2012

Evaluating the value of contractor involvement in the design phase

Nicola Jane Newsham West
Iowa State University

Evaluating the value of contractor involvement in the design phase

by

Nicola J. N. West

A thesis submitted to the graduate faculty

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Civil Engineering (Construction Engineering and Management)

Program of Study Committee:
Douglas D. Gransberg, Major Professor
Jennifer Shane
Konstantina Gkritza

Iowa State University

Ames, Iowa

2012

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

There are a number of people I would like to acknowledge and thank for their input into this thesis.

First of all I am hugely grateful to Dr. Gransberg for all his mentoring and guidance throughout this research. I would like to thank him for offering continuous time, knowledge, and advice throughout the development of my thesis. I feel very privileged to have had the opportunity to work as his student.

Secondly, I would like to acknowledge Jim McMinimee who co-authored the paper contained in Chapter 3 of this thesis. I appreciate his prompt feedback and comments and I valued working with such an experienced industry member.

Last, but not least, I would like to acknowledge the members of my thesis committee. I would like to thank Dr. Shane and Dr. Gkritza for offering their time and support. It is greatly appreciated.

ABSTRACT

The use of alternative project delivery methods for transportation projects has grown in the in the U.S. out of a necessity to upgrade a rapidly deteriorating transportation infrastructure. As a result, contracting methods including design-build (DB), construction manager/general contractor (CMGC), early contractor involvement (ECI), public private partnership (P3), and alliancing have all been implemented in an effort to accelerate project schedules, manage risk and achieve enhanced project quality. The distinguishing feature of alternative project delivery methods is the ability to involve the construction contractor in the preconstruction phase of a project, providing input to the planning and design processes. Furthermore, the quality of a constructed project is a function of the quality of its design. Therefore, this research evaluates the value added to a project by involving the contractor in the preconstruction phase.

Three research objectives are developed to address contractor added value. First, understand the factors that go into maximizing the benefit possible from cooperation during the design phase. Secondly, investigate the relationship between construction document quality, preconstruction costs, and early contractor involvement. Then finally, validate the major benefits of contractor preconstruction involvement given in literature.

Research instruments including literature reviews, content analyses, case studies, and cost data analyses form the methodology for this thesis in order to evaluate data from 404 transportation projects, 44 case studies, and sufficient literature.

This thesis finds that involving the contractor in the preconstruction phase increases cost certainty, produces cost and time savings, and inherently enhances project quality by contributing to the development of effective construction documents.

CHAPTER 1. INTRODUCTION

Evaluating the value of contractor involvement in the design phase requires investigating a number of subject areas related to construction projects. This chapter presents the findings from a comprehensive literature review, which provided insight into the theoretical background and previous work regarding contractor involvement in the design phase. The chapter then goes on to establish the problem statement and research objectives underlying this thesis. Finally, this chapter explains the organization of the remaining chapters in this thesis.

THEORETICAL BACKGROUND AND PREVIOUS WORK

In order to determine whether the contractor adds value to a project by being involved in the design phase it was necessary to review current industry literature in areas such as:

- Project delivery methods,
- Preconstruction cost,
- Project quality,
- Cost growth, and
- Early estimate quality.

The literature review revealed a gap in industry knowledge when looking at design fee in relation to project quality. The remainder of this section situates this research in current industry knowledge.

Project Delivery Methods and the Design Process

The design process for a construction project is approached differently depending on the chosen project delivery method. A project delivery method is "the comprehensive process of assigning the contractual responsibilities for designing and constructing a project", as defined by the Associated General Contractors of America (AGC 2004). There are a number of project delivery methods utilized on construction projects beyond the traditional design-bid-build (DBB). Each method involves a unique set of contractual relationships between the owner, the designer, and the builder. In addition, there are a number of methods with the same basic set of contractual relationships, but different names. For example, construction manager-at-risk (CMR) may be referred to as CMGC, depending on the context of the project. However, the Construction Industry Institute (CII) (2003) suggests DBB, CMR, and DB as the three fundamental project delivery methods. Consequently, this thesis will primarily focus on the contractual relationships and design process for these three project delivery methods.

The following sections provide a standardized definition of each project delivery method, as found in Transportation Research Board reports (Scott et al. 2006). Furthermore, a figure for each project delivery method is included to show the contractual relationship between each project party, and to describe the design process. Figures 1 through 3 include both contract lines and communication lines. The contract lines "designate contract requirements to exchange information and other services during design and construction" (Gransberg and Shane 2009). Lines of communication are shown to represent the ability of project parties to exchange information through formal and informal requests for information (Gransberg and Shane 2009).

Design-bid-build (DBB)

Design-bid-build is known as the traditional project delivery method. In this method the project owner is responsible for the design process and is required to provide a complete design. The owner may utilize in-house design professionals or seek a designer to produce the project design (Gransberg and Shane 2009). As a result, the project owner is responsible for the details of the design during the construction phase. According to the "Spearin Doctrine" (Mitchell 1999), the owner is then "financially liable for the cost of any errors or omissions encountered in construction" (Gransberg and Shane 2009).

Once the construction documents are complete, the owner advertises the project and awards a construction contract to a builder. One defining aspect of the DBB method is that the builder has little or no input to the design. Any constructability reviews are conducted by the designer. Therefore, the owner is responsible for the design details and the quality of the construction documents (Gransberg and Shane 2009). In addition, the designer is charged by the owner to keep the design within budget.

Figure 1 displays the two contracts held by the owner, one with the designer, and one with the builder. The construction contract in a DBB project can be awarded on a low bid, negotiated or best-value basis. However, a low bid award is more likely to introduce project cost growth. This is because the winning builder, who bid with the lowest margin, may need to consider post-award changes in order to make a profit on the project (Scott et al. 2006). Conversely, on DBB projects that are awarded on a negotiated or best-value basis, the builder is driven by the desire to be selected for future projects with the owner (Gransberg and Shane 2009), and therefore, has more incentive to minimize cost growth.

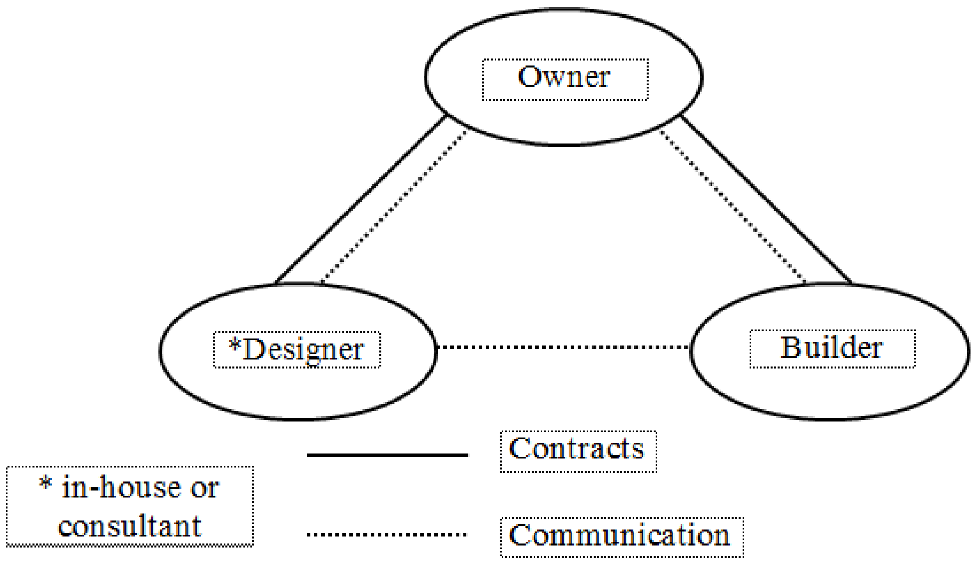


Figure 1. Design-bid-build (Gransberg and Shane 2009, adapted from AIACC 1996)

Construction Manager-at-Risk (CMR)

The CMR project delivery method is an integrated delivery method in which the owner has two contracts with a construction manager and one with a designer. The initial contract with the construction manager is for preconstruction services during design and the second is for the construction phase of the project (Gransberg and Shane 2009). This method provides the owner with professional management services that may otherwise be deficient (Strang 2002). Furthermore, the CMR method places the construction manager at risk for the final construction cost and schedule.

The design process for a CMR project is similar to DBB in that the owner is responsible for obtaining a complete design using in-house design professionals or an out-sourced designer. The construction documents are then given to the construction manager for the construction phase. However, in contrast to DBB, the construction manager is brought onto the project early in the design process in order to collaborate with the owner and the designer on aspects such as planning, design, constructability reviews, material selection, and cost engineering reviews (Gransberg and Shane 2009). Including the construction manager in the design process adds value to the project, through the constructability process, by enhancing the quality of the design and encouraging a buildable project (Jeargas and Van der Put 2001; Dunston et al. 2002).

Generally, construction manager contracts for the CMR method require a guaranteed maximum price (GMP). Once the GMP is established, the owner is not liable for payment beyond the original project scope (Gransberg and Shane 2009). Typically the construction manager has the opportunity to share any cost savings with the owner due to incentive clauses.

Figure 2 shows the contractual relationships in a CMR project. The contractual coordination line indicates the high level of collaboration required between the designer and the construction manager. This collaboration makes the CMR method a suitable choice for delivering complex transportation projects and implementing new construction technologies. Further benefits of the CMR method include improved constructability and real-time construction pricing capability (Gransberg and Shane 2009).

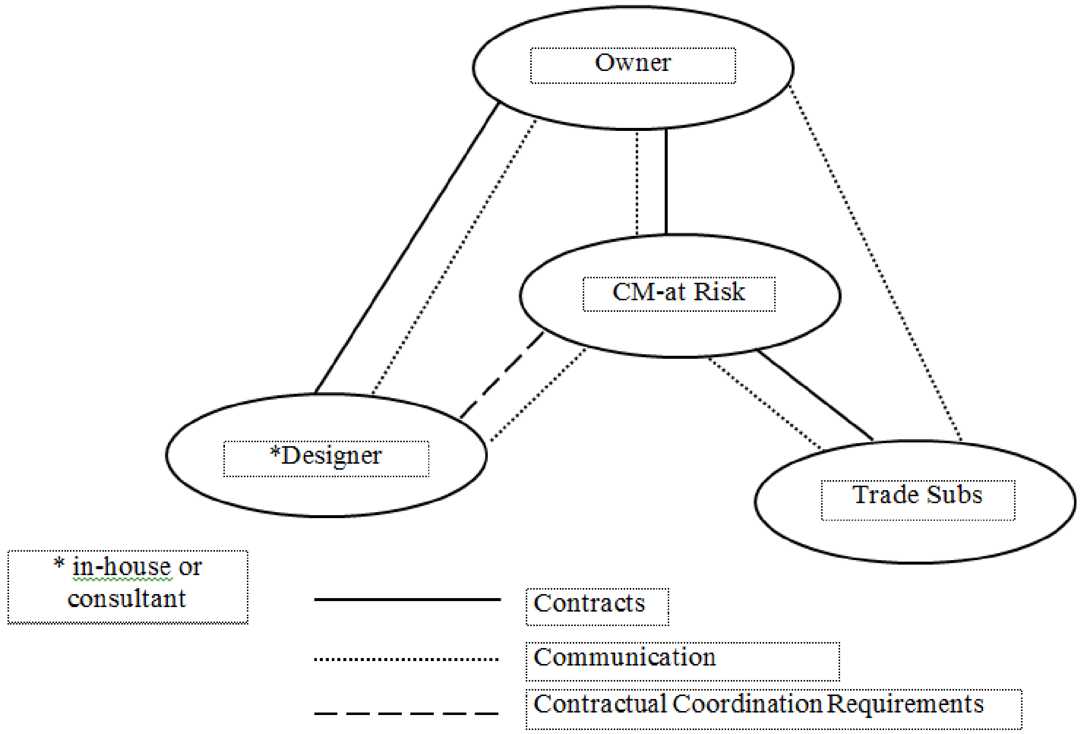


Figure 2. Construction Manager-at-Risk (Gransberg and Shane 2009, adapted from AIACC 1996)

Note, in some states' legislation the CMR method is called CMGC. However, CMGC is also used to describe a contract where the contractor self-performs some of the construction work, unlike CMR where the construction work is subcontracted out (AGC 2004). Figure 2 applies to both CMR and CMGC; therefore, both terms will be used synonymously in this thesis.

Design-Build (DB)

The DB project delivery method is characterized by a single contract between the owner and a design-builder. A design-builder is a legal entity able to provide both design and construction services (Gransberg and Shane 2009).

Unlike the design process for DBB and CMR projects, the owner does not have to provide the design-builder with complete construction documents for a DB project. Instead, the owner produces a Request for Qualifications and/or a Request for Proposals that outlines the project details. Once proposals have been submitted and evaluated, the owner awards a contract to a design-builder (Gransberg and Shane 2009). The owner is not responsible for the design in a DB project because the design-builder is trusted to provide constructability input to the design and manage the project delivery. In addition, the design-builder is typically required to supply a firm, fixed price as part of their proposal and is liable for all design and construction costs (El Wardani et al. 2006).

Figure 3 shows the contractual relationships in a DB project. It can be seen that the owner holds a single contract with the design-builder and therefore has less day-to-day control over the project delivery process.

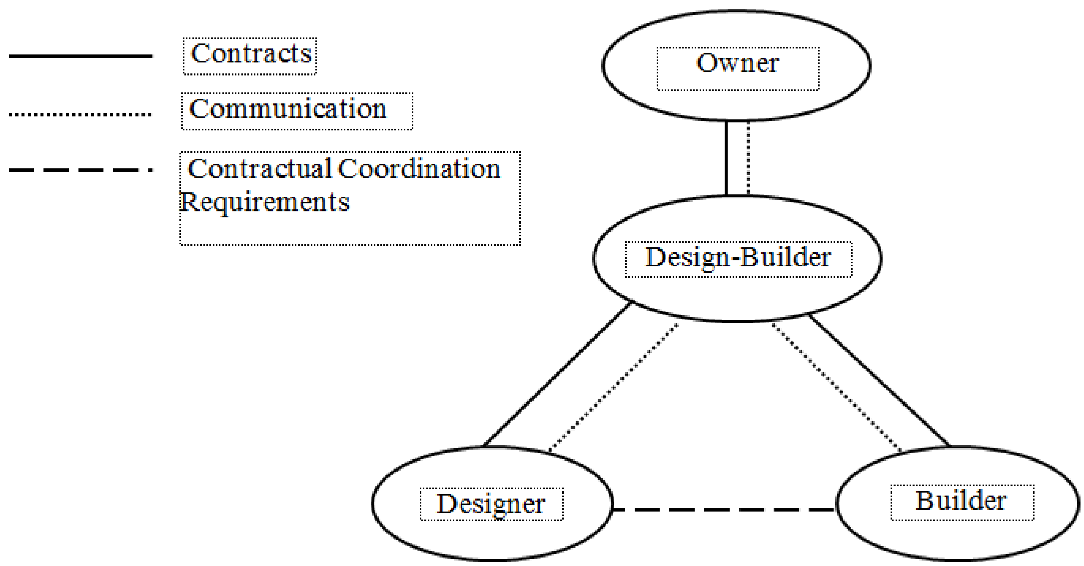


Figure 3. Design-Build (Gransberg and Shane 2009, adapted from AIACC 1996)

One of the most well-known benefits of the DB delivery method is the ability to compress the project delivery period (Alder 2007). The Federal Highway Administration (FHWA) (2006) adds to this by saying DB has "the ability to reduce overall duration of the project development process by eliminating a second procurement process for the construction contract, reducing the potential for design errors and omissions, and allowing for more concurrent processing of design and construction activities".

In the late 1980s, when DB was introduced to the construction industry, professionals from the design industry argued that the project delivery method would degrade the project quality by "compromising the integrity of the design process" (Gransberg et al. 2007). The

National Society of Professional Engineers (1995) Position Statement #1726 reflected a similar sentiment by stating "Design decisions may be determined or inappropriately influenced by team members other than the designer." The statement goes on to say that the leader on a design-build team is likely to be a non-designer who may look to maximize profit by pressuring designers to reduce their quality criteria or design standards. However, according to a study by Ernzen and Feeney (2002) from the Arizona Department of Transportation, these concerns are not necessary. The study compared quality assurance data from both DB and DBB projects and found that the quality of material on the DB project was similar to the quality of the DBB project and exceeded the project specification. Finally, the fact that DB is still considered as a viable delivery method today indicates that the project quality is not being compromised.

Project Delivery Method Schedules

Project schedule is one of the distinguishing factors of project delivery methods. Figure 4 shows that the traditional DBB method is a linear process in which project phases follow on from each other (McMinimee 2011). On the other hand, in the DB method the design phase continues throughout the selection and construction phases concurrently, finishing part way through construction. As a result, DB offers the advantage of being able to start construction while the design is being completed, potentially reducing the overall project schedule (McMinimee 2011). Similarly, CMGC involves concurrent design and construction phases in addition to a condensed selection process. Therefore, alternative delivery methods are able to offer time savings.

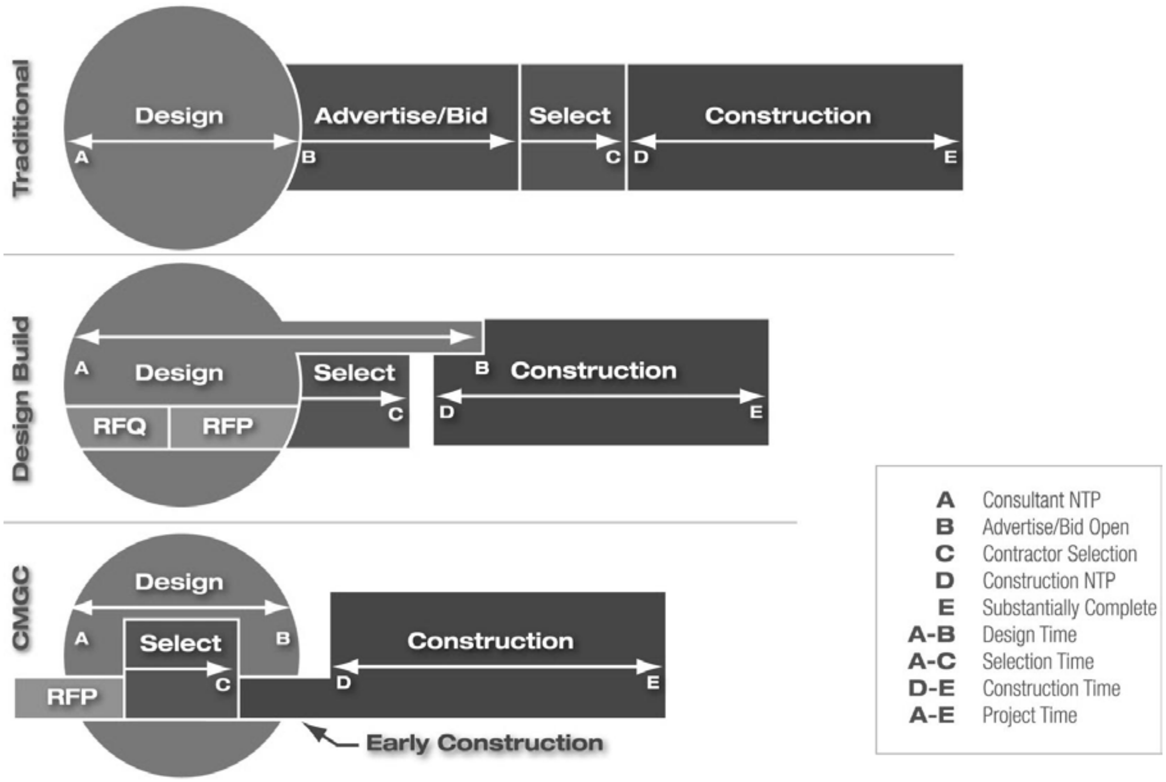


Figure 4. Alternative Delivery Method Schedules (McMinimee 2011)

Preconstruction Cost

Included in this thesis will be a study of project preconstruction costs in relation to contractor involvement in the preconstruction phase. The term preconstruction cost throughout this thesis refers to costs incurred prior to the completion of the construction documents. For DB and CMGC delivery methods this would include the fee paid to the designer and the fee paid to the design-builder or construction manager for preconstruction services. In addition, some CMGC preconstruction costs include a fee paid to an independent cost estimator. Conversely, DBB preconstruction costs only consist of the fee paid to the designer. Therefore this thesis talks of design fees only when referring to DBB projects and preconstruction costs when discussing alternative project delivery methods.

Regardless of the method for computing the amount for a project preconstruction cost, it is evident that they are often underestimated. According to Carr and Beyor (2005), design fees have not kept up with the change in inflation over the past thirty years. As a result, Carr and Beyor (2005) suggest that “the high-quality professional services rightfully expected by the public will become increasingly difficult [to attain] if the erosion in fees continues unabated into the future". This is a concern because quality is likely to be compromised as design fees are less than the amount necessary to fund a thorough design analysis. Furthermore, there is speculation that "large public projects have been intentionally under budgeted in order to obtain voter support for the financing approvals" (Beemer 2005). This indicates the presence of initial cost estimating errors, which necessitate increased funding in order complete the projects.

In their report titled "The quality of design documents: what can the cm do?", McSkimming, Peck, Hoy, and Carr (2005), state that "all CMAA [Construction Management Association of America] members present believe there has been a downward movement on A/E [designer] fees, which ultimately is affecting design quality" (McSkimming et al. 2005). McSkimming et al. (2005) went on to suggest that owners should be educated on the costs of design fees and the ramifications of a reduction in fees. This thesis aims to address this lack of education by highlighting the impact of preconstruction costs, as they relate to contractor involvement in the design phase.

There is potential for owners of construction projects to reduce construction cost growth by investing in the design phase. Design errors and omissions require large amounts of time and money to correct (Brown 2002). Venters (2004) suggests that the cost of correcting design errors during the construction phase of a project is higher than the cost of producing quality construction documents during the design phase.

Project Quality

This thesis addresses project quality, as it relates to the design process, by investigating the value of contractor involvement in the design phase. The term quality has been defined in a number of ways in literature and can be related to design or construction. For example, the definition provided by the American Society for Quality (ASQ) (1998) describes quality as "the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs". This general definition is relevant to this thesis because it requires needs to be satisfied. According to this definition, the product of a construction project would be considered a poor quality product if it does not satisfy the owner's needs. This may stem from a poor quality design that did not satisfy the owner's need due to errors or omissions.

Gransberg et al. (2007) make a similar statement in saying "the design phase of a DB project is the phase where the ultimate quality of the constructed facility is quantified through the production of construction documents".

Furthermore, Gransberg and Molenaar (2004) conducted a DB quality management study in which they indicated that quality needs to be methodically designed and built into a project, rather than assumed. The same study presented the results of a survey in which "two thirds of the respondents indicated that they rated detailed design criteria as having a high or very high impact on the project's ultimate quality". Therefore, literature indicates that the project quality is defined during the design phase.

The quality definition that will be used for this thesis comes from the Transportation Research Circular E-C074: Glossary of Highway Quality Assurance Terms (Leahy et al. 2005) and defines quality as:

- "the degree of excellence of a product or service;
- the degree to which a product or service satisfies the needs of a specific customer; or
- the degree to which a product or service conforms to a given requirement".

It is clear that the construction industry is beginning to realize the importance of design quality in relation to project quality. There are many examples of studies that have focused on this topic. The study by Gransberg et al. (2007) concluded by saying "managing the ultimate quality of the design product may be more important than managing the quality of the construction product, because the design product defines the quality standards for the construction". Additionally, Love (2002) found that construction cost growth is produced through a lack of any formal design quality management. A similar study by Burati et al. (1992) discovered that 79% of all modification costs and 9.5% of the project cost can be explained by actions taken to correct design errors. These studies all suggest that an increase in design quality would lead to an increase in project quality, and ultimately a reduction in construction cost growth.

The next step is to highlight the relationship between design fee and design quality, which ultimately affects project quality. The Memphis Shelby County International Airport came close on their CMR project when they included a clause in their design contract that put "10% of the design fee at risk for the quality of the construction documents (measured by the number of design changes made during construction due to errors and omissions).” (Gransberg and Shane 2009) Touran et al. (2008) stated that the inclusion of such a clause caused the engineer to view the constructability and design reviews as an important element of the design quality management program.

In DBB projects the quality is established by producing completed construction documents which proposers base their bids on (Ellis et al. 1991). The construction manager is then able to notify the owner of the expected project cost; based on the quality defined in the completed design documents and the project schedule (Gransberg et al. 2006). On the other hand, the achievable level of quality for a DB project is determined by budget and schedule constraints (Gransberg et al. 2007). Regardless of the project delivery method, it is important for owners to understand project quality is influenced from the earliest stages of a project.

Cost Growth as a Measure of Cost certainty

It is evident in literature that enhanced cost certainty is a benefit of CMGC (Dodson 2011, McMinimee 2011). This section presents literature relating cost growth to cost certainty. Gransberg et al. (2007) suggest that cost growth can be either positive or negative where a positive cost growth “indicates that the final cost of construction exceeded the initial estimate”. Conversely, a negative cost growth “indicates that the final cost of construction was less than the initial estimate” (Gransberg et al. 2007). In both cases the final cost of construction varied from the initial estimate, indicating that the initial estimate held little certainty. Furthermore, either case may be undesirable if positive cost growth is the product of scope changes or quantity inaccuracies and negative cost growth is an “inefficient use of available capital in public works” (Gransberg and Villarreal 2002). Consequently, the most desirable result is to have a project finish on budget where the initial estimate is a true indication of the final cost of construction. This would occur when there is certainty in the initial estimate and the cost growth is zero. Therefore, the information presented in this section supports the use of cost growth as a measure of cost certainty, as used in this research. This reflects sentiment expressed by Gransberg et al. (2007) who state that cost growth as a performance metric “measures the public owner’s ability to control the ultimate cost of the project through “investing” in the design phase and then fully utilizing the available project funding”.

Early Estimate Quality

Finally, it is important to acknowledge that early cost estimates are not accurate. Evidence of this is presented in a report by Molenaar (2005) that states "construction cost estimating on major infrastructure projects has not increased in accuracy over the past 70 years. The underestimation of cost today is in the same order of magnitude that it was then." A similar study by Flyvbjerg et al. (2002) found that costs were underestimated 90% of the time on infrastructure projects. Molenaar (2005) indicates that technical difficulty, limited design, and political pressures add complexity to the task of providing an early cost estimate. Project costs are then underestimated as a bias is produced in order to gain project approval and funding (Molenaar 2005). Trost and Oberlander (2003) explain similar issues by saying that early estimates are often produced with "limited scope definition" and "stiff time constraints".

These studies indicate that early cost estimates have issues associated with them. However, a project owner will use an early cost estimate to determine a suitable design fee as it is the most up-to-date estimate available to the owner. Therefore, it is important to research the influence of design fee on project quality.

PROBLEM STATEMENT

It is known that the quality of the ultimate constructed project is a direct function of the quality of its design (Gransberg et al. 2005). Additionally, survey results by Yates and Battersby (2002) portray the sentiment that firstly "architects and engineers with extensive construction experience could produce the most effective documents", and secondly, "allowing the constructor to be involved in the design from conceptualization would produce the most effective documents". Therefore, this research seeks to answer the following question:

Does involving the construction contractor in the design phase add value to a construction project and ultimately contribute to the production of effective construction documents and enhance the overall quality of the project?

RESEARCH OBJECTIVES

The problem statement for this thesis is approached by developing three studies, each with an individual objective that contributed to the goal of investigating the value added by contractor involvement in the design phase of a project delivered using alternative methods.

The objective of the first study was to understand the factors that go into maximizing the benefit possible from cooperation between the designer and the contractor during the design phase. In order to achieve this objective feedback from the construction industry on projects that successfully utilized early contractor involvement was collected. The synthesis and analysis of the project feedback will furnish useful tools for developing the designer-contractor cooperation that will potentially enhance the quality of the project.

The objective of the second study was to investigate the relationship between the quality of construction documents, preconstruction costs, and contractor involvement in the design phase. This builds on the first study's output by testing the hypothesis that involving the contractor in the design phase increases the preconstruction costs, but adds value by increasing the project cost certainty. Consequently cost data, from projects of different delivery methods, will be used to establish comparisons of preconstruction costs and cost growths where construction cost growth will be used as a measure of cost certainty. As a result, this study will quantify the value added by the contractor in the design phase.

Finally, the third study had the objective of validating the major benefits of contractor preconstruction involvement given in literature. This will be done by analyzing 44 case studies of construction projects delivered using alternative delivery methods in which the contractor is involved in the design phase.

Achievement of the three aforementioned objectives will establish tools for involving the contractor in the preconstruction process, quantify the value added by a contractor in the preconstruction phase, and validate cited benefits of contractor involvement in the preconstruction phase.

CONTENT ORGANIZATION

As previously mentioned, the research documented in this thesis was conducted in three separate studies. Consequently, Chapters 2, 3, and 4 each represent an individual study. Each study is written as a stand-alone paper; however the studies all cover aspects of contractor involvement in the preconstruction phase and combine to provide a view of project tools, benefits and case studies applicable to alternative delivery methods. Chapters 2, 3, and 4 each provide an explanation of the methodology relevant to the chapter content. Therefore, a methodology is not provided for the entire thesis.

Chapter 2 comprises a paper, authored by Nicola West and co-authored by Douglas Gransberg, and Jim McMinimee, accepted for publication in the 2012 Transportation Research Record. The chapter describes a content analysis of conference presentations by DOTs with CMGC experience and compares that information with information found in literature.

Chapter 3 includes a paper written by Nicola West to be submitted to the American Society of Civil Engineers (ASCE) Journal of Management in Engineering. The paper is on alternative delivery methods and investigates the costs incurred during the design phase and cost growths as a measure of cost certainty. In doing this Chapter 3 explores the cost of adding a contractor to the design phase and the resulting value added to the project.

Chapter 4 consists of a paper authored by Nicola West and co-authored by Douglas Gransberg that has been submitted to the 2012 Australasia and South East Asia Structural Engineering and Construction Conference in Perth, Australia. It validates the benefits of contractor preconstruction involvement reported in the literature and goes on to provide case studies of projects that benefited from early contractor involvement.

Chapters 2, 3, and 4 guide the reader through the benefits of early contractor involvement from the start of a project to the end. Chapter 2 gives tools for successful project team cooperation during design phase. Chapter 3 then provides preconstruction cost and cost certainty comparisons to bear in mind during the cost estimation process. Finally Chapter 4 displays validated benefits that may be realized throughout a project. The thesis conclusions, contributions, and recommendations for future research are then given in Chapter 5.

CHAPTER 2. EFFECTIVE TOOLS FOR PROJECTS DELIVERED USING THE CONSTRUCTION MANAGER/GENERAL CONTRACTOR METHOD

West, N., Gransberg D. D., and McMinimee, J. (2011). "Effective Tools for Projects Delivered Using the Construction Manager/General Contractor Method." 2012 Transportation Research Record, Accepted for publication.

ABSTRACT

Construction Manager/General Contractor (CMGC) is an alternative project delivery method that is fast becoming more prevalent to accelerate the delivery of highway projects. The FHWA's Every Day Counts program is encouraging state departments of transportation (DOT) to adopt CMGC as a tool to deliver badly needed rapid renewal projects. As part of the program, a CMGC Peer Exchange conference was held in June 2011 in Salt Lake City. This paper synthesizes the tools used in implementing CMGC project delivery that were reported in those conference presentations by DOTs with CMGC experience. It compares that information with similar information found in the literature in order to document the current state-of-the-practice in CMGC highway project delivery. The paper concludes that jointly managing risk and developing a collaborative business climate are the two most important aspects of successful CMGC project delivery.

INTRODUCTION

Construction Manager/General Contractor (CMGC) is an alternative delivery method for transportation projects in which the owner engages a design professional and a CMGC under separate contracts. The CMGC contract is awarded during the design phase and provides preconstruction services such as estimating, scheduling, and constructability reviews. Once the design has been advanced to a point where a guaranteed maximum price (GMP) can be established, the CMGC assumes the role of the general contractor and completes the construction (Gransberg and Shane 2010). Typically this method requires the CMGC to self-perform a predetermined percent of the project (McMinimee 2011) and the CMGC is at-risk for costs per the GMP. The CMGC method is typically implemented via two separate contracts, one for preconstruction services and the other for construction (Gransberg and Shane 2010).

The Federal Highway Administration (FHWA) sponsored a CMGC Peer Exchange in Salt Lake City, Utah in June of 2011 as part of its Every Day Counts (EDC) program (Mendez 2010). The event was attended by members of state Departments of Transportation (DOTs), FHWA and the construction industry. Throughout the Peer Exchange agencies with CMGC experience gave presentations on CMGC projects that are currently underway. Other speakers discussed their experiences with implementing the method. As a result, the research team was able to capture the state-of-the-practice and lists of key points for achieving successful CMGC project delivery. Furthermore, many agencies described project delivery tools and practices that have proven to be effective on CMGC projects. Therefore, the objective of this paper is to compare tools described in the Peer Exchange with the effective CMGC tools found in National Cooperative Highway Research Program (NCHRP) Synthesis 402: Construction Manager-at-Risk Project Delivery for Highway Programs, (Gransberg and Shane 2010) and other literature to document the current-state-of-the practice in this emerging technique for accelerating the delivery of critical infrastructure projects.

MOTIVATION

The FHWA EDC program is actively encouraging state DOTs to implement CMGC (Mendez 2010). For those that decide to adopt CMGC, it will be the first attempt at the alternative delivery method for transportation projects. For this reason, it is critical to document past efforts and transfer lessons learned regarding keys to success and effective CMGC tools from agencies with CMGC experience. Sharing this type of knowledge as quickly as possible within the industry allows for greater consistency across the nation and more efficient progression up the learning curve for DOTs.

EFFECTIVE TOOLS IN LITERATURE

The following list of effective practices for CMGC (Note: this document uses CMR in the same sense as CMGC) is taken directly from NCHRP Synthesis 402 (Gransberg and Shane 2010).

1. "The case study interviews noted that agencies can develop a documented procedure for selecting CMR as the project delivery method based on project characteristics. Additionally, a similar policy can be developed for selecting the CMR contractor based on the same project characteristics.
2. A CMR selection process is transparent, logical and defensible appears to be less likely to be susceptible to protest.
3. Eight of ten case study agencies utilized the same Quality Assurance (QA) program for CMR as they do for DBB [Design-bid-build]. Therefore, it appears that no modification is necessary to a DOT's QA program to implement CMR project delivery.
4. The two most often cited preconstruction services in transportation projects were design reviews and constructability reviews. Both of these are essential components of the design QC [Quality Control] program. Thus, detailing the roles and responsibilities for design QC for both the designer and the CMR in the procurement phase facilitates collaboration.
5. Joint development of the preconstruction service cost model before commencing design allows the designer and the CMR to be able to leverage it [the cost model] to make design decisions and to benchmark value engineering savings.
6. Splitting the contingency between the owner and the CMR appears to make accounting for contingency allocation less onerous.
7. An open books approach to contingency calculation and allocation enhances the spirit of trust between the owner and CMR.
8. Detailing the specific preconstruction services the agency wants to be provided in the preconstruction services contract in the solicitation document leads to responsive proposals. This is critical to getting a reasonable proposal if costs are included in the selection process.

9. Including the submittal of an outline of the proposed CMR project quality management plan with the statement of qualifications or proposal allows the agency to evaluate each competitor's understanding of the QA [Quality Assurance] challenges in the project.
10. Assigning the CMR the duties of scheduling for both design and construction during the preconstruction phase enhances collaboration between the parties. This service was rated as the second most valuable preconstruction service by both the case study agencies and contractors, and the ability to fast track was cited by ten of the fifteen papers [reviewed in the synthesis].
11. The agency can furnish a list of the cost categories to be used in preconstruction and where it wants various costs, such as fees and contingencies, to be accounted for in the CMR contract. Doing so eliminates confusion as to where each cost is to be allocated and facilitates the Guaranteed Maximum Price negotiations."

This list of effective practices was compiled based on information gained through case studies, surveys, a content analysis of CMGC solicitation documents, and structured interviews with suitable agencies. These effective practices are next compared to the effective tools described in the CMGC Peer Exchange later in this report.

KEYS TO SUCCESS FOR THE CMGC PROJECT DELIVERY METHOD

A content analysis of the presentation transcripts from the CMGC Peer Exchange was conducted in order to find keys to success for implementing the CMGC method. This type of analysis can be used to develop "valid inferences from a message, written or visual, using a set of procedures" (Neuendorf 2002). The primary approach is to develop a set of standard categories into which words that appear in the text of a written document can be placed and then the method utilizes the frequency of their appearance as a means to infer the content of the document (Weber 1985). Thus, in this study, the content analysis consisted of two stages. First, all instances of each word were found in each presentation and the context was recorded. Secondly, that context was used to determine, if possible, the relative success of each practice. This allowed an inference to be made regarding the effectiveness of each tool/practice on the presenter's CMGC projects. When the results are accumulated for the entire population, trends can be identified and reported.

Eight agencies were represented in the presentations. Of these, three state DOTs and one Construction Company were found to include CMGC keys to success. These keys were suggested based on past CMGC experience and highlight aspects to focus on during a CMGC project. Table 1 displays the keys to success suggested by Utah DOT, Sundt Construction, Colorado DOT and Oregon DOT.

Table 1. CMGC keys to success suggested by entities with CMGC experience

Keys to Success	Utah DOT (6)	Sundt Construction (7)	Colorado DOT (8)	Oregon DOT (9)	Total Count
Partnering/Teamwork; Co-location and Collaboration	X	X	X	X	4
Manage Risk	X	X	X		3
Cultivate Good Relationships; Commitment	X	X	X		3
Active Project Management; Measure Success	X		X	X	3
Proactive Leadership; Objectivity to each Team Member		X	X	X	3
Timely Issue Resolution; Proactively solve challenges and prevent disputes without blame; Competition ends at Selection	X	X	X		3
Trust		X	X		2
Stimulate Innovation; Flexibility and Adaptability	X		X		2
Communication; Regular Meetings	X	X			2
Common Goals and Objectives		X			1
Good Intentions and Mutual Purpose			X		1
Cooperation in Design Effort	X				1
Understand the Scope and Delivery Method			X		1

In addition, Table 1 shows that partnering is cited by all four entities as an important key to success for CMGC projects. This makes it the most commonly given key to success, followed by risk management, relationship cultivation, active project management, proactive leadership, and timely issue resolution.

EFFECTIVE CMGC TOOLS

Throughout the course of the CMGC Peer Exchange a number of effective techniques for CMGC projects were described. Those that were described most frequently by multiple presenters include Blind Bid Comparison, Selection Process Interviews, Selection Criteria Weighting, Iterative Pricing, Open Books Accounting, and Measuring and Recording Success. These tools have each been used by an agency for a CMGC project in the past and have proven to be effective practices for the delivery method. Table 2 shows the project phase to which each tool relates.

Table 2. Effective CMGC tools described at the CMGC Peer Exchange

Tool	Project Phase
Blind Bid Comparison	Procurement
Selection Process Interviews	Procurement
Selection Criteria Weighting	Procurement
Iterative Pricing	Preconstruction/Construction
Open Books Accounting	Preconstruction/Construction
Measuring and Recording Success	Entire Project

Blind Bid Comparison

Blind Bid Comparison is an effective tool that has been adopted by Utah DOT for all CMGC projects (Alder 2011). The Blind Bid Comparison process involves three estimates:

- The CMGC's estimate;
- The Engineer's estimate; and
- The Independent Cost Estimator's (ICE) estimate.

When the CMGC is ready to establish the GMP, the three estimates are compared. The CMGC is then told whether or not their estimate is within 10% of the ICE's estimate. If the CMGC's estimate is within the 10% range, the project may be awarded. However, if the

CMGC's estimate does not fall within the 10% range, the CMGC, the Designer, and ICE meet to discuss the reasons for the differences in estimates. This discussion is not to negotiate price, but rather to compare the assumptions affecting the price and to establish a common understanding of the bid items (McMinimee 2011). Often the price differences are found to be due to differences in applied or perceived risk. For example, in Utah DOT's Mountain View Corridor Project, the Engineer's estimate for the most likely project cost was $307.5 million with a contingency of $42.4 million. The CMGC's estimate for the same project was $346.2 million with a contingency of $56.7 million (Alder 2011). Once the assumptions have been compared the Owner can choose to accept the risk, do more design work, or adopt a method to mitigate the risk. The CMGC is then given the opportunity to reevaluate and estimate a new GMP. A new Engineer's estimate and ICE are developed for the next GMP submittal. This process is iterative and continues until an acceptable GMP is reached. If an acceptable price cannot be reached the Owner may choose to have the design completed and proceed with construction using Design-Bid-Build delivery (Alder 2011). However, in Utah DOT's experience, prices usually converge after two or three iterations.

Selection Process Interviews

Conducting interviews during the selection process is highly recommended by more than one agency at the CMGC Peer Exchange as being a valuable practice (Alder 2011, Rowley 2011, Acimovic 2011, and Dodson 2011). Interviews allow the owner to judge the chemistry and dynamics of a group of people before selecting a project team. This is important for a delivery method such as CMGC because partnership, teamwork, and trust have been identified as keys to success. In addition, this interview process gave the interview team a way to clarify and understand the contractor's proposal. Interviews are typically conducted as part of the selection process for a CMGC project. For example, Colorado DOT forms a selection panel and decides on a short list of contractors for each CMGC project (Acimovic 2011). Interviews are then performed in which each contractor is asked the same questions. The interview questions cover the following four areas:

- Qualifications;
- Approach;
- Innovations; and

- CMGC Process.

Each interview is scored and the winning contractor is subsequently chosen (Acimovic 2011).

Selection Criteria Weighting

Four of the presentations at the CMGC Peer Exchange contained information regarding selection criteria used for selecting a contractor. Selection criteria are chosen and weighted by an agency in order to determine which CMGC firm offers the best value. Table 3 displays the maximum possible score for the selection criteria used by three of the four agencies when selecting a CMGC firm for a project.

Table 3. Sample selection criteria and criteria weighting

	Maximum Score		
Selection Criteria	**Arizona DOT (10)**	**City of Phoenix Street Transportation Department (11)**	**Utah DOT (6)**
General Information		5	
Qualifications of Firm	20	20	
Experience of Key Personnel	15	20	20
Project Understanding	30	25	15
Safety	10		
Miscellaneous	15		
Interview	20		
Quality Control and Safety Program		10	
Subcontractor Selection Plan		10	
Overall Evaluation of the Firm		10	
Innovations			10
CMGC Design Process			25
Price			10
Approach to Price			20
Maximum Total Score	110	100	100

It can be seen that both Arizona DOT and the City of Phoenix Street Transportation Department exclude criteria related to pricing when evaluating CMGC firms. Historically, in early projects Utah DOT also excluded pricing criteria from the selection process. However, pricing criteria was added at the request of the construction industry in order to prevent the process from becoming a ‘beauty contest’ (McMinimee 2011). In their experience with CMGC projects, Utah DOT has found that including pricing criteria is important as contractors become more skilled at writing proposals (Alder 2011).

As shown in Table 3, Utah DOT weighted the evaluation of Proposals at 70% for the experience portion and 30% for the price and approach to price portions, for the Mountain View Corridor Project (Alder 2011). In performing such evaluations, the Utah DOT are applying a “1/3 Rule” for both price and technical factors. This rule says that in order to avoid awarding the contract to a contractor whose bid is more than 10% over the low bidder then the qualification component of the evaluation should not be more than 30%. This method is the result of some evolution in which a variety of scoring criteria and weightings were tried. Utah DOT would now admit that there is not one best portion combination, but rather each project should be considered individually to arrive at the best method specific to the project.

The fourth system is used by Oregon DOT and involves calculating the best value proposal based on equations for both Project Proposal Factor (PF1) and Price Proposal Factor (PF2) (Dodson 2011). The Project Proposal Factor takes into account legal requirements, proposer’s organization and expertise, CMGC roles and responsibilities, and project approach in each proposal. Similarly, the Price Proposal Factor considers the CMGC fee and proposal security in each proposal (ODOT 2008). This system assigns a weight of 85% to the Project Proposal and 15% to the Price Proposal. The Total Score of a proposal is calculated using Equation 1.

$$\textit{Total Score} = (\textit{Project Proposal Weight x PF1}) + (\textit{Price Proposal Weight x PF2}) \qquad (1)$$

Similarly, the values for PF1 and PF2 for each proposal are calculated using Equations 2 and 3 respectively.

$$PF1 = \frac{\textit{Proposer's Project Proposal Score}}{\textit{Highest Project Proposal Score}} \qquad (2)$$

$$PF2 = \frac{\textit{Lowest CMGC Fee Percentage}}{\textit{Proposer's CMGC Fee Percentage}} \quad (3)$$

Iterative Pricing

Iterative pricing is an effective tool used by Utah DOT in order to obtain cost estimate comparisons at regular intervals (McMinimee 2011 and Alder 2011). An Opinion of Probable Cost of Construction (OPCC) is determined through analysis of the project cost and risks. As each estimate is determined, project risks are both realized and resolved. Table 4 displays the Base Cost Drivers that were used to produce each OPCC for Utah DOT's Mountain View Corridor Project in Salt Lake City, Utah.

Table 4. UDOT Mountain View Corridor Project base cost drivers for each Opinion of Probable Construction Cost

	OPCC1	OPCC2	OPCC3	OPCC4
% of Roadway and Structure Design Complete	30%	45%	60%	60% - 75%
% of Drainage Design Complete	0%	30%	60%	80%
Base Cost Uncertainty Range	+11% to +20%	-18% to +15%	-9% to +9%	-7% to +7%

The initial OPCC typically involves only the owner and the designer in the risk analysis. Subsequent estimates include the CMGC. As a result, the second OPCC is usually higher due to risks identified from the contractor's perspective. Subsequent OPCCs are lower as the project team works through cost versus technical issues during design. Furthermore, with each OPCC Utah DOT found that the required contingencies are reduced releasing additional funding for construction. Iterative pricing using OPCCs creates an opportunity for an owner to reduce project cost as a result of employing contractor knowledge and experience.

Open Books Accounting

Open Books Accounting is a tool that was recommended at the CMGC Peer Exchange by three speakers. It is said that the GMP, used in CMGC projects allows open book accounting and design to progress, leading to minimized risk and reduced hidden contingencies (Balis

2011). Open Books Accounting is effective because it provides transparency and develops trust among project team members.

Measuring and Recording Success

Keeping track of the records that document success, such as cost and time savings, throughout an entire CMGC project is an effective tool that was recommended by representatives from two different agencies at the CMGC Peer Exchange. Utah DOT recognizes the value of collecting and documenting data from a project in order to maintain ongoing, verifiable statistics to promote CMGC as a delivery method. For example, Utah DOT is currently involved in a large highway project in Salt Lake City called the Mountain View Corridor Project. An approach to documenting savings in constructability and innovation has been implemented on this project and has allowed the project team to gain otherwise unknown information relating to project savings. For example, Utah DOT maintains a record of changes in project cost estimates as design advances. This allows Utah DOT to see the mitigation savings for a project. Figure 5 displays the progression of project cost estimates (where OPCC denotes a cost estimate known as an Opinion of Probable Cost) for the Utah DOT Mountain View Corridor Project (Alder 2011).

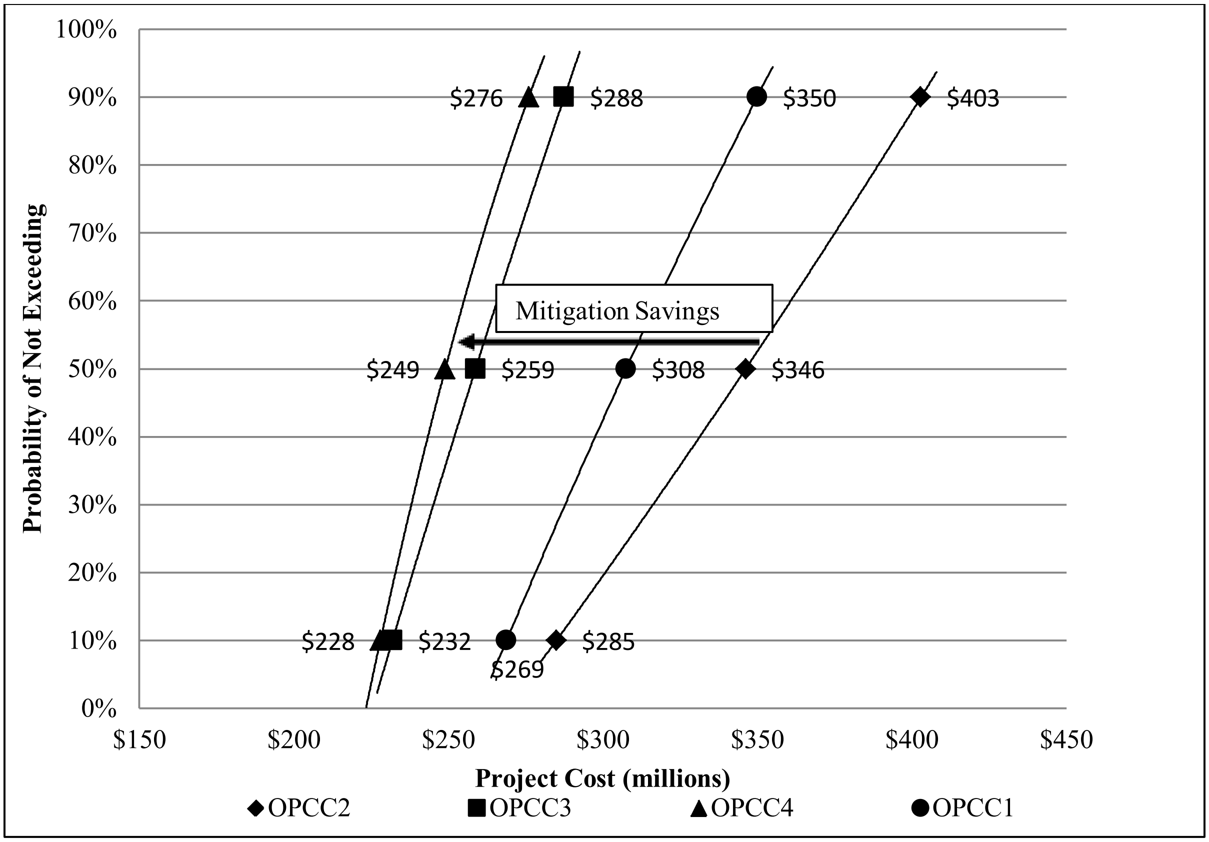


Figure 5. Mountain View Corridor Project cost estimates and mitigation savings

Utah DOT also utilizes project documentation by viewing change orders and overruns in order to gain insight into overall project savings.

The City of Phoenix Street Transportation Department has also found value in measuring and recording project successes (Bearup 2011). They implement the tracking of cost estimates during the pre-bid phase of the project in order to identify increases or decreases in cost. This is done to eliminate the possibility of surprises on bid day.

COMPARISON OF EFFECTIVE TOOLS

A comparison of the effective tools described in the CMGC Peer Exchange and those listed in the NCHRP Synthesis 402 (Gransberg and Shane 2010) revealed three obvious similarities. First, the literature states that developing a policy “for selecting the [CMGC] contractor based on [specific] project characteristics” is an effective means to maximize the CMGC’s experience with the project’s requirements. This aligns with the Selection Criteria

Weighting tool reported in the CMGC Peer Exchange. Implementing the Selection Criteria Weighting tool requires an agency to establish selection criteria that includes important project characteristics and the resulting criteria form the policy CMGC selection based on project characteristics. This also implies that the weighting of the scoring criteria consider the project.

Secondly, the literature lists “an open books approach to contingency calculation… [and] allocation enhances the spirit of trust between the owner and the CMR” (Gransberg and Shane 2010). This practice is consistent with Open Book Accounting described in the CMGC Peer Exchange due to the trust and transparency described by both the literature and the tools discussed in the presentations.

Last, there is a linkage between the literature and the effective Peer Exchange tools as each relates to cost categories. The literature states that “the agency can furnish a list of the cost categories to be used in preconstruction” to “eliminate confusion as to where each cost is to be allocated” (Gransberg and Shane 2010). This practice is consistent with the Blind Bid Comparison process in which price discussions take place to establish assumptions and bid item understanding. Therefore, both practices call for some form of price clarification, eliminating confusion and potential misunderstanding by mandating information-rich communications.

RELATIONSHIP BETWEEN EFFECTIVE TOOLS AND KEYS TO SUCCESS

Each of the effective tools identified at the CMGC Peer Exchange supports one or more of the keys to success given in the presentations. Table 5 is a matrix that shows the interrelationships between the two. It is clear from Table 5 that managing risk is a common key to success that is achieved by the implementation of most of the effective tools. This is desirable because risk discussions are critical to the success of the CMGC delivery method and to project pricing (McMinimee 2011). One of the primary goals of the CMGC delivery method is to minimize risk wherever possible and to determine where it should be allocated. The elimination and mitigation of risk is critical to ensuring that a good project price is achieved. The remainder of the tools generally relate to the quality of the business relationships established inside the CMGC contract between the various stakeholders.

Having common goals and objectives that are set and maintained via information-rich communications that take place in a routine manner in regular meetings appears to be critical to the successful delivery of a CMGC project.

Table 5. Keys to success achieved by implementing the effective tools

Keys to Success (Rank ordered by number of observations)	#	**Blind Bid Comparison**	**Selection Process Interview**	**Iterative Pricing**	**Selection Criteria Weights**	**Measuring and Recording Success**	**Open Books Accounting**
Manage Risk	5	X	X	X	X		X
Communication; Regular Meetings	5	X		X	X	X	X
Common Goals and Objectives	5	X	X	X	X	X	
Cultivate Good Relationships; Commitment	4		X	X		X	X
Timely Issue Resolution; Proactively solve challenges and prevent disputes without blame; Competition ends at Selection	4	X	X	X			X
Cooperation in Design Effort	4	X	X			X	X
Partnering/Teamwork; Co-location and Collaboration	3		X			X	X
Active Project Management; Measure Success	3			X		X	X
Proactive Leadership; Objectivity to each Team Member	3		X	X	X		
Develop an Environment of Trust	3		X	X			X
Stimulate Innovation; Flexibility and Adaptability	3		X	X	X		
Good Intentions and Mutual Purpose	2		X				X
Understand the Scope and Delivery Method	2		X				X

CONCLUSIONS

The review of the CMGC Peer Exchange and its comparison with the literature has identified a number of effective CMGC implementation tools. Each of the tools lines up with at least one of the keys to CMGC success that were detailed during the presentations. The fact that the keys to the success came from both DOT and contractor entities validates their selection. The following conclusions are drawn from the above analysis:

- Managing risk is one of the most important aspects of CMGC project delivery success. Risk can be managed by a number of mechanisms such as open books accounting, partnering, iterative pricing, and blind bid comparison.
- Creating an environment of trust is also important to CMGC success. Through selection process interviews and the weighting of selection criteria, the DOT is able to pick its CMGC on a basis of qualifications and past performance, and is no longer "stuck" with the low bidder. Therefore, the ability to work in an open and honest manner is possible. Mechanisms like open books accounting furnish a means for the owner to understand the CMGC's perception of risk and the use of iterative pricing provides a format where both sides can adjust and revise their numbers during GMP negotiations.
- The first two conclusions are essential to maximizing the benefit possible from cooperation during the design effort. When the designer has access to the construction contractor's real-time pricing and the ability to review the constructability of the design before it is completed, there is no longer an excuse to exceed the published budget for the project. Using tools like co-location and collaboration creates instant access for the designer to the builder and the owner, which permits timely questions and design decisions being made in an information-rich environment.

CHAPTER 3. ANALYSIS OF THE IMPACT OF PROJECT DELIVERY METHOD ON COST CERTAINTY

West, N. (2012). "Analysis of the Impact of Project Delivery Method on Cost Certainty". To be submitted to the ASCE Journal of Management in Engineering.

Utilizing the established tools for successful cooperation during the design phase would allow the contractor to access pricing details and review constructability of the design before it is complete. Therefore, there should be no reason for project cost growths due to construction document quality issues. This chapter investigates preconstruction costs for projects delivered using traditional and alternative delivery methods and analyzes cost growth as a measure of cost certainty.

INTRODUCTION

The objective of this study is to investigate the relationship between the quality of construction documents, preconstruction costs, and contractor involvement in the design phase. The quality of construction documents has declined (CMAA 2003). However, the expectation of a quality design is unwarranted if the design fees are not appropriate (Carr and Beyor 2005). If design fees are inadequate the owners may be unintentionally shifting the detailed design decisions from the design phase to the construction phase. Two methods for addressing this matter are explored in this study. The first is to increase the design fee so that designers have the necessary resources to produce a quality design. The second method is to have a contractor work with the designer to provide constructability knowledge and allow detailed design decisions regarding fabrication, means, and methods to be made in the design phase rather than the construction phase. This study tests the hypothesis that involving the contractor in the design phase increases the preconstruction costs, but adds value by increasing the project cost certainty.

Quality of Construction Documents

An owner survey of the quality of construction documents conducted by the Construction Management Association of America (CMAA) in 2003 found that 57% of the respondents believed that construction documents frequently have significant amounts of information missing. This indicates that construction documents are not meeting the quality that is expected of them. Carr and Beyor (2005) provide a reason for the decline in construction document quality by stating that “the high-quality professional services rightfully expected by the public will become increasingly difficult if the erosion in fees continues”. Additionally, a later study (Gransberg et al. 2007) expressed the same concern by saying pricing pressure and minimized design activities may result in the declining quality of construction documents. It went on to suggest that the decline in construction document quality noted by CMAA is “further exacerbated by the recent demand by owners to compress project delivery periods” (Gransberg et al. 2007). Thus, it becomes clear that the quality of construction documents is related to the amount of resources required in the design phase. These resources could include increased design fees to relieve pricing pressure and eliminate the need to minimize design activities to meet billable hour constraints, or the addition of a contractor to provide knowledge and management to the design phase under a compressed schedule.

Design Fee

Gransberg et al. (2007) conclude that “the design fee should be viewed as an investment at a point in time where the ability to impact the project is the highest and can accrue the benefit of reduced cost growth”. Similarly, the Federal Highway Administration (2006) states that “greater cost efficiencies are most likely to occur for design-build projects as a result of enabling the design-builder to propose more cost-effective ways to realize the performance objectives of the project”. These two statements agree that investment in the design phase results in cost efficiencies. In essence, paying an appropriate design fee enables quality construction documents to be produced which subsequently reduce cost growth. However, Carr and Beyor (2005) argue that appropriate design fees are not being paid and say “broad efforts to reestablish fair and responsible fees are overdue.” Therefore, investing more money in the design phase would allow designers sufficient time to produce the high quality documents that are expected and hopefully accrue a return on that investment via enhanced construction cost certainty and reduced cost growth due to design errors and omissions identified during construction.

Alternative Project Delivery Methods

In addition to paying appropriate design fees, an owner can seek to enhance the quality of construction documents by using alternative project delivery methods to involve the contractor early in the design process. A study of design and construction professionals done by Yates and Battersby (2002) investigated the amount of construction experience a design professional needs to be able to minimize errors and omissions in the design phase and produce a constructible design. As part of their study architecture, engineering, and construction professionals were surveyed and concluded that “a high percentage of the respondents felt that designer construction knowledge obtained prior to starting a design career is important” and “designers and nondesigners felt that errors and omissions insurance [claims] would be reduced if designers received construction training”. However, “many respondents did not think that design firms provide enough training for their employees” (Yates and Battersby 2002). This study recognizes that designers with a high degree of constructability knowledge are required in order to produce quality construction documents. However, this can be difficult to achieve given the lack of training in their career.

In addition, the study asked respondents to select the most important factors that contribute to effective construction documents. Most of the respondents (45%) said “architects and engineers with extensive construction experience could produce the most effective documents”. The second most common response was that “allowing the constructor to be involved in the design from conceptualization would produce the most effective documents” (Yates and Battersby, 2002). Therefore, if it is not possible to secure designers with a high degree of constructability knowledge then it is necessary to involve a contractor in the design process to enhance the quality of construction documents. This is often done through the use of alternative delivery methods such as DB and CMGC, which is also known as construction manager-at-risk.

Alternative project delivery methods are explored in this study as methods for involving the contractor in the design process. Specifically, the costs incurred during design and cost growths for DBB, DB, and CMGC projects are compared to develop an understanding of the cost of adding a contractor to the design process and the value added by doing so. Prior to commencing this investigation some terminology needed to be defined. To begin with, the term design fee throughout this study refers to the fee paid to the designer of record. Most commonly this term is used in reference to DBB projects in which the design fee is the only preconstruction cost incurred by the owner. However, in CMGC projects the design fee is just a portion of the total preconstruction cost. A CMGC preconstruction cost typically contains the design fee and the fee paid to the construction manager to perform services before construction starts. In some cases the CMGC preconstruction cost will also contain the fee paid to an independent cost estimator (ICE). Finally, a DB preconstruction cost is likely to contain the design fee as well as the cost to the design-builder for preconstruction services. However, it is not possible to know the exact split between the design fee and preconstruction services fee in each DB project.

For the purposes of this study, the comparison of costs incurred prior to the completion of the construction documents is made. Therefore, the DBB design fees are compared to CMGC and DB preconstruction costs. This allows for the analysis of comparable values assigned for all design and preconstruction activities.

METHODOLOGY

The data for this paper was obtained through a literature review of national and international resources and from a database of information about more than 400 construction projects. The data from the literature review is a set of recommended design fees that was analyzed and compared with database design fees for projects that were delivered using DBB, DB or CMGC. Additionally, preconstruction cost data from the database was utilized to determine cost growth and absolute cost growth as a measure of cost certainty.

Literature review

A literature review of design fees was conducted, and five organizations provided sufficient information about construction design fees for this study (see Table 6):

- The Institution of Professional Engineers New Zealand (IPENZ);
- American Society of Civil Engineers (ASCE);
- Arkansas State University – Capital Development Policies and Procedures;
- Ontario Society of Professional Engineers; and

- Newfoundland Association of Architects (NAA) and the Association of Professional Engineers and Geoscientists of Newfoundland (APEGN).

Table 6. Comparison of design fees recommended as a percentage of construction costs

Construction Project Cost	IPENZ (IPENZ 2004)	ASCE (ASCE 1981)	Arkansas (ASU 2001)	Ontario (OSPE 2011)	Newfoundland (NAA and APEGN 2003)
$75,000			9.00%		
$100,000	8.40%	9.01%	8.75%		
$200,000		8.11%	8.50%		
$300,000			8.25%		
$400,000			8.00%		8.01%
$500,000		7.00%	7.75%	9.30%	7.67%
$600,000			7.50%	9.30%	7.67%
$700,000			7.25%	9.30%	7.67%
$800,000			7.00%	9.30%	7.37%
$900,000			6.75%	9.30%	7.37%
$1,000,000	8.00%	6.22%	6.50%	8.60%	7.04%
$2,000,000				7.80%	6.78%
$3,000,000					6.61%
$4,000,000					6.46%
$5,000,000		5.32%		7.50%	6.23%
$7,500,000					5.94%
$10,000,000	7.60%	4.97%			
$20,000,000			6.50%		
$22,500,000			6.25%		
$25,000,000			6.00%		
$27,500,000			5.75%		
$30,000,000			5.50%		
$32,500,000			5.25%		
$35,000,000			5.00%		
$37,500,000			4.75%		
$40,000,000			4.50%		
$42,500,000			4.25%		
$45,000,000			4.00%		
$47,500,000			4.00%		
$50,000,000		4.68%	4.00%		
$100,000,000	7.25%	4.61%			

The recommended design fees range from 4.0% of the construction project cost to 9.3%, for projects varying in size from $75,000 to $100,000,000. Table 6 displays the five sets of recommended design fees and the corresponding construction project costs adapted from published tables. Three countries, New Zealand, the United States, and Canada, recommend very similar design fees. Therefore, Table 6 is assumed to portray design fees considered to be appropriate within the industry.

Analysis of Recommended Design Fees

The five sets of recommended design fees were graphed and the appropriate trend line, with the highest coefficient of determination (R^2 value), was found for each set of recommended design fees. The resulting design fee trend lines were found to display either exponential or logarithmic regression. The equations to the resulting trend lines were then used to generate recommended design fees for actual construction project costs. Figure 6 displays recommended design fee curves that were produced for hypothetical construction project costs to show the differences in the design fees recommended by each organization. These design fees are recommended for traditional DBB projects and are not directly comparable to DB or CMGC preconstruction cost data due to procurement differences.

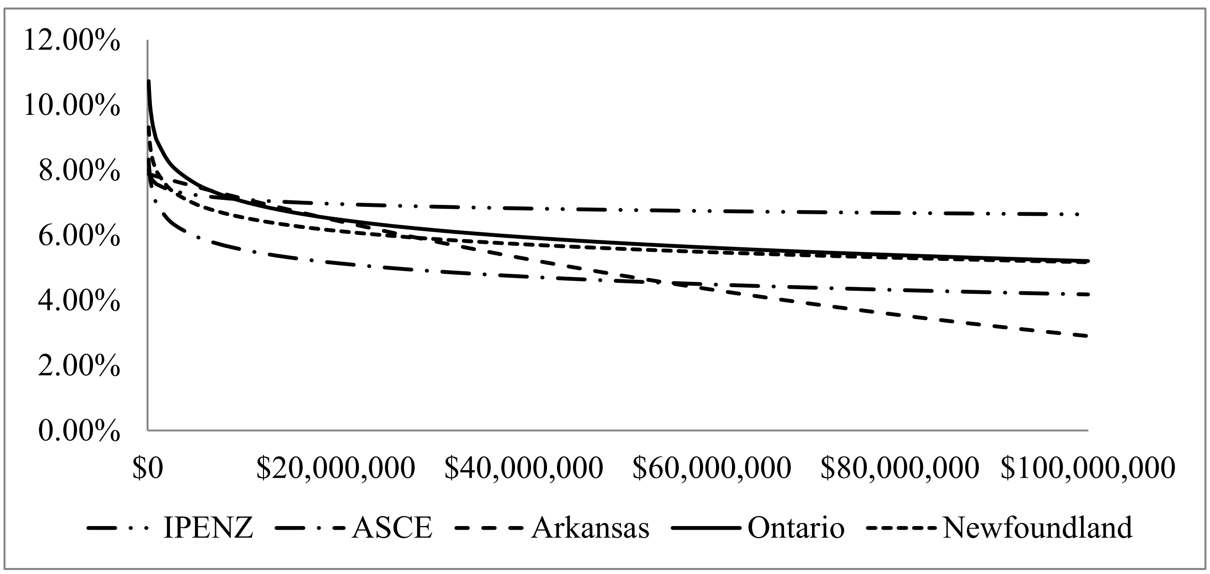


Figure 6. Recommended design fees established using design fee curve equations

Database of Preconstruction Cost Data

The preconstruction cost data (Appendices 1, 2, and 3) used for this study was taken from an existing database of information on over 400 projects, assembled from 1996 onwards from a number of previous project delivery method research projects (Gransberg et al. 1997, Gransberg and Molenaar 2005, Gransberg et al. 2006, Touran et al. 2008, and Touran et al. 2009). The database contained information on road, bridge, and other types of projects, delivered using DBB, DB or CMGC. For the purposes of this study a number of projects were removed from the database as there was inadequate information on them for the desired analysis. The resulting database of project information utilized for this study is summarized in Table 7.

Table 7. Construction project database details

	DBB	DB	CMGC
Number of Projects	357	32	15
Total Value	$1,835,189,854	$927,793,155	$1,154,052,121
Range	$36,437 - $403,118,022	$490,354 - $682,000,000	$4,846,002 - $200,000,000
Types	Road, Bridge, and Other	Road, Bridge, and Other	Road and Bridge

Comparison of Recommended Design Fees and DBB Design Fees

Once the database of preconstruction cost data was finalized, the DBB design fee data was compared to the recommended design fees shown in Table 6. To make the comparison, the DBB construction project costs were graphed against the actual DBB design fees expressed as a percentage of the construction contract value and the recommended design fees for the same construction costs, found using the exponential and logarithmic equations shown in Figure 6. This comparison furnished a benchmark for design fees. The DB and CMGC preconstruction cost data was not compared to the recommended design fees because the recommendations were developed for DBB projects where the designer is required to produce a set of biddable construction documents, unlike DB and CMGC.

Preconstruction Cost Descriptive Statistics

An analysis of all the preconstruction cost data was carried out by calculating the descriptive statistics for each of the project delivery method populations. The statistical values calculated included the mean, median, mode, standard deviation, variance, maximum, and minimum. These values were then compared in order to determine the differences in preconstruction cost data between the DBB, DB, and CMGC populations.

Cost Growth Determination

Finally, the cost growth values were calculated for each of the DBB, DB, and CMGC preconstruction cost data populations as a measure of cost certainty. No outliers were removed from the preconstruction cost data populations for the cost growth calculations. In simple terms, the “cost growth” measures the change in a project’s cost from the original cost to the final cost (Gransberg et al. 2007). Since the research objective is to evaluate the potential benefits of involving a contractor in the preconstruction phase, it is appropriate to calculate the “cost growth” The cost growth for each population was calculated as a percentage using the following equation (Migliaccio et al. 2010).

$$\text{Cost growth} = \frac{\text{Final construction cost} - \text{original contract cost}}{\text{Original contract cost}} \qquad (4)$$

In Equation 4, original contract cost denotes the construction contract value at award and final construction cost refers to the construction contract value after construction completion. The resulting cost growth values were found to be either positive or negative due to modifications that occurred over the duration of the construction project.

Additionally, the absolute cost growth values for each population of preconstruction cost data were calculated to show the overall change in project construction cost, regardless of whether the cost increased or decreased. These values were used as a second measure of cost certainty as they portrayed the difference between the original contract value and the final construction value. A large difference between the original and final construction values would indicate that the original contract value carried with it a large amount of uncertainty. On the other hand, if the original and final construction values are equal, the original contract value would be seen as having no uncertainty associated with it. Once the cost growth values and the absolute cost growth values were established for each population, the mean and median values were calculated and these were compared to compare cost certainty of the three project delivery methods under investigation.

Lilliefors Test for Normality

The Lilliefors test for normality is one of the most well-known tests for normality (Abdi and Molin 2007) and is performed on each of the data populations used in this research. This test is done to test the assumption of normality for each population. The null hypothesis for the test states that "there is no difference between the observed distribution of the error and a normal distribution." (Abdi and Molin 2007) Conversely, the alternative hypothesis states that the error is not normally distributed (Abdi and Molin 2007). For this research the criterion for the Lilliefors test is defined at 10%. If the test statistic associated with the population undergoing testing is less than the critical value at 10% then the null hypothesis is rejected in favor of the alternative hypothesis and the population distribution is defined as being not normal. Table 8 displays the distributions for the DBB, DB, and CMGC populations for cost growth, preconstruction cost, and final cost populations, tested using the Lilliefors test for normality.

Table 8. Results from the Lilliefors test for the DBB, DB and CMGC populations

		Test Stat.	**Critical Value (10%)**	**Distribution**
Entire Cost Growth	DBB	0.2669	0.0433	Not Normal
	DB	0.1394	0.1413	Normal
	CMGC	0.2521	0.2502	Not Normal
Preconstruction Cost	DBB	0.2308	0.0433	Not Normal
	DB	0.1785	0.1434	Not Normal
	CMGC	0.1166	0.2069	Normal
Final Cost	DBB	0.4094	0.0433	Not Normal
	DB	0.4751	0.1434	Not Normal
	CMGC	0.1344	0.2626	Normal

It is important to note that only the obvious outliers in each population have been removed using visual inspection. Therefore, the populations contain nearly all of the raw data in order to analyze current industry practices. Table 8 shows that each population category, cost growth, preconstruction cost, and final cost, contain populations that are normally and not normally distributed. As a result, nonparametric testing is required to test for statistical significance. Parametric testing would only be appropriate if the DBB, DB, and CMGC populations in each category were all normally distributed.

Kruskal-Wallis Test

The Kruskal-Wallis test is performed on the DBB, DB, and CMGC populations for final construction cost, preconstruction costs, and cost growth. It is a nonparametric test for testing independent samples and is done to test the equality of the population medians due to the varying population sizes (Washington et al. 2011). The Kruskal-Wallis test is for testing k populations where k is greater than two (Washington et al. 2011). The null and alternative hypotheses for the Kruskal-Wallis test are as follows (Washington et al. 2011):

- H_0: All k populations have the same locations (median or mean); and
- H_a: At least two of the k population locations differ.

The tests produce asymptotic significance values (asymp. sig.) which represent the probability that the results are due to chance. A small asymptotic significance value means that there is a small probability that the results are due to chance (Washington et al. 2011). In this case the results are considered significant if the asymptotic significance value is less than 0.10, where the confidence level is 90%.

Table 9 shows the results of the Kruskal-Wallis tests. The Kruskal-Wallis test results for the preconstruction cost populations were significant with an asymptotic significance value of 0.047. The test results for the final cost populations and the cost growth populations were also significant with asymptotic significance values of 0.000 and 0.070 respectively.

Table 9. Kruskal-Wallis test results for the DBB, DB, and CMGC populations

	Populations of Preconstruction Costs			**Populations of Final Costs**			**Populations of Cost Growths**		
	DBB	DB	CMGC	DBB	DB	CMGC	DBB	DB	CMGC
N	357	32	15	357	32	9	356	32	9
Mean Rank	197.3	242.0	241.9	187.9	278.5	380.6	203.5	163.5	149.1
Chi-Square	6.103			41.031			5.328		
Asymp. Sig.	0.047			0.000			0.070		

RESULTS AND ANALYSIS

Comparison of Recommended Design Fees and DBB Design Fees

To determine the difference, if any, between the recommended design fees and the actual DBB design fees a comparison of the two sets of data was performed. The results of the comparison are displayed in Figure 7.

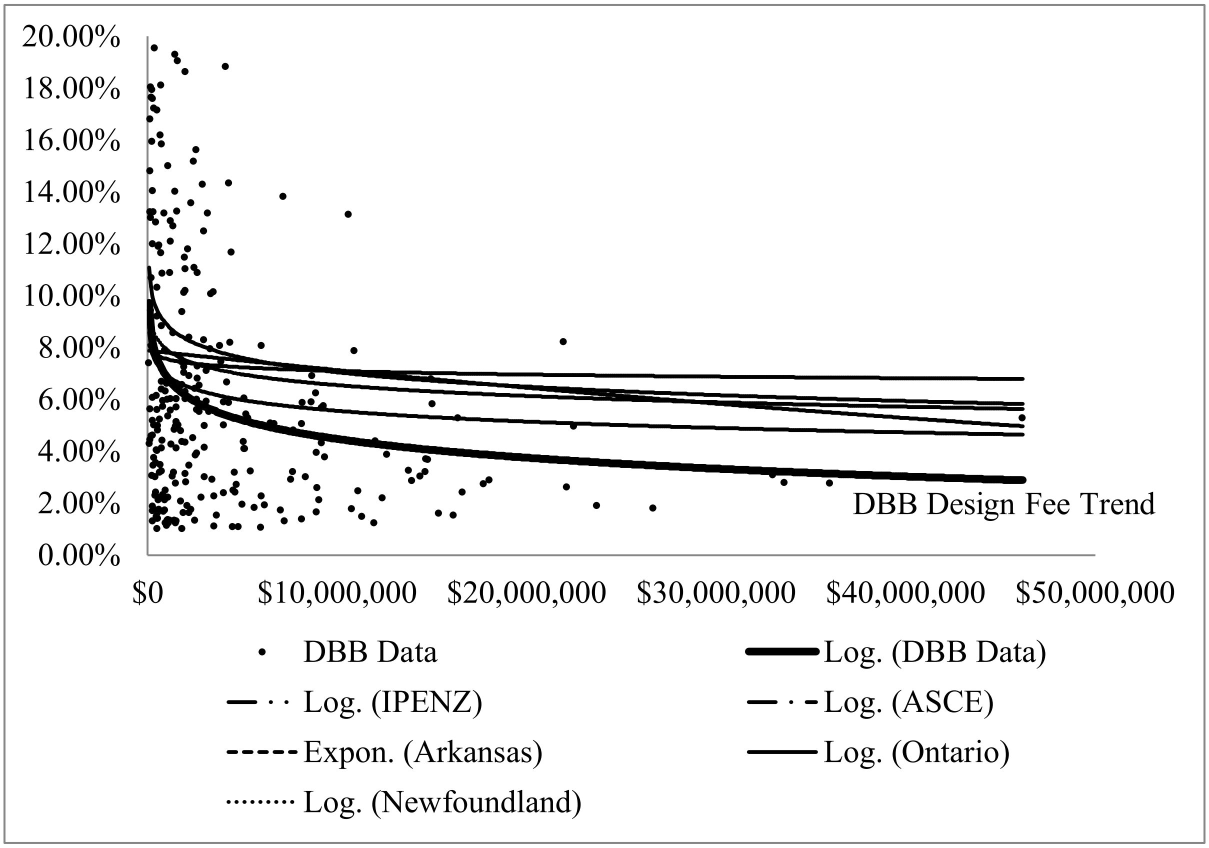
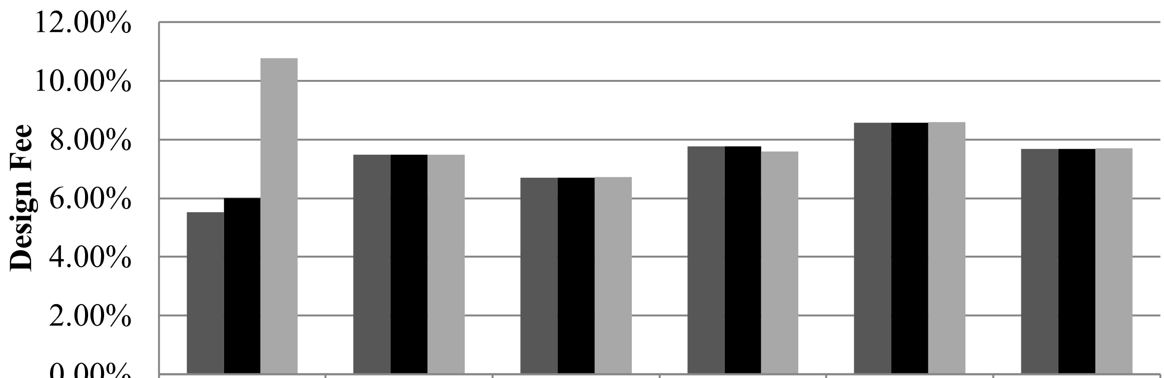


Figure 7. Comparison of recommended design fees and actual DBB design fee data

The trend line for the DBB design fees indicates that owners appear to be spending less on design fees than internationally recommended. Assuming that the recommended design fees are considered to be appropriate, this finding supports Carr and Beyor's (2005) conclusion that suggests current design fees are not appropriate. This finding creates an inference that construction document quality could suffer due to reduction in the amount of resources and/or time available during design caused by unintentional financial constraints placed on the designer by the owner.

The inference is reinforced by the results portrayed in Figure 8. An inspection of the mean values alone would indicate that the design fees for actual DBB projects are much higher than recommended. The average design fee for a DBB construction project is shown to be 2.18% higher than the closest average of recommended design fees, as given by the Ontario Society of Professional Engineers. However, Figure 8 displays results from all DBB projects in the database and therefore contains outliers which are likely to skew the mean value.



	DBB Data	IPENZ	ASCE	Arkansas	Ontario	New Foundland
Median	5.52%	7.48%	6.70%	7.76%	8.56%	7.69%
Mode	6.00%	7.48%	6.70%	7.76%	8.56%	7.69%
Mean	10.77%	7.48%	6.72%	7.60%	8.59%	7.71%

Figure 8. Central tendencies of recommended design fees and DBB design fees

To gain a better understanding of the design fee comparison it is also necessary to consider the median and mode values. One textbook (Washington et al. 2011) defines the mode as being "the value that occurs most frequently", while the median is described as being "the central most point of ranked data". In this case, it is appropriate to consider the median because "it is resistant to extreme observations or outliers in the data" and "may serve as a more reliable measure" than the mean (Washington et al. 2011). A review of the median and mode values in Figure 8 reveals that the design fee for a DBB construction project is most likely to be below the corresponding recommended design fees. This result is consistent with the trend line for DBB design fee data shown in Figure 7. Therefore, a benchmark is established in which the DBB design fees are lower than recommended design fees.

Preconstruction Cost Descriptive Statistics

The next step in this study was to compare the DBB design fees to DB and CMGC preconstruction costs. Yates and Battersby (2003) conclude that it is important for a designer to have construction knowledge. However, it is not always possible to employ a designer with construction knowledge for each construction project. Therefore, alternative project delivery methods provide a mechanism in which the construction contractor brings requisite construction knowledge to the design process.

Alternative delivery methods ensure that a contractor is involved in the design process and construction knowledge is being applied to the design process. However, it would be reasonable to assume that the contractor must be paid for its services for their involvement in the design process. As a result, DB and CMGC preconstruction costs are expected to be higher than DBB design fees because DBB does not acquire contractor services during the design phase.

Consequently, Figure 9 was produced in which the DBB design fee descriptive statistics were compared to those of the DB and CMGC preconstruction costs from the database. The mean values of the three populations indicate that the amount of money spent on preconstruction for DB and CMGC projects is less than the design fee for DBB projects. However, once again, the median serves as a more reliable measure of central tendency than the mean because the data may contain numerous outlying observations (Washington et al. 2011). The medians of the DB and CMGC preconstruction cost data are both higher than the median of the DBB by at least 2.5%. Similarly, the mode for the CMGC population is higher than the mode for the DBB population. The mode for the DB population is expected to be closer to the mode value for the CMGC population; however, the amount paid to the contractor for preconstruction services on a DB project is not known, since the standard of practice only requires the post-award design fee and the lump sum amount for construction to be disclosed in the bidding documents. As a result, the preconstruction cost data may not include this value whereas the CMGC preconstruction cost data does. Overall, the median and mode values suggest that more money is spent on preconstruction costs for projects involving the contractor in the design phase, such as CMGC and DB, than in DBB projects.

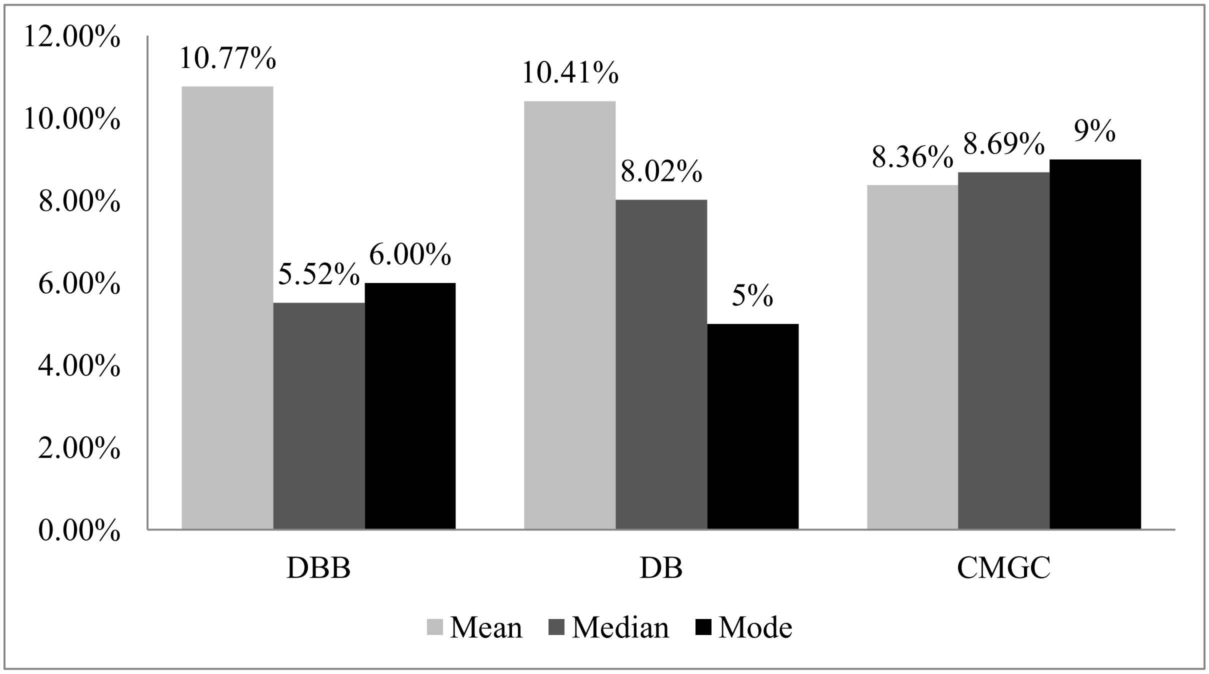


Figure 9. Central tendencies of the DBB, DB, and CMGC project preconstruction cost data sets

Cost Growth Determination

After confirming that more money is spent in preconstruction costs for DB and CMGC projects than DBB projects this study sought to investigate the value added to a project as a result of increased preconstruction costs. The Federal Highway Administration (2006) reported that DB contracting can reduce the potential for cost growth. This suggests that DB contracting can offer greater cost certainty than DBB. Consequently, the mean and median values for DBB, DB, and CMGC cost growth were computed to determine whether greater cost certainty is achieved by involving the contractor in the design phase. Figure 10 displays the mean and median values for the absolute cost growths for the DBB, DB, and CMGC populations.

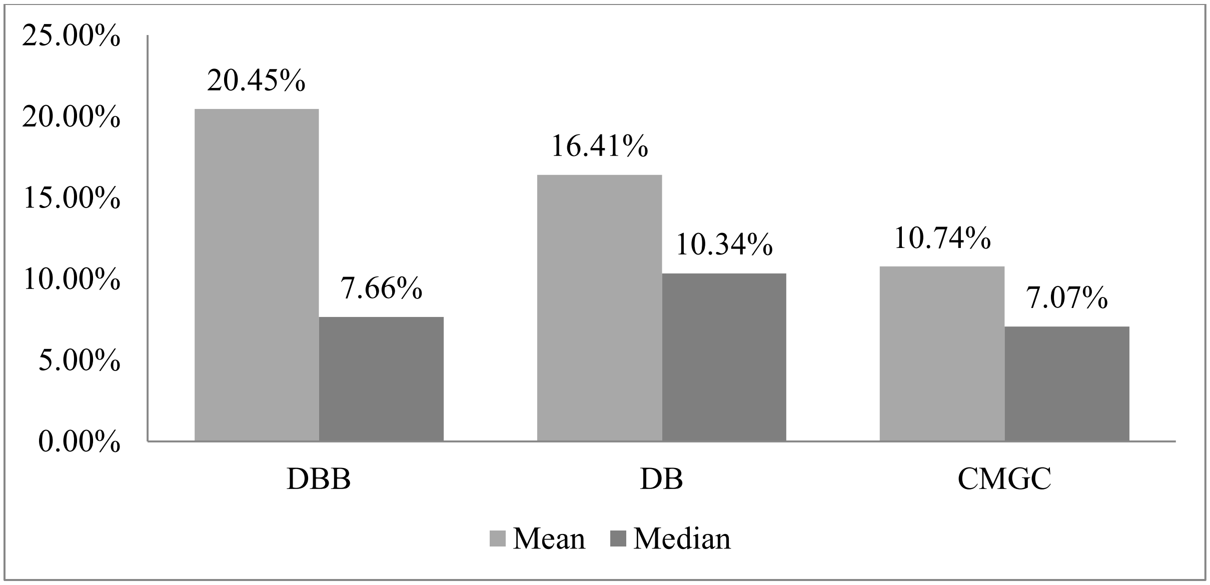


Figure 10. Mean and median absolute cost growth for DBB, DB, and CMGC project data sets

The mean absolute cost growth for DBB projects is almost double the CMGC mean absolute cost growth. Furthermore, both the DB and CMGC mean absolute cost growth values are below the DBB mean value. This indicates that the final construction cost of a DBB project is likely to differ from the original contract cost more than a DB or CMGC project. In other words, projects with contractor involvement in the design phase appear to offer higher cost certainty than DBB projects.

However, it is also important to consider the median of absolute cost growth for each of the populations as this is the more reliable measure of central tendency (Washington et al. 2011). Figure 10 shows that the median absolute cost growth for DBB projects is slightly more than for CMGC projects and is less than the median absolute cost growth for DB projects. Therefore, an analysis of both the mean and the median values for absolute cost growth indicate that the final construction cost of a DBB project is likely to differ from the original contract cost more than a CMGC project. Additionally, DB projects have the potential to produce a smaller difference between the final construction cost and the original construction cost than DBB projects.

In summary, CMGC projects appear to offer higher cost certainty than DBB projects while DB projects have the potential to do the same. This finding agrees with the conclusion reached by a previous study (Gransberg et al. 2007) that found "the design fee should be viewed as an investment at a point in time where the ability to impact the project is the highest and can accrue the benefit of reduced cost growth".

Similarly, the mean and median cost growths for the DBB, DB, and CMGC data sets were graphed to further investigate the value added to a project by investing more in preconstruction costs. Figure 11 shows a comparison of the mean and median cost growths and indicates that DB and CMGC projects are completed below the original contract cost. Conversely, traditional DBB projects finish with a positive cost growth, meaning that the final construction cost is above the original contract cost. Therefore, a project delivered using an alternative project delivery method is likely to finish with a negative cost growth which is more desirable than finishing with a positive cost growth which is likely on a DBB project.

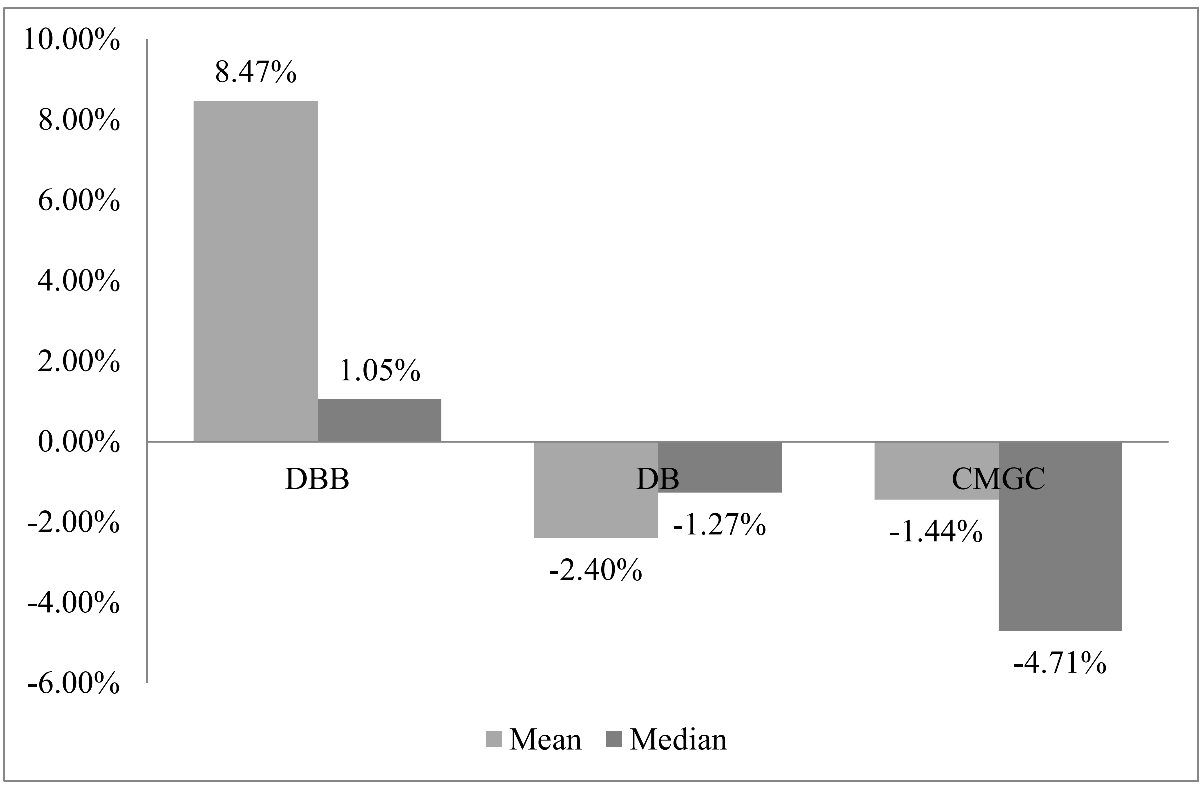


Figure 11. Mean and median cost growth for DBB, DB, and CMGC project data sets

CONCLUSIONS

This study examined preconstruction costs, and contractor involvement in the design phase as factors to consider to potentially remedy issues with poor quality construction documents. Analysis and comparison of preconstruction costs and cost growth data provided the following conclusions:

- Current DBB design fees are lower than design fees recommended by three countries. This conclusion supports the notion espoused by Carr and Beyor (2005) that since design fees have not kept up with inflation the quality of construction documents has suffered and may be the cause for the decline in document quality observed in the 2003 CMAA study.
- Preconstruction costs for CMGC and DB projects, in which the contractor is involved in the design process, are higher than in traditional DBB projects. However, the incremental additional cost appears to add value to the project in two ways. First, DB and CMGC projects recorded lower absolute means of cost growths than DBB with CMGC's mean absolute cost growth being approximately half that observed in DBB projects. Secondly, the mean and median cost growths for DB and CMGC projects were negative whereas the same metrics for DBB projects were positive. While it is inappropriate to ascribe cost savings to the two alternative project delivery methods, the data do indicate that when a DB or CMGC project is awarded that the owner can be more confident that the project will be completed at or below the budget prescribed in the contract award.

In summary, the research detailed in this paper demonstrates that the additional incremental cost of involving the contractor in the preconstruction design process using DB or CMGC buys the project owner increased cost certainty, which in turn enhances the confidence of all the stakeholders in the project that its budget will be adequate to complete the construction.

CHAPTER 4. QUANTIFYING THE VALUE OF CONSTRUCTION CONTRACTOR PRECONSTRUCTION INVOLVEMENT

West, N. and Gransberg, D. D. (2012). "Quantifying the Value of Construction Contractor Preconstruction Involvement". Accepted for presentation at The First Australasia and South-East Asia Structural Engineering and Construction Conference, Perth, Australia.

Chapter 3 showed that the additional cost of involving the contractor in the preconstruction phase can provide enhanced cost certainty. This is one benefit of using alternative delivery methods to involve the contractor in the preconstruction phase. However, past projects and literature provide examples of a range of benefits incurred through early contractor involvement. This chapter investigates these benefits and provides in-depth case studies demonstrating cost and time savings possible through early contractor involvement.

ABSTRACT

The U.S. transport sector has experienced an unprecedented growth of alternative project delivery method use as a result of the increasingly deteriorated condition of the nation's transportation infrastructure. Contracting methods such as DB, CMGC, ECI, Alliancing, and P3 have all been used to effectively deliver projects with reduced project schedules. The common theme in most alternative project delivery methods is the involvement of the contractor in the preconstruction planning and design process with the contractor making substantive input to the final design. This paper reports the results of case study research on 44 airport, highway, and commuter rail projects worth more than U.S.$23 billion in 18 U.S. states, as well as similar projects in Canada, New Zealand, and the United Kingdom that were designed and built using alternative project delivery methods. It identifies enhanced constructability, increased cost certainty, and the ability to accelerate the project schedules as the benefits of construction contractor involvement in the preconstruction design phase. The paper finds that the "reality check" brought by the constructor to the design process is the fundamental benefit and it results in enhanced understanding of actual risk and its impacts on project pricing. The paper also finds that project delivery methods like CMGC and ECI that do not require the contractor to commit to a fixed price upon award are able to control cost

risk through a negotiated guaranteed maximum price process, which permits the client to essentially select which risks it wants to keep/shed before the start of the construction phase. Finally the paper recommends that alternative project delivery methods be applied judiciously to those projects where the client needs the involvement of the contractor to achieve its budget, schedule, and functional objectives for a given project.

INTRODUCTION

The primary difference between alternative delivery methods and the traditional DBB method is the contractor involvement in the preconstruction planning and design process with the contractor making substantive input to the final design. Previous authors have credited the difference as creating a delivery environment that provides the benefits of reduced schedule, increased constructability, and cost savings (Khalil 2001, Jergeas and Van der Put 2001, Konchar and Sanvido 1998, and Molenaar and Songer 1996). Past studies of alternative delivery method performance typically compare only one or two alternative methods with DBB. Therefore, this study seeks to investigate the potential benefits of alternative delivery methods that permit the construction contractor to make significant input to the project's design and document the benefits, if any, of contractor contributions during design. The project delivery methods studied include DB, CMGC, P3, ECI, and Alliancing. In doing so, 44 case study projects are evaluated through a comprehensive content analysis, 35 literature sources are reviewed, and cost data from 79 projects is analyzed.

Alternative Project Delivery Methods

Project delivery method can be defined as "the comprehensive process of assigning the contractual responsibilities for designing and constructing a project. A delivery method identifies the primary parties taking contractual responsibility for the performance of the work." (AGC 2004) Historically public agencies have been limited by public procurement law to the DBB delivery method for construction projects (Touran et al. 2008). However, as public procurement laws have changed to accommodate the need to rapidly renew deteriorating transportation infrastructure, a number of project delivery methods are now available worldwide for the delivery of construction projects, including DB, CMGC, P3, ECI, and Alliancing. Since the 1980s, owners have pushed the architecture/engineering /construction (A/E/C) industry to improve project quality, reduce cost, and compress the project schedule (Touran et al. 2008). Consequently, all but four U.S. states now have state legislation that permits DB as an option for project delivery (DBIA 2012).

The five alternative delivery methods evaluated in this study are DB, CMGC, P3, ECI, and Alliancing. Figure 12 provides a conceptual view of each of the alternative delivery methods in relation to each other over a project timeline. The traditional DBB delivery method only spans the construction phase of the project. The alternative delivery methods all start before the construction phase in Figure 12, distinguishing contractor involvement as an important aspect of alternative project deliver methods.

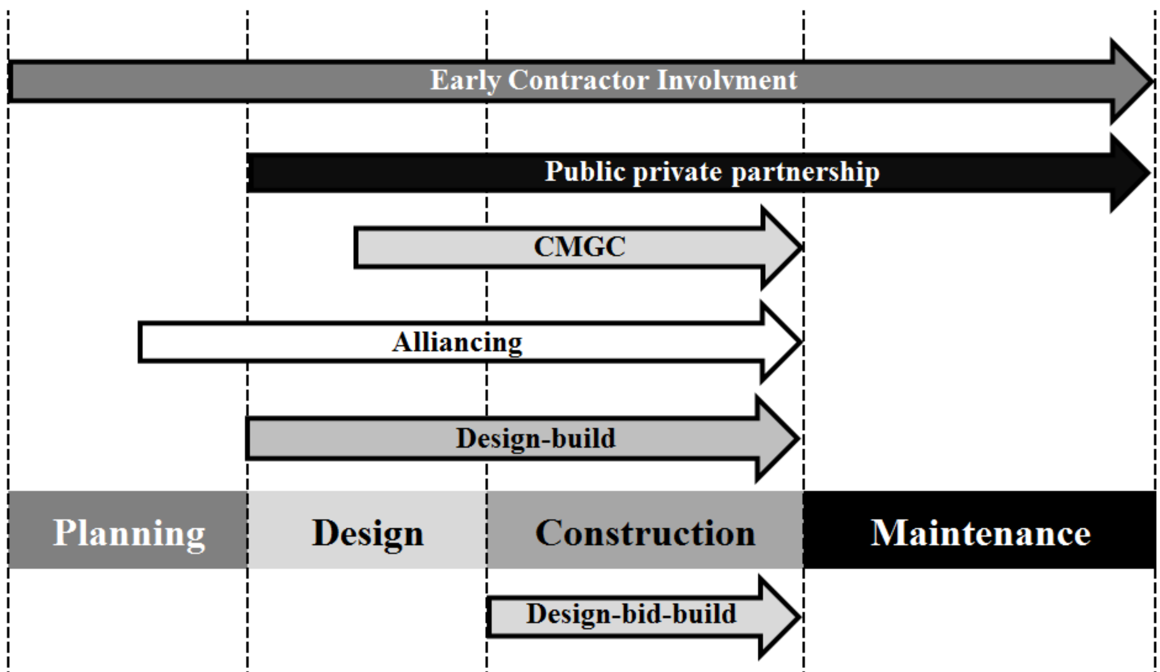


Figure 12. Contractor Involvement via alternative delivery method model (adapted from Gransberg and Scheepbouwer 2010).

Each alternative project delivery method is unique and offers varying tangible and intangible benefits. This study explores these benefits and seeks to determine the major benefits primarily through case study analysis. However, first it is important to define and explain each of the alternative delivery methods discussed, in order to inform the reader of the context of this study.

Design-Build

Design-build (DB) is a project delivery method where the owner contracts a single entity to perform the design and construction under a single contract (Konchar and Sanvido 1998). As a result, a single entity is responsible for both the design and construction services which can eliminate the adversarial relationship that may occur in DBB projects (Khalil 2001). Benefits associated with the DB delivery method include a reduced project schedule and constructability input during design (Khalil 2001).

There are several variations of the DB delivery method such as design-build-operate-maintain (DBOM) and design-supply-build (DSB). For the purposes of this study these methods are considered DB projects, due to their design-build component, and are compared to other alternative delivery methods without loss of accuracy.

Construction-Manager/General Contractor

Construction manager/general contractor (CMGC), also known as construction manager-at-risk, is a project delivery method that utilizes an integrated team approach to plan, design and construct a project (Gransberg and Shane 2010). As with a DBB project, the owner of a CMGC project has a contract with a designer. Additionally, the owner also has a two-part contract with a construction manager. The first part of this contract is for preconstruction services while the second part of the contract is for the project construction. An important aspect of a CMGC project is that "a guaranteed maximum price (GMP) is established at a point where the design is sufficiently advanced and the contractor can furnish a price with a minimal contingency for possible increases in scope" (Gransberg and Shane 2010). Consequently, a CMGC owner is able to effectively manage project risk and employ constructability knowledge during design. The use of CMGC in the transportation industry is growing; however the method has "long been used in the building industry to deliver projects that require early contractor involvement to optimize cost, schedule, and quality" (Gransberg and Shane 2010).

Early Contractor Involvement

Early contractor involvement (ECI) is an alternative project delivery method that involves two separate contracts. One contract is required for the design development phase, while a second contract is developed for the design and construction phase (Edwards 2009). During phase 1 of an ECI project the owner holds the responsibility for the project risk. The risk is then transferred to the contractor in the second phase of the project due to the contractual obligations. As a result, "an ECI contract could be thought of as a risk transfer contract that incorporates risk mitigation processes beforehand" (Edwards 2009).

It is important to note that the U.S. Army Corps of Engineers (USACE) use the term ECI when referring to their projects delivered in the same manner as CMGC projects. Therefore, USACE ECI projects should be compared to CMGC projects rather than ECI projects. The Tuttle Creek Dam Project is an example of a USACE ECI project and is explained in further detail in this paper.

Public Private Partnership

Public Private Partnership (P3) is an alternative project delivery method consisting of two key factors; "private sector financing and integrated design and lifecycle obligations" (Becker and Murphy 2008). A P3 delivery method is used in situations where private capital is required to fund a piece of infrastructure in order to accelerate the delivery of service to the public. Due to the size and complexity of P3 projects, there are a number of variations of the delivery method. However, P3 project delivery is known to offer the benefit of effective cost management (Becker and Murphy 2008).

Alliancing/Partnering

Alliancing is a project delivery method in which the owner, designer and the contractor form a legal consortium to deliver a given project (Gransberg and Scheepbouwer 2010). In this method the project parties integrate to form a collaborative team. The project team shares in the decision making and risk management of the project and subsequently shares the outcome of the project.

Included in the data for this study is a project delivered using collaborative partnering. This project was delivered in the United Kingdom where partnering closely resembles the alliancing methods used in the U.S. Consequently, the collaborative partnering project is considered in the same category as the alliancing projects for the purposes of this study.

METHODOLOGY

The study used the following research instruments:

- a comprehensive literature review,

- a content analysis of case study information, and
- a database of project cost information.

The case study protocol followed a rigorous qualitative research design and analysis methodologies based on Eisenhardt, 1989, 1991; Yin 2009; Miles and Huberman, 1994. The protocol included a research synopsis including objectives, projects, field procedures detailing the logistical aspects of the investigation such as permission to access projects for data collection, interview questions, documentation to collect; and a format for documenting and analyzing the individual case studies for internal research team distribution (Eisenhardt, 1989, 1991; Yin 2009). Additionally, a plan was developed for cross-case comparisons to determine similarities and differences between cases (Eisenhardt, 1989; Miles and Huberman, 1994). A qualitative research protocol based on Bazeley and Richards (2000) was used to aid in the coding and content analysis of the case studies. This tool allowed the researchers to manage data and ideas as well as query the data to report results across multiple cases.

Finally, three case studies were chosen for in-depth analysis and provide examples of the benefits of alternative project delivery methods. These four research instruments were used to search for evidence of the impact of contractor involvement in terms of constructability, cost certainty, and the ability to accelerate the project schedules. The findings from each of the methods formed conclusions for this study.

Literature Review

To achieve the objectives of this study literature on the topic of benefits offered by alternative project delivery methods was reviewed. The literature was analyzed in two groups. The first group contained journal papers and presentation documents that held information on one or more alternative delivery methods and their corresponding benefits. The second group of literature was made up of journal papers and articles detailing case studies of projects delivered using alternative delivery methods.

A review of the first group of literature revealed 35 documents that described benefits of alternative delivery methods (Appendix 4). Fifteen of these citations were included in the NCHRP Synthesis 402 title “Construction Manager-at-Risk Project Delivery for Highway Programs” (Gransberg and Shane 2010), which provided a table listing the advantages of the construction manager-at-risk delivery method as cited by numerous authors. This table provided the coding structure around which additional updated literature was reviewed (Bazeley and Richards 2000). A similar tabular matrix was developed as each new article was reviewed; citing benefits of the project delivery methods of interest. The resulting table included DB, CMGC, ECI, and Alliancing/Partnering delivery methods. Table 10 displays the 15 recorded benefits.

Table 10. Number of citations per benefit from the literature and case studies

	Number of Times Cited	
	Literature	**Case Studies**
Constructor Design Input	25	35
Ability to accelerate schedule	28	38
Early Knowledge of Costs	19	29
Ability to bid early work packages	14	17
Owner Control of Design	16	19
Contract type creates cost control incentive	10	19
Reduces design costs	6	5
Select GC on qualifications	5	13
Open books contingency accounting	7	15
Focus on Quality and Value	16	31
Flexibility During Design/Construction	14	36
Spirit of Trust	13	23
Competitive bidding possible	7	20
CMGC is owners advocate during design	5	5
Third-party coordination facilitated	7	23
Less Radical change from DBB than DB	3	10
Risk Management	18	32

The second group of literature consisted of 44 case studies of projects identified in previous research reports that had been designed and built using alternative project delivery methods. The case study details were evaluated to build on information gained through the first group of literature. As shown in Figure 13, the case study projects have a combined value of more than US$23 billion and are from 18 U.S. states, Canada, New Zealand, and the United Kingdom. Within the United States the case studies were well distributed and represented a cross-section of projects.

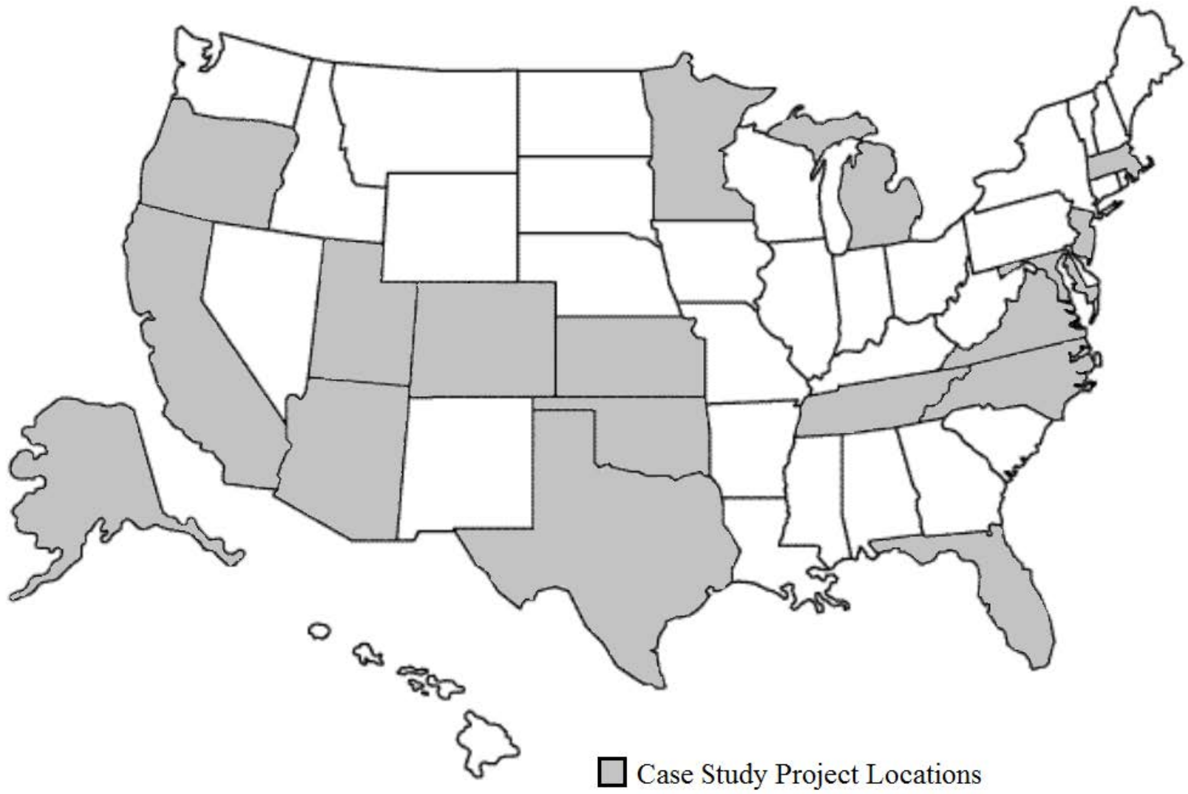


Figure 13. Location of case study projects in the United States

In addition to geographical diversity, the case studies represented a range of project types including airport, highway, building, bridge, and rail transit projects as shown in Table 11.

Table 11. Number of case studies per project type

Project Type	Number of Case Studies
Road	17
Airport	9
Transit	8
Bridge	5
Building	3
Dam	1
Tunnel	1
Total	**44**

Similarly, the case studies covered DB, CMGC, ECI, and Alliancing project delivery methods. Table 12 displays the number of case study projects reviewed for each alternative project delivery method. The total number of case studies displayed in Table 12 is 37 rather than 44 due to the removal of seven airport case studies. These case studies examined an agency rather than a specific project; thus they related to more than one alternative delivery method. Only one of the case studies reviewed in this study was an ECI project (Tuttle Creek Dam) so it was included in the CMGC case study project population for purposes of analysis. Additionally, ECI was the subject of seven of the analyzed literature documents.

Table 12. Number of case studies per alternative project delivery method

Project Delivery Method	Number of Case Studies
CMGC	19
DB	11
P3	5
Alliancing/Partnering	2
Total	**37**

Case Study Content Analysis

The case study content analysis involved reviewing literature for each of the 44 case study projects (Appendix 5) using the protocol proposed by Neuendorf (2002) and recording the benefits as a result of involving the contractor in the design phase and using an alternative project delivery method. The same table used to document the benefits found in the literature was used for the case study benefits. The completed table was then evaluated to determine the most common benefits gained with respect to project type and project delivery method.

Cost Growth Determination

An early study of alternative project delivery (Songer and Molenaar 1996) found that project owners more often used DB to achieve cost certainty than to accrue cost savings. Cost certainty relates to the change in contract price between the time it is awarded and the time construction is complete (FHWA 2006) and as such often measured using a metric defined as cost growth (Konchar and Sanvido 1998). A database of cost performance information for 79 transportation projects provided data to calculate and compare the cost growth of projects delivered using DBB, DB, and CMGC (Appendices 1, 2, and 3).

The database was limited to projects with a final construction cost of $5 million or more, A previous study found that when measuring cost growth in highway construction projects a single large change to the contract amount on a project less than $5 million had a disproportionate mathematical impact on cost growth when compared to a change of the same magnitude on a project whose value was greater than $5 million (Gransberg et al. 1999). Since that study was comparing the cost growths of partnered and non-partnered DBB projects and thus differentiated the impact of changing the business relationships in a similar manner to using alternative project delivery methods (Gransberg et al. 1999), it was decided to utilize the $5 million value as a means of reducing outliers in the sample populations.

Cost growth is a measure of the change in a project's cost from the original cost to the final cost (Migliaccio et al. 2010). Since the research objective is to evaluate the potential benefits of involving a contractor in the preconstruction phase, it is appropriate to calculate the cost growth. Cost growth calculations were determined as positive or negative percentages using Equation 4 in Chapter 3 (Migliaccio et al. 2010). The original contract cost is the name given to the construction contract value at award while final construction cost refers to the construction contract value after construction completion.

Additionally, the absolute cost growth values were calculated to show the overall change in project construction cost, regardless of whether the cost increased or decreased. These values were used as a second measure of cost certainty as they portrayed the difference between the original contract value and the final construction value. A large difference between the original and final construction values would indicate that the original contract value carried with it a large amount of uncertainty. Conversely, a small difference between the original and final construction values would indicate that the original contract value has very little uncertainty associated with it.

The cost growth values and the absolute cost growth values were then averaged to determine the mean values for each project delivery method population. Finally, the mean were compared to each other to determine the cost certainty of each project delivery method.

Lilliefors Test for Normality

The Lilliefors test for normality, as described in Chapter 3, is used to determine the distribution of the DBB, DB, and CMGC cost growth populations for projects with a value of more than $5 million.

Table 13 indicates that the DB and CMGC cost growth populations are normally distributed because the test statistic for each population is less than the corresponding critical value at 10%; therefore, the null hypothesis is accepted. Conversely, the DBB cost growth population is not normally distributed because the associated test statistic is greater than the critical value at 10% and the null hypothesis is rejected. Once again, the nonparametric Kruskal-Wallis test is required to test for statistical significance because the populations are not all normally distributed.

Table 13. Results from Lilliefors test on the cost growth population of projects over $5 million

		Test Stat.	Critical Value (10%)	Distribution
Cost Growth Population of Projects Over $5M	DBB	0.1310	0.1036	Not Normal
	DB	0.2237	0.2394	Normal
	CMGC	0.2508	0.3143	Normal

Kruskal-Wallis Test

The Kruskal-Wallis test is performed on the DBB, DB, and CMGC populations for cost growth for projects over $5 million. The nonparametric test indicates that the null hypothesis can be accepted at a confidence level of 85% where the asymptotic significance level is less than 0.15. This confidence level is considered acceptable for this test because CMGC is still an emerging project delivery method. CMGC has not yet developed into a uniform method; therefore it is unreasonable to expect a confidence level higher than 85% at this early stage.

Table 14 displays the asymptotic significance value for the Kruskal-Wallis test as 0.123. This value is less than 0.15 therefore the null hypothesis can be accepted meaning that the populations have the same locations of median or mean and are statistically significant.

Table 14. Kruskal-Wallis Test results for the cost growth populations of projects over $5 million

	Cost Growth over $5M		
	DBB	DB	CMGC
N	62	11	6
Mean Rank	42.65	32.68	26.00
Chi-Square	4.189		
df	2		
Asymp. Sig.	0.123		

Case Studies

Four case studies were chosen for an in-depth analysis to demonstrate the benefits gained by involving the contractor in the preconstruction phase and to further support the initial findings. The four case studies are examples of how cost savings and schedule savings can occur by enabling early contractor involvement. The four projects were case studied for previous research; therefore, this study utilized literature to gain information for each case study. The case studies include one DB project, the Hastings River Bridge in Minnesota and three CMGC projects, namely the, Mountain View Corridor in Utah, Sellwood Bridge in Oregon, and Tuttle Creek Dam in Kansas. The Mountain View Corridor project highlights the benefit of having a contractor involved in early project estimates to successfully manage risk, while the remaining three case studies display possible cost and schedule savings.

RESULTS AND ANALYSIS

The literature review determined the most commonly cited benefits to be gained from using alternative project delivery methods that allow the involvement of the contractor in the preconstruction phase and is shown in Figure 14.

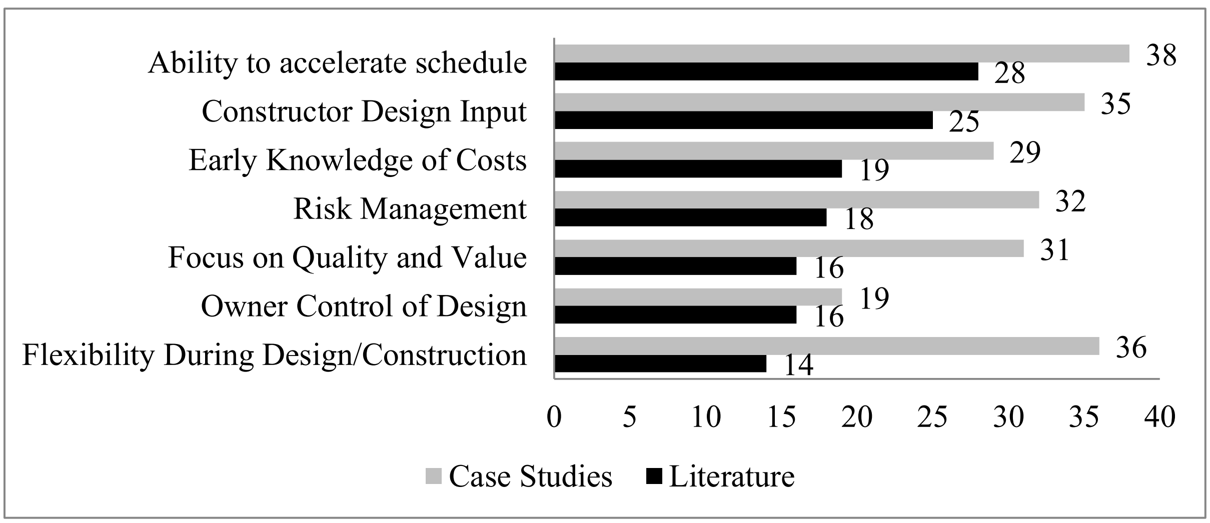


Figure 14. The most commonly cited benefits of alternative project delivery methods as cited in literature and in case studies

From the literature analysis two benefits stood out as being cited more often than the rest. The most commonly cited benefit, cited in 28 out of 35 literature sources, was found to be the ability to accelerate the project schedule. This is not surprising considering that alternative project delivery methods have been used for some time now to achieve FHWA's project delivery mantra of "get in- get out- and stay out" (Mendez 2010). This finding also confirms the notion that alternative project delivery methods can provide reduced project schedules.

The second most commonly cited benefit from the literature, and the benefit of interest for this study, was contractor design input. This benefit was cited in 25 out of 35 literature sources, as seen in Figure 14. According to a survey by Yates and Battersby (2002), many respondents agree that "allowing the contractor to be involved in the design from conceptualization would produce the most effective [final construction] documents". Therefore, it is feasible to expect alternative project delivery methods to encourage effective construction documents due to contractor design input.

The case study content analysis was done to build on the literature review and investigate the benefits found in projects delivered using alternative methods. The ability to accelerate the project schedule was cited in 38 out of 44 case studies, making it the most highly cited benefit, displayed in Figure 14. This finding agrees with the literature review and suggests that the most widely recognized advantage to using alternative delivery methods is the ability to reduce a project schedule.

The second most cited case study benefit was flexibility during design/construction, which was cited in 36 out of 44 case studies. This benefit is closely related to contractor design input and reflects the need to make corrections to the design throughout the design and construction phases. The literature indicated that contractor design input contributes to an effective design and reduces errors and omissions through the input of construction knowledge (Yates and Battersby 2002). However, since all parties to the contract are human and circumstances can change necessitating design alterations, flexibility during design/construction phases is necessary to keep the project on track to a successful completion (Newell 2011).

After establishing the main benefits incurred through alternative delivery methods, as cited in literature and case studies, a further investigation was carried out to determine whether the benefits are consistent across project type and project delivery method. This was done by dividing the results of the literature review and the case study content analysis into appropriate categories. Initially, the results were categorized by project delivery method and four categories were formed, namely CMGC/ECI, DB, P3, and Alliancing/Partnering, as shown in Table 15.

Table 15. Benefits of alternative delivery methods categorized by delivery method

	CMGC (19)	**DB (11)**	**P3 (5)**	**Alliancing /Partnering (2)**
Contractor design input	17	8	3	1
Ability to accelerate schedule	17	9	5	1
Early knowledge of costs	13	9	3	0
Ability to bid early work packages	10	1	0	1
Owner control of design	13	1	0	0
Contract type creates cost control incentive	12	2	1	0
Reduces design costs	2	1	1	0
Select GC on qualifications	11	0	1	0
Open books contingency accounting	9	0	0	0
Focus on quality and value	15	7	2	1
Flexibility during design/construction	17	10	3	2
Spirit of trust	10	6	2	0
Competitive bidding possible	11	4	0	0
Third-party coordination facilitated	9	5	3	2
Risk management	15	8	2	2

Three out of the four delivery methods, DB, CMGC/ECI, and Alliancing/Partnering, displayed flexibility during design/construction as the most commonly incurred benefit. Additionally, the ability to accelerate the project schedule was shown to be the most common benefit of alternative delivery methods for both CMGC and P3. The most frequent benefit of P3 was the ability to accelerate schedule, while DB and CMGC benefits were primarily design-related. This may be because P3 typically spans the design, construction and maintenance phases whereas DB and CMGC only include the design and construction phases. Therefore more focus may be centered on the design phase in a DB or CMGC project than in a P3 project.

The results of the literature review and case study content analysis were then categorized by project type and five categories including airport, bridge, building, road, and transit were formed. The most common benefit for three of the five categories (bridge, road, and transit) was ability to accelerate schedule, as shown in Table 16. This confirms that, regardless of delivery method or project type, the ability to accelerate the project schedule is the benefit of using alternative delivery methods that is incurred most frequently according to 44 case studies and 35 literature sources.

Table 16. Benefits of alternative delivery methods categorized by project type

	Airport (9)	Bridge (5)	Building (3)	Road (17)	Transit (8)
Focus on quality and value	8	3	1	11	7
Contractor design input	7	5	3	12	7
Ability to accelerate schedule	7	5	1	15	8
Open books contingency accounting	7	1	1	5	1
Risk management	7	3	2	10	8
Owner control of design	6	2	3	4	2
Flexibility during design/construction	6	5	1	15	7
Early knowledge of costs	5	4	2	11	7
Ability to bid early work packages	5	2	2	6	1
Contract type creates cost control incentive	5	3	1	6	3
Spirit of trust	5	1	1	9	6
Competitive bidding possible	5	2	3	4	6
Third-party coordination facilitated	5	4	0	9	5
Select GC on qualifications	2	2	3	4	1
Reduces design costs	1	0	0	4	0

Table 16 indicates that two of the five project type categories, the bridge and the building categories, displayed contractor design input as the most common benefit gained through alternative project delivery. This is consistent with the literature review in which contractor design input was the second most frequently cited benefit. Flexibility during design/construction is also shown as a common benefit in the bridge and road categories. It is possible that the design-related benefits are more frequently recognized in the bridge and building categories due to the increased complexity of the design required for such projects when compared to road, transport, and airport projects.

After confirming that the most common benefits of alternative delivery methods are the ability to accelerate the project schedule and contractor design input this study sought to investigate increased cost certainty as a benefit of alternative delivery methods. In 2006 the Federal Highway Administration reported that DB contracting can reduce the potential for cost growth, indicating that it is possible to obtain greater cost certainty through DB than traditional contracting. With this finding in mind, the mean and median cost growth and the absolute cost growth values of 79 DBB, DB, and CMGC projects over $5 million were calculated, as shown in Figure 15.

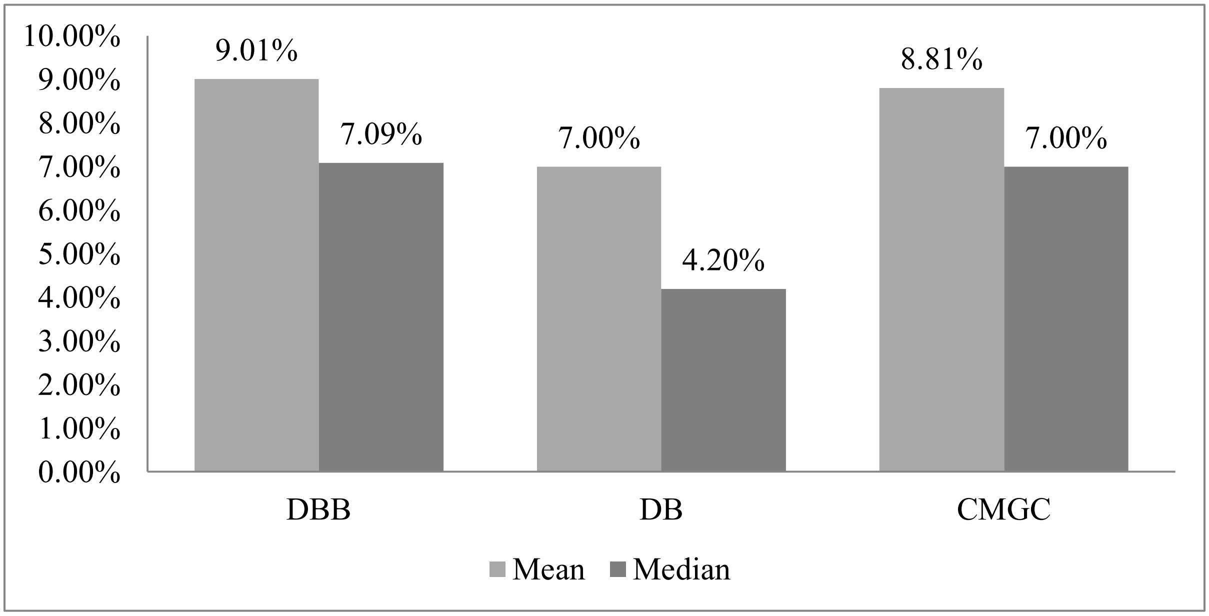


Figure 15. Mean absolute cost growth values of DBB, DB, and CMGC projects valued at greater $5 million

An analysis of the mean and median absolute cost growth values for each of the project delivery methods showed that both DB and CMGC result in a lower absolute cost growth on average than DBB. This means that the final construction cost of a DB or CMGC project is less likely to differ from the original contract cost than that of a DBB. Consequently, cost certainty is likely to be higher on projects over $5 million that utilize alternative delivery methods to facilitate contractor involvement in the preconstruction phase.

Similarly, a comparison of the mean and median cost growth values for DBB, DB, and CMGC projects indicated that, on average, DB and CMGC projects were completed with a final construction cost below the original contract, as shown in Figure 16. Additionally, DBB projects are shown to finish above the original contract cost on average.

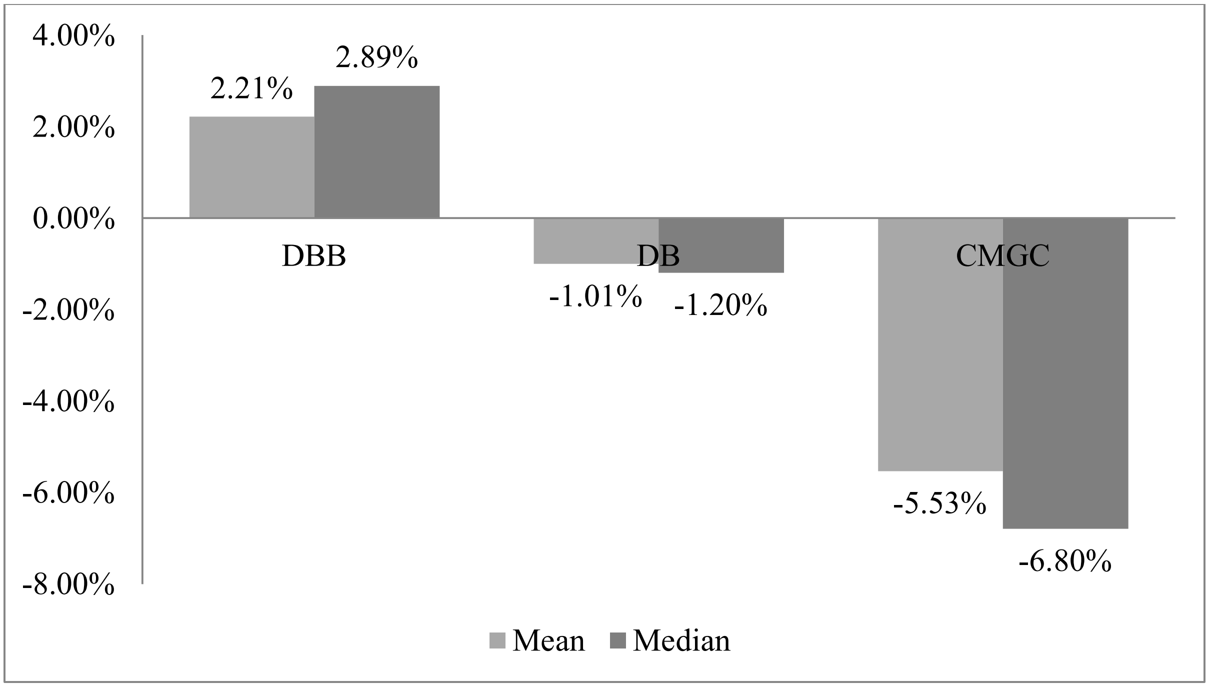


Figure 16. Mean cost growth values of DBB, DB, and CMGC projects valued at greater than $5 million

CASE STUDIES

The previous analyses show that the major benefits of contractor design involvement are the ability to accelerate the project schedule, while permitting flexibility during design and construction that leads to enhanced cost certainty. While none of these benefits are guaranteed for every project delivered using alternative methods, the study has shown that the probability of accruing benefits by using something other than DBB project delivery is increased. To illustrate the potential for enhanced project performance and document specific benefits that have been or are being accrued on specific projects, four case study projects are now analyzed in depth to reinforce the findings discussed in previous sections of this paper.

Hastings River Bridge

Project Information

The Hastings River Bridge project is an on-going four-year DB project with an original award value of $119,830,890 and a substantial completion deadline of June 1, 2014. The project is located over the Mississippi River on TH 61 near the city of Hastings in Minnesota.

The Minnesota DOT (Mn/DOT) adopted a best-value procurement process for the project and lump sum payment was specified.

The scope of the project involves the removal of the existing bridge and the design and construction of a new four lane bridge over the Mississippi, including the north and south approaches. A tied arch, free standing main span of 545 feet is to be constructed using a low float-in operation. Meanwhile, the south approach is to be protected with a secondary wearing course and includes two side-by-side five-span bridges that are cast-in-place, post-tensioned concrete slabs. Similarly, the north approach is to be a five-span, low maintenance concrete girder bridge. A lot of planning consideration had to be given to the north approach as there was extremely high risk associated with the subgrade geotechnical conditions of the approach. The existing bridge was jacked up several times due to differential settlement; therefore, the project contract included a performance criterion that specified less than two inches of total settlement is allowed within three months of constructing the column-supported embankment.

Major Benefit of Alternative Delivery Method

Mn/DOT chose DB project delivery to accelerate the schedule of the Hastings River Bridge project. DB delivery also allowed the owner to facilitate pre-proposal communication to hear ideas from the proposers and to clarify design and construction quality criteria. The solicitation specified that each competitor could confidentially propose alternative technical concepts, which were in turn reviewed and approved or disapproved by Mn/DOT before the final technical and price proposals were due. As a result, the winning DB team was able to propose an innovative column supported embankment for the north approach that led to a cost savings of nearly $100 million (Mn/DOT 2011). Thus, Mn/DOT was able achieve cost savings through contractor involvement in the procurement phase.

Pre-proposal communication between the owner and each proposer was allowed through an Alternative Technical Concept (ATC) process in which the owner conducted one-on-one meetings with each proposer to discuss alternative solutions and to negotiate the design quality criteria. After listening to the proposers ATCs the owner evaluated each ATC and gave an indication of acceptability using the following comments:

- The ATC is acceptable;

- The ATC is unacceptable;
- The ATC is unacceptable in its present form, but may be acceptable upon the satisfaction of certain identified conditions that must be met or clarifications or modifications that must be made;
- The submittal does not qualify as an ATC, but may be included in the proposal; and
- The submittal does not qualify as an ATC and may not be included in the proposal.

Approved ATCs are incorporated into the proposal as a Pre-approved Elements (PAE) and proposers were allowed to submit one or more acceptable ATC with their proposal (Mn/DOT 2011).

The PAE process was valuable to both the owner and the proposers because the owner was able to gain an idea of what to expect from the bids while the proposers were able to gain a clear understanding of the owner's requirements. The process was completely confidential, enabling the proposers to retain any advantages established.

The PAE process was most valuable in dealing with the high risk geotechnical conditions of the north approach. Column supported fill for the north embankment was suggested through the PAE process and would not have been incorporated into the project if the proposers were not given the opportunity to discuss their ideas before submitting bids. In this case the use of an alternative delivery method enabled the owner to award the project at a value $100 million below the $220 million not-to-exceed value. For high risk projects such as this, contractor involvement in the preconstruction phase is able to positively impact both the cost and schedule risk.

Mountain View Corridor

Project Information

The Mountain View Corridor project is an on-going CMGC project that covers Salt Lake County and northwest Utah County in Utah. The project was procured through best-value procurement. Furthermore, the original awarded value of the project is $450 million and a guaranteed maximum price payment provision was utilized. The projected construction completion date for the original project delivery period is December 2013, with subsequent phases of the project to be constructed as funding becomes available.

The scope of the Mountain View Corridor project includes the construction of two outside lanes in each direction along with signalized intersections. Aside from excavating and laying new pavement, activities pertaining to the new roadway include grading, relocating utilities, installing drainage systems, acquiring property, and building bridges. Additional lanes and interchanges will be constructed in the future to provide a fully functional freeway.

Major Benefit of Alternative Delivery Method

The Mountain View Corridor project was scheduled to be underway at the same time as another large project being delivered using DB in the Utah area. As a result, CMGC was selected to deliver the Mountain View Corridor project to avoid the risk of insufficient UDOT staffing resources. In other words, UDOT's most significant reason for selecting CMGC was risk management. A CMGC delivery method enabled the owner to seek contractor input for multiple project cost estimates throughout the design phase. These cost estimates were known as Opinions of Probable Construction Cost (OPCCs). Each OPCC involved the analysis of project cost and risks (Alder 2011) and led the project team to gain an enhanced understanding of actual risk and how it affects project pricing.

Four OPCCs were produced in total, one at the beginning of the project, one at 30% design completion, one at 50% design completion, and one at 90% design completion. Figure 5 in Chapter 2 displays the value of each OPCC.

The initial OPCC of $346 million was produced by the designer and the owner. However, the second OPCC was estimated at $308 million with the difference between OPCC1 and OPCC2 being the input of the contractor. The second OPCC is lower because the contractor offers a different perception of risk and innovation which is subsequently priced into the second OPCC. The third and fourth OPCCs are formed after the project team has had an opportunity to manage and reduce risk (Alder 2011). As a result, the cost estimates decrease from the second OPCC through to the fourth OPCC. The final OPCC is $249 million which is $97 million below the initial OPCC. Therefore, including the contractor in the OPCC process led the project to mitigation savings of $97 million.

If the Mountain View Corridor project had been delivered using DBB the contractor would not have been involved in the design and the cost savings would not have been realized. Similarly, if the project had been delivered using DB, the project would have been awarded at 30% design completion, at the time of OPCC2, shown in Figure 5. As a result, Mn/DOT would have awarded the project for approximately $52 million more than the final estimate, OPCC4. The Mountain View Corridor Project is a clear example of the benefit to be gained by involving the contractor in the design phase when they can provide valuable risk knowledge and mitigation savings.

Sellwood Bridge

Project Information

The Sellwood Bridge Project is a $160 million CMGC project which crosses the Willamette River five miles south of Portland, Oregon. The project is on-going, with project completion scheduled for December 2016. Furthermore, the Sellwood Bridge Project was procured using best-value procurement and the price was determined through a unit price guaranteed maximum price.

The project scope includes replacing the current 84 year old bridge with a three-span concrete decked bridge with a steel truss. The cross section of the new bridge is to vary to accommodate two, three, and four lanes of traffic as necessary. Further project scope includes construction of the two bridge approaches, demolition of the existing bridge and installation of on-bridge utilities.

Major Benefit of Alternative Delivery Method

The Sellwood Bridge project was delivered using CMGC for a number of reasons. The owners wanted to accelerate the schedule, enable risk redistribution, satisfy complex project requirements, maintain flexibility during construction, and reap the benefits of early contractor involvement such as enhanced constructability (Multnomah County 2010)). As a result, early contractor involvement and effective communication saved $6 million and up to a year of construction time due to a suggestion that the existing bridge be jacked to the side of its existing alignment and used as a detour, eliminating the need for a temporary bridge (Sellwood Bridge Project 2012). The detour bridge will involve laterally moving the existing bridge by 90 feet onto temporary foundations and bents, where it will remain throughout the project. This will be achieved by erecting temporary piers, sliding the deck truss into the new location using hydraulic jacks, and installing temporary approach spans. The detour bridge is expected to provide the following benefits (Sellwood Bridge Project 2012):

- Traffic flow is removed from the construction zone, safely separating workers from drivers;
- The new bridge can be constructed in one phase saving construction time;
- Redundant structural features are not required; and
- Fewer temporary bridge and in-water impacts.

The Sellwood Bridge Project provides examples of a number of benefits to be gained from early contractor involvement. However, the primary benefits are the time savings and substantial cost savings of $6 million. It must be noted that at the time the project was advertised, the owner had yet to identify about $5 million in funding and the contractor suggested revision to the sequence of work actually eliminated the need to obtain those funds. These benefits are the result of employing construction experience and knowledge at a time in the project when it can have a large impact.

Tuttle Creek

Project Information

The U.S. Army Corps of Engineers (USACE) Tuttle Creek Dam Project was an ECI dam safety assurance project with an original program amount of $206 million. The project lasted six and a half years and was completed in December, 2010. Tuttle Creek Dam is located in Kansas on the Big Blue River, north of the city of Manhatten. The project was procured using best-value selection and adopted a progressive guaranteed maximum price as the payment provision.

The Tuttle Creek Dam Project consisted of a number of dam repair contracts; however, the base contract was a $49 million ground modification contract for the high risk active dam. Additional contracts were implemented for the structural reinforcement and bearing rehabilitation of the spillway tainter gates and for the replacement of the wire ropes for the tainter gates.

Major Benefit of Alternative Delivery Method

The Tuttle Creek Dam Project was delivered using ECI in much the same manner as CMGC delivery. The primary reason for choosing this delivery method was to get early specialty contractor involvement throughout the design phase of this complex project. The feedback offered by the contractor throughout the development of the design led the project team to produce a design that incorporated previously untried ground modification technology using both jet grouting and subterranean soil mixing. As a result, the project finished $75 million under budget and was completed two years early.

The ground modification technology used on the Tuttle Creek Dam Project was the destructive testing of jet grouting methodology, done to validate production and performance. The jet grouting methodology proved successful for certain applications and seismic modeling meant that some features of work could be removed. Overall the dam safety concerns were minimized and the seismic upgrade was completed with both cost and time savings. It is worth noting that the owner used in-house design resources, which allowed USACE to bring the maximum flexibility to the design process. This was needed because the new jet grouting technology was being developed throughout the project. This meant that new performance specifications were required to be developed by the USACE design team and solutions to previously untried quality management issues had to be generated by the USACE construction quality assurance team.

CONCLUSIONS

This study used 44 case studies, 35 literature sources, and the cost data from 79 construction projects to investigate the benefits of alternative delivery methods, characterized by contractor involvement in the design phase. The following findings portray the major benefits of construction contractor involvement in the design process and do much to recommend alternative project delivery methods as a means to bring construction knowledge to early phases of the project to those owners who require the involvement of the contractor to achieve their budget, schedule, and functional objectives for a given project:

- The ability to accelerate a project schedule is the most commonly cited benefit in literature and case studies because it reduces schedule risk;
- Contractor design input is the second and third most commonly recorded benefit in literature and case studies respectively because it enhances constructability and innovation and creates potential for cost savings through effective design solutions;

- DB and CMGC display lower cost growths than DBB and therefore provide greater cost certainty;
- DB project delivery enabled a savings of nearly $100 million on the Hastings River Bridge project;
- Involving the contractor in multiple cost estimates throughout the design phase produced mitigation savings of approximately $97 million on the Mountain View Corridor project;
- The Sellwood Bridge project saved $6 million and up to a year of construction time due to early contractor involvement; and
- The Tuttle Creek Dam project finished two years early at $75 million under budget through ECI.

Regardless of the project type, adopting an alternative delivery method provides early contractor involvement which enables the project team to reap a number of recognized and unrecognized benefits. Two obvious benefits of early contractor involvement are enhanced constructability and risk management which both lead to cost and time savings, as proven by case study examples.

CHAPTER 5. CONCLUSIONS

This chapter presents an overview of the value gained from the three studies of contractor preconstruction involvement and contributions and recommendations resulting from the research. The conclusions are grouped into three categories, including project cost, schedule, and quality conclusions. A summary of the conclusions is then given, followed by contributions and recommendations associated with the objectives of this research.

COST CONCLUSIONS

Chapters 3 and 4 produced three important conclusions relating to project cost. In addition, four case studies showed examples of cost savings as a result of contractor involvement in the preconstruction process.

Initially the research presented in this thesis sought to establish a benchmark for preconstruction fees in the construction industry and found that current DBB design fees are lower than design fees recommended by three countries. This may be the cause of the decline in construction document quality observed in the 2003 CMAA study. Consequently, the research went on to find that preconstruction costs for CMGC and DB projects are higher than DBB projects. However, the additional cost appears to add value to the project through increased cost certainty. Cost growth data used as a measure of cost certainty identified less cost growth in CMGC and DB projects than in DBB indicating that alternative delivery methods offer increased cost certainty.

Finally, early contractor involvement enabled by alternative delivery methods provides cost certainty in the beginning of the project and has also been shown to provide cost savings at the end of a project. The following list displays the cost savings from four case studies that are all of the result of contractor input in the design phase:

- Nearly $100 million on the DB Hastings River Bridge Project;
- $97 million on the CMGC Mountain View Corridor Project;
- $6 million on the CMGC Sellwood Bridge Project; and
- $75 million on the ECI Tuttle Creek Dam Project.

Therefore, preconstruction costs, cost growths, and case studies have shown that an increase in preconstruction costs to involve the contractor in the design phase can lead to increased cost certainty and potential cost savings.

SCHEDULE CONCLUSIONS

Time savings were not studied quantitatively in this research; however, a literature review and case study content analysis found that the ability to accelerate a project schedule is the most commonly cited benefit of alternative delivery methods. Contractor involvement in the preconstruction process enables project phases to occur concurrently which provides the benefit of a reduced project schedule. For example, the Sellwood Bridge Project saved up to a year of construction time because the contractor was able to suggest design solutions during the design phase. Similarly, the Tuttle Creek Dam project finished two years early. In this case the ECI delivery method gave the project team the flexibility necessary to develop quality management systems and specifications for new technology, as the project was taking place. Therefore, alternative delivery methods enable contractor involvement in the preconstruction phase which provides the knowledge and flexibility required to accelerate a project schedule.

QUALITY CONCLUSIONS

Regardless of the project delivery method, it is important for owners to understand that project quality is influenced from the earliest stages of a project. Involving the contractor in the early stages of a project increases the resources available to enhance project design quality. This is reflected in the conclusion from Chapter 4 that says contractor design input is the second and third most commonly recorded benefit in literature and case studies respectively. Maximizing the benefit of contractor involvement in the design requires cooperation. Chapter 2 identified managing risk and creating an environment of trust as important factors for a successful CMGC project as they ensure successful cooperation during the design effort.

SUMMARY OF CONCLUSIONS

Table 17 summarizes all of the conclusions resulting from this research. These conclusions were reached by satisfying the three project objectives of understanding the factors that go into maximizing the benefit possible from cooperation, investigating the relationship between construction document quality, preconstruction costs, and early contractor involvement, and validating the major benefits of contractor preconstruction involvement given in literature.

Table 17. Summary of conclusions

Conclusions	Type of Conclusion	Conclusion Location
Current DBB design fees are lower than design fees recommended by three countries	Cost	Chapter 3
Preconstruction costs for CMGC and DB projects are higher than in traditional DBB projects		Chapter 3
DB and CMGC projects provide more cost certainty than DBB projects		Chapter 3 and 4
DB project delivery enabled a savings of nearly $100 million on the Hastings River Bridge project		Chapter 4
Contractor input produced $97 million of mitigation savings for the Mountain View Corridor project		Chapter 4
The Sellwood Bridge project saved $6 million through CMGC		Chapter 4
The Tuttle Creek Dam Project finished $75 million under budget through ECI		Chapter 4
The Sellwood Bridge Project saved up to a year of construction time due to early contractor involvement	Schedule	Chapter 4
The Tuttle Creek Dam Project finished two years early through ECI		Chapter 4
The ability to accelerate a project schedule is the most commonly cited benefit in literature and case studies		Chapter 4
Managing risk is one of the most important aspect of CMGC project delivery success	Quality	Chapter 2
Contractor design input is the second and third most commonly recorded benefit in literature and case studies respectively	Quality	Chapter 4
Creating an environment of trust is important to CMGC success		Chapter 2

The majority of the conclusions are related to project costs due to the quantitative analysis of cost data described in Chapter 3. Overall, the research found that contractor involvement in the design phase can provide many benefits and lead to potential cost and time savings. Additionally, alternative delivery methods have higher preconstruction costs than DBB, but this additional cost buys the owner increased cost certainty.

LIMITATIONS

The research presented in this thesis has a number of limitations, primarily due to the limited populations of projects delivered using alternative project delivery methods. The following limitations must be understood to put this research in the proper context.

- Chapter 2
  - The study presented in Chapter 2 only applies to CMGC projects. Therefore, it is not appropriate to compare the results given to projects delivered using delivery methods other than CMGC. However, the methodology may be adopted to study other project delivery methods.
  - The study is based on a literature review and a presentation content analysis only. No attempt was made to interview conference attendees or collect surveys. Hence, the results of this study are based on the author's interpretation and are subjective.
- Chapter 3
  - The study presented in Chapter 3 compares DB and CMGC data to DBB data. However, the study does not investigate further alternative project delivery methods such as ECI, P3 and Alliancing. The preconstruction costs and value added by the contractor for these methods would require further investigation.
  - Only the obvious outliers were removed from the data by visual inspection. This was done to retain a view of the current industry practice. However, the presence of unobvious outliers potentially skewed statistics such as the mean values.
- Chapter 4
  - Only one ECI case study was analyzed. This case study serves as an example of the benefits provided by alternative project delivery methods, but is not intended to be representative of all ECI projects.

- Only five P3 projects and one Alliancing project were included in the analysis of benefits offered by alternative delivery methods. These delivery methods are not used as often as DBB or DB. As a result there are fewer P3 and Alliancing projects to study.

CONTRIBUTIONS

The last time research such as this was published was in 1998 by Konchar and Sanvido. Their study only investigated three project delivery methods. Since that time the number of delivery methods in use in the construction industry has increased and there are more projects delivered using alternative delivery methods to analyze. The research presented in this thesis has taken a similar approach to Konchar and Sanvido; however, it reviews transportation projects specifically and accounts for new policies that have formed since 1998.

This research has identified for the first time that the involvement of the contractor in the design phase has quantifiable benefits in terms of increased cost certainty. Additionally, it found that involvement of the contractor in the design process via alternative project delivery methods enhances the management of cost, schedule, and quality risks. The following list provides examples of these enhancements:

- CMGC and DB are found on average to have negative cost growth while DBB projects have positive cost growth indicating that alternative delivery methods provide greater cost certainty.
- Schedule risk is reduced through alternative delivery methods as shown by the Sellwood Bridge Project which finished up to a year ahead of schedule and the Tuttle Creek Dam Project which finished two years ahead of schedule
- Projects delivered using alternative delivery methods are finishing closer to their initial estimate which shows that these projects involve construction documents that are of a better quality and are constructible. For example, during the design phase of the Hastings River Bridge Project the contractor suggested using column supported embankment for one end of the bridge. This solution produced a project of enhanced quality compared to the original design.

RECOMMENDED FUTURE RESEARCH

Alternative project delivery methods are continuously developing and growing in popularity. As a result the population of projects available to study is growing. Future research in this area will provide a more representative view of the value of contractor involvement in the design phase. The following list provides recommendations for future research.

- The correlation between project cost growth from early estimates and design fees was explored as part of this research; no conclusive trends were found. A study of Oklahoma Turnpike Authority projects found that the absolute percentage of construction cost growth increases as design fees decrease (Gransberg et al. 2007). This study could be reproduced using projects from across the U.S. to investigate whether the same trend exists across the country.
- The study described in Chapter 2 that gave effective tools for CMGC projects could be formalized. The study utilized a literature review and a content analysis of presentation slides; however, structured interviews, surveys and case study research could be adopted to produce a more formal, objective analysis of effective tools for CMGC.
- There is a need to investigate the value of involving an ICE in the construction cost estimation process. CMGC projects have been successfully delivered both with and without an ICE involved. Therefore, case study research would provide insight into the value for money on the ICE's fee.

REFERENCES

Abdi, H. and Molin, P. (2007). "Lilliefors/Van Soest's test of normality." *Sage Publications*, Thousand Oaks, California.

Acimovic, B. (2011). "Eisenhower Johnson Memorial Tunnel (EJMT) 2400 V MCC Switchgear Replacement, CM/GC Delivery Method." *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

Affeldt, J. (2009). "Early Contractor Involvement (ECI)." *NAVFAC Atlantic Industry Forum*.

Alder, R. (2011). "UDOT CMGC Process: Innovative Contracting." *2011 CM/GC Peer Exchange*, FHWA, Salt Lake City, Utah.

Alder, R. (2007). "UDOT Construction Manager General Contract (CMGC) Annual Report." Utah Department of Transportation Project Development Group, Engineering Services and Bridge Design Section, Salt Lake City Utah, 39.

Alvarado, J. (2011). "Case Study I-17 Cordes Junction Traffic Interchange Improvements." *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

American Society of Civil Engineers (ASCE). (1981). "Manuals and reports on engineering practice–No. 45. Consulting engineering—A guide for the engagement of engineering services." New York.

Arkansas State University (ASU). (2001). "Capital Development Policies and Procedures." (November 2001).

Associated General Contractors of America (AGC). (2004). "Project Delivery Systems for Construction." *Associated General Contractors of America,* Washington, D.C.

Balis, J. (2011). "Alternative Project Delivery." *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

Bearup, W. (2011). "Local Government Perspective on CMAR." *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

Becker, J. and Murphy, T. (2008). "Alternative Construction Delivery Methods." <http://www.mcmillan.ca/Files/AlternativeConstructionDeliveryMethods.pdf> (March 2012).

Beemer, J. (2005). "The cost of perfection in public works projects: a design professional's perspective." *American Council of Engineering Companies*, Government Advocacy, <http://www.acec.org/advocacy/pdf/ tcop_2006-04-20.pdf> (November 10, 2011).

Bubshait, A.A., Al-Said, F.A. and Abolnour, M. M. (1998). "Design fee versus design deficiency." *J. of Arch Engrg*, ASCE, 4(2), 44-46.

Burati, J.L., Farrington, J. J., and Ledbetter, W. B. (1992). "Causes of quality deviations in design and construction." *J. of Constr. Engrg. and Mgmt.*, ASCE, 118(1), 34-36.

Carr, P.G. and Beyor, P. S. (2005). "Design fees, the state of the profession, and a time for corrective action." *J. of Mgmt in Engrg.,* ASCE, 21(3), 110-117.

Construction Industry Institute (CII). (2003). “Owner’s Tool for Project Delivery and Contract Strategy Selection.” Research Summary 165, *Construction Industry Institute*, Austin, Texas.

Construction Management Association of America (CMAA). (2003). Speed, communication, and commissioning issues are top owner concerns.” *FMI/CMAA survey finds*. <http://cmaanet.org/owners_survey.php> (January, 2012).

Design-Build Institute of America (DBiA). (2012). “State Legislation.” <http://www.dbia.org/advocacy/state/> (March 2012).

Dodson, T. (2011). “I-5 Willamette River Bridge, Oregon Dept. of Transportation First CMGC Project.” *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

Edwards, R. (2009). “Early Contractor Involvement Contracts in the South Australian Transport Infrastructure Construction Industry.”

Eisenhardt, K. M. (1989). "Building Theories from Case Study Research." *The Academy of Management Review*, 14(4), 532-550.

Eisenhardt, K. M. (1991). "Better Stories and Better Constructs: The Case for Rigor and Comparative Logic." *Academy of Management Review*, 16(3), 620-627.

El Wardani, Messner, M. J., and Horman, M. (2006). “Comparing Procurement Methods for Design-Build Projects.” *Journal of Construction Engineering and Management*, ASCE 132(3).

Ellis, R. D., Herbsman, Z., and Kumar, A. (1991). “Evaluation of the FDOT design/build program.” Final Report, Submitted to Florida Dept. of Transportation, State Project No. 99700-7543-010, Department of Civil Engineering, University of Florida, Gainesville.

Ernzen, J. and Feeney, T. (2002). “Contractor-Led Quality Control and Quality Assurance Plus Design-Build: Who Is Watching The Quality?” *Transportation Research Record 1813, Transportation Research Board, National Research Council*, Washington, D.C., 253-259.

Federal Highway Administration. (2006). “Design-Build Effectiveness Study.” Final Report to Congress as Required by TEA-21, <http://www.fhwa.dot.gov/reports/designbuild/designbuild0.htm> (February 22, 2011).

Federal Transit Administration (FTA). (2006). “Construction Project Management Handbook”, Federal Transit Administration, Washington DC, 3-7.

Flyvbjerg, B., Holm, M., and Buhl, S. (2002). “Underestimating costs in public works projects: Error or lie?” *J. Am. Plan. Assn.,* 68(3), 279–295.

Gransberg, D. D. and Villarreal, M. E. (2002). “Construction project performance metrics. 2002 transactions.” AACEI, Portland, Ore., CSC.02.01–CSC.02.05.

Gransberg, D. D., Lopez del Puerto, C., and Humphrey, D. (2007). “Relating Cost Growth from the Initial Estimate to Design Fee for Transportation Projects.” *Journal of Construction Engineering and Management*, 133, 404-408.

Gransberg, D.D. (1999). “The Cost of Inaction: Does Massachusetts Need Public Construction Reform?” *Pioneer Institute for Public Policy Research, Center for Restructuring Government*, White Paper No. 7, Boston, Massachusetts.

Gransberg, D.D. and Molenaar, K. R. (2004). “Analysis of Owner’s Design and Construction Quality Management Approaches in Design-Build Projects.” *Journal of Management in Engineering,* ASCE, 20 (4).

Gransberg, D.D. and Scheepbouwer, E. (2010). “Performance Based Construction Contracting: The US versus the World.” *2010 Transportation Research Board*, Paper # 10-0093, National Academies, Washington, D.C.

Gransberg, D.D. and Molenaar, K. R. (2005). “A Framework for Developing Life Cycle Performance Criteria for Design-Build Transportation Projects.” Submitted to the DBIA Education and Research Foundation.

Gransberg, D.D., Koch, J. E., and Molenaar, K. R. (2006). “Preparing for Design-Build Projects: A Primer for Owners, Engineers, and Contractors.” *ASCE Press*, Reston, Virginia, 266.

Gransberg, D.D., Molenaar, K. R., and Datin, J. N. (2007). “Quality Assurance in Design-Build Projects.” NCHRP Synthesis 376, *Transportation Research Board National Academies*, Washington, D.C., ISBN 978-0-309-09795-5, 139.

Gransberg, D.D., Reynolds, H. L., and Boyd, J. (1997). “Evaluation of Past and Future Partnering Efforts.” Research Report No. TX-97/0-1729-1R, Submitted to Texas Department of Transportation, Texas Tech University, Lubbock, Texas.

Gransberg, D.D., Robson, K. R., and Lopez del Puerto, C. (2006). “Estimating Design Fees for Transportation Projects: Phase 1.” OU Transportation Research Report, Submitted to the Oklahoma Transportation Authority.

Gransberg, D.D. and Shane, J. S. (2010). “Construction Manager-at-Risk Project Delivery for Highway Programs.” NCHRP Synthesis 402, *Transportation Research Board,* National Research Council, Washington, DC, 88.

Hammontree, E. (2011). “Point Bonita CMGC in Golden Gate National Recreation Area.” *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

Jacobsen, W. M. (1996). “Construction Documents The Final Word, Petroleum Equipment & Technology.”

Jergeas, G. and Van der Put J. (2001). “Benefits of Constructability on Construction Projects.” *Journal of Construction Engineering and Management*, 127(4), 281.

Khalil, M. (2001). “Selecting the appropriate project delivery method using AHP.” *International Journal of Project Management*, 20, 469–474.

Konchar, M. and Sanvido, V. (1998). ‘‘Comparison of U.S. projects delivery systems.’’ *J. Constr. Eng. Manage.,* 124(6), 435–444.

Love, P. (2002). “Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects.” *Journal of Construction Engineering and Management*, 128(1), 18.

McMinimee, J. (2011). “CMGC, Utah-Peer Exchange.” *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

McSkimming, J., Peck, B., Hoy, B., and Carr, S. (2005). “The quality of design documents: what can the cm do?” *CMAA forum on quality of design documents*, <http://cmaanet.org/user_images/forum.quality_of_design_documents_-_mcskimming.pdf> (November 10, 2011).

Mendez, V. (2010). “Every Day Counts: Innovation Initiative.” *Federal Highway Administration*, Washington, D.C., 1-2.

Migliaccio, G. C., Bogus, S. M., and Chen, A. (2010). “Effect of Duration of Design–Build Procurement on Performance of Transportation Projects.” *Journal of the Transportation Research Board,* Transportation Research Board of the National Academies, Washington D.C., 2151, 67-73.

Miles, M. B. and Huberman, A. M. (1994). "Qualitative data analysis: an expanded sourcebook." *Sage Publications*, Thousand Oaks, California.

Minnesota Department of Transportation members. Structured interview. 22 March 2011.

Mitchell, B.P. (1999). “The Applicability of the Spearin Doctrine: Do Owners Warrant Plans and Specifications?” *Find Law for Legal Professionals*, <http://library.findlaw.com/1999/Aug/1/128038.html> (November, 2011).

Molenaar, K.R. (2005). “Programmatic cost risk analysis for highway megaprojects.” *J. of Constr. Engrg. and Mgmt.*, ASCE, 131(3), 343-353.

Moore, J. (2008). “ECI (Early Contractor Involvement) Acquisition Methodology.” *The Associated General Contractors of America Federal Conference*.

Multnomah County. (2011). “Innovative Contracting Practices Special Experimental Project No. 14 Sellwood Bridge Project (Multnomah County), CM/GC Project.” *U.S. Department of Transportation Federal Highway Administration.*<http://www.fhwa.dot.gov/programadmin/contracts/sep14or2010.cfm> (November 2011).

Nadeau, G. (2011). “Every Day Counts’ Innovating our way to being faster, better, smarter.” *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

National Society of Professional Engineers, (NSPE) (1999). “Qualifications based selection issue paper.” *NSPE Issue Briefs*, <http://www.nspe.org/govrel/gr2%2D4022.asp> (January, 2012).

Neuendorf, K.A. (2002) “The Content Analysis Guidebook.” *Sage Publications*, Thousand Oaks, California, 2002, 300.

Newbold. (1988) “Statistics for Business and Economics.” 2nd Edition. Prentice Hall. Englewood Cliffs, New Jersey USA, 462-463.

Newell, T. (2011). “Mountain View Corridor: CMGC Case Example No. 2.” *2011 CMGC Peer Exchange,* FHWA, Salt Lake City, Utah.

Newfoundland Association of Architects (NAA) and Association of Professional Engineers and Geoscientists of Newfoundland (APEGN). (2003). “Guidelines and Recommended Minimum Fees for Architectural and Engineering Projects.” Jointly published by NAA and APEGN.

Ogilvie, R. A. (2010). “ECI Schedule Early contractor involvement hastens Brighton Bypass up to 15months.” *Civil Contractors Federation Magazine*, <http://www.earthmover.com.au/news/2010/august/early-contractor-involvement-hastens-brighton-bypass-up-to-15months> (August, 2010).

Ontario Society of Professional Engineers (OSPE). (2011). “Engineer’s Fee Guidelines.” Efficiency Engineering Incorporated, <http://www.ee solutions.com/Lists/Resources/DispForm.aspx?ID=5> (January, 2012).

Oregon Department of Transportation (ODOT). (2008). “Request For Proposals Instructions To Proposers For The I-5: Willamette River Bridge Bundle 220 Key No. 14259 Construction Manager/General Contractor Project.” 29-35.

Park, R. (2011). “Leadership Perspective.” *2011 CMGC Peer Exchange*, FHWA, Salt Lake City, Utah.

Procurement on Performance of Transportation Projects”. *2010 Transportation Research Record.* (1) 67-73.

Queensland Government Chief Procurement Office (2008). “Relational Procurement Options - Alliance and Early Contractor Involvement Contracts.” *Procurement Guidance Series Alliance Contract.*

Rowley, C. (2011). “Design & Construction is Intended to be an Integrated Process.” *2011 CMGC Peer Exchange,* FHWA, Salt Lake City, Utah.

Scott, S. Molenaar, K., Gransberg, D, Smith, N. (2006). “Best Value Procurement Methods for Highway Construction Projects.” *National Cooperative Highway Research Programs (NCHRP),* Report 561, Washington, D.C.

Sellwood Bridge Project Multnomah County. (2012). “Detour Bridge.” Sellwood Bridge Project, <http://www.sellwoodbridge.org/?p=detour-bridge-approach2> (March, 2012).

Songer, A. D. and Molenaar, K. R. (1996). ‘‘Selective design-build: Public and private sector owner’s attitudes.’’ *J. Manage. Eng.,* 12(6), 47–53.

Strang, W. (2002). “The Risk in CM at-Risk.” *CM eJournal, Construction Management Association of America*, 1-9.

The Institution of Professional Engineers NZ (IPENZ) and The Association of Consulting Engineers NZ (ACENZ). (2004). “Fee Guidelines for Consulting Engineering Services.” (January 2004).

Touran, A., Gransberg, D. D., Molenaar, K. R., Bakshi, P., and Ghavamifar, K. (2009). “A Guidebook for the Selecting Airport Capital Project Delivery Methods.*” ACRP Report*

21, Transportation Research Board, National Academies, Washington, D.C., ISBN: 978-0-309-11804-0, 101.

Touran, A., Gransberg, D. D., Molenaar, K. R., Ghavamifar, K., Mason, D. J., and Fithian, L A. (2008). "Evaluation of Project Delivery Methods." *TCRP Web-Only Document 41, Transportation Research Board, National Academies*, Washington, D.C., 240.

Trost, S.M. and Oberlender, G. D. (2003). "Predicting accuracy of early cost estimates using factor analysis and multivariate regression." *J. of Constr Eng Manage,* 129(2), 198.

Utah Department of Transportation members. Personal interview. 29 June 2011.

Van Valkenburg, M., Lenferink, S., Nijsten, R., and Arts, J. (2008). "Early Contractor Involvement a New Strategy for Buying the Best in Infrastructure Development in the Netherlands." *3rd International Public Procurement Conference Proceedings,* 323-356.

Venters, V.G. (2004). "Cost of Quality," 20*04 Transactions*, AACEI, Washington, D.C., EST.04.01-EST.04.07.

Washington, S.P., Karlaftis, M.G., Mannering, F.L. (2011). Statistical and Econometric Methods for Transportation Data Analysis." *Chapman & Hall / CRC Press*, Boca Raton, FL.

Weber, R.P. (1985). "Basic Content Analysis." *Sage Publications*, Beverly Hills, California.

Yates, J. K. and Battersby, L. C. (2002). "Master Builder Project Delivery System and Designer Construction Knowledge." *Journal of Construction Engineering and Management,* ASCE, 129 (6).

APPENDIX 1. DESIGN-BID-BUILD COST DATA

Table A1.1. Design-bid-build population of project cost data

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$36,437	$36,437	25.97%	0.00%	0.00%
$40,000	$40,000	33.56%	0.00%	0.00%
$65,287	$65,287	7.38%	0.00%	0.00%
$71,279	$70,959	77.01%	-0.45%	0.45%
$102,805	$102,805	4.29%	0.00%	0.00%
$88,000	$105,407	59.84%	19.78%	19.78%
$107,193	$106,327	44.93%	-0.81%	0.81%
$114,800	$107,029	60.18%	-6.77%	6.77%
$114,790	$114,790	16.81%	0.00%	0.00%
$125,795	$115,749	37.76%	-7.99%	7.99%
$116,555	$118,973	58.24%	2.07%	2.07%
$116,002	$120,653	25.24%	4.01%	4.01%
$124,664	$124,663	4.43%	0.00%	0.00%
$134,094	$126,041	72.50%	-6.01%	6.01%
$120,236	$129,446	47.46%	7.66%	7.66%
$119,602	$129,818	25.73%	8.54%	8.54%
$127,790	$130,866	5.61%	2.41%	2.41%
$170,359	$137,777	20.47%	-19.13%	19.13%
$127,857	$142,082	14.79%	11.13%	11.13%
$148,223	$143,890	21.10%	-2.92%	2.92%
$135,941	$150,694	13.23%	10.85%	10.85%
$152,794	$152,794	9.42%	0.00%	0.00%
$153,697	$157,402	18.03%	2.41%	2.41%
$181,705	$158,165	10.67%	-12.96%	12.96%
$164,685	$160,451	24.74%	-2.57%	2.57%
$147,102	$161,058	55.37%	9.49%	9.49%
$242,377	$167,607	64.69%	-30.85%	30.85%
$139,107	$168,118	40.49%	20.86%	20.86%
$175,460	$170,060	51.82%	-3.08%	3.08%
$171,906	$171,906	12.99%	0.00%	0.00%
$176,965	$186,100	21.02%	5.16%	5.16%
$177,019	$188,347	17.64%	6.40%	6.40%
$189,165	$193,614	52.54%	2.35%	2.35%
$187,197	$194,119	34.85%	3.70%	3.70%
$194,990	$194,989	4.59%	0.00%	0.00%
$188,814	$204,665	24.11%	8.40%	8.40%
$202,809	$218,334	51.99%	7.65%	7.65%
$206,175	$220,388	26.39%	6.89%	6.89%
$221,887	$221,887	23.13%	0.00%	0.00%
$212,580	$223,756	38.42%	5.26%	5.26%
$224,891	$225,772	27.42%	0.39%	0.39%
$229,178	$228,939	17.94%	-0.10%	0.10%
$253,662	$231,960	17.59%	-8.56%	8.56%
$235,812	$233,412	25.66%	-1.02%	1.02%
$246,193	$238,731	4.61%	-3.03%	3.03%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$242,221	$242,221	3.05%	0.00%	0.00%
$237,701	$242,473	21.63%	2.01%	2.01%
$242,382	$243,611	15.92%	0.51%	0.51%
$207,000	$244,821	58.38%	18.27%	18.27%
$262,050	$252,972	11.99%	-3.46%	3.46%
$255,871	$255,871	1.69%	0.00%	0.00%
$257,448	$257,448	5.16%	0.00%	0.00%
$259,009	$259,009	1.87%	0.00%	0.00%
$231,204	$259,227	29.24%	12.12%	12.12%
$250,000	$262,195	14.04%	4.88%	4.88%
$500,000	$284,487	5.60%	-43.10%	43.10%
$791,000	$285,110	5.94%	-63.96%	63.96%
$400,000	$303,302	3.00%	-24.17%	24.17%
$307,253	$307,252	13.23%	0.00%	0.00%
$308,789	$308,789	22.01%	0.00%	0.00%
$610,301	$310,302	1.74%	-49.16%	49.16%
$312,000	$313,347	54.01%	0.43%	0.43%
$315,064	$315,065	3.75%	0.00%	0.00%
$279,598	$321,146	3.44%	14.86%	14.86%
$275,000	$324,523	1.31%	18.01%	18.01%
$316,266	$325,123	17.22%	2.80%	2.80%
$500,000	$336,500	37.71%	-32.70%	32.70%
$244,861	$341,177	6.05%	39.33%	39.33%
$900,000	$342,005	7.89%	-62.00%	62.00%
$353,851	$353,851	47.77%	0.00%	0.00%
$345,054	$354,223	7.84%	2.66%	2.66%
$1,250,000	$364,196	4.25%	-70.86%	70.86%
$425,344	$365,274	2.42%	-14.12%	14.12%
$627,787	$370,768	5.22%	-40.94%	40.94%
$358,184	$376,327	19.52%	5.07%	5.07%
$398,104	$398,103	2.27%	0.00%	0.00%
$460,129	$402,571	21.89%	-12.51%	12.51%
$5,136,000	$404,773	4.09%	-92.12%	92.12%
$416,529	$411,640	3.54%	-1.17%	1.17%
$427,394	$427,394	24.01%	0.00%	0.00%
$430,214	$430,214	1.71%	0.00%	0.00%
$470,677	$470,677	1.48%	0.00%	0.00%
$484,871	$472,344	43.43%	-2.58%	2.58%
$513,951	$484,757	1.39%	-5.68%	5.68%
$493,228	$493,228	25.77%	0.00%	0.00%
$466,214	$512,404	6.14%	9.91%	9.91%
$526,020	$513,459	1.39%	-2.39%	2.39%
$503,500	$514,549	4.00%	2.19%	2.19%
$320,000	$531,389	5.00%	66.06%	66.06%
$531,744	$531,744	1.62%	0.00%	0.00%
$538,740	$550,958	4.96%	2.27%	2.27%
$562,724	$562,724	2.10%	0.00%	0.00%
$521,283	$567,794	22.39%	8.92%	8.92%
$575,455	$580,216	11.89%	0.83%	0.83%
$546,164	$588,549	4.81%	7.76%	7.76%
$497,953	$590,285	17.14%	18.54%	18.54%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$593,926	$593,926	0.88%	0.00%	0.00%
$683,000	$598,644	2.20%	-12.35%	12.35%
$805,851	$598,814	5.73%	-25.69%	25.69%
$337,477	$599,489	7.77%	77.64%	77.64%
$600,125	$605,953	11.93%	0.97%	0.97%
$610,032	$610,032	0.81%	0.00%	0.00%
$800,867	$622,301	21.29%	-22.30%	22.30%
$457,025	$626,318	4.04%	37.04%	37.04%
$535,123	$635,011	0.19%	18.67%	18.67%
$684,010	$640,070	18.09%	-6.42%	6.42%
$652,683	$674,085	3.48%	3.28%	3.28%
$682,854	$676,054	16.19%	-1.00%	1.00%
$1,500,000	$676,767	4.11%	-54.88%	54.88%
$616,672	$677,724	49.28%	9.90%	9.90%
$1,500,000	$689,580	5.70%	-54.03%	54.03%
$692,491	$692,490	0.91%	0.00%	0.00%
$882,010	$693,886	0.52%	-21.33%	21.33%
$683,670	$694,891	38.28%	1.64%	1.64%
$696,620	$696,618	11.63%	0.00%	0.00%
$701,200	$701,163	30.67%	-0.01%	0.01%
$623,615	$712,899	3.17%	14.32%	14.32%
$748,853	$721,814	8.83%	-3.61%	3.61%
$730,972	$730,972	0.69%	0.00%	0.00%
$741,434	$738,777	4.11%	-0.36%	0.36%
$732,249	$740,066	15.84%	1.07%	1.07%
$1,050,000	$748,424	5.98%	-28.72%	28.72%
$1,500,000	$783,786	6.00%	-47.75%	47.75%
$790,500	$790,424	2.30%	-0.01%	0.01%
$782,722	$810,782	10.84%	3.59%	3.59%
$500,000	$829,907	1.00%	65.98%	65.98%
$897,502	$830,983	22.65%	-7.41%	7.41%
$823,000	$839,874	30.50%	2.05%	2.05%
$1,000,000	$881,599	6.60%	-11.84%	11.84%
$874,769	$883,799	13.17%	1.03%	1.03%
$912,748	$884,953	1.72%	-3.05%	3.05%
$750,000	$897,439	6.67%	19.66%	19.66%
$920,000	$908,623	1.23%	-1.24%	1.24%
$938,220	$910,472	27.18%	-2.96%	2.96%
$927,096	$927,095	0.41%	0.00%	0.00%
$750,000	$935,552	6.39%	24.74%	24.74%
$769,200	$939,808	4.42%	22.18%	22.18%
$804,750	$940,520	34.22%	16.87%	16.87%
$500,000	$943,899	9.20%	88.78%	88.78%
$957,167	$957,167	0.72%	0.00%	0.00%
$954,031	$986,706	20.80%	3.42%	3.42%
$389,900	$1,007,155	50.25%	158.31%	158.31%
$1,097,452	$1,028,526	1.23%	-6.28%	6.28%
$1,045,000	$1,035,876	1.32%	-0.87%	0.87%
$727,995	$1,043,113	3.22%	43.29%	43.29%
$1,200,000	$1,050,555	5.56%	-12.45%	12.45%
$1,060,554	$1,072,286	2.20%	1.11%	1.11%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$940,000	$1,080,275	2.49%	14.92%	14.92%
$1,006,000	$1,087,238	1.13%	8.08%	8.08%
$1,063,437	$1,093,240	1.35%	2.80%	2.80%
$899,346	$1,111,596	2.13%	23.60%	23.60%
$1,063,900	$1,114,558	15.00%	4.76%	4.76%
$1,184,586	$1,122,742	10.86%	-5.22%	5.22%
$1,157,406	$1,146,762	0.38%	-0.92%	0.92%
$850,609	$1,150,321	1.66%	35.23%	35.23%
$1,217,400	$1,152,888	12.88%	-5.30%	5.30%
$485,000	$1,154,444	10.31%	138.03%	138.03%
$1,145,394	$1,171,427	20.86%	2.27%	2.27%
$1,214,862	$1,188,075	12.07%	-2.20%	2.20%
$2,000,000	$1,228,526	4.33%	-38.57%	38.57%
$1,524,000	$1,265,344	0.81%	-16.97%	16.97%
$1,396,337	$1,296,924	1.33%	-7.12%	7.12%
$2,000,000	$1,317,295	6.00%	-34.14%	34.14%
$1,500,000	$1,332,458	5.13%	-11.17%	11.17%
$1,410,000	$1,342,323	4.82%	-4.80%	4.80%
$1,344,904	$1,344,904	8.55%	0.00%	0.00%
$1,349,312	$1,360,653	21.79%	0.84%	0.84%
$1,178,473	$1,379,032	1.32%	17.02%	17.02%
$1,311,367	$1,380,769	3.02%	5.29%	5.29%
$1,483,371	$1,395,602	0.04%	-5.92%	5.92%
$1,200,000	$1,402,837	6.00%	16.90%	16.90%
$1,992,018	$1,426,464	10.17%	-28.39%	28.39%
$675,000	$1,426,820	34.77%	111.38%	111.38%
$1,537,072	$1,428,689	13.25%	-7.05%	7.05%
$730,000	$1,443,886	7.16%	97.79%	97.79%
$950,000	$1,443,891	6.32%	51.99%	51.99%
$1,334,231	$1,444,381	12.66%	8.26%	8.26%
$1,434,582	$1,471,102	20.89%	2.55%	2.55%
$1,473,528	$1,473,527	2.76%	0.00%	0.00%
$1,490,888	$1,490,888	1.23%	0.00%	0.00%
$1,439,758	$1,499,359	14.01%	4.14%	4.14%
$1,459,460	$1,521,802	0.67%	4.27%	4.27%
$1,438,607	$1,540,763	19.29%	7.10%	7.10%
$1,549,791	$1,549,791	0.48%	0.00%	0.00%
$1,500,000	$1,558,584	6.00%	3.91%	3.91%
$3,800,000	$1,574,824	8.06%	-58.56%	58.56%
$1,067,377	$1,578,157	5.36%	47.85%	47.85%
$1,582,100	$1,583,514	19.03%	0.09%	0.09%
$787,059	$1,624,188	35.60%	106.36%	106.36%
$1,493,623	$1,665,945	4.96%	11.54%	11.54%
$1,500,000	$1,667,339	1.31%	11.16%	11.16%
$2,100,000	$1,672,984	1.88%	-20.33%	20.33%
$1,753,057	$1,687,685	2.08%	-3.73%	3.73%
$2,200,000	$1,690,858	6.89%	-23.14%	23.14%
$1,745,635	$1,692,784	4.77%	-3.03%	3.03%
$1,907,025	$1,713,382	7.03%	-10.15%	10.15%
$4,020,000	$1,714,300	5.88%	-57.36%	57.36%
$1,818,598	$1,831,919	9.36%	0.73%	0.73%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$2,006,031	$1,832,657	2.80%	-8.64%	8.64%
$3,179,850	$1,850,366	13.16%	-41.81%	41.81%
$1,811,361	$1,862,140	6.54%	2.80%	2.80%
$1,500,000	$1,877,510	5.13%	25.17%	25.17%
$1,804,734	$1,881,491	1.00%	4.25%	4.25%
$1,773,266	$1,883,681	7.43%	6.23%	6.23%
$4,101,300	$1,885,710	18.82%	-54.02%	54.02%
$1,986,498	$1,935,030	18.61%	-2.59%	2.59%
$1,798,175	$1,966,138	4.36%	9.34%	9.34%
$1,681,894	$2,009,391	0.11%	19.47%	19.47%
$2,578,682	$2,038,172	5.99%	-20.96%	20.96%
$1,885,317	$2,090,707	1.63%	10.89%	10.89%
$1,907,426	$2,153,176	24.11%	12.88%	12.88%
$1,978,741	$2,160,393	11.02%	9.18%	9.18%
$1,977,454	$2,172,197	6.28%	9.85%	9.85%
$2,188,561	$2,216,300	1.62%	1.27%	1.27%
$2,049,826	$2,221,885	22.44%	8.39%	8.39%
$2,195,328	$2,269,208	8.38%	3.37%	3.37%
$2,290,741	$2,285,245	1.75%	-0.24%	0.24%
$1,390,000	$2,309,832	3.18%	66.17%	66.17%
$3,488,100	$2,315,062	1.09%	-33.63%	33.63%
$2,171,658	$2,344,531	0.83%	7.96%	7.96%
$1,932,523	$2,353,474	7.24%	21.78%	21.78%
$2,171,723	$2,373,068	3.44%	9.27%	9.27%
$1,960,000	$2,387,232	11.47%	21.80%	21.80%
$2,446,238	$2,412,917	11.06%	-1.36%	1.36%
$2,426,410	$2,422,865	15.15%	-0.15%	0.15%
$2,400,698	$2,449,504	4.51%	2.03%	2.03%
$2,567,479	$2,515,164	15.61%	-2.04%	2.04%
$2,519,079	$2,530,185	3.84%	0.44%	0.44%
$2,605,929	$2,589,093	5.60%	-0.65%	0.65%
$2,422,365	$2,629,985	0.49%	8.57%	8.57%
$2,742,270	$2,653,022	6.54%	-3.25%	3.25%
$3,500,000	$2,686,229	2.25%	-23.25%	23.25%
$2,822,285	$2,822,285	2.21%	0.00%	0.00%
$1,995,000	$2,822,285	3.12%	41.47%	41.47%
$2,270,708	$2,831,308	13.57%	24.69%	24.69%
$2,494,318	$2,841,798	24.70%	13.93%	13.93%
$3,000,000	$2,853,624	4.98%	-4.88%	4.88%
$2,500,000	$2,957,434	1.32%	18.30%	18.30%
$2,965,200	$2,988,827	8.28%	0.80%	0.80%
$2,638,458	$3,032,552	6.80%	14.94%	14.94%
$3,100,000	$3,038,861	5.90%	-1.97%	1.97%
$2,120,000	$3,074,203	11.79%	45.01%	45.01%
$2,979,549	$3,084,623	12.47%	3.53%	3.53%
$3,004,148	$3,094,310	4.14%	3.00%	3.00%
$2,612,142	$3,139,983	10.86%	20.21%	20.21%
$2,668,198	$3,295,824	0.46%	23.52%	23.52%
$2,836,761	$3,334,108	0.47%	17.53%	17.53%
$3,095,866	$3,339,163	0.25%	7.86%	7.86%
$3,336,648	$3,420,979	10.06%	2.53%	2.53%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$2,734,466	$3,444,944	5.52%	25.98%	25.98%
$7,500,000	$3,455,840	0.82%	-53.92%	53.92%
$3,219,176	$3,494,536	5.51%	8.55%	8.55%
$3,312,470	$3,500,616	7.94%	5.68%	5.68%
$3,104,270	$3,556,167	7.09%	14.56%	14.56%
$1,600,000	$3,595,016	5.00%	124.69%	124.69%
$5,425,000	$3,631,824	3.24%	-33.05%	33.05%
$4,281,315	$3,645,429	5.86%	-14.85%	14.85%
$3,574,504	$3,668,239	0.96%	2.62%	2.62%
$5,000,000	$3,766,729	1.95%	-24.67%	24.67%
$4,700,000	$3,812,310	2.70%	-18.89%	18.89%
$3,641,665	$3,879,526	1.51%	6.53%	6.53%
$2,500,000	$3,887,175	6.40%	55.49%	55.49%
$2,902,241	$3,902,901	14.29%	34.48%	34.48%
$4,000,000	$4,107,632	5.00%	2.69%	2.69%
$4,188,906	$4,158,201	6.65%	-0.73%	0.73%
$4,399,971	$4,227,351	11.67%	-3.92%	3.92%
$3,000,000	$4,286,982	3.00%	42.90%	42.90%
$9,125,116	$4,365,980	0.29%	-52.15%	52.15%
$3,471,789	$4,451,164	0.18%	28.21%	28.21%
$4,337,687	$4,464,352	8.18%	2.92%	2.92%
$4,347,740	$4,510,633	0.32%	3.75%	3.75%
$1,929,080	$4,521,852	10.10%	134.40%	134.40%
$4,000,000	$4,927,620	2.38%	23.19%	23.19%
$2,616,298	$4,956,038	7.28%	89.43%	89.43%
$4,285,429	$5,011,277	14.32%	16.94%	16.94%
$5,178,005	$5,178,123	0.10%	0.00%	0.00%
$5,279,198	$5,220,041	5.26%	-1.12%	1.12%
$3,485,764	$5,237,602	10.14%	50.26%	50.26%
$3,884,526	$5,313,940	7.44%	36.80%	36.80%
$5,180,296	$5,326,330	5.42%	2.82%	2.82%
$4,568,783	$5,401,474	3.17%	18.23%	18.23%
$4,472,369	$5,459,916	1.07%	22.08%	22.08%
$5,083,598	$5,493,041	6.02%	8.05%	8.05%
$4,630,682	$5,582,515	2.41%	20.55%	20.55%
$5,095,458	$5,587,517	4.08%	9.66%	9.66%
$5,041,200	$5,619,177	4.36%	11.47%	11.47%
$3,400,000	$5,693,915	2.91%	67.47%	67.47%
$4,803,223	$5,741,442	1.07%	19.53%	19.53%
$5,639,838	$5,865,018	1.81%	3.99%	3.99%
$5,990,313	$6,176,794	8.07%	3.11%	3.11%
$6,187,007	$6,187,007	1.92%	0.00%	0.00%
$5,963,160	$6,338,647	1.04%	6.30%	6.30%
$6,000,000	$6,604,317	2.25%	10.07%	10.07%
$6,687,089	$7,152,841	5.06%	6.96%	6.96%
$8,900,100	$7,183,940	1.64%	-19.28%	19.28%
$9,185,098	$7,317,293	5.67%	-20.34%	20.34%
$7,648,624	$7,635,785	3.20%	-0.17%	0.17%
$8,954,427	$7,636,041	2.59%	-14.72%	14.72%
$7,555,962	$7,709,724	2.90%	2.03%	2.03%
$7,827,252	$7,827,251	0.52%	0.00%	0.00%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$11,953,900	$7,837,063	1.22%	-34.44%	34.44%
$9,358,087	$7,943,101	3.77%	-15.12%	15.12%
$8,141,000	$7,945,320	1.36%	-2.40%	2.40%
$7,150,650	$7,953,505	13.82%	11.23%	11.23%
$7,214,767	$7,962,842	1.30%	10.37%	10.37%
$8,118,807	$8,120,488	5.04%	0.02%	0.02%
$7,684,665	$8,381,841	4.80%	9.07%	9.07%
$8,673,228	$8,624,833	6.90%	-0.56%	0.56%
$12,000,000	$8,673,526	4.37%	-27.72%	27.72%
$6,300,000	$8,786,382	0.71%	39.47%	39.47%
$22,103,000	$8,807,258	2.60%	-60.15%	60.15%
$8,732,199	$8,819,319	0.75%	1.00%	1.00%
$9,043,231	$9,006,758	2.12%	-0.40%	0.40%
$8,873,756	$9,136,496	6.24%	2.96%	2.96%
$9,174,677	$9,247,984	4.30%	0.80%	0.80%
$8,904,353	$9,775,009	3.93%	9.78%	9.78%
$14,800,000	$9,908,183	3.66%	-33.05%	33.05%
$11,306,129	$10,240,811	1.48%	-9.42%	9.42%
$10,581,623	$10,505,332	13.12%	-0.72%	0.72%
$8,346,221	$10,575,911	2.99%	26.71%	26.71%
$7,000,000	$10,601,614	1.73%	51.45%	51.45%
$9,275,770	$10,671,674	5.75%	15.05%	15.05%
$8,623,896	$10,856,180	5.88%	25.88%	25.88%
$8,152,146	$10,883,512	5.85%	33.50%	33.50%
$10,749,588	$11,008,443	1.78%	2.41%	2.41%
$2,600,000	$11,522,803	3.90%	343.18%	343.18%
$4,500,000	$11,535,054	2.48%	156.33%	156.33%
$12,605,936	$11,696,314	3.87%	-7.22%	7.22%
$10,894,534	$11,710,959	7.86%	7.49%	7.49%
$15,358,762	$11,946,787	1.59%	-22.22%	22.22%
$13,757,790	$12,211,673	3.26%	-11.24%	11.24%
$12,397,939	$12,497,119	2.19%	0.80%	0.80%
$11,095,427	$13,299,804	2.45%	19.87%	19.87%
$13,937,962	$13,302,897	2.86%	-4.56%	4.56%
$14,381,114	$13,552,675	3.04%	-5.76%	5.76%
$16,617,247	$14,054,895	2.40%	-15.42%	15.42%
$2,110,821	$15,056,954	63.47%	613.32%	613.32%
$15,035,647	$15,933,002	5.80%	5.97%	5.97%
$17,716,142	$16,487,563	2.73%	-6.93%	6.93%
$14,943,379	$16,549,283	6.77%	10.75%	10.75%
$16,138,608	$16,761,837	1.52%	3.86%	3.86%
$22,488,166	$17,004,360	4.94%	-24.39%	24.39%
$16,376,629	$17,146,458	5.27%	4.70%	4.70%
$26,672,511	$17,306,131	1.80%	-35.12%	35.12%
$14,691,099	$17,439,313	3.68%	18.71%	18.71%
$23,712,246	$18,136,265	1.89%	-23.52%	23.52%
$18,018,522	$19,177,032	2.87%	6.43%	6.43%
$21,959,598	$22,826,085	8.20%	3.95%	3.95%
$14,650,000	$22,975,809	3.20%	56.83%	56.83%
$33,582,194	$31,801,200	2.78%	-5.30%	5.30%
$6,477,000	$34,334,884	5.09%	430.10%	430.10%

Original Estimate	Final Construction Cost	Design Fee	Cost Growth	Abs. Cost Growth
$33,002,556	$37,297,245	3.06%	13.01%	13.01%
$59,502,000	$39,757,072	0.71%	-33.18%	33.18%
$36,000,000	$43,995,317	2.74%	22.21%	22.21%
$46,168,487	$48,728,725	5.27%	5.55%	5.55%
$53,447,000	$67,386,807	0.04%	26.08%	26.08%
		MEAN	8.47%	20.45%
		STD.DEV	52.16%	48.72%
		VARIANCE	27.21%	23.74%
		MEDIAN	1.05%	7.66%
		MIN	-92.12%	0.00%
		MAX	613.32%	613.32%
		SAMPLE	356	356

APPENDIX 2. DESIGN-BUILD COST DATA

Table A2.1. Design-build population of project cost data

Original Estimate	Final Construction Cost	Preconstruction Cost	Cost Growth	Abs. Cost Growth
$531,000	$490,354	2.04%	-7.65%	7.65%
$1,073,640	$585,291	2.27%	-45.49%	45.49%
$1,142,467	$972,000	3.32%	-14.92%	14.92%
$588,000	$1,000,000	3.58%	70.07%	70.07%
$2,500,000	$1,648,000	3.89%	-34.08%	34.08%
$1,700,000	$1,800,000	4.14%	5.88%	5.88%
$1,929,399	$1,892,244	4.64%	-1.93%	1.93%
$1,489,546	$1,962,179	4.67%	31.73%	31.73%
$3,429,000	$2,025,000	4.74%	-40.94%	40.94%
$1,980,000	$2,271,110	4.78%	14.70%	14.70%
$3,346,000	$2,307,000	6.30%	-31.05%	31.05%
$2,400,000	$2,400,000	6.64%	0.00%	0.00%
$2,900,000	$2,800,000	6.99%	-3.45%	3.45%
$4,598,661	$3,313,800	7.39%	-27.94%	27.94%
$3,648,300	$3,711,542	7.93%	1.73%	1.73%
$4,724,000	$4,448,189	8.01%	-5.84%	5.84%
$6,500,000	$5,400,000	8.03%	-16.92%	16.92%
$6,666,169	$6,640,755	8.58%	-0.38%	0.38%
$7,098,000	$7,012,769	9.18%	-1.20%	1.20%
$7,117,000	$8,835,000	9.43%	24.14%	24.14%
$8,059,000	$8,996,000	11.22%	11.63%	11.63%
$17,635,000	$9,946,000	11.38%	-43.60%	43.60%
$9,825,700	$10,715,700	11.45%	9.06%	9.06%
$12,630,000	$12,100,000	12.41%	-4.20%	4.20%
$17,252,000	$14,823,000	13.46%	-14.08%	14.08%
$16,600,048	$16,995,221	16.63%	2.38%	2.38%
$17,586,000	$17,659,000	16.67%	0.42%	0.42%
$16,200,000	$19,620,000	19.95%	21.11%	21.11%
$15,000,000	$19,700,000	20.00%	31.33%	31.33%
$26,680,000	$26,323,000	21.18%	-1.34%	1.34%
$27,400,000	$27,400,000	28.38%	0.00%	0.00%
$725,000,000	$682,000,000	34.01%	-5.93%	5.93%
		MEAN	-2.40%	16.41%
		STD.DEV	23.86%	17.24%
		VARIANCE	5.69%	2.97%
		MEDIAN	-1.27%	10.34%
		MIN	-45.49%	0.00%
		MAX	70.07%	70.07%
		SAMPLE	32	32

APPENDIX 3. CONSTRUCTION MANAGER/GENERAL CONTRACTOR COST DATA

Table A3.1. Construction manager/general contractor population of project cost data

Original Estimate	Final Construction Cost	Preconstruction Cost	Cost Growth	Abs. Cost Growth
$144,000,000	$116,000,000	4.27%	-19.44%	19.44%
$150,000,000	$135,000,000	4.55%	-10.00%	10.00%
$70,000,000	$63,700,000	4.81%	-9.00%	9.00%
$99,000,000	$92,000,000	6.37%	-7.07%	7.07%
$17,000,000	$16,200,000	7.11%	-4.71%	4.71%
$196,000,000	$187,000,000	7.40%	-4.59%	4.59%
$97,303,370	$102,000,000	8.69%	4.83%	4.83%
$200,000,000	$210,000,000	8.90%	5.00%	5.00%
$4,846,002	$6,397,411	9.28%	32.01%	32.01%
		MEAN	-1.44%	10.74%
		STD.DEV	14.61%	9.27%
		VARIANCE	2.13%	0.86%
		MEDIAN	-4.71%	7.07%
		MIN	-19.44%	4.59%
		MAX	32.01%	32.01%
		SAMPLE	9	9

APPENDIX 4. BENEFITS CITED IN LITERATURE

Table A4.1. Summary of benefits of early contractor involvement cited in literature

	Project Type	PDM	Constructor Design Input	Ability to accelerate schedule	Early Knowledge of Costs	Ability to bid early work packages	Owner Control of Design	Contract type creates cost control incentive	Reduces design costs	Select GC on qualifications	Open books contingency accounting	Focus on Quality and Value	Flexibility During Design/Construction	Spirit of Trust	Competitive bidding possible	Third-party coordination facilitated	Risk Management
1			X	X		X	X	X	X						X	X	
2			X	X					X								
3						X	X		X		X	X		X			X
4			X	X	X	X	X	X		X	X	X	X	X			
5			X	X		X							X				
6			X	X	X	X				X			X				
7			X	X	X						X	X					
8			X		X	X	X				X						
9			X	X	X	X	X										
10			X		X	X		X							X	X	
11			X	X	X	X		X		X				X		X	
12			X	X				X		X				X			X
13					X		X								X		
14					X		X		X								
15			X	X	X	X	X	X	X			X	X		X		
16		CMGC	X	X													X
17		CMGC						X									
18		CMGC		X	X												X
19		CMGC		X	X		X	X				X			X		X
20		CMGC		X			X						X		X		
21		CMGC										X		X			X
22		CMGC		X		X							X			X	X
23	Bridge	CMGC	X	X			X					X	X				X
24	Tunnel	CMGC		X		X	X	X					X	X			X
25	Bridge	CMGC	X	X	X	X							X			X	X
26	Road	CMGC	X	X	X		X					X	X	X			X
27		CMGC	X	X	X	X				X	X	X	X	X			X
28		CMGC	X	X	X		X		X			X	X	X		X	X
29		ECI	X	X	X		X	X				X	X	X			X
30		ECI	X	X								X		X			
31		ECI	X	X								X		X			X
32		ECI	X	X								X				X	X

	Project Type	PDM	Constructor Design Input	Ability to accelerate schedule	Early Knowledge of Costs	Ability to bid early work packages	Owner Control of Design	Contract type creates cost control incentive	Reduces design costs	Select GC on qualifications	Open books contingency accounting	Focus on Quality and Value	Flexibility During Design/Construction	Spirit of Trust	Competitive bidding possible	Third-party coordination facilitated	Risk Management
33		ECI	X	X	X								X	X	X		X
34		ECI	X	X	X						X	X					
35		ECI	X	X			X				X	X					X
TOTALS (out of 35)			**25**	**28**	**19**	**14**	**16**	**10**	**6**	**5**	**7**	**16**	**14**	**13**	**7**	**7**	**18**

APPENDIX 5. BENEFITS CITED IN CASE STUDIES

Table A5.1. Summary of benefits of early contractor involvement cited in case studies

	Project Type	PDM	Constructor Design Input	Ability to accelerate schedule	Early Knowledge of Costs	Ability to bid early work packages	Owner Control of Design	Contract type creates cost control incentive	Reduces design costs	Select GC on qualifications	Open books contingency accounting	Focus on Quality and Value	Flexibility During Design/Construction	Spirit of Trust	Competitive bidding possible	Third-party coordination facilitated	Risk Management
1	Airport	CMGC	X	X	X		X	X		X	X	X	X				X
2	Road	CMGC	X	X				X			X	X	X				X
3	Road	CMGC	X	X	X	X	X	X		X	X	X	X	X	X	X	X
4	Road	CMGC	X	X	X			X			X	X	X				
5	Bridge	CMGC	X	X	X	X	X	X		X	X	X	X	X	X	X	X
6	Road	CMGC	X	X		X				X	X	X	X	X	X	X	X
7	Road	CMGC	X	X	X	X	X	X	X	X	X	X	X	X		X	X
8	Airport		X	X	X	X					X	X	X	X	X		X
9	Airport		X			X	X	X			X	X	X	X		X	X
10	Airport		X	X	X	X		X			X	X					X
11	Airport			X			X							X	X		
12	Airport		X	X	X	X	X				X	X	X		X	X	
13	Airport		X	X	X	X	X	X	X		X	X		X	X	X	X
14	Airport		X	X			X	X		X	X	X	X	X	X	X	X
15	Transit	CMGC	X	X	X		X	X		X	X	X	X	X	X	X	X
16	Transit	CMGC	X	X	X		X	X				X	X	X	X	X	X
17	Blding	CMAR	X		X		X			X			X		X		
18	Blding	CMGC	X	X		X	X	X		X	X			X	X		X
19	Blding	CMAR	X		X	X	X			X		X			X		X
20	Road	P3	X	X	X							X	X				X
21	Bridge	P3	X	X				X					X			X	
22	Road	P3	X	X	X							X					
23	Electr.	CMGC		X		X	X	X					X	X			X
24	Bridge	CMGC	X	X	X	X							X			X	X
25	Road	DSB	X	X	X				X			X	X				X
26	Transit	DB	X	X	X							X	X		X		X
27	Bridge	DB	X	X	X		X					X	X				X
28	Airport	Partner.										X	X			X	X
29	Transit	DBOM	X	X	X	X						X	X		X	X	X
30	Road	CMGC		X	X	X	X		X			X	X		X		

	Project Type	**PDM**	**Constructor Design Input**	**Ability to accelerate schedule**	**Early Knowledge of Costs**	**Ability to bid early work packages**	**Owner Control of Design**	**Contract type creates cost control incentive**	**Reduces design costs**	**Select GC on qualifications**	**Open books contingency accounting**	**Focus on Quality and Value**	**Flexibility During Design/Construction**	**Spirit of Trust**	**Competitive bidding possible**	**Third-party coordination facilitated**	**Risk Management**
31	Road	CMGC	X	X	X		X					X	X	X			X
32	Transit	DB	X	X									X	X		X	X
33	Road	P3		X	X				X	X			X	X		X	X
34	Road	DB			X								X				
35	Road	DB			X								X	X		X	
36	Transit	DB	X	X	X							X	X	X	X	X	X
37	Road	CMGC	X	X		X		X				X	X	X	X	X	X
38	Road	Allianc.	X	X		X							X			X	X
39	Bridge	CMGC	X	X	X			X		X		X	X		X	X	
40	Road	P3		X										X		X	
41	Road	DB	X	X				X					X	X		X	
42	Transit	DB		X	X			X				X		X			X
43	Dam	ECI (CMGC)	X	X			X			X		X	X				X
44	Transit	DB	X	X	X							X	X	X	X		X
TOTALS (out of 44)			**35**	**38**	**29**	**17**	**19**	**19**	**5**	**13**	**15**	**31**	**36**	**23**	**20**	**23**	**32**