail system		CMAR	GMP			4
3083809951	Owner	AZ	Airport rail system		CMAR	GMP			4
3083769407	Owner	AZ	Airport rail system		CMAR	GMP			4
3083741450	Owner	AZ	Roadway improvement, box culverts, bridges, multi-use trail	7.5 miles new two lane roadway, 23 box culverts, 3 bridges, 5 mile trail, 10 pedestrian bridges	CMAR	GMP			5
3083718280	Owner	AZ	Roadway improvement, box culverts, bridges, multi-use trail	7 miles new roadway, 2 bridges, trails	CMAR				4
3083478628	Owner	AZ	New roadway, bridges, box culverts	6.8 miles new roadway, 3 bridges, 23 box culverts	CMAR	GMP	1979	$19,094,000	2
2956308910	Owner	UT	New roadway	60 lane miles	CMAR				1
2910069916	Owner	AZ	New roadway and storm drain system		CMAR	GMP			2
2908715082	Owner	AZ	Replace existing bridge with box culvert	6 lane bridge	CMAR	GMP	1888	$8,482,000	1
2908265671	Owner	AZ	New roadway through nature preserve in desert	12 lane miles	CMAR				2
2869648543	Owner	UT	New interchange	5 Lanes	CMAR	Fixed Price			3
2862083889	Owner	UT	Roadway reconstruction and widening	19 lane miles of new roadway with full shoulders.	CMAR	Unit Price	915	$15,793,000	3
2860529086	Owner	LA	Bridge and roadway approaches	5.5 miles bridge work (2 Lane)	CMAR	Unit Price			2
2855916389	Owner	UT	Retaining walls, rock protection, drainage	2 lane miles	CMAR	Unit Price	123	$1,805,000	1
3084047272	Owner	FL	Taxiways and center lights		DB		1005	$31,925,005	2
3084024662	Owner	MN	New Highway	12 miles	DB		1310	$484,000,000	5
3084001941	Owner	DC	Perimeter security bollard emplacement	8.5 mile	DB		3440	$140,000,000	4
2979291310	Owner	MD	4 lane roadway dualization	10 lane miles - 2.5 miles per lane for 4 lanes total	DB	Fixed Price	1612	$54,682,000	3
2972081949	Owner	MD	Widen overpass bridge, widen ramp, improvements		DB	Unit Price	1096		3
2964952336	Owner	MD	Bridge replacement and interchange	1 mile of additional lane and 1/2 mile of auxiliary lanes	DB	Fixed Price			4
2951957323	Owner	MD	Highway and bridge widening and reconstruction	6.5 lane miles	DB	GMP	1127		3
2906735424	Owner	UT	Roadway new construction	30 lane miles	DB	Fixed Price		$280,850,000	4
2873632044	Owner	TN	Interstate improvements, widening, new lanes	10 miles	DB	Cost Plus	700	$56,592,000	3
2872725069	Owner	UT	New freeway lanes		DB	Fixed Price			3
2857368546	Owner	UT	Widen 7 miles from 2 lanes to 3 lanes, widen structures.	42 lane miles (14 new lane miles)	DB	Fixed Price			3
2856165567	Owner	MT	Interstate major rehabilitation	11 miles of 4-lane interstate	DB	Fixed Price	930	$16,995,220	3
2853177586	Owner	FL	New interstate connector	5 miles	DB				2
2851622653	Owner	GA	New collector-distributor lanes	4.7 miles	DB	Fixed Price	863	$31,455,000	3
2850512773	Owner	AK	New runway	4500' runway	DB	Fixed Price	598	$75,707,000	4
2850457436	Owner	AK	New runway	4,000' Runway w/ 2 mile access road	DB	Fixed Price		$881,000	2
2849107730	Owner	GA	New interstate connector	0.94 miles	DB	Fixed Price	900		1
2848778188	Owner	AK	New runway and support facilities	4500'	DB	Fixed Price	573	$72,684	1
2848402456	Owner	GA	New highway	3 miles	DB	Fixed Price	1626	$101,800,000	2
2845478706	Owner	GA	New interstate connectors	29.7 miles	DB	Fixed Price			1
2843155679	Owner	GA	Bypass	6.8 miles	DB	Cost Plus			2

Survey ID	Role	State	Scope	Capacity	Delivery Method	Pricing Method	Calendar Days	Total Project Cost $	Complexity Rating 1 - low 5-high
3084040243	Owner	FL	Taxiways and center lights		DBB		1157	$22,937,754	2
3084033037	Owner	FL	Taxiways and center lights		DBB		973	$23,720,985	2
3083979252	Owner	CA	Freeway interchange		DBB		2616	$63,000,000	3
3083954004	Owner	CA	Wharf and backlands		DBB	Fixed Price	2590	$54,229,187	3
3083911474	Design	AZ	Marine terminal container yard	25 acres	DBB	Fixed Price	1156	$25,200,000	2
3022173684	Owner	FL	Reconstruction widening	3.5 miles	DBB				1
3020606282	Design	ID	Total interchange bridge replacement	4 lanes	DBB	Unit Price	1157	$11,401,000	3
2972888685	Owner	MD	Bridge replacement, roadway realignment, storm water management facilities	1/2 mile	DBB	Unit Price			3
2965353370	Owner	MD	Bridge replacement	1 mile	DBB	Unit Price	1614		3
2951991679	Owner	MD	Bridge replacement	100' prestressed girder bridge	DBB	Unit Price			2
2951751863	Design	TN	Grade, drain, bridges & paving	20 lane miles	DBB	Unit Price			1
2924371772	Owner	AK	Obstruction removal, runway relocation	6300'x150' RW & safety areas new access rd. 2 lane Miles	DBB	Unit Price			1
2899370606	Design	WY	Road way reconstruction	8.6 lane Miles	DBB	Unit Price	1248	$7,478,000	1
2896970382	Owner	ID	Grading, draining, placing base and bituminous surfacing	8.81 Miles	DBB	Unit Price			1
2888330352	Owner	FL	Add lanes and reconstruction widening	6.496 miles	DBB	Unit Price	1079	$11,560,522	1
2882464036	Design	ID	Bridge replacement, new lanes, improvements		DBB	Unit Price			2
2882116534	Design	ID	Concrete reconstruction	6 miles	DBB	Fixed Price		$416,000	1
2873702724	Owner	UT	New roadway		DBB	Unit Price			1
2872721476	Owner	TN	Interchange modification	Widen bridges, 2 lanes to 3 lanes,	DBB	Unit Price			2
2867717012	Owner	TN	Grade, base, pavement, signing and marking	7.42 Miles	DBB	Fixed Price			1
2862266401	Owner	ID	Expansion, reconstruction	248.5 lane miles, 5 new interchanges, 9 interchanges rebuilt or improved, over 16 new or improved bridges and structures	DBB	Unit Price	3348	$938,000,000	5
2860442752	Owner	GA	Arterial widening	3 miles	DBB	Unit Price			1
2858396876	Owner	AK	Reconstruction of interstate highway	from 2 to 4 lanes	DBB				1
2858043194	Owner	LA	Add lanes, rubbilize existing lanes, overlay, striping,	11 miles - six lane divided	DBB	Unit Price			1
2856804018	Owner	UT	Replace bridge decks on two structures	0.25 miles	DBB	Unit Price	368		2
2856040726	Owner	GA	Widening 2 to 4 lanes plus a median, bridge replacement	16.4 lane miles	DBB	Unit Price			4
2855457024	Design	AK	Runway overlay, lighting, striping	6820' x 150' runway	DBB	Unit Price		$721,000	1
2855250183	Owner	GA	Bridge reconstruction/rehabilitation	.21 Miles	DBB	Cost Plus	1644	$7,000,000	2
2854142996	Owner	WY	Highway repair		DBB	Unit Price	578	$1,900,000	1
2853668757	Owner	WY	Grading, drainage, utility, sidewalk, bridge	Divided 4-Lane	DBB	Unit Price	5298	$17,177,000	1
2853601606	Owner	AK	Highway widening, grade raises, replacement of drainage structures, surfacing, repairs to several bridges.	32 lane miles	DBB	Unit Price			3
2853547897	Design	CO	Minor widening, HMA overlay, bridge replacement, installation of ITS and signage	14 miles, 2 lanes each direction	DBB	Unit Price			1
2851388285	Owner	ID	Bridge replacement on interchange	1 New Interchange	DBB	Unit Price	1128	$898,698	1
2849079933	Owner	AK	Marine service center		DBB	Fixed Price	365	$4,638,171	1
2848931458	Owner	AK	Roadway reconstruction	41 lane miles	DBB	Unit Price		$11,788,000	1
2848670656	Design	AK	Highway reconstruction and widening from 4 to 6 lanes, frontage roads	16 lane miles	DBB	Unit Price	1979	$53,865,215	3
2848525618	Design	AK	Highway reconstruction and widening	5 lane miles	DBB	Unit Price	2008	$31,165,000	2
2848340808	Owner	GA	Widening	2.24 miles of 4 lane, divided roadway	DBB	Unit Price	3775		1
2844872597	Owner	DE	Bridge replacement	60 feet	DBB	Unit Price			3
2842624671	Design	DE	Multi-use pathway	9.5 miles	DBB	Unit Price	915		2
2855256792	Owner	FL	New road	Sub rural to 6 lanes divided, 3.5 miles		Unit Price			1

APPENDIX D

APDM LITERATURE – TRANSPORTATION PROJECTS

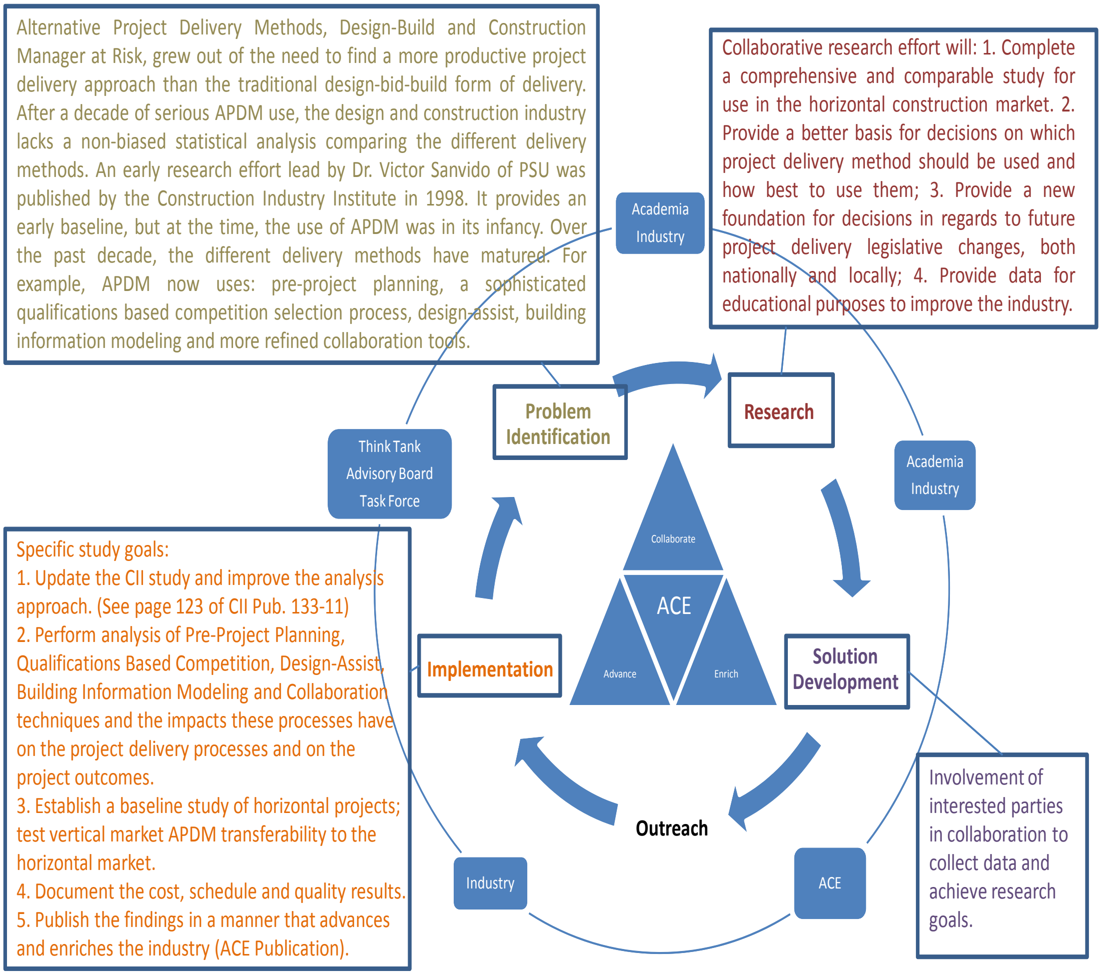
Conclusions	Publication Type	Sample size	Project type	Author	Organization	Title	Year
DB projects had 4.7% less cost growth and 9.3% less time growth. Best value projects had 2.0% less cost growth and 18.5% less time growth	Case Study		Highway projects		National Cooperative Highway	**Design Build Contracting for Highway**	**2006**
Estimated that Design Build project delivery reduced the overall duration of their projects by 14 percent, reduced the total cost of the projects by 3 percent, and maintained the same level of quality as compared to Design Bid Build	survey of project managers	69	Highway projects		USDOT - Federal Highway Administratio	**Design Build Effectiveness Study – As Required by**	**2006**
Claims to be the most "comprehensive analysis of CMAR; Comparing the cost of CMAR projects to state average prices showed that the CMAR projects were 15% more cost-effective. (This figure was derived by comparing bid prices, and factoring in the reduced change orders and overruns.) Change Orders and Overruns and Under runs were 6.6% compared to traditional projects and 6% compared to Design Build projects. Direct savings attributed to the contractor's input during design on recent projects showed 6-9% savings to project costs	Survey of project teams,19 in-process projects	19	Highway projects	UDOT	UDOT	**Utah Department of Transportation annual report**	**2009**
The average fee for pre-construction services on highway projects was found to be 0.80% of estimated construction costs. The Utah DOT has experienced a 40% savings on its design contracts, whereas the U.S. Army Corps of Engineers reported a savings of 2% of on its design costs for medical facilities. Savings associated with actual costs being less than the GMP were less than 1% in the projects reviewed with shared savings clauses	Case Study. Surveys, interviews	47 surveys, 10 case studies,	Highway projects	TRANSPO RTATION RESEARC H BOARD	National Cooperative Highway Research Program	**Construction Manager-at-Risk Project Delivery for Highway NCHRP Synthesis 402 Programs**	**2010**
The study results show that the construction speed and project delivery speed per lane mile of DB projects were significantly faster than that of DBB projects.	Project study	21	Highway projects	Gibson, Shrestha	Journal of Construction Engineering	**Performance Comparison of Large Design**	**2011**

Conclusions	Publication Type	Sample size	Project type	Author	Organization	Title	Year
Reduced cost and shortened duration were the top ranked 59% of DB projects were with 2% or better factors for selecting DB of the established budget. DBB N/A 77% of DB projects were within 2% or better of the established	Research article	108	Industrial, building	Songer, Molenaar		**Selection factors and success criteria for Design**	**1996**
Design Build *unit cost* was at least 4.5 percent less than construction management at risk and six percent less than Design Bid Build. Design Build *construction speed* was at least seven percent faster than construction management at risk and 12 percent faster than Design Bid Build. Construction management at risk construction speed was at least 6 percent faster than Design Bid Build. Design Build *delivery speed* was at least 23 percent faster than construction management at risk and 33 percent faster than Design Bid Build. In addition, construction management at risk delivery speed was at least 13 percent faster than Design Bid Build.	Research Report	271	Buildings	Victor Sanvido and Mark Konchar	The Construction Industry Institute under the guidance of the Design Build Research Team Number 133	**Project Delivery Systems: Cm At Risk, Design Build, Design Bid Build**	**1998**
59% of DB projects were with 2% or better of the established budget. DBB N/A 77% of DB projects were within 2% or better of the established schedule.	Research Article	104	Industrial, buildings, and highways	Molenar		**Design Builder selection for small highway projects.**	**1999**
This report had the goals of developing a set of definitions for the three primary delivery methods—encouraging consensus on a set of defining characteristics for each delivery method, and providing the industry with a set of definitions that others can use as a baseline.	Collaborative Documentation	0	Highway projects		The American Institute of Architects and The Associated General Contractors of America	**Primer on Project Delivery**	**2004**
Best Practices Decision Tree was developed, study the authors outline key decision-making points and illustrate a general approach for decision-makers when choosing the Design Build method of project delivery.	Case studies	8	Highway projects	The Louis Berger Group, Inc.	AASHTO, National Cooperative Highway Research	**Design Build Environmental Compliance Process and Level of Detail:**	**2005**
Design Build Performance it was found that 76% of the projects were completed ahead of the schedule established by the owner, the cost growth rates were less than 4% as opposed to an average of 5-10% characteristic	Study of national DB projects	21	Highway projects	Tom Warne and Associates, LLC	Tom Warne and Associates, LLC	**Design Build Contracting for Highway Projects A**	**2005**

APPENDIX E

ACE APDM RESEARCH EFFORT

Alliance for Construction Excellence – Alternative Project Delivery Research Effort



APPENDIX F

LESSONS LEARNED CITY OF PHOENIX – SONORAN BLVD

Lessons Learned: Sonoran Blvd Case Study

During a lesson learned session between the designers, engineers, contractors, and consultants for a recently completed construction project: Sonoran Blvd, The topics of APDM usage was the primary discussion. The City of Phoenix and Haydon Build Corp conducted this lesson leaned activity to improve their project delivery procedures. They learned the following from the Sonoran Blvd project:

From meeting notes taken by Evan Bingham on June 28, 2013

- Project started as a Design Bid Build but was changed to CMAR
- Needed comprehensive earth work analysis, this led to a difficult design better handles by a CMAR delivery.
- CMAR saved the project when Hayden was able to step in and do geotechnical work providing information for design.
- Lost value by not having CMAR earlier. Contractor was brought in later then typical for CMAR, reducing the benefits gained from CMAR
- APDM led to good coordination and early good communication between all parties
- Owner felt that construction manager should be brought in at 30 percent design for future projects
- Project that involve the construction manager between 30 percent -60 percent of design get the most benefit because after 60 percent design contractor feedback feels more like criticism then teamwork or coordination
- When multiple designers are involved it is important to have one designer take the lead.
- Key team members should be involve in pre-construction services
- The CM said "The design team continues very little after initial design, it is helpful to have an element of the design team stay on for historical experience on the job"
- The inspection staff should have been prepared for how fast the project would be going, more inspectors were needed to keep up with production
- Conflicts in specs arose from non-flexible nature of the specs. The specs were driving the design instead of the existing conditions and constructability reviews.
- Testing team felt that the standards driving the job were generic and did not always apply to this job. Also the CM did not want to use the outline procedure to achieve results; they wanted to use their own procedure to achieve the same or better results. Specs where written for procedure and not outcome. Once this was better understood and agreed upon the project ran smoother
- Need a spec verification meeting before significant design.
- Single point of contact is critical in communication between parties

- Unknown condition led to general specifications. CMAR allowed for improved design and change of specifications as existing conditions were discovered.
- The Gross Maximum Price (GMP) should be delivered based on a known set of expectations when the expectations change so should the GMP.
- Rigid specs should translate to higher GMP as CM takes on more risk.
- In CMAR the owner has flexibility to make changes to do things the right way, they are not limited by the contract
- Early communication is the key to avoiding large conflicts in the future
- The design and contractor team needs to be able to ask the question: "will this design or method change the quality of the project?" if not the design should be flexible enough to do the work right but not necessarily the way it was originally designed; firm on quality and application, flexible on design.

APPENDIX G

CALL FOR PARTICIPANTS SURVEY

Call for Participants - Horizontal Project Delivery

Call for Participation

The Alliance for Construction Excellence (ACE) is pursuing research on the topic of improving project delivery through analysis of critical project parameters. This study will be limited to horizontal infrastructure projects from which we will collect and analyze project data to identify specific parameters that are critical to improving project outcomes, reducing the cost of design and construction, preserving schedule, reducing risk during project execution, improving project team alignment and communication, assuring customer satisfaction, and improving the probability of successful project delivery.

SCOPE

With the introduction and wide acceptance of alternative project delivery methods (APDM) such as Design-Build (DB) and Construction Manager at Risk (CMR) for horizontal projects, the industry has sought to decrease the discrepancy between predicted and realized project outcomes.

There is an industry wide need for research designed to definitively identify specific critical parameters that contribute to project success. This research project will involve collaboration between academia and industry to gather and analyze relevant data that can be used to guide delivery method choices and implementation procedures that will maximize project success. This research effort will also include publication and distribution of results that can be directly applied within the industry. Between 40 and 60 projects will be analyzed with regard to project performance in terms of deviation from budget, prevalence of change orders, delays in time to completion, and customer satisfaction as a measure of quality.

The results of this research will provide helpful documentation on topics such as preconstruction services, project contracting, project delivery methods, and best practices. The research will focus on horizontal infrastructure projects. Therefore we are seeking data from horizontal construction projects involving the transportation of people or freight, energy, and fluids, including but not limited to:

• Highways • Water Distribution
• Railways • Levees
• Airports • Pipelines
• Canals • Electric Transmission & Distribution
• Tunnels • Border Security Fencing
• Waste Water Collection • Wide Area Networks

GOALS

Specific goals of this research include:

1. Provide a better basis for decisions on the selection of the optimal delivery method for each project.
2. Identify best management practices for implementation of each project delivery method.
3. Increase agency understanding and knowledge of APDM.
4. Develop of a guide for estimating preconstruction services.
5. Improve predicting, documenting, and administering the GMP using these methods.
6. Develop a guide for CMR preconstruction cost modeling.
7. Publish the findings in a form useful to the industry (ACE Publication).
8. Provide data for educational purposes to contribute to the future growth of the industry.

If you would be able to participate, please complete the following brief survey to provide us with a basic description of your project. If your project is chosen, you will be sent a longer survey with comprehensive questions about all aspects of your project. Please understand that it may take 1-2 hours to complete the larger survey.

Your input will be critical to making accurate conclusions about project delivery practices and to developing useful recommendations for the industry.

Your participation will be very much appreciated. You will also be the first to receive publications generated from this research.

Thank you,
The ACE team

Call for Participants - Horizontal Project Delivery

Project Background Information

1. Company Name

2. Project Type

- ○ People/Freight Transportation
- ○ Fluids Transmission/Retention
- ○ Energy Transmission
- ○ Boundaries/Fencing

Other (please specify)

3. Point of Contact

Name

Title

Address

Phone

Email

4. General Project Information

Project Name

Project ID Number (if applicable)

Location of Project

Scope of Work

Capacity of Facility Built

5. Which delivery method was used for this project?

- ○ Design-Build, One Step
- ○ Design-Build, Two Step
- ○ Design-Build, Qualifications Based Selection
- ○ Design-Bid-Build
- ○ Construction Manager at Risk, CMGC

Other (please specify)

Call for Participants - Horizontal Project Delivery

Conclusion

Thank you very much for providing your project information. We will contact you shortly to let you know whether your project was chosen for inclusion in this research project.

6. If it is not chosen, may we keep this project on file for use in future research?

◯ Yes

◯ No

APPENDIX H

DRAFT PAPER SURVEY, ONLINE SURVEY

Project Delivery Processes for Horizontal Projects

Project Questionnaire

Improving Project Delivery through Variance Analysis of Infrastructure Projects

Over the centuries builders have tried to lessen the gap between predicted and actual project cost, schedule, and scope. With the introduction and wide acceptance of alternative project delivery methods (APDM) such as Design-Build (DB) and Construction Manager at Risk (CMR), and their increasingly wide use on infrastructure projects, the industry has sought to lessen the variance between key project outcomes. After a decade of serious APDM use, the design and construction industry needs a non-biased statistical analysis of infrastructure projects that could identify the leading factors that cause dramatic differences in predicted and actual project outcomes.

Scope

The industry is in need of a collaborative research effort that will:

1. Complete a comprehensive and comparable study of variance for use in the horizontal infrastructure market among several delivery methods.

2. Provide a better basis for decisions on the selection of project delivery method.

3. Identify tested best management practices within each project delivery method.

4. Increase agency understanding of and knowledge of APDM.

5. Develop of a guide for estimating preconstruction services.

6. Improve predicting, documenting, and administering the GMP using these methods.

7. Develop a guide for CMR preconstruction cost modeling.

8. Publish the findings in a manner that advances and enriches the industry (ACE Publication).

9. Provide data for educational purposes to improve the industry.

Collaboration Efforts

This research effort will require the collaboration of industry professionals as well as academia in the collection of data as well as the interpretation and implementation of findings. 40-60 projects using different delivery methods will be analyzed. Projects will be compared using project performance in terms of original budgets, GMP, and final costs.

Dear Participant:

The Alliance for Construction Excellence (ACE) is pursuing research on the topic of Improving Project Delivery through Variance Analysis of Infrastructure Projects. As a part of this research our multi-disciplinary research team is looking to collect specific project data that will result in valuable information and publications. This research should significantly enhance the project environment in the infrastructure industry by improving predictability of project parameters, reducing the cost of design and construction, preserving schedule, reducing risk during project execution, improving project team alignment and communication, assuring customer satisfaction, and improving the probability of a successful project.

The research effort seeks to produce helpful documentation on topics such as preconstruction services, project contracting, project delivery methods, best practices and more. The research will focus on infrastructure projects. Therefore we are seeking data from infrastructure projects involving the transportation of people or freight, energy, and fluids, including but not limited to:

- Highways
- Railways
- Airports
- Canals
- Tunnels
- Waste Water Collection
- Water Distribution
- Levees
- Pipelines
- Electric Transmission & Distribution
- Border Security Fencing
- Wide Area Networks

Enclosed are survey instruments that will provide information for the identified sample project. The questionnaire should require between one and three hours to complete.

Please complete the Questionnaire and return it in PDF format via email to Evan.Bingham@asu.edu *or fax to* (480)-965-1769. If you have any questions in regard to the questionnaire and or the research project in general, please feel free to contact me at (602) 541-1580, Evan Bingham@asu.edu

ACE will be publishing the results of this investigation including conclusions and recommendations. All of the information gathered will be held in the strictest confidence with the input only seen and evaluated by the ACE research team. Companies providing data will be listed as a participant in the project and will receive copies of the research summary when published in 2014. All attributable information published will be direct consent of the providing parties.

Your participation in this effort is appreciated by the research team and the Alliance for Construction Excellence. You will be making a significant contribution toward the development of a valuable industry publications and the information provided to you in return should also directly benefit your future infrastructure projects.

Sincerely,

PROJECT BACKGROUND INFORMATION

1.0. Date: ______________________________

1.1. Company Name: ________________________

1.2. Point of Contact:

1. Name: __________________________
2. Title/Role: __________________________
3. Address: ____
4. Tel. No.: ________________________
5. E-mail: _________________________

2.0. General Project Information:

1. Project Name: _________________________________-
2. Project ID Number (*if applicable*): _________________________
3. Where is the project located?_________________________________
4. What type of facility is this project? (*choose one* and describe)

[ ] People/Freight Transportation (*highways, railways, airports)*
____

[ ] Fluids Transmission (*canals, pipelines)*
____

[ ] Energy Transmission (*electronic transmission and distribution, wide area networks)*
____

[ ] Other____

5. What is the project name?____

6. Size of project? (i.e., 23.3 mile divided highway,16 km gravity sewer line).
____
____

7. Capacity of project? (i.e., cars per day, gallons per day)
____
____

8. Is there anything unique about this project? (e.g., project required relocation of Native American burial site)
Please describe:
____
____
____
____

9. What was the execution contracting approach that you used on your project?
   [ ] Design-Build (one step method)
   [ ] Design-Build (two step method)
   [ ] Design-Build (qualifications based selection)
   [ ] Design-Bid-Build
   [ ] Construction-Manager at Risk, CMGC
   [ ] Other (*please specify*) ______________________________

10. Rank the top 5 motivating factors that led to the selection of this contracting approach from greatest (1) to least importance (5). (reflecting on your answer to #9)

Rank	
	Cost of project
	Urgency of project
	Opportunity for innovation
	Opportunity for appropriate risk transfer/ best method for risk allocation
	Required by owner/regulation
	Regulatory initiatives
	Lack of in-house resources
	Quality
	Multiple Stakeholder Coordination
	Other – specify:
	Other – specify:
	Other – specify:

11. In your opinion was the selected contracting approach the best fit for this project?

[ ] Yes [ ] No

If No, What contracting approach was a better fit and why? (please explain)

____
____
____
____

12. What was the primary method for pricing the construction work?

[ ] Fixed Price
[ ] Unit Price
[ ] GMP(Guaranteed Maximum Price)
[ ] Cost plus
[ ] Other (*please specify*) ______________________________

13. What was the basis for award sum:
[ ] Competition
[ ] Negotiated

14. What was the primary motivator for the selection of this pricing method?
____
____

15. If GMP, what was the original GMP at first agreement? (if not GMP skip to question 20)

16. If GMP, what was the final GMP or second agreement?
____

17. At what percentage of completion was the GMP developed?
____

18. Were there any changes to the GMP throughout, (*please explain*)

[ ] Yes [ ] No

____
____

19. Did the project require significant right-of-way acquisition?

[ ] None
[ ] Less than 10% of total project cost
[ ] 10-30% of total project cost
[ ] More than 30% of total project cost

Please Describe right of way issues encountered (if applicable)

____
____
____

20. What was the organization of the project team?

[ ] Designer as prime
[ ] Builder as prime
[ ] Joint Venture
[ ] Design-builder integration
[ ] Multiple prime contracts

2.1 <u>Team Selection and Alignment</u>:

1.What was the method of team selection? (please explain)

2.Rank how important team alignment was to the success of the project.

1- Not Important 7- Very important (*circle one*)

1 3 5 7

3. At what stages in construction were key team players introduced to the project

a. Team Players: Architect, General Contractor, Engineering Firm, Project Manager, others

Stages:

i. Opportunity analysis
ii. Conception design
iii. Project definition
iv. Detailed design
v. Construction
vi. Startup
vii. Closeout

4. Rank the project team in the following categories:

Team Alignment Practice	1- Fell short of expectations 7- Exceeded expectations
Establish expectations	1 3 5 7
Define project success	1 3 5 7
Evaluate risk	1 3 5 7
Measure team alignment	1 3 5 7
Develop individual and group roles and responsibilities	1 3 5 7
Communicate amount stakeholders	1 3 5 7
Resolve conflicts	1 3 5 7
Address concerns	1 3 5 7
Document project details (short comings, successes)	1 3 5 7
Involve all project stakeholders	1 3 5 7
Define project leadership and accountability	1 3 5 7
Establish project priorities (i.e. costs, schedule, public relations)	1 3 5 7
Conduct productive team meetings	1 3 5 7
Welcome team trust honesty and shared values	1 3 5 7
Instituted team building programs	1 3 5 7
Organize using planning tools (organizational charts, integrated daily schedules	1 3 5 7
Conduct adequate pre- project or front end planning procedures	1 3 5 7
	1 3 5 7
	1 3 5 7

5. What aspect of team alignment created the most discord within the team?

(Please describe)

6.What aspect of team alignment created the best synergy within the team?

(Please describe)

7. What aspect of the construction process, team make-up, un-foreseen circumstance, or situation during the project posed the greatest challenge to the project team?

(Please describe)

8. What aspect of the construction process, team make-up, un-foreseen circumstance, or situation during the project posed the greatest challenge to the project itself?

(Please describe)

9. Identify management practices used during this project; explain their contribution to the project.

Management Practice	Used during the project	Contribution to Project
Alignment of Project Participants	[ ] Yes [ ] No	
Benchmarking and Metrics	[ ] Yes [ ] No	
Change Management	[ ] Yes [ ] No	
Constructability	[ ] Yes [ ] No	
Disputes Prevention and Resolution	[ ] Yes [ ] No	
Front End Planning	[ ] Yes [ ] No	
Lessons Learned	[ ] Yes [ ] No	
Materials Management	[ ] Yes [ ] No	
Partnering	[ ] Yes [ ] No	
Planning for Startup	[ ] Yes [ ] No	
Project Risk Assessment	[ ] Yes [ ] No	
Quality Management	[ ] Yes [ ] No	
Team Building	[ ] Yes [ ] No	

Zero Accidents Techniques	[ ] Yes [ ] No	
Sustainability	[ ] Yes [ ] No	
Value Engineering	[ ] Yes [ ] No	
Life Cycle Costing	[ ] Yes [ ] No	
Other:		

10. Looking back, what were the most significant lessons learned on this project that the project team will try to implement on future projects?
____
____
____
____

2.2. Schedule Information:

1. Please provide the following **schedule** information:

Item	Planned (mm/yy)	Actual (mm/yy)
Start Date of Detailed Design		
End of Detailed Design		
Start Date of Construction		
Date of Substantial Completion		

Do you have any comments regarding any causes or effects of schedule changes (e.g., special causes, freak occurrences, etc.)?
____
____
____

2.3. Cost Information:

1. Please provide the following **cost** information:

Item	Budgeted Costs at **Start** of Detailed Design	Actual **End** Cost of Project
Total Design Costs		
Construction Costs		
Right of Way and Utility Adjustment Costs		
Pre-Construction Service Costs		
Owner's Contingency		
Other		
Total Project Cost		

2.4. Change Information:

1. What was the total number of change orders issued (including during both detailed design and construction)? _____________

2. What were the absolute value total dollar amounts of all change orders? _____________

3. What was the net duration change in the completion date resulting from change orders? ____________ months

4. Did the changes increase/decrease final price?

   [ ] Increase [ ] Decrease

5. What was the net change in dollars? _________________________

6. Did the changes increase or decrease the length of the original project duration?

   [ ] Increased [ ] Decreased [ ] No impact

7. Do you have any additional comments regarding causes or effects of significant change orders?
   ____
   ____
   ____

8. Describe the three most significant change orders:

1.____

2.____

3.____

9. Looking back, what could have been done during preconstruction services to avoid these changes? (i.e. constructability reviews, project risk assessments, etc.) (please explain for each major change order)

1.____

2.____

3.____

2.5. <u>Financial/Investment Information</u>:

1. The decision to design and construct a project relies heavily on specific project financial performance measures such as capital turnover, return on investment, benefit/cost ratio, return on equity, return on assets, etc. For the major financial criteria used on this project to date, how well has the actual financial performance matched the expected financial performance measurement using the scale below?

   Using a scale of 1 to 5, with 1 being fallen far short of expectations to 5 being far exceeded expectations at authorization, *please circle only one.*

1	2	3	4	5
fallen far short		matched closely		far exceeded

2. What type of specific project financial measurement was used to authorize the project (e.g., Return on Assets, Return on Equity, Internal Rate of Return, Benefit/Cost Ratio, Payback Period, etc.)?

____

2.6. Operating Information:

1. Since being placed in service, has the operational performance of the project, which include capacity and availability, met the expectations as set forth in the project plan prior to detailed design?

   [ ] Yes [ ] No

If "No", please describe:
____
____
____

2. Since being placed in service, has the operations and maintenance costs of the project met the expectations as set forth in the project plan prior to detailed design?
   [ ] Yes [ ] No

If "No", please describe:
____
____
____

2.7. Customer Satisfaction:

1. Reflecting on the overall project, rate the success of the project using a scale of 1 to 5, with 1 being very unsuccessful to 5 being very successful: (*circle only one*)

   1 2 3 4 5
   very unsuccessful --> very successful

Describe why you gave the project this overall score:
____
____
____
____
____

2.7 <u>Preconstruction Services</u>:

Rank your project team on how well they accomplished the following preconstruction elements. What management practices or tools were implemented to reach this level of success? What management practices would have improved success?

Preconstruction Element	Rank how well the element was accomplished 7 - Without flaw 1- Poorly or N/A	What management practices or tools were implemented to reach this level of success?	What management practice or tool would have improved success?	What percent of pre-construction costs can be associated with this element?
Identification of Project Objectives	1 3 5 7 NA			
Risk Identification and Assessment	1 3 5 7 NA			
Risk Mitigation	1 3 5 7 NA			
Design Management	1 3 5 7 NA			
Agency Coordination and Estimating	1 3 5 7 NA			
Constructability/BidabilityAnalysis	1 3 5 7 NA			
Value Analysis/Engineering	1 3 5 7 NA			
Bid Packaging	1 3 5 7 NA			
Schedule Development	1 3 5 7 NA			
Site Logistics Planning	1 3 5 7 NA			
Construction Buyout	1 3 5 7 NA			
Disruption Avoidance Planning	1 3 5 7 NA			
Small, Women, and Minority Owned Business Enterprise Participation	1 3 5 7 NA			
Construction Phase sequencing	1 3 5 7 NA			
Subcontractor Prequalification	1 3 5 7 NA			
Multiple Bid Package Planning	1 3 5 7 NA			

Real-time Cost Feedback	1 3 5 7 NA			
Building Information Modeling	1 3 5 7 NA			
Total Cost of Ownership Analysis	1 3 5 7 NA			
Cost Estimating	1 3 5 7 NA			
Budget Management	1 3 5 7 NA			
Stakeholder Managment	1 3 5 7 NA			
Other: please define	1 3 5 7 NA			
Other: please define	1 3 5 7 NA			
	1 3 5 7 NA			
	1 3 5 7 NA			

Please answer the following.

Approximately how long did this assessment take? ______ hours

Do you have any comments concerning the questionnaire:

APPENDIX I

ONLINE SURVEY

Project Delivery - Horizontal Projects 3

Introduction

Thank you for participating in this important research effort. This survey has been designed for projects that have been COMPLETED OR ARE NEAR COMPLETION. If your current project does not meet these specifications, then please use a past project to answer the questions. Ideally these projects will have a total cost over $5 million; however, this is not a necessary condition. It is desirable for the survey to be completed in one sitting; however, if it is necessary for you to leave the survey, you can do so at any time and continue where you left off by clicking on the link that was provided to you. Please note that if you follow the link from a new computer, the survey will think you have begun a new survey. To continue on previous work, please return to the survey on the same device. The survey ENDS AT QUESTION 37, questions 38-40 are feedback on the survey. If you have any questions please contact: Evan Bingham at evan.bingham@asu.edu or call any time (602) 541-1580. Again, thank you for your participation!

Contact Information

1. Contact Information

Name:

Company:

Address:

Address 2:

City/Town:

State:

ZIP:

Country:

Email Address:

Phone Number:

2. What was your role on the project?

- ◯ Owner
- ◯ Contractor
- ◯ Design Team

Other (please specify)

Project Background Information

Project Delivery - Horizontal Projects 3

3. General Project Information

Project Name

Project ID Number (if applicable)

Location of Project

Scope of Work

Capacity of Facility Built (ie lane miles or pipe length)

4. Project Type

- ◯ People/Freight Transportation
- ◯ Fluids Transmission/Retention
- ◯ Energy Transmission
- ◯ Boundaries/Fencing

Other (please specify)

5. Which delivery method was used for this project?

- ◯ Design-Build
- ◯ Design-Bid-Build
- ◯ Construction Manager at Risk, CMGC

Other (please specify)

Delivery Method Analysis

Project Delivery - Horizontal Projects 3

6. Rate the following factors with regard to their importance in the selection of the delivery method from question 5, where 1 indicates least importance and 7 indicates greatest importance. You may use any rating multiple times.

	1	2	3	4	5	6	7
Cost of project	○	○	○	○	○	○	○
Urgency of project	○	○	○	○	○	○	○
Opportunity for innovation	○	○	○	○	○	○	○
Opportunity for appropriate risk transfer or best method for risk allocation	○	○	○	○	○	○	○
Required by owner or regulatory agency	○	○	○	○	○	○	○
Regulatory initiatives	○	○	○	○	○	○	○
Lack of in-house resources	○	○	○	○	○	○	○
Quality concerns	○	○	○	○	○	○	○
Multiple stakeholder coordination	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

Specify "other" entry above, if any

[ ]

7. Do you think that the chosen delivery method was the best fit for this project?

○ Yes

○ No

8. If no, which delivery method would have been a better fit?

○ Design-Build

○ Design-Bid-Build

○ Construction Manager at Risk, CMGC

○ N/A

Other (please specify)

[ ]

Project Delivery - Horizontal Projects 3

9. Use the drop down menus to indicate the aspects of the project that would have benefited from the use of the delivery method you chose in the previous question as a better fit. If N/A leave blank.

	Project Parameters
Most Important	
Second Most Important	
Third Most Important	

Project Pricing

10. What was the primary pricing method used for this project?

- ◯ Fixed Price
- ◯ Unit Price
- ◯ GMP - Guaranteed Maximum Price
- ◯ Cost Plus

Other (please specify)

11. What was the basis for award sum?

- ◯ Competition
- ◯ Negotiated

12. What was the primary motivator for choosing this pricing method?

- ◯ Mandated by customer/owner
- ◯ Regulatory requirement
- ◯ Risk management
- ◯ Familiarity from past projects

Other (please specify)

Project Team Information

Project Delivery - Horizontal Projects 3

13. Rate how influential the following criteria were in selecting the project team, where 1 represents no influence and 7 represents a primary motivating factor. You may use any of the ratings multiple times.

	1	2	3	4	5	6	7
Location of team member	◯	◯	◯	◯	◯	◯	◯
Licensure and professional registrations	◯	◯	◯	◯	◯	◯	◯
History with company	◯	◯	◯	◯	◯	◯	◯
Project experience	◯	◯	◯	◯	◯	◯	◯
Experience in selected delivery method	◯	◯	◯	◯	◯	◯	◯
Budget compliance	◯	◯	◯	◯	◯	◯	◯
Schedule compliance	◯	◯	◯	◯	◯	◯	◯
Legal obligation	◯	◯	◯	◯	◯	◯	◯
Safety record	◯	◯	◯	◯	◯	◯	◯
Team training/apprenticeship	◯	◯	◯	◯	◯	◯	◯
Experience with local conditions/regulatory officials	◯	◯	◯	◯	◯	◯	◯
Workload	◯	◯	◯	◯	◯	◯	◯
Contractual obligation	◯	◯	◯	◯	◯	◯	◯

14. Team alignment exists when all team members are focused on a common set of values, behavioral norms, goals and priorities. On a scale of 1 to 7 where 1 is not at all and 7 is very influencial, how influential was team alignment to the success of the project?

	1	2	3	4	5	6	7
Influence of Team Alignment	◯	◯	◯	◯	◯	◯	◯

15. Were there any key management changes during the project?

☐ Yes

☐ No

16. If there were management changes, rate the disruption caused on a scale of 1 to 7, where 1 is least and 7 is most disruptive.

	1	2	3	4	5	6	7
Level of disruption	◯	◯	◯	◯	◯	◯	◯

Project Delivery - Horizontal Projects 3

17. Rate the project team with respect to the following team alignment practices on a scale of 1 to 7, where 1 is "fell short of expectations", 7 is "exceeded expectations",and 4 is "met expectations". You may use any of the ratings multiple times.

	1	2	3	4	5	6	7
Established expectations	○	○	○	○	○	○	○
Defined project success	○	○	○	○	○	○	○
Evaluated risk	○	○	○	○	○	○	○
Measured team alignment	○	○	○	○	○	○	○
Developed individual and group roles and responsibilities	○	○	○	○	○	○	○
Communicated effectively with stakeholders	○	○	○	○	○	○	○
Resolved conflicts appropriately	○	○	○	○	○	○	○
Addressed concerns	○	○	○	○	○	○	○
Documented project details, including short comings and successes	○	○	○	○	○	○	○
Involved all project stakeholders appropriately	○	○	○	○	○	○	○
Defined project leadership and accountability	○	○	○	○	○	○	○
Established project priorities such as costs, schedule, public relations, etc.	○	○	○	○	○	○	○
Conducted productive team meetings	○	○	○	○	○	○	○
Established team trust, honesty, and shared values	○	○	○	○	○	○	○
Instituted effective team building programs	○	○	○	○	○	○	○
Effectively used planning tools such as organizational charts and integrated daily schedules	○	○	○	○	○	○	○
Conducted adequate pre-construction or front end planning practices	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

Specify "other" entry above, if any

Page 6

Project Delivery - Horizontal Projects 3

18. Using the drop boxes below, rank the top three aspects of team alignment that, due to poor implementation, created the most discord within the team, making them the most disruptive to the project.

	Effect of Team Alignment Practices on Team Discord
Most Disruptive	
Second Most Disruptive	
Third Most Disruptive	

19. Using the drop down list below, choose the one aspect of team alignment that was most beneficial to the team.

	Team Alignment Practices
Most Beneficial Practice	

20. Which of the following challenged the PROJECT TEAM the most during the execution of the project?

	PROJECT TEAM challenges
Most challenging	
Second most challenging	
Third most challenging	

Specify "other" entry above, if any

21. Which aspects of the project posed the greatest challenges to successful completion of the PROJECT ITSELF?

	Challenges to success of the PROJECT ITSELF
Most challenging	
Second most challenging	
Third most challenging	

Specify "other" entry above, if any

Project Management Practices

Project Delivery - Horizontal Projects 3

22. Rate the management practices used during this project in terms of the importance of their contribution to project success. Use the scale from 1 to 7, where 1 is less important and 7 is very important. If any of the management practices were not used on this project, choose N/A.

	1	2	3	4	5	6	7	N/A
Alignment of project participants	○	○	○	○	○	○	○	○
Benchmarking of other projects	○	○	○	○	○	○	○	○
Change management process	○	○	○	○	○	○	○	○
Constructability	○	○	○	○	○	○	○	○
Disputes prevention and resolution	○	○	○	○	○	○	○	○
Front end planning	○	○	○	○	○	○	○	○
Use of lessons learned system	○	○	○	○	○	○	○	○
Materials management	○	○	○	○	○	○	○	○
Partnering	○	○	○	○	○	○	○	○
Planning for startup	○	○	○	○	○	○	○	○
Project risk assessment	○	○	○	○	○	○	○	○
Quality management techniques	○	○	○	○	○	○	○	○
Team building	○	○	○	○	○	○	○	○
Zero accidents techniques	○	○	○	○	○	○	○	○
Sustainable design and construction	○	○	○	○	○	○	○	○
Value engineering	○	○	○	○	○	○	○	○
Life cycle costing	○	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○	○

Specify "other" entry above, if any

Project Delivery - Horizontal Projects 3

23. Had it been done better, which one management practice could have improved project outcomes most?

- ◯ Alignment of project participants
- ◯ Benchmarking of other projects
- ◯ Change management process
- ◯ Constructability
- ◯ Disputes prevention and resolution
- ◯ Front end planning
- ◯ Use of lessons learned system
- ◯ Materials management
- ◯ Partnering
- ◯ Planning for startup
- ◯ Project risk assessment
- ◯ Quality management techniques
- ◯ Team building
- ◯ Zero accidents techniques
- ◯ Sustainable design and construction
- ◯ Value engineering
- ◯ Life cycle costing
- ◯ Other from the previous question

Pre-construction Services

Pre-construction services are critical elements that, when done well, keep projects on budget, on schedule and result in better project success and customer satisfaction. There are many activities that fall under the umbrella of pre-construction services, making evaluation and quantification of the effectiveness of their use complicated.

You will find three questions on this page, all in matrix format. For each of 21 elements of pre-construction services, you will first be asked to rate how well that element of was accomplished on the project. Secondly, you will then be asked to choose the top three management practices that were used to accomplish that element. In the final matrix, you will be asked to choose the top three management practices that could have been used more effectively to better accomplish that element.

Project Delivery - Horizontal Projects 3

24. Rate your project team on how well they accomplished to following preconstruction elements using a scale of 1 to 7, where 1 is poor and 7 is excellent. Choose N/A if your project did not use that element. You may use any rating number multiple times.

	1	2	3	4	5	6	7	N/A
Identification of project objectives	○	○	○	○	○	○	○	○
Risk identification and assessment	○	○	○	○	○	○	○	○
Risk mitigation	○	○	○	○	○	○	○	○
Design management	○	○	○	○	○	○	○	○
Agency coordination and estimating	○	○	○	○	○	○	○	○
Constructability/bidability analysis	○	○	○	○	○	○	○	○
Value analysis/engineering	○	○	○	○	○	○	○	○
Bid packaging	○	○	○	○	○	○	○	○
Schedule development	○	○	○	○	○	○	○	○
Site logistics planning	○	○	○	○	○	○	○	○
Disruption avoidance planning	○	○	○	○	○	○	○	○
Small, women, and minority owned business enterprise participation	○	○	○	○	○	○	○	○
Construction phase sequencing	○	○	○	○	○	○	○	○
Subcontractor prequalification	○	○	○	○	○	○	○	○
Multiple bid package planning	○	○	○	○	○	○	○	○
Real-time cost feedback	○	○	○	○	○	○	○	○
Building information modeling	○	○	○	○	○	○	○	○
Total cost of ownership analysis	○	○	○	○	○	○	○	○
Cost estimating	○	○	○	○	○	○	○	○
Budget management	○	○	○	○	○	○	○	○
Stakeholder management	○	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○	○

Specify "other" entry above, if any

Project Delivery - Horizontal Projects 3

25. Considering each of the elements of pre-construction services on the left, use the drop down menu to choose the most important management practice used to achieve that element. The element titled "Other" on the left refers to the "other" pre-construction service you specified in the previous question, if any. The dropdown option "other" refers to the "other", if any, that you specified in the question about management practices.

	Most important
Identification of project objectives	
Risk identification and assessment	
Risk mitigation	
Design management	
Agency coordination and estimating	
Constructability/bidability analysis	
Value analysis/engineering	
Bid packaging	
Schedule development	
Site logistics planning	
Disruption avoidance planning	
Small, women, and minority owned business enterprise participation	
Construction phase sequencing	
Subcontractor prequalification	
Multiple bid package planning	
Rea-time cost feedback	
Building information modeling	
Total cost of ownership analysis	
Cost estimating	
Budget management	
Stakeholder management	
Other	

Project Delivery - Horizontal Projects 3

26. Considering each of the elements of pre-construction services on the left, use the drop down menu to choose the most important management practice that could have been better used to improve the execution of that element.

	Most important
Identification of project objectives	
Risk identification and assessment	
Risk mitigation	
Design management	
Agency coordination and estimating	
Constructability/bidability analysis	
Value analysis/engineering	
Bid packaging	
Schedule development	
Site logistics planning	
Disruption avoidance planning	
Small, women, and minority owned business enterprise participation	
Construction phase sequencing	
Subcontractor prequalification	
Multiple bid package planning	
Real-time cost feedback	
Building information modeling	
Total cost of ownership analysis	
Cost estimating	
Budget management	
Stakeholder management	
Other	

Information on Project Changes

Project Delivery - Horizontal Projects 3

27. Please fill in the following basic information about changes incurred on this project.

Total number of change orders issued, including both detailed design and construction.

Absolute dollar value of all change orders. Treat all change order differential costs as positive numbers.

Actual project cost difference after all change orders.

28. Did the changes increase or decrease the final price? (For projects near completion, did the changes increase or decrease the projected final price?)

- Increase
- Decrease
- No Change

29. How did the changes affect project completion date? (For projects near completion, how did the changes affect the current projected completion date?)

- Delayed the project
- Accelerated the project
- No impact

If completion date was changed, state the number of months by which it differed from initial schedule.

30. Looking back, indicate what could have been done during the phases of front end planning, design, or pre-construction to avoid these changes?

	Choose the most important factor
Most important	
Second most important	
Third most important	

Schedule Information

You're almost there! Don't give up now!

31. Please provide the PLANNED dates in mm/dd/yy format.

Planned Start Date of Detailed Design

Planned End Date of Detailed Design

Planned Start Date of Construction

Planned Date of Substantial Completion

Page 13

Project Delivery - Horizontal Projects 3

32. Please provide the ACTUAL dates in mm/dd/yy format. (For projects that are near completion, use current projected ending dates)

Actual Start Date of Detailed Design

Actual End Date of Detailed Design

Actual Start Date of Construction

Actual Date of Substantial Completion

Project Cost Information

33. Please provide the following BUDGETED costs, rounded to the nearest $1000.

Total Budgeted Design Costs

Budgeted Pre-Construction Service Costs (soft costs)

Budgeted Right of Way and Utility Adjustment Costs

Total Budgeted Owner's Contingency

Other Budgeted Costs

Total Budgeted Project Cost

34. Please provide the following ACTUAL FINAL project costs, rounded to the nearest $1000. (For projects near completion, use current projected values.)

Total Actual Design Costs

Actual Pre-Construction Service Costs (soft costs)

Actual Right of Way and Utility Adjustment Costs

Total Actual Owner's Contingency

Other Actual Costs

Total Actual Project Cost

Financial and Investment Information

Project Delivery - Horizontal Projects 3

35. For the major financial criteria used on this project, rate how well the actual financial performance matched the expected financial performance using a scale of 1 to 7, with 1 indicating that performance fell far short of expectations, 7 indicating that performance far exceeded expectation, and 4 indicating that expectations were met.

	1	2	3	4	5	6	7
Level of financial performance	○	○	○	○	○	○	○

Operating Information

36. Rate the operational performance of the project in terms of how well expectations were met. Use a scale from 1 to 7, where 1 means the project did not meet expectations, 7 means expectations were exceeded, and 4 means the project met expectations.

	1	2	3	4	5	6	7
Performance of project team	○	○	○	○	○	○	○

37. Since being placed in service, have operations and maintenance costs met expectations? A rating of 1 means expectations were not met, 4 means that expectations were met, and 7 indicates that expectations were exceeded.

	1	2	3	4	5	6	7
Operations and maintenance costs	○	○	○	○	○	○	○

Conclusion

Thank you for participating in this research project

38. How long did it take to complete this survey?

39. Are any of the questions unclear or do any contain terms that are not adequately defined? If so, please list the question number(s)..

40. Please share any further comments or thoughts regarding the survey.

Page 15

APPENDIX J

PRE-CONSTRUCTION SERVICES DEFINITIONS

Pre-Construction Services Definitions

Adapted from the "Dictionary of Project Management Terms" (Ward 2008)

Identification of project objectives: Documentation of the project goals and objectives in clear, articulated, and agreed upon manner. Documentation of the requirements for the project, understanding of goals and aspirations, identification of key attributes, critical constraints, expected durations, budget, technologies, tools, and techniques to be used, quality requirements, and benefits to be achieved.

Risk identification and assessment: Determining the risk events that are likely to effect the project and classifying them according to their cause and source. Review, examination, and judgment to see whether identified risks are acceptable according to proposed actions.

Risk mitigation: Risk response strategy that decreases risk by lowering the probability of a risk event occurrence or reducing the effect of the risk should it occur.

Design management: Formal, documented, comprehensive and systematic examination of a design to evaluate its ability to meet specified requirements, identify problems, and propose solutions.

Agency coordination and estimating: Management of functions and activities of representatives of agencies; facilitating decisions regarding the sharing of limited resources and the financial obligations of parties.

Constructability/bidability analysis: Review of design documents to ensure the documents are clear, the construction details efficient, and the architectural, structural, mechanical and electrical drawings are coordinated.

Value analysis/engineering: Activity concerned with optimizing cost performance. Systematic use of techniques to identify the required function of an item, establish values for those functions at the lowest overall cost without loss of performance. Examines each element of a product or system to determine if there is a more effective way to achieve the same function.

Bid packaging: Ensuring that all the documents necessary for response and participation in a bidding process are complete.

Schedule development: Analysis of activity sequences, activity durations, and resource requirements used to develop the project schedule. Involves assigning start and end dates to the project activities. These dates can be determined initially by applying the activity duration estimates to the activities in the project network diagram.

Site logistics planning: Producing a site specific plan to establish efficient and safe working conditions for all parties adjacent to and within the construction zone. The plan is inclusive of major equipment placement, pedestrian and vehicular travel paths, staging of facilities and required temporary functions, lay down areas as well as means of emergency operation routes.

Disruption avoidance planning: Identification of potential disruptions to the project with specific planning for circumvention and prevention.

Small, women, and minority owned business enterprise participation: Planning and coordination to meet goals for participation with a diverse group of business enterprises. Capturing the economic and social benefits of diverse business relationships.

Construction phase sequencing: Systematic structuring of related project activities resulting in major deliverables.

Subcontractor prequalification: Determination of sub-contractor's responsibility prior to issuing a solicitation, request for proposal or tender.

Multiple bid package planning: Creation of multiple bid packages based on design documents. Administration of contracts with the owner.

Real-time cost feedback: A system or mode of software operation in which cost computation is performed during the actual time that the external process occurs.

Building information modeling: (BIM) is a process that involves creating and using an intelligent 3D model to inform and communicate project decisions. Design, visualization, simulation, and collaboration, provides greater clarity for all stakeholders across the project lifecycle.

Total cost of ownership analysis: Systematic process of examining the cost of owning, deploying and using a product, including the purchase price as well as support and maintenance of the life cycle of the product. Designed to guide in product selection and life cycle management.

Cost estimating: Process of estimating the cost of the resources needed to complete project activities. May include an economic evaluation an assessment of project investment cost, and a forecast of future trends and costs.

Budget management: Administration and oversight of resource requirements.

Stakeholder management: Action taken by the project team to curtail stakeholder activities that would adversely affect the project.

APPENDIX K

BEST PRACTICE DEFINITIONS

Best Practice Definitions

Adapted from the CII glossary (CII 2014)

Alignment: The condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives.

Benchmarking & Metrics: The systematic process of measuring an organization's performance against recognized leaders for the purpose of determining best practices that lead to superior performance when adapted and utilized.

Change Management: The process of incorporating a balanced change culture of recognition, planning, and evaluation of project changes in an organization to effectively manage project changes.

Constructability: The effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best possible time and accuracy at the most cost-effective levels.

Disputes Prevention & Resolution: Techniques that include the use of a Disputes Review Board as an alternate dispute resolution process for addressing disputes in their early stages before affecting the progress of the work, creating adversarial positions, and leading to litigation.

Front End Planning: The essential process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project.

Lessons Learned: A critical element in the management of institutional knowledge, an effective lessons learned program will facilitate the continuous improvement of processes and procedures and provide a direct advantage in an increasingly competitive industry.

Materials Management: An integrated process for planning and controlling all necessary efforts to make certain that the quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available when needed.

Partnering: A long-term commitment between two or more organizations as in an alliance or it may be applied to a shorter period of time such as the duration of a project.

The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant's resources.

Planning for Startup: Startup is defined as the transitional phase between plant construction completion and commercial operations, that encompasses all activities that bridge these two phases, including systems turnover, check-out of systems, commissioning of systems, introduction of feedstocks, and performance testing.

Project Risk Assessment: The process to identify, assess, and manage risk. The project team evaluates risk exposure for potential project impact to provide focus for mitigation strategies.

Quality Management: Quality management incorporates all activities conducted to improve the efficiency, contract compliance and cost effectiveness of design, engineering, procurement, QA/QC, construction, and startup elements of construction projects.

Team Building: A project-focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members and that seeks to improve team members' problem-solving skills.

Zero Accidents Techniques: Include the site-specific safety programs and implementation, auditing, and incentive efforts to create a project environment and a level of training that embraces the mind-set that all accidents are preventable and that zero accidents is an obtainable goal.

Sustainable Construction: Addresses the triple bottom line **–** the social, economic and environmental performance of the industry; delivering buildings and structures that provide greater satisfaction, well-being and added value to customers and users; respecting community, improving health and safety, enhancing site and welfare conditions, enhancing and protecting the natural environment, minimizing consumption of natural resources and energy throughout the life of the facility.

Value Engineering: A systematic process of review and analysis of a project, during the concept and design phases to provide recommendations for needed functions safely, reliably, efficiently, and at the lowest overall cost, improving the value and quality of the project; and reducing the time to complete the project.

Life Cycle Costing: Method used to measure the costs of ownership of a building. It takes into account the initial capital, cost of maintaining and servicing the building over its whole life.

APPENDIX L

PROJECT COMPLEXITY

Survey ID	Role	State	Delivery Method	Project Size Weight	Project Variety Weight	Project Interdependency Weight	Project Context-Dependence Weight	Complexity Rating
3084040243	Owner	FL	DBB	0.013	0.200	0.019	0.005	0.243
3084033037	Owner	FL	DBB	0.013	0.200	0.016	0.004	0.240
3083979252	Owner	CA	DBB	0.036	0.200	0.043	0.031	0.327
3083954004	Owner	CA	DBB	0.031	0.200	0.043	0.026	0.315
3083911474	Design	AZ	DBB	0.014	0.200	0.019	0.005	0.246
3022173684	Owner	FL	DBB	0.050	0.200	0.024	0.024	0.324
3020606282	Design	ID	DBB	0.006	0.200	0.019	0.002	0.231
2972888685	Owner	MD	DBB	0.050	0.200	0.024	0.024	0.324
2965353370	Owner	MD	DBB	0.050	0.200	0.027	0.027	0.328
2951991679	Owner	MD	DBB	0.050	0.200	0.024	0.024	0.324
2951751863	Design	TN	DBB	0.050	0.400	0.024	0.049	0.548
2924371772	Owner	AK	DBB	0.050	0.200	0.024	0.024	0.324
2899370606	Design	WY	DBB	0.004	0.200	0.021	0.002	0.229
2896970382	Owner	ID	DBB	0.050	0.200	0.024	0.024	0.324
2888330352	Owner	FL	DBB	0.007	0.200	0.018	0.002	0.230
2882464036	Design	ID	DBB	0.050	0.200	0.024	0.024	0.324
2882116534	Design	ID	DBB	0.000	0.200	0.024	0.000	0.225
2873702724	Owner	UT	DBB	0.050	0.456	0.024	0.056	0.611
2872721476	Owner	TN	DBB	0.050	0.400	0.024	0.049	0.548
2867717012	Owner	TN	DBB	0.050	0.200	0.024	0.024	0.324
2862266401	Owner	ID	DBB	0.529	1.000	0.055	1.000	2.848
2860442752	Owner	GA	DBB	0.050	0.200	0.024	0.024	0.324
2858396876	Owner	AK	DBB	0.050	0.200	0.024	0.024	0.324
2858043194	Owner	LA	DBB	0.050	0.400	0.024	0.049	0.548
2856804018	Owner	UT	DBB	0.050	0.200	0.006	0.006	0.287
2856040726	Owner	GA	DBB	0.050	0.400	0.024	0.049	0.548
2855457024	Design	AK	DBB	0.000	0.200	0.024	0.000	0.225
2855250183	Owner	GA	DBB	0.004	0.200	0.027	0.002	0.235
2854142996	Owner	WY	DBB	0.001	0.200	0.010	0.000	0.211
2853668757	Owner	WY	DBB	0.010	0.400	0.087	0.034	0.535
2853601606	Owner	AK	DBB	0.050	0.600	0.024	0.073	0.773
2853547897	Design	CO	DBB	0.050	0.400	0.024	0.049	0.548
2851388285	Owner	ID	DBB	0.001	0.400	0.019	0.000	0.420
2849079933	Owner	AK	DBB	0.003	0.600	0.006	0.001	0.611
2848931458	Owner	AK	DBB	0.007	0.800	0.024	0.013	0.847
2848670656	Design	AK	DBB	0.030	0.600	0.033	0.059	0.737
2848525618	Design	AK	DBB	0.018	0.200	0.033	0.012	0.271
2848340808	Owner	GA	DBB	0.050	0.400	0.062	0.124	0.661
2844872597	Owner	DE	DBB	0.050	0.200	0.024	0.024	0.324
2842624671	Design	DE	DBB	0.050	0.400	0.015	0.030	0.520
3105296867	Owner	AZ	CMAR	0.005	0.200	0.014	0.001	0.223
3105279948	Owner	AZ	CMAR	0.000	0.510	0.013	0.000	0.524
3105255187	Owner	AZ	CMAR	0.025	0.200	0.037	0.019	0.293
3084014844	Owner	MI	CMAR	0.225	0.800	0.020	0.356	1.514

Survey ID	Role	State	Delivery Method	Project Size Weight	Project Variety Weight	Project Interdependency Weight	Project Context-Dependence Weight	Complexity Rating
3083741450	Owner	AZ	CMAR	0.050	1.000	0.020	0.101	1.196
3083718280	Owner	AZ	CMAR	0.050	0.800	0.020	0.081	0.976
3083478628	Owner	AZ	CMAR	0.011	1.000	0.033	0.035	1.084
2956308910	Owner	UT	CMAR	0.050	0.800	0.024	0.098	0.997
2908715082	Owner	AZ	CMAR	0.005	0.800	0.031	0.012	0.850
2908265671	Owner	AZ	CMAR	0.050	0.400	0.024	0.049	0.548
2869648543	Owner	UT	CMAR	0.050	0.600	0.024	0.073	0.773
2862083889	Owner	UT	CMAR	0.009	0.600	0.015	0.008	0.636
2860529086	Owner	LA	CMAR	0.050	0.800	0.024	0.098	0.997
2855916389	Owner	UT	CMAR	0.001	0.200	0.002	0.000	0.204
3084047272	Owner	FL	DB	0.018	0.200	0.017	0.006	0.249
3084024662	Owner	MN	DB	0.273	0.600	0.022	0.353	1.384
3084001941	Owner	DC	DB	0.079	0.400	0.057	0.179	0.754
2979291310	Owner	MD	DB	0.031	0.400	0.027	0.033	0.505
2972081949	Owner	MD	DB	0.050	0.413	0.018	0.037	0.544
2964952336	Owner	MD	DB	0.050	0.200	0.024	0.024	0.324
2951957323	Owner	MD	DB	0.050	0.200	0.019	0.019	0.312
2906735424	Owner	UT	DB	0.158	0.800	0.024	0.309	1.371
2873632044	Owner	TN	DB	0.032	0.400	0.012	0.015	0.474
2857368546	Owner	UT	DB	0.050	0.800	0.024	0.098	0.997
2856165567	Owner	MT	DB	0.010	0.600	0.015	0.009	0.638
2853177586	Owner	FL	DB	0.050	0.200	0.024	0.024	0.324
2851622653	Owner	GA	DB	0.018	0.200	0.014	0.005	0.246
2850512773	Owner	AK	DB	0.043	0.200	0.010	0.008	0.282
2850457436	Owner	AK	DB	0.000	0.200	0.024	0.000	0.225
2849107730	Owner	GA	DB	0.050	0.200	0.015	0.015	0.305
2848778188	Owner	AK	DB	0.000	0.200	0.009	0.000	0.210
2848402456	Owner	GA	DB	0.057	1.000	0.027	0.154	1.266
2845478706	Owner	GA	DB	0.050	0.800	0.024	0.098	0.997
2843155679	Owner	GA	DB	0.050	0.200	0.024	0.024	0.324