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The Performance of Risk Management and Innovation in
Construction Manager/General Contractor Delivery
in Civil Construction Applications

Rebecca M. Owens

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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School of Technology
Brigham Young University
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ABSTRACT

The Performance of Risk Management and Innovation in Construction Manager/General Contractor Delivery in Civil Construction Applications

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Project teams that deliver high risk, complex projects in the civil construction industry need tools to enable successful delivery. Construction Manager/General Contractor (CM/GC) is an innovative alternate delivery method, providing one such a tool. CM/GC furnishes public agencies with an attractive option for delivering projects in a less adversarial and more constructive manner by involving the contractor during design. The sophisticated public owner does not have to relinquish control of the details of the design in order to accelerate the schedule or see the benefits of real-time cost estimating data. There are also significant cost and schedule benefits with not degradation in quality. However, because CM/GC is relatively unknown to the civil construction industry much remains to be investigated about how CM/GC processes effect successful project delivery.

This research investigated how CM/GC processes affect the three critical elements of construction process risks (including quality, schedule, cost and collaboration), project specific risks, and innovation. By identifying the processes that benefit these elements, successes can be repeated and increased. Additionally, an understanding of the differences in the perception of CM/GC processes, given by contractors, owners, and design engineers, provided perspective into improving the process.

Analyzing data on current CM/GC projects and programs, as well as the compiled experience of field-experienced project teams, provided the information the industry needs to pursue implementation. Identified advantages of the process can be tied to strategies for successful delivery. Identified disadvantages expose barriers to implementation to be overcome by the project team. Project teams state that while the process does have disadvantages, many are perceptual and not fatal flaws to the method. Findings of this research link CM/GC processes to robust risk management results and the opportunity for successful innovation.

Keywords: CM/GC, project delivery methods, innovation, risk management

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1 INTRODUCTION

1.1 Background

Considering the deteriorating condition of the nation’s highway network, “pressures to develop transportation projects that are biddable, buildable, and maintainable may be greater today than ever before” (Gransberg 2013b, 21). Research leads to the conclusion that “public transportation agencies must find ways to deliver infrastructure projects better, faster, cheaper” (Gransberg 2013b, 19). These infrastructure projects are often complex, schedule-driven, and high-profile (Ghavamifar and Touran 2009), and public agencies and their supporting project teams need appropriate risk management tools and innovative processes to provide solutions to complex construction issues.

“The demand to deliver highway design and construction in less time under limited budgets has resulted in governments adopting alternative methods of contracting and delivering highway projects” (Tran et al. 2013, 3). Construction Management/General Contractor (CM/GC) is an alternative delivery method in response to this demand. CM/GC project delivery provides public owners, contractors, and design engineers with the tools to achieve project goals specifically benefitting project risk management and innovation.

This risk management and innovative ability is showcased by the Utah Department of Transportation (UDOT) SR-14 Emergency Repair. In October 2011, a massive landslide left State Road 14 in Cedar Canyon, Utah impassable, covered with 1 million cubic yards of debris

and rocks over 100 feet deep in some areas. Stabilizing slopes, moving earth and debris, and constructing a new road would be required to restore service to the surrounding area (Gransberg 2013b). Immediately following the slide, UDOT initiated the process of funding and designing an emergency repair and in late February 2012 announced that SR-14 would be opened for limited access by June 1, 2012—just 9 months after the landslide occurred and 4 months after beginning construction (Gransberg 2013b, UDOT 2012).

The risks associated with delivering this project on time and under budget were exacerbated by the emergent nature of the project. According to one researcher, in an emergency project “the agency is expected to react to the emergency as expeditiously as possible,” but can also be “exposed to potential criticism of its non-routine emergency procurement procedures by special interest groups” (Gransberg 2013b). The SR-14 delivery team faced the following project-specific risks:

- An undefined project scope
- The need to determine project funding, budget and schedule during design
- High public impact accelerating the delivery schedule
- Unidentified risks threatening cost and schedule
- Environmental concerns and unknown site conditions (i.e. mine shafts and water levels)
- Slope instability requiring specialized equipment
- Indefinite quantities in the amount of roadway excavation and the amount of rock in the excavation (Friant and Alder 2012).

CM/GC delivery processes allowed the project team to manage these risks and implement innovative construction practices on the project. As a result the refined design allowed the project team to decrease excavation from 1.1 M cubic yards to 0.4 M cubic yard and the initial

cost estimate dropped from \$20M to \$11M. Due to the minimized scope, time, and multiple overlapping work packages the road was opened by May 28, 2012, ahead of the projected schedule.

The successful delivery of high-risk civil construction projects, such as the SR-14 emergency repair, requires the application of “a broad set of program and project management tools” that allow control over scope, design, cost and schedule (Ashley, Diekmann and Molenaar 2006, 1). An “integrated team approach to the planning, design, and construction of a highway project” through CM/GC delivery offers the tools to “control schedule and budget, and to ensure quality for the project owner” (Gransberg and Shane 2010, 1) while also managing risk and innovation.

The civil construction industry is in need of new tools, like CM/GC to facilitate the delivery of projects like the SR-14 emergency repair. The Federal Highway Association (FHWA) states that “agencies and the industry should strive to innovate and develop new risk allocation techniques that align all team members with customer goals” such as “client satisfaction with the product, client satisfaction with the service, predictability of time, predictability of cost, safety, and process improvement” (Ashley, Diekmann and Molenaar 2006, 33). While CM/GC project delivery provides the framework to meet these requirements, the process is still “relatively uncommon in highway and bridge construction” (Dodson 2013, 1). Noting the “need for the rapid renewal of the nation’s aging highway infrastructure,” the industry calls for research focused on CM/GC and other alternative project delivery methods (Gransberg 2013, 10). Researchers also state that because “CM/GC project delivery clearly will become more common...training is urgently needed” for the public agency owners, contractors, and design engineers adopting CM/GC (Gransberg 2013, 14).”

1.2 Statement of the Problem

CM/GC project delivery processes provide a possible tool for successfully delivering challenging civil construction projects. However, because CM/GC is relatively uncommon in the civil construction application, research is required to identify its effectiveness in managing risk and promoting innovation. Likewise, training is necessary for successful implementation by public agencies, heavy-civil contractors, and design engineers.

1.3 Purpose of the Research and Research Objectives

Recognizing the benefits, disadvantages and best practices of the CM/GC process, as perceived by experienced public owners, contractors and engineers, removes barriers to the successful implementation of CM/GC throughout the U.S. Understanding how CM/GC processes promote risk management and innovation allows for improvement and transfer to other delivery methods.

The purpose of this research was to:

1. Provide a synthesis of the general processes, advantages, and disadvantages of CM/GC project delivery as used currently in the highway/heavy civil industry,
2. Investigate the effectiveness of CM/GC project delivery in promoting risk management and innovation,
3. Identify barriers to implementation, as reported by project teams with CM/GC experience, and
4. Provide recommendations for future parties participating in CM/GC project delivery.

In order to achieve these purposes, this thesis is broken down into the following: Chapter 2 provides a summary of current literature regarding traditional delivery methods, CM/GC

processes, the management of typical risk found in civil construction projects, and innovation. Chapter 3 discusses the research methods employed to identify CM/GC process effectiveness, and Chapter 4 contains the results of those research methods. Within the results, Section 4.1 examines the overall results, Sections 4.2 through 4.6 examine the effectiveness of CM/GC in managing construction process risks related to quality, schedule, and cost, Section 4.7 explores the effect of CM/GC processes on project-specific risks, and Section 4.8 investigates CM/GC's response to innovation. Finally, Chapter 5 provides conclusions, recommendations and suggested future research based on the findings.

1.4 Assumptions, Limitations, and Definitions

This research was based on the following assumptions and limitations:

- Both the background and implementation of CM/GC discussed in this research were focused around highway, heavy civil and transportation projects.
- Reference made to the typical project delivery methods within this thesis were based on the use of the three most common project delivery methods: Design Bid Build (DBB), Design Build (DB), and CM/GC, also identified as Construction Manager at Risk (AIA and AGC 2004).
- CM/GC project experience investigated and cited in this thesis was gathered principally from public agencies in the Northwest U.S., centered on the public agencies with the most CM/GC experience including Utah, Nevada, Oregon and Colorado. With over 8 years and 25 projects of experience, UDOT is the nation's leader in CM/GC project delivery, having developed both processes and performance measures. Though CM/GC experience exists outside of UDOT and the Northwest

U.S., many programs are not comparably developed. UDOT is the nation's most CM/GC experienced public agency/practitioner (NCHRP 15-46 2014, Gransberg 2013).

The following terms used throughout this research were defined as follows:

Project Delivery Method –The Associated General Contractors of America (AGC) defines a project delivery method 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 (Gransberg 2013, 10; AGC 2004).

Design-Bid-Build Project Delivery (DBB) – DBB is the traditional project delivery method in which the design is completed either by an in-house professional engineering staff or a design consultant before the construction contract is advertised (Leahy et al. 2009). The three primary players—owner, designer, and builder—operate under two separate contracts, one between the owner and designer, and other between the owner and builder (AIA and AGC 2004).

Design-Build Project Delivery (DB) – DB is an alternative to traditional project delivery methods, in which both the design and the construction of the project are simultaneously awarded to a single entity (Leahy et al. 2009). DB is characterized by a single contract established between the owner and the architect-contractor or design-build entity (AIA and AGC 2004).

Construction Manager/General Contractor Project Delivery (CM/GC) – CM/GC is an alternative to traditional project delivery methods, in which the public owner engages both a designer and a qualified construction manager under a negotiated contract to provide both preconstruction services and construction. The construction manager acts as consultant to the

owner in the development and design phases providing consulting and estimating services, and acts as the equivalent of a general contractor during the construction phase, providing management and construction services (AGC and NASFA 2007; Leahy et al., 2009).

Risk – Risk in the context of this thesis is “an uncertain event or condition that, if it occurs, has a positive or negative effect on a project’s objectives” regarding cost, time, quality, etc. (Ashley, Diekmann and Molenaar 2006, 55).

2 LITERATURE REVIEW

2.1 A Discussion of Risk in the Construction Industry

The principle of risk management is an important concept for discussion in the construction industry. Risk is a given factor to be considered in any construction project. The presence of risk determines cost, impacts schedule, and affects quality.

Roles and responsibilities of a project team revolve around offsetting the risk that accompanies construction. A general contractor, and the more recently-developed contractor role of construction manager, has become more than a builder in today's industry. The responsibilities delegated to a general contractor or a construction manager, such as preconstruction, scheduling, cost estimating, contracting and subcontracting, etc. all contribute to managing the risk of construction. General contractors, construction managers, and project managers are then risk managers by profession, and as such are in constant need of tools that facilitate the minimization and management of project risk for the successful delivery of construction projects. As any industry striving to keep up with a quickly-changing environment, the construction industry must be continually unsatisfied with industry tools as they now exist. If project owners require higher quality projects while enjoying the benefits of more cost savings, all delivered faster than ever, tools must be continually developed and improved.

Each construction project is based on a specific set of delivery requirements or project specific objectives established by the project owner or project team. While the specifics of these

requirements, and the priority these requirements assume will vary from project to project, they are generally measured by the metrics of time, cost and quality (AIA and AGC 2004). Nearly all projects are constrained by time and cost, to finish within a specific time frame and under a specific dollar amount.

2.1.1 Process Risk vs. Project Risk

The FHWA defines risk as “an uncertain event or condition that, if it occurs, has a positive or negative effect on a project’s objectives” (Ashley, Diekmann and Molenaar 2006, 55). For clarity within this research, risks were classified as either process-related risks or project-related risks. Process risks are those inherent to the construction process, present in the industry and typically found in every project. They are associated with project objectives relating to project quality, schedule, or cost. Examples of these risks are exceeding budgeted costs, delays in schedule, and low quality.

Project risks are the specific risks associated with a unique construction project. Examples of project risks are similar to these found in the risk register of a recent UDOT project:

- Traffic management
- Unidentified/unknown utilities or hazardous waste
- Impact on historic properties
- Specific material availability
- Controversy on environmental grounds
- Right-of-way acquisitions
- Specific design changes
- Supply/cost of labor (UDOT 2009).

2.1.2 Risk Factors Specific to Civil Construction

The “distinguishing characteristics of transit projects, e.g. size, complexity, public funding and scrutiny, going through dense urban areas, underground works,” etc. may cause uncertainties and unexpected challenges (Ghavamifar and Touran 2009, 230). High public visibility and impact often create tight time constraints and drive a rigorous schedule, necessitating innovation to construction processes. Federal and state funded highway projects follow less-than-negotiable budgets that are very difficult to change when unexpected circumstances arise. Additionally, as highway projects are often subject to changes in design or scope based on the needs and the availability of funding, a need for flexibility introduces more risk, particularly to the project budget.

The combination of these risk factors also introduces a number of additional risks. An unqualified and/or inexperienced project team unable to respond capably to project risks may expose the project to additional risk. Also, the presence of multiple project team members can lead to the risk of conflicting interests. The project owner seeks to deliver an effective project while respecting the public’s tax dollar while the contractor seeks to meet owner requirements and still turn a profit.

Agencies that effectively manage risk must identify and quantify both risks such as these, and their implications, in order to choose tools and strategies to best control and mitigate them (Ashley, Diekmann and Molenaar 2006). Table 1 is adapted from a list found in the FHWA’s guide for Risk Assessment and Allocation for Highway Construction Management. Risks typically identified in the highway construction industry are given within this list, classified by the particular project phase (Ashley, Diekmann and Molenaar 2006).

Table 1: Risks Typical to Highway Construction

Project Phase	Typical Risk Issue
Programming	<ul style="list-style-type: none"> • Significant environmental economic impacts • Funding uncertainty • Uncertain political and public support • Competing interests and competing projects
Preliminary Engineering	<ul style="list-style-type: none"> • Changes to project scope and budgets • Appropriate procurement methods • Changes in design requirements • Right-of-way acquisition • Technical uncertainties • Errors or omissions in quantities, inaccurate unit prices • Market conditions • Funding uncertainty • Cost of environmental compliance
Final Design	<ul style="list-style-type: none"> • Changes in project scope and budget • Errors or omissions in quantities, inaccurate unit prices • Changes in design requirements • Market conditions, permit requirements
Construction	<ul style="list-style-type: none"> • Contractor performance, construction quality • Final permitting, right-of-way acquisition • Unanticipated site/working conditions • Field design changes • Construction safety

2.2 The Construction Industry's Response to Risk

While it is impossible to avoid or mitigate risk entirely, risk can and must be managed to some extent (Zaghloul and Hartman 2003). As published by the FHWA,

“The business case for including risk assessment and allocation as a standard project management component of major projects is unambiguous. The ability to better understand potential risks and how to manage those risks, yields benefits far in excess of the costs of adopting risk management practices. A 1979 study by the Massachusetts Institute of Technology...found a high benefit-to-cost ratio in dealing with contractual risk through improving both contract clarity and contract management practices. The Construction Industry Institute states that there is a realistic prospect of a 5 percent cost savings through better contracting practice, of which risk identification and allocation are major components” (Ashley, Diekmann and Molenaar 2006, 4).

Thus, the motivating idea behind developing and implementing risk management tools and techniques is that when construction risks are “understood and their consequences are measured, decisions can be made to allocate risks in a manner that minimizes costs, promotes project goals, and ultimately aligns the construction team (agency, contractor, and consultants) with the needs and objectives of the traveling public” (Ashley, Diekmann and Molenaar 2006, 7).

2.2.1 Managing Risk through Project Delivery Methods

While risk can be addressed by implementing specific risk management tools and processes, it is essential that the framework of project management tools available to the project enable risk management. The framework typically used by transit agencies to manage and control risk is defined through a project delivery method (Ghavamifar and Touran 2009; Zaghoul and Hartman 2003).

The term project delivery method is used to refer to “all contractual relations, roles, and responsibilities of the entities involved in a project” (Gransberg and Shane 2010, 6). The Associated General Contractors of America (AGC) defines a project delivery method as “the comprehensive process of assigning the contractual responsibilities for designing and constructing a project” (AGC 2004). A project delivery method identifies the primary parties taking contractual responsibility for the performance of the work (Gransberg 2013, 10; AGC 2004). Understanding these roles, relationships, and responsibilities, as defined by the project delivery method, is essential for assigning risk ownership.

“A construction project’s success can be measured by how its delivery method controls scope, costs, schedule, and quality” (Dodson 2013, 1). These delivery methods also contribute to

risk management by establishing roles and processes to facilitate problem-solving by the project team. Because the project delivery method will become the framework for management of the project, special consideration must be taken to fit the project delivery method to the needs of the project, as well as the risk factors that must be addressed. Responsibilities for meeting project objectives relating to cost, quality, and time vary with each delivery method, and thus each delivery method offers a different level of risk to the project team members (AIA and AGC 2004). While many risk management processes and tools may be successfully applied for the management of risk in any project delivery method, some project delivery methods may be better suited to the application of risk management processes in specific projects as explained further by this research.

2.2.2 Balancing Risks Associated with Quality, Schedule, and Cost

In a 2006 textbook on alternative project delivery by D.D. Gransberg, project delivery methods are graphically compared to a stool with three legs, with each one representing quality, schedule and cost, respectively. The stool itself represents a “fair and stable contract,” showing that instability in any one of those three areas diminishes the overall stability of the contract and delivery of the project (Gransberg & Shane 2010, 13). Balance between the three legs, demonstrates the effectiveness of a project delivery method. This analogy is used to compare the benefits and disadvantages of common project delivery methods in their ability to address quality, time, and cost. Each of the three major project delivery methods attempts in a different way to secure one or multiples of the three legs in order to create a fair and stable contract (Gransberg and Shane 2010). Figure 1 illustrates this example.

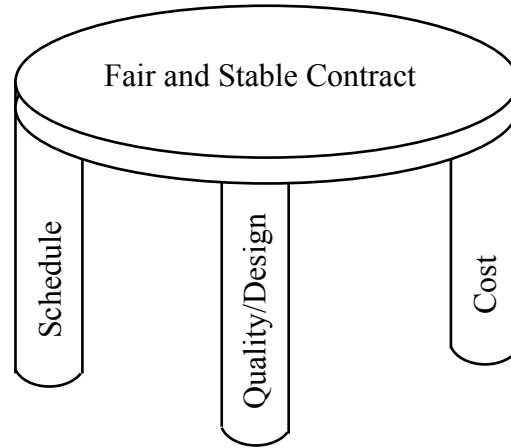


Figure 1: Fair and Stable Project Delivery Concept

The three most common project delivery methods for transit projects included in the scope of this research are Design Bid Build (DBB), Design Build (DB), and Construction Manager/General Contractor (CM/GC), the latter often equated with Construction Manager at Risk in vertical construction (Ghavamifar and Touran 2009). Research has shown that while no single delivery method is right for all projects, one delivery method is optimal for each individual project (Tran et al. 2013).

Any of these three projects delivery methods can effectively minimize some of the risk associated with civil construction. Closer inspection exposes each method's effectiveness at managing highway industry-related and project-specific risks. In order to select the most appropriate project delivery method for the project, owners must develop a number of criteria based on the particular project and then compare the characteristics of the delivery method, and how they would positively affect those criteria. One of the most essential of these criteria is the "ability to manage risk effectively and exert control over the project" (Ghavamifar and Touran 2009, 230).

2.3 Design Bid Build (DBB) Project Delivery

Design Bid Build (DBB) is the most traditional and familiar delivery method for highway projects (Gransberg 2013). “For most of the 20th century, public work has been routinely built using the DBB delivery method” (AIA and AGC 2004). In DBB project delivery, an owner completes a design either through an agency’s in-house design professionals or by contracting with a consultant to provide design services. Following design completion, the owner becomes responsible for the design, warranting the quality of the construction documents to the contractor. The designer and contractor are not contractually obligated to one another (Gransberg 2013, 10). Typically, public DBB projects are awarded to the lowest responsible bidder following advertisement (AIA and AGC 2004). Figure 2 shows graphically the contracts and communication under DBB project delivery.

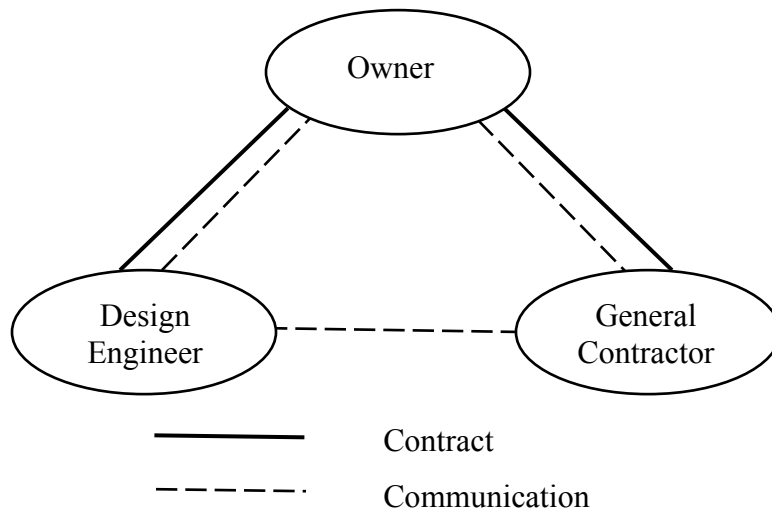


Figure 2: Design Bid Build Project Delivery

2.3.1 Managing Risk through DBB Project Delivery

Because of the price-competitive selection process used under DBB, the owner runs the risk that his project team may not be sufficiently qualified to actualize a demanding project to the required quality specifications. The owner also assumes risks related to errors and omissions in the design, leaving him responsible for mistakes in the drawings or specifications after approval of the construction documents (Ghavamifar and Touran 2009; Kenig 2011). The design, bidding and construction phases may stretch over multiple construction seasons, risking price inflations or the possibility of scope changes. Likewise, the project schedule is linear, eliminating the possibility of starting construction before the design is finished (Gransberg 2013, 10). DBB also provides few protections to the owner against risks and additional costs that can stem from an incomplete or unfeasible design, or conditions not fully understood by the engineer during design (Kenig 2011).

Under DBB arrangements, adversarial relationships often develop between the parties (Gransberg 2013, 10). DBB project delivery is characterized by minimal builder input to the design. In most cases, design has been completed before a contractor is consulted. The owner relies on the designer's input alone for any constructability review and "trusts the designer to ensure that the design does not exceed the budget" (Gransberg and Shane 2010, 7).

While a competitive bid may promote competitive cost initially, the costs associated with potential changes and overruns require substantial owner and contractor contingencies for a DBB project to remain within a project's budget. Research has shown that DBB projects have a higher average growth in costs than projects delivered with alternative methods (Gransberg 2013). An NCHRP Report by the Transportation Research Board on Best-Value Procurement Methods for Highway Construction Projects stated that under DBB "there is no contractual

incentive for the builder to minimize the cost growth in this delivery system. Indeed, there can be an opposite effect. A builder who has submitted a low bid may need to look to post-award changes as a means to make a profit on the project after bidding the lowest possible margin to win the project” (Scott et al. 2006).

Researchers state that these factors contribute to DBB’s risk-adverse culture. Low bidding procurement practices, design completion prior to contractor input, and the use of prescriptive specifications can also inhibit contractor innovation and extend delivery time. The thorough risk identification and risk allocation possible through alternative delivery methods “can promote thoughtful risk taking that can result in more efficient project delivery” (Tran et al. 2013, 9).

2.4 Design Build (DB) Project Delivery

DB is a more recent response to project delivery that has quickly grown in reputation in civil infrastructure projects over recent years. According to a recent study, DB is used by over 80% of DOTs, the majority of them transitioning to the process in the 2000’s (NCHRP 15-46 2014). Under DB project delivery, and owner contracts both design and construction services to a single entity known as a design-builder. The design-builder can be led by a construction firm having contracted a design engineer made responsible for the design, or design engineer having procured the services of a general contractor, a joint venture, or multiple other combinations (AIA and AGC 2004). The owner develops the essential project requirements, or the performance standards the agency will require, and presents these standards in the form of a Request for Qualifications or Request for Proposal. The DB entity is typically chosen by the owner based on qualifications and a firm, fixed price provided in its proposal, and then becomes

liable for all design and construction costs (El Wardani et al. 2006). Figure 3 represents contracts and communications under DB project delivery.

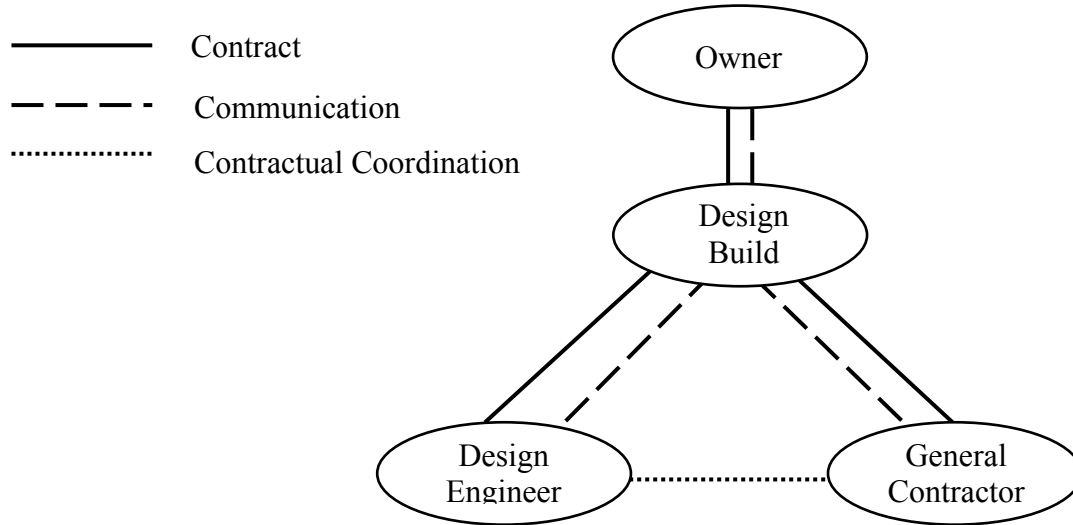


Figure 3: Design Build Project Delivery

2.4.1 Managing Risk through DB Project Delivery

The DB project delivery method mitigates some of the risks that the DBB project delivery method does not, by a contractual partnership formed between the designer engineer and contractor. This increases the quality of the design through constructability input (Gransberg and Shane 2010). The DB entity is also committed to cost certainty early in the delivery process, which is beneficial for the owner and his funding sources. Additionally, DB gives the project team the greatest ability to compress the project delivery period and as a result is often used for ‘fast-track’ projects (Alder 2007). A report to Congress by the FHWA provided a summary of the performance of DB projects, stating that on average DB projects may reduce overall project

duration by 14%, decrease the total project cost by 3%, maintain the same level of quality, and lessen the number of change orders when compared with DBB projects (Tran et al. 2013, 3).

One major appeal of DB delivery is the ability of the owner to delegate almost all project risk to the DB entity, because the design-builder literally controls the project delivery process following the award of the contract (Gransberg and Shane 2010). However, this delegation of risk to the design-builder, while arguably the greatest benefit of DB, can also impact the effectiveness of DB in some highway construction applications (Kenig 2011). Researchers state that where the risk relates to the “environment, ground conditions, political issues,” and the need for community relations is high, “simply selecting DB to transfer those risks is not a good option because the risk factor is considered by the bidders in the proposal and the owner will receive highly priced proposals, especially if the contractor is selected mainly based on price” (Ghavamifar and Touran 2009, 231). Under DB the owner runs the risk of losing control over the design, as both design and construction are delegated early on to the DB entity. The “transfer of risks...gives the power and responsibility to the DB contractor to have a better control over design and construction phases of the project” and as such, decreased owner control over the project (Ghavamifar and Touran 2009, 231).

Innovations developed by the DB entity belong to the design-builder and as such may not benefit the owner’s future projects (Alder 2012). Also, though DB can benefit from innovation, risk management, and process improvement savings, after contract award any additional savings go to the contractor and not the owner (Alder 2012). Additionally, cost and schedule as determined early in the process are not flexible to adapt with the owner’s needs if they change over the course of the project. This could potentially lead to costly change orders, endangering the project budget. Also, given the impact of changes, overruns, and risk-related contingencies

on project cost, it is difficult for agencies to understand just how much it costs to delegate project risk to the design-builder.

While this delivery method transfers more risks to the design-builder at the outset, changes in scope in DB projects are usually more costly. “If an owner has not fully defined the scope and needs to have more control over the project to change its direction, he should not choose a delivery method that ‘freezes’ the project early, although it may transfer more risks to the contractor at the outset. Changes in scope in DB...are usually more costly” (Ghavamifar and Touran 2009, 231).

One author used the example of a light rail project performed in two phases, one by DBB delivery and one by DB delivery method. The observation offered following the project’s completion was that “the level of owner’s control over the scheduling of the project was far less during the design phase in the DB project which resulted in some delays in the project; also, less control over construction diminished the quality of the systems” (Ghavamifar and Touran 2009, 231). Other experts have suggested that when the owner needs more control over the contractor’s means and methods, if the project is located in a densely populated area, or is characterized by significant risk requiring owner control, DB may not be the best response (Ghavamifar and Touran 2009).

2.5 Managing Risk through Innovation

Additional responses for managing risk associated with construction come from applying problem-solving innovations in materials, means and methods, and even delivery framework. Robert E. Skinner Jr., executive director of the National Research Council Transportation

Research Board gave the following four main factors that contribute to the “urgent and continuing need for innovation” (Skinner, Jr. 2008, 6).

1. The highway industry experiences a continual increase in traffic volume and loadings, demonstrated by U.S. Department of Transportation estimates that the annual cost of traffic congestion in metropolitan areas for businesses and citizens is nearly \$170 billion (Skinner, Jr. 2008).
2. Traffic disruptions in highway construction must be kept to a minimum. Disruptions such as lane and roadway closings, especially those in major metropolitan areas often require that repair and reconstruction operations be done at night, “which introduces a variety of additional complexities and safety issues” (Skinner, Jr. 2008, 6).
3. Environmental, community, and safety requirements involved have become more stringent. “Designs to promote safety, measures to mitigate a growing list of environment impacts, and attention to aesthetics have fundamentally changed the scope of major highway projects in the United States. For example, on Maryland’s \$2.4 billion Intercounty Connector project...environmental mitigation accounts for 15 percent of project costs, or about \$15 million per mile” (Skinner, Jr. 2008, 7).
4. Costs continue to rise. While building and maintaining highways in a cost effective manner is the goal of engineering, cost increases in highway construction have grown “due in part to the expanded scope of highway projects and construction in demanding settings” and the rising cost of “mainstay materials—Portland cement, asphalt binder and steel” because of China’s

construction binge. “The FHWA’s cost indices for Portland cement concrete pavement, asphalt pavement, and structural steel increased by 51 percent, 58 percent, and 70 percent respectively between 1995 and 2005” (Skinner, Jr. 2008, 6).

Innovations can provide the response to these and other industry risks. Skinner listed a few examples of recent innovation or innovation areas impacting the industry: the Superpave design system, prefabricated components, use of specialty Portland cement concretes and waste/recycled materials, visualization tools, and global positioning systems (Skinner, Jr. 2008). He also noted that “challenges to the U.S. highway system will be even more daunting” in the future and require a commitment to innovations that address “materials, roadway and bridge designs, design and construction methods, road safety, and a variety of environmental, community, and aesthetic concerns” (Skinner, Jr. 2008, 11).

2.5.1 Innovative Contracting

Innovative contracting techniques provide additional responses for risk management and innovation to meet project and customer goals. Both DB and CM/GC delivery methods are considered innovative or alternative contracting methods. A+B (time plus cost) bidding, an additional contracting method, provides a means to allocate the risk for early completion to the contractor to achieve a customer goal of satisfaction with service. As another example of innovative techniques, lane rental provides a means to allocate the risk for creating congestion during construction to the contractor. Likewise, warranties provide a means for passing long-term performance of the facility to the contractor. These and other innovative methods and techniques provide a means for “aligning the construction partner’s goals with the customer

goals, and they can be effective when used on the right project” (Ashley, Diekmann and Molenaar 2006, 34).

In 1990, the FHWA implemented “Special Experimental Project No. 14 – Innovative/Alternative Contracting” (SEP-14) to provide a means for evaluating project-specific recommendations for risk allocation in innovative contracting practices. Many innovative methods—such as A+B (time plus cost) bidding, lane rental, and warranties—have become mainstream and no longer require SEP-14 approval on projects with Federal-aid financing (Ashley, Diekmann and Molenaar 2006). With the passage of Moving Ahead for Progress in the 21st Century (MAP-21), an act funding surface transportation programs and transforming the policy and programmatic framework for infrastructure development, SEP-14 approval is no longer required for State DOTs to use CM/GC so long as their state statutes allow for it (FHWA 2012).

Another step promoting innovative practices is the FHWA’s Every Day Counts (EDC) initiative. In June 2010, the EDC was introduced to accelerate the implementation of innovative practices (Gransberg 2013). According to FHWA Administrator Victor Mendez, the purpose of EDC is “to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment” with the intent of pursuing “better, faster, and smarter ways of doing business” (Gransberg 2013, 10). EDC focuses on a set of initiatives, encourages FHWA teams to work with state, local, and industry partners to implement the initiatives and develop performance measures to gauge their success. The first group of innovations was identified in 2010, followed by another set of initiatives in 2012 (FHWA 2012). Both CM/GC and DB were initially two of the 13 EDC initiatives (Gransberg 2013).

2.6 CM/GC Project Delivery in a Highway Application

CM/GC project delivery has been experimentally implemented by a small number of public agencies as an innovation in project delivery. While CM/GC is often equated with Construction Management at-Risk (CMAR), a project delivery method widely known and used in the vertical construction arena, the differences between the two delivery methods should be noted in the context of a highway application. In both CM/GC and CMAR, a project owner contracts with a construction firm to act as a construction manager, offering preconstruction services during the design phase of a project. This may include the contractor's field-tested input regarding constructability, value engineering, material choices, possible alternates and the actual construction schedule (AIA and AGC 2004). Then, having participated in the development of a design that is both complete and feasible because of the construction manager's input, the construction firm has the sufficient background to submit an accurate Guaranteed Maximum Price (GMP). After that GMP is accepted by the owner, the construction firm assumes the role of general contractor to physically complete the project during the construction phase (FHWA 2012; Kenig 2011). Two contracts are involved; one for preconstruction services during design and the other for the construction" (Gransberg 2013, 11).

Within vertical construction CMAR exists essentially as a tool for owners with little construction internal experience or limited time and opportunity to manage a complex construction project (Schierholz, Gransberg and McMinimee 2011). The CM is put "at-risk" because it holds the trade contracts and is responsible for delivery at the GMP (AGC and NASFA 2007). Because the segments of the project performed by specialty contractors are competitively bid, the general contractor's overall GMP is essentially a compilation of

competitive bids plus his own fee, meaning that the actual cost of construction would be comparable to a competitively-bid DBB project.

In a CM/GC project the awarded contractor, who was chosen partially because of the organization's civil construction specialty experience, will generally self-perform a significant portion of the work. Less of the GMP is comprised of competitive subcontractor bids. It is therefore more difficult to compare the GMP the contractor proposes to the project cost if bid competitively through DBB. In this situation the construction manager/general contractor holds less risk associated with holding subcontractor bids; therefore the name Construction Manager at-Risk doesn't clearly represent the highway application of this delivery method.

Another difference centers on the involvement of a sophisticated, highly-involved project owner, the public agency itself. The agency, representing the interests of the public, typically has the knowledge and experience to manage the project, but gains added benefits from the early involvement of the integrated project team, especially from involvement of the contractor. The contractor's input is necessary to deliver crucial expertise and innovation, while allowing the agency to maintain control over the overall design, budget, and schedule and hold construction cost contingencies. The agency's project manager relies on the information provided to him by an involved and knowledgeable project team, while still maintaining the ability to make project decisions himself.

CM/GC project delivery is meant to further reduce the risk associated with construction by promoting an integrated team approach to problem solving early in the design process and throughout construction. The selection of the engineer and contractor are based on qualifications, allowing the owners to select a team that they have confidence will provide "quality workmanship, dependable performance, fair and reasonable pricing, and efficient

management” (AGC and NASFA 2007, 14). Both the design and construction processes are directed by the owner, allowing him control over the design and flexibility in meeting the changing needs of the project.

Users of CM/GC project delivery claim “enhanced constructability, real-time construction pricing capability, and speed of implementation,” all beneficial characteristics for the transportation industry (Gransberg and Shane 2010, 9). Unlike DBB, CM/GC brings the builder into the design process at a stage where definitive input can have a positive impact on the project. CM/GC has also been used to implement new and innovative technologies because the typical CM/GC project environment is rich in collaboration, even for delivering complex projects (AGC 2004). In the CM/GC delivery method, “there is much more flexibility and ability to handle the unexpected and there is a level of control over the design process that is not possible within an arrangement where the designer and constructor are contractually linked” (Ghavamifar and Touran 2009, 232). Figure 4 represents a typical CM/GC contract and communication set-up.

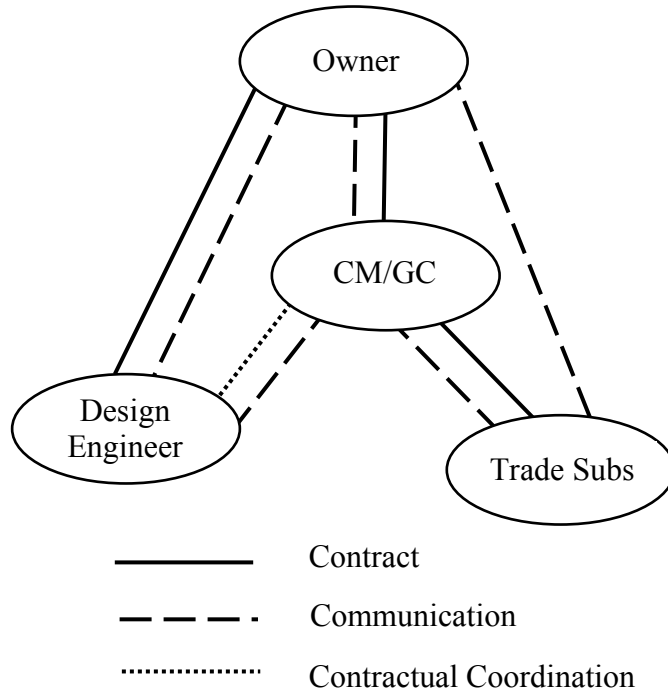


Figure 4: CM/GC Project Delivery

2.6.1 CM/GC Processes

The CM/GC process typically includes concept development, design and preconstruction, and construction. During the concept development phase the contractor is selected for use by the agency based on criteria applicability, the agency seeks appropriate state or federal approvals, and develops a consulting scope with associated costs. The agency negotiates the selection of a consultant, based on response to a Request for Qualifications or from a consultant pool, and develops an initial staffing plan, financial plan, schedule, and cost model (FHWA 2011).

The design team develops and advertises a Request for Proposal (RFP) and selects a contractor to provide input during the design phase. The selection is typically based on technical proposal, price proposal (in UDOT best value selection), and interviews (UDOT 2011). The contractor then contributes to design development by verifying designer’s assumptions, breaking

the project down into tasks and estimating the costs, duration and sequence of the tasks, identifying risks and mitigation efforts, identifying possible innovations, identifying and pricing design alternatives (FHWA 2011). The contractor provides “potential solutions to problems and highlighting areas where costs can be reduced without compromising the overall success of the project” (FHWA 2011, 1).

The GMP is developed through a negotiation phase. The contractor participates in blind bid openings with engineer and Independent Cost Estimator (ICE) estimates to identify and resolve any bid items more than 10% above engineer and ICE estimates. The final bids are submitted and the agency chooses to award the contractor with the construction contract, or severs the CM/GC process to prepare the project for DBB (FHWA 2011). CM/GC delivery owners are not liable for payment of costs above the GMP threshold, as long as the scope of the project does not change. If agreement cannot be reached on the price, “the owner can pay off the preconstruction contract and can advertise the completed design for bids, as in DBB” (Gransberg 2013, 11). UDOT calls the GMP a Targeted Maximum Price (TMP).

During the construction process, construction proceeds as normal, with the exception that the designer is expected to participate in problem solving during construction. The team follows up on risks that were initially identified by the integrated team in the design phase. Also, the design and construction phases may overlap under two types of early construction contracts:

- Early procurement, for the obtaining of long-lead items in time for construction start, and
- Preliminary phases of work, released in order to begin some early phases of construction while remaining elements of design are finalized (FHWA 2011).

These early contracts are separate from the rest of the project. This way the agency has the option to selecting a different contractor for the remaining work. Figure 5 shows a comparison DBB, DB and CM/GC delivery timelines.

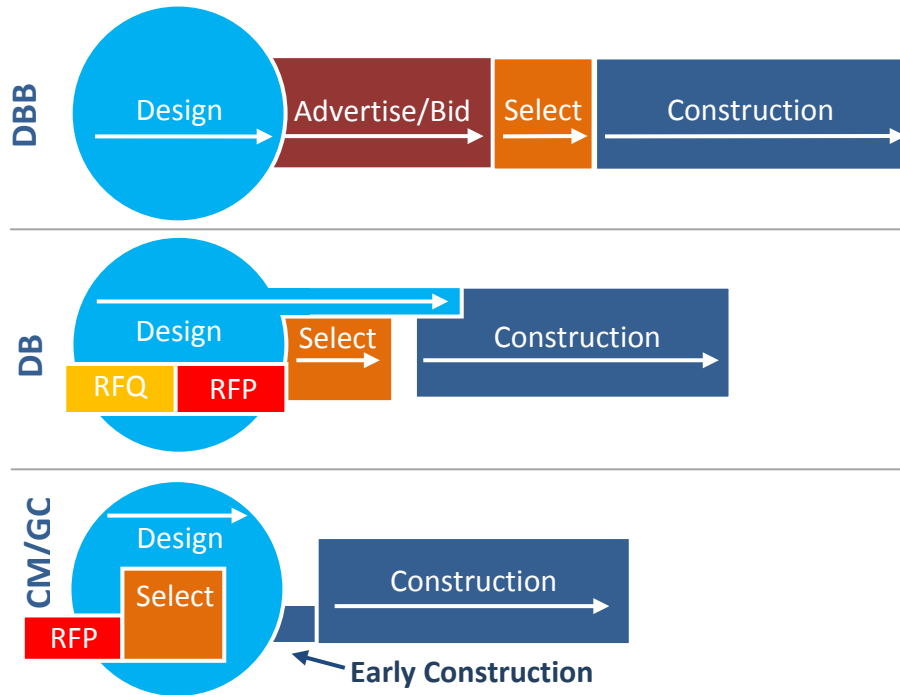


Figure 5: Delivery Timeline Comparison

2.6.2 Roles and Responsibilities of Associated Parties

When compared with typical DBB and DB contractor responsibilities, the responsibilities of contractors under the CM/GC delivery method are unique. In a DBB project, roles are well-established and broadly documented. Contractor responsibilities are comparable each time. In DB, roles are established and documented on a project-by-project basis for roles (AIA and AGC 2004). Under CM/GC delivery specific contractual arrangements determine the roles of the

players (AIA and AGC 2004). Table 2 is based on typical services provided by the contractor (AGC 1991; AGC and NASFA 2007).

Table 2: CM/GC Responsibilities by Project Phase

Project Phase	CM/GC Services
Preconstruction	<ul style="list-style-type: none"> • Scheduling • Value Analysis • System Analysis • Constructability Reviews • Progress Document Reviews • Subcontractor Involvement and Prequalification • Subcontractor Bonding • Budgeting and Price Guarantees <ul style="list-style-type: none"> -Schematic Documents Budget -Design Documents Budget -Construction Documents Budget • Contingency Planning • Periodic Cost Estimates/Pricing Alternates • Setting Guaranteed Maximum Price (GMP)
Construction	<ul style="list-style-type: none"> • Team Management and Coordination • Scheduling • Cost Forecasting • Cost Control and Change Order Management • Submittal Process • Subcontracting • Field Management • Safety Programs • Quality Programs • Project Close Out Process

2.6.3 The Current Application of CM/GC Project Delivery

As explained previously, the FHWA's implementation of Special Experimental Project No. 14 (SEP-14) allowed state DOTs to evaluate non-traditional contracting techniques like CM/GC for potential approval for wider use. SEP-14 was originally used to evaluate then

experimental or non-traditional processes and tools such as cost-plus-time bidding, lane rental, warranty clauses, and even DB project delivery. Following evaluation, these practices were found suitable for general application. Under SEP-14 procedures, state DOTs were required to submit a work plan through the local FHWA Division Office, as well as to FHWA Headquarters for review and approval of CM/GC projects (FHWA 2012). New transportation legislation, through MAP-21, has provided significant incentives for state DOTs by reducing the state's share for CM/GC projects from 10 percent to 5 percent, and authorizing CM/GC for routine use "without having to file for experimental project permission" (Gransberg 2013, 14).

With the passage of MAP-21, SEP-14 approval is no longer required for State DOTs to use CM/GC so long as their state statutes allow for it" (FHWA 2012, 1). A recent NCHRP study, Construction Manager-at-Risk Project Delivery for Highway Programs, found that "only three states have experience delivering projects with CM/GC" (Tran et al. 2013, 3). "By 2011, 44 states had full authorization to use DB and 14 states had full authorization to use CM/GC" (Tran et al. 2013, 3).

Recently FMI Consulting and the Construction Management Association of America conducted a study based around owners' perceptions of various project delivery methods (Doren et al. 2005). In areas where CM/GC had been introduced, owners were asked which delivery method was used most frequently. DBB was reportedly used 66% of the time while CM/GC was used 19% of the time. "However, when asked which method delivers the best value, both [CM/GC] (35%) and DB (29%) rated higher than DBB (23%) (Gransberg and Shane 2010, 27; Doren et al. 2005, italics added for emphasis). The same study also states that while public and government organizations predominately use DBB, "many have tried other methods and most would consider either [CM/GC] or DB to be the best value alternatives. Changing the delivery

methods used, in the case of these organizations, will often require changing laws and politics, but that is happening too. Because the public is best served when it gets the best value for its tax dollars...[CM/GC] will likely become the dominant delivery method for this group as long as the experience is positive” (Gransberg and Shane 2010, 27; Doren et al. 2005).

2.6.4 State Experience

Currently UDOT leads the U.S. in CM/GC experience (NCHRP 15-46 2014, Gransberg 2013). In 2006, UDOT entered into an agreement with the FHWA to implement and evaluate a series of experimental CM/GC projects. Federal funding was initially authorized for 24 UDOT CM/GC projects over a 2-year period. 24 additional projects were authorized for state-only funding (Alder 2007). Until changes in legislation occurred in 2012, at the end of each year UDOT submitted a report of their findings, gauging project results against their developed performance measures in order to develop an ever-improving model (Alder 2010). At the publication of the most recent Annual Report, UDOT had 22 Federal and State CM/GC projects either approved, in selection, in design, under construction or completed (Alder 2012).

A survey conducted in 2009 by the Transportation Research Board meant to identify state DOTs with CM/GC experience showed that additional CM/GC use in highway construction was limited. Florida DOT had used CM/GC for projects with significant vertical construction, such as the \$1.3 billion multi-modal center in Miami. Arizona’s experience with CM/GC was mostly at the county and municipal level where agencies had developed programs for CM/GC delivery. Alaska, Oregon, Nevada and Colorado each reported growing CM/GC experience, while other states such as Washington and Wyoming expressed interest in implementing CM/GC projects on a pilot basis. Some states, such as Texas expressed their view that CM/GC was not appropriate

for horizontal projects, and others had neither experience nor knowledge of CM/GC (Gransberg and Shane 2010).

Since the approval of the research needs statement for a recent NCHRP Project, the number of state DOTs with authority to use CM/GC to deliver construction projects has risen from five to 14. Connecticut and Minnesota had received enabling legislation by May 2012. The California House of Representatives also unanimously passed a bill supporting CM/GC that same month. Maine, Massachusetts, and Tennessee are actively pursuing legislation. On the survey for NCHRP Project 10-85 Maryland, Missouri, Mississippi, and Montana indicated that they may have authority to use CM/GC but have not tested it.

Growing interest was also evidenced by an FHWA-hosted a CM/GC peer exchange in Boston, Massachusetts, in May of 2012, where representatives from 32 DOTs participated in CM/GC training and heard presentations from state DOTs that have used the approach” (Gransberg 2013, 14). Figure 6 demonstrates implementation of CM/GC nationwide as reported by the FHWA in 2012. These numbers have increased over the last year. The growing interest in CM/GC and corresponding state experience demonstrated in the previous paragraphs evidence the need for research and training about CM/GC, partially completed by this thesis.

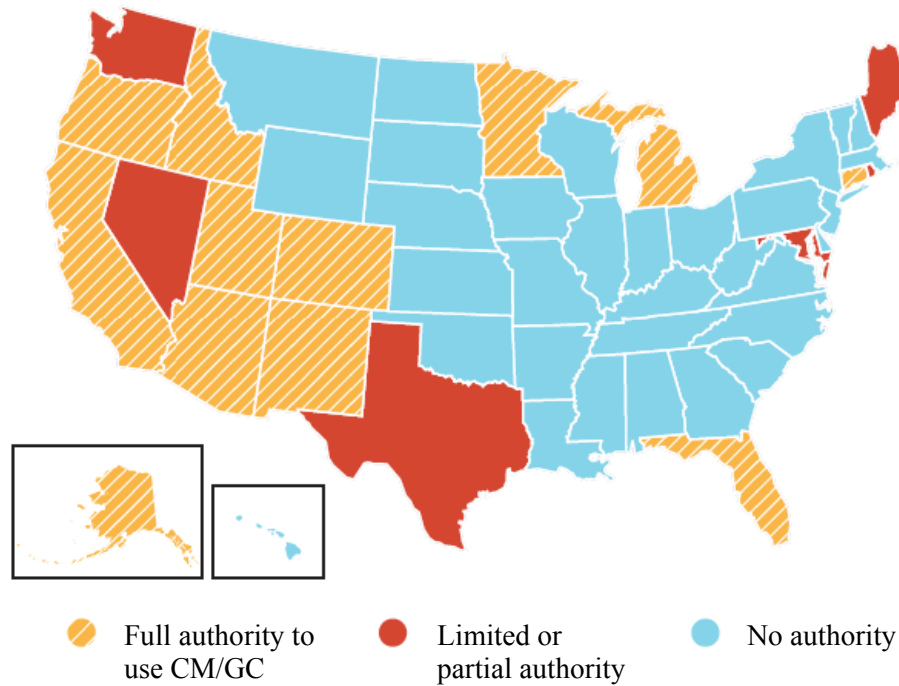


Figure 6: Use of CM/GC; FHWA Division Office Survey as of 2012

2.6.5 Risk Allocation and Contracting Methods

There is a significant relationship between trust and risk allocation that can result in cost savings in the construction industry (Zaghloul and Hartman 2003). The contract is “the vehicle for risk allocation” and “defines their roles and responsibilities for risks.” The allocation of risk in any contract affects cost, time, quality, and the potential for disputes, delays, and claims. In fact, contractual misallocation of risk has been found to be “a leading cause of construction disputes in the United States” (Ashley, Diekmann and Molenaar 2006, 31).

Reaching a better risk allocation process can be done by encouraging a relationship of trust between the contracting parties first. Research on the cost of mistrust in the construction industry supports the following principles necessary for trust building:

- Develop a clear understanding of the risks being born by each party, and who can best own or manage that risk;
- Invest significant time and effort at the front end of a project and significant experience to manage or mitigate the risks, and to administrate the contract;
- Include a negotiation phase prior to the start of the contract;
- Promote an adequate risk sharing or risk reward system to share the benefits if the risk does not occur during the project life cycle (Zaghloul and Hartman 2003).

Allocating risks to the party best able to manage them will ultimately result in the lowest overall price because contractors will not be forced to include contingencies for possible financial losses or take gambles in an extremely competitive bidding environment. Inappropriate risk shifting from the owner to the contractor can result in misaligned incentives, mistrust, and an increase in disputes” (Ashley, Diekmann and Molenaar 2006, 31-32).

Research indicates that the ideal project delivery method is one that “facilitates risk transfer but still gives the owner a high level of control over the project” (Ghavamifar and Touran 2009, 230). Yet there is a tradeoff between risk and control, meaning that if a delivery method allows an owner to transfer risk, that same method will limit the owner’s control over the project, and vice versa. A project delivery method allows the project owner to:

- 1) Transfer the risk and accept the higher cost that the contractor requires to manage it, or
- 2) Exert more effort into planning and controlling the risk himself (Ghavamifar and Touran 2009).

DB relies on the first method: the potential risks associated with the project are assigned to the design-builder, who offers a firm, fixed price to complete both design and construction of the project. DBB follows the second method more closely: The owner exerts control over the

project by completing project design and guaranteeing the accuracy of the design to the contractor before a fixed price and construction start.

Most project delivery methods do not allow for the simultaneous use of both approaches; however, in a CM/GC approach to risk management the project team members, including the contractor, contribute to planning and controlling potential risks in conjunction with the owner during preliminary design phases by contract (Ghavamifar and Touran 2009). Improved information and scope definition in uncertain areas of the project, such as underground conditions, decreases risk. Remaining risk can then be transferred, as the owner chooses, when the contractor offers a fixed price for the construction phase of the project that the contractor is already familiar with. Thus, the owner is benefitted by transferring some project risks “while retaining some important controls over the project” (Ghavamifar and Touran, 2009, 232).

Figure 7 demonstrates the differences between the three major project delivery methods in terms of their ability to distribute risk and control between the owner and the contractor. DBB is represented by high owner control and minimal risk transfer; DB leans towards more risk transfer and minimal owner control. CM/GC is placed in between DBB and DB on the risk/control scale, showing a more even distribution of risk and control.

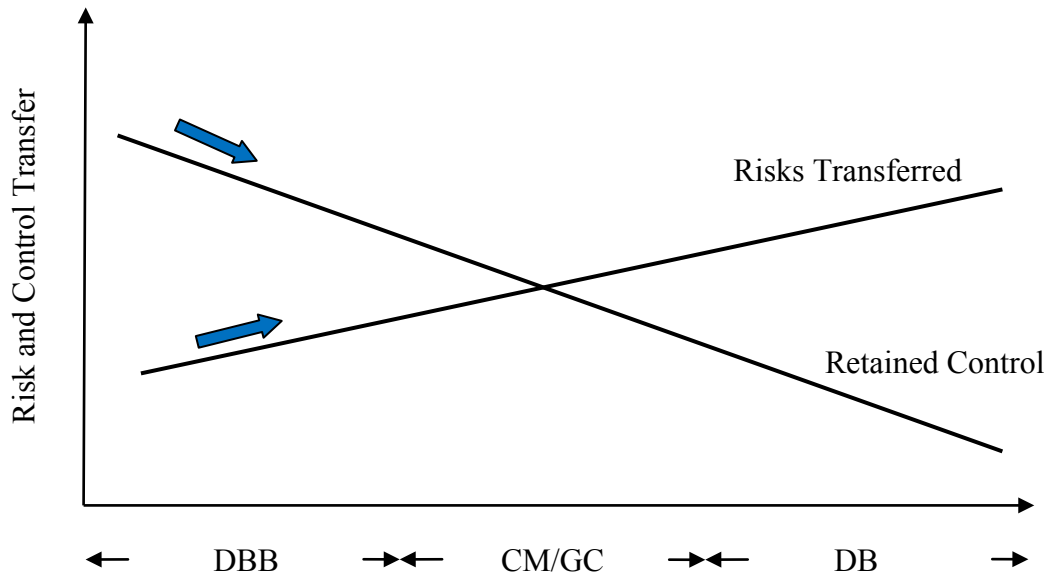


Figure 7: Risk and Control Transfer in Delivery Methods

2.7 A Comparison of Delivery Methods for Risk Management

Returning to the analogy comparing a fair and stable contract to a three-legged stool, each of these project delivery methods anchors certain aspects of project delivery by contract in order to manage risk and meet project objectives (Gransberg and Shane 2010). In DBB delivery, contractors bid on complete construction documents, addressing quality-related risk, and commit by contract to meet the project’s completion date, addressing schedule-related risk. Cost-related risk is also addressed by contract, yet contractor bids will vary on cost to deliver the specified quality within the specified time, and changes are typical.

In DB, the design-builder guarantees a lump sum proposal, addressing cost-related risk. The schedule-related risk is also fixed by contract. The variable leg is quality, which could fluctuate with interpretation and ability of the design-builder. Also, “if the contractor has miscalculated the bid because the design was not complete the only way to recuperate financially

is to sacrifice quality because cost and schedule are fixed” (Alder 2012, 13). Quality may change because the owner no longer controls details of the design.

The difference with CM/GC delivery partially results from contractor input during project design. By early involvement, the sophisticated owner and an experienced contractor and designer are encouraged to optimize quality, schedule and cost before each is fixed. For example, the contractor “reduces project risks by reducing the potential constructability conflicts, while working under the owner’s control” (Ghavamifar and Touran 2009, 232). Thus, CM/GC “holds potential for developing the high degree of collaboration necessary to maximize quality within the project’s time and cost constraints without the interference of the contracts” (Gransberg and Shane 2010, 13). Because of the scope of responsibilities and contractual relations in this delivery method, some experts believe that “[CM/GC] theoretically reduces the amount of risk for every entity involved in the project” (Ghavamifar and Touran 2009, 232). Responses from two DOTs (Lee 2008; Alder 2007) confirm the inference that CM/GC “may be used on projects where the owner desires a high degree of collaboration but wants to maintain control over the design and other salient aspects of the project” (Gransberg & Shane 2010, 9).

The information contained in this chapter regarding the presence of risk in the civil construction industry and the industry’s current response through DBB and DB project delivery methods as well as innovation provides an appropriate setting for discussing the value of CM/GC to the civil industry. An additional project delivery tool that manages process risks related to quality, schedule, and cost, and provides an appropriate environment for owner control over effective project risk management and innovation is what the industry needs to handle the complexity of projects typical in the transportation sector. For these reasons, there is growing

interest in CM/GC and the corresponding need for additional research to better understand CM/GC processes and training for the individuals investigating implementation.

3 MEANS AND METHODS

The purpose of this research was to demonstrate the effect of CM/GC project delivery on the critical project components of innovation and risk, meeting the objectives previously stated in Chapter 1 of this document. These objectives were met through three primary means: an extensive review of existing literature concerning CM/GC use, an analysis of CM/GC project reports, peer exchange materials and data, and a survey of industry members with CM/GC project experience.

3.1 Analysis of State CM/GC Reports and Data

An analysis of existing CM/GC reports and data provided the background for the response of CM/GC to process risk, project specific risk, and innovation. Prior to approval of current legislation, UDOT compiled an annual report of CM/GC projects completed or in progress during each year, in order to comply with an agreement between the UDOT and FHWA. These reports dating from 2007 through 2011 contain information regarding “UDOT’s knowledge regarding the benefits of CMGC, the performance of CM/GC projects as compared to traditional projects, the best applications of CM/GC, and UDOT’s formal CMGC process” (Alder 2010, 4). They contain summarized information from approximately 22 CM/GC projects either completed,

under design or under construction in the last 6 years, including the analysis of budgets, schedules, innovations, and other performance measures, and claim to be “the most comprehensive analysis of CM/GC available for horizontal construction” (Alder 2012, 4) .

Additionally, since 2007 UDOT has compiled multiple project reports as separate analyses of individual UDOT CM/GC projects, as well as project team interviews containing lessons learned during each specific project, successes within the project, and challenges the project faced. The project reports include a comparison of cost estimates and evaluation criteria for the individual project including: risk, benefits to the public, design and constructability, innovation, and learning opportunities.

An external analysis of this data, project presentations, as well as materials provided by a CM/GC Peer Exchange in 2012, meet the objectives of this thesis by providing a synthesis of the actual current use of CM/GC by departments of transportation that lead the nation in CM/GC experience. It is also a means to understand the owner, or public agency’s perception of CM/GC effectiveness, in order to be contrasted with the contractor and design engineer’s perceptions. The analysis also aids the identification of areas of improvement. Additionally, these materials provided the necessary information for CM/GC project case studies showcasing innovation and risk management.

3.2 Survey of CM/GC Project Participants

Objectives of this research were furthered by a survey investigating the perception of CM/GC-experienced contractors, owners, and designers about the delivery method’s response to managing construction process risks (relating to quality, schedule, and cost), project specific risks, and innovation. Characteristics of the heavy civil industry, such as “dynamic work

environments, transient nature, exposure to the elements, coordination of multiple trades and engineering disciplines, multidisciplinary engineering, and the workplace hazards often make traditional objective research infeasible” (Hallowell and Gambatese 2010, 100). In order to provide legitimate consensus among industry experts about CM/GC, this research included the surveys of project participants conducted using an adapted version of the Delphi Method and content analysis.

The literature review, as well as the adapted Delphi Method and content analysis, as described in this section, were critical to the success of this research. An extensive literature review was essential in developing content for the surveys. In a pre-survey trial, industry experts were then consulted prior the distribution of initial surveys for analysis of survey effectiveness. Surveys were distributed to participants and collected using the adapted Delphi method. Responses were compiled using content analysis to identify consensus and hierarchy. Finally, industry experts were consulted in identifying and providing resolution to ambiguity left by survey consensus.

3.2.1 Trial Run of Surveys

Prior to the distribution of these surveys to the three groups (owners, contractors, and design engineers), the survey questions were submitted to an industry expert with CM/GC experience for review. As it was expected that project participants, especially contractors, would have particular views and issues they wish to express, this review ensured that the survey addressed the correct areas, and phrased questions in an understandable way. Based on this review, the questions were revised before being sent to project participants for completion. A

complete list of the revised survey questions as distributed to the participating contractors is found in Appendices A through C of this thesis.

3.2.2 The Delphi Method

Based on the varied experiences of different project participants and the roles each has played within those projects, the Delphi Method is ideal for gaining a more complete consensus on the effectiveness of CM/GC project delivery. According to published literature, “the Delphi method is well suited as a research instrument when there is incomplete knowledge about a problem or phenomenon....The Delphi method works especially well when the goal is to improve our understanding of problems, opportunities, or solutions, or to develop forecasts” (Skulmoski, Hartman and Krahn 2007, 1). This method has been called particularly useful in contemporary research when objective data is “unattainable, there is a lack of empirical evidence, [or where] experimental research is unrealistic or unethical” (Hallowell and Gambatese 2010, 99). Researchers use the Delphi process to “quantify risk, impact factors, or perception of process quality” (Hallowell and Gambatese 2010, 100).

The Delphi Method is widely used for gathering data from experts in a certain subject area and then reaching an agreement about issues within that subject area. A consensus is built using a series of questionnaires delivered in iterations to first collect data from a panel of selected subjects, and then develop qualitative responses based on that data. Because of the iterations, the subjects are invited to become more problem-solving oriented and offer their opinions more insightfully than through a simple survey. The ‘staticized groups’ adaptation of the Delphi Method excludes feedback or iteration. The responses are the aggregate of the experience of experts from their initial questioning. The lack of interaction between panel

members means that members are less likely to conform to an incorrect value given by other panelists (Hallowell and Gambatese 2010).

3.3 Analysis of Survey Data

Once responses to these three surveys were gathered, responses were compared and analyzed for trends by performing a content analysis. Additional analysis allowed conclusions to be drawn between contractor, owner, and design engineer perceptions. Content analysis has been long used by transportation researchers to develop “valid inferences from a message, written or visual, using a set of procedures” (Schierholz, Gransberg, and McMinimee 2011, 5). Researchers develop a set of key words or categories by which to separate written responses. The frequency of their appearance is “computed to infer the content of the document” (Schierholz, Gransberg, and McMinimee 2011, 5). Summarizing results for the entire population permits trends to be identified and reported (Schierholz, Gransberg, and McMinimee 2011). In the case of this research content analysis provided the ability to glean information from panelists without prompting their responses. Also, context of the response was used to determine how the response should be categorized.

In determining the number of panelists to be consulted for this research, multiple studies were consulted. Hallowell and Gambatese suggest that the “specific number of panelists should be dictated by the characteristics of the study such as the number of available experts, the desired geographic representation, and the capability of the facilitator” (2010, 101) but recommend a minimum of eight panelists. Another study states that where the sample group is homogeneous, a smaller sample of ten to fifteen people can yield sufficient results (Skulmoski, Hartman and Krahn 2007).

Three groups were targeted to participate in surveys to meet the objectives of this thesis: contractors, public owners, and design engineers with past CM/GC experience. Investigations into the perceptions of these three groups, in addition to existing literature and project data, provided a wider perspective of CM/GC effectiveness and best practices than has been provided in the past. Within each survey, each group of questions was designed to meet the objectives of this thesis stated earlier in this chapter.

3.3.1 Survey of Contractors with CM/GC Project Experience

Contractors were approached to participate in this survey based on their experience with CM/GC projects, generated from the input of state agency project and division managers, as well as other CM/GC project consultants. Additional contractors were approached based on the direction of industry experts. The CMGC Experienced Contractor Survey, as found in Appendix A of this thesis, was a structured questionnaire based on an extensive review of existing literature. These questions were formatted to provide quantitative results concerning contractor perceptions of CM/GC. The survey also included open-ended questions, as recommended by literature, inviting contractors to provide explanations of their responses and recommendations to improve future CM/GC projects. Open ended, broad initial questioning widely casts “the research net” (Skulmoski, Hartman and Krahn 2007, 10).

The first set of questions for contractors with CM/GC experience addressed the top advantages and disadvantages of CM/GC projects, both to the overall project and to the contractor himself. This explained something of the contractor’s motivation to participate in CM/GC projects, and whether the claims made by existing literature were consistent with the contractor’s perception. The second set of questions was aimed at understanding how a

contractor's project roles and responsibilities may differ under CM/GC as opposed to typical project delivery methods (DBB and DB). Within this section contractors were asked to provide a scale explaining how their time and effort was spent under different project delivery methods.

The next set of questions addressed the contractor's perception of his ability to impact the principal contributing factors of a successful project under each delivery method, i.e., how well is a contractor able to impact cost, quality, and schedule under each delivery method.

Contractors were asked to provide input concerning which method of delivery (DBB, DB, or CM/GC) they would prefer, given the choice.

The last set of questions focused on risk minimization and management, as well as innovation. Based on UDOT literature (as explained in Chapter 4 of this research), it is supposed that risk in a CM/GC project is firstly, reduced and secondly, shared equally between the owner and contractor. Contractors were asked to provide their perception of CM/GC's effectiveness at enabling risk minimization, management, and risk-sharing, in order to compare this perception to UDOT's view.

3.3.2 Survey of State Agency Project Managers with CM/GC Project Experience

Project managers to be surveyed were selected based on their role in past DOT CM/GC projects. Questions asked to project managers were similar to those asked to contractors with CM/GC experience, in order to draw comparisons between the perceptions and experience of the two groups. The complete set of questions is found in Appendix B of this thesis.

As with the surveys distributed to CM/GC contractors, the first set of questions given to project managers addressed the advantages and disadvantages of CM/GC project delivery.

Project managers were then asked to analyze the project team's ability to impact project factors

impacting success such as cost, quality, and schedule, under each of the project delivery methods. Finally, project managers then identified their perception of risk minimization and management in a CM/GC project, and how that risk is shared. In addition to these questions, a set of questions asked these project managers to identify the contractor's impact on past CM/GC projects and the specific skills and abilities (individual project team member skills or general company characteristics) that allowed the contractor to make that impact.

3.3.3 Survey of Design Engineers with CM/GC Project Experience

This process was repeated in a survey to design engineers, containing similar questions to those given to contractors and owners, in order to provide an accurate view of project relationships within the CM/GC process. The design professionals surveyed had past experience with CM/GC projects. The complete survey is found in Appendix C of this thesis.

4 ANALYSIS OF RESULTS

This chapter explores three predominant themes: the ability of CM/GC processes to address 1) the construction process risks related to quality, schedule, and cost, 2) project specific risks, and 3) innovation. This chapter further examines the differences in perception, regarding CM/GC effectiveness, between contractors, owners, and design engineers. This information is principally based on the compiled survey responses of those with field experience in CM/GC projects.

4.1 Analysis of Advantages and Disadvantages of the CM/GC Process

A portion of the scope of this research was to present the benefits and disadvantages of the CM/GC processes as they affect a project team's ability to manage construction process risk, project specific risk, and innovation. Information on these benefits and disadvantages spurs interest in CM/GC project delivery. In a 2008 presentation to the Western Association of State Highway and Transportation Officials, Jane Lee of Oregon DOT provided one such list of reasons Oregon implements CM/GC:

1. "Collaboration and cost control;
2. Concurrent execution of design and construction;
3. Well-suited for complex projects, tight time frames;
4. Owner, A/E (architect/engineer), CM/GC have mutual project goals;

5. Risk management team identifies—Owner control; and
6. Collaborative process minimizes risk of construction and design disputes” (Lee 2008, 14).

UDOT confirmed Lee’s reasoning and added “to introduce innovation and new technologies” as another reason to use CM/GC (Alder 2007).

4.1.1 Respondents Demographics

The findings reported within this research were based on the survey responses of: 15 individuals with CM/GC experience from the standpoint of the contractor, 18 individuals with CM/GC experience from the standpoint of the owner, and 10 individuals with CM/GC experience in the capacity of the design engineer. Eight additional expert opinions were also solicited, for a total of 51 individuals contacted for analysis. Those who were contacted and responsive represent a large percentage of individuals with CM/GC experience, and thus results include a high level of expertise in CM/GC field-based practice.

Experience among these individuals was varied. Some were CM/GC veterans, while others had minimal but valid experience. Some had experience in multiple capacities, from the side of the owner and contractor, designer or ICE consultant. These experienced respondents were geographically located mainly in the Northwest U.S and affiliated with the organizations shown in Table 3. This location demographic centered mainly on DOTs or agencies with the most CM/GC experience. For example, between the Utah Department of Transportation (UDOT) and Utah Transit Authority (UTA), over 30 CM/GC projects had been completed in the intermountain West (NCHRP 15-46 2014).

Table 3: Participating Organizations

Company	Location
Geneva Rock, Construction Division	Orem, UT
Interstate Rock General Engineering Contractor	Hurricane, UT
Kiewit Construction, Engineering and Mining Services	Phoenix, AZ
Ralph L. Wadsworth construction Company	Draper, UT
W.W. Clyde & Company	Springville, UT
Stacy and Witbeck, Incorporated	Salt Lake City, UT
Granite Construction	Salt Lake City, UT
Gerber Construction Company	Lehi, UT
Progressive Contracting, Incorporated	St. George, UT
Association of General Contractors, Federal Highway & Transportation Division	Washington, D.C.
Utah Department of Transportation	Salt Lake City, UT
Colorado Department of Transportation	Denver, CO
Nevada Department of Transportation	Carson City, NV
Oregon Department of Transportation	Salem, OR
Minnesota Department of Transportation	St. Paul, MN
Utah Transit Authority	Salt Lake City, UT
Federal Highway Administration	Salt Lake City, UT
Stanley Consultants, Incorporated	Salt Lake City, UT
Horrocks Engineers, Incorporated	Pleasant Grove, UT
Michael Baker Corporation	Salt Lake City, UT
Parsons Brinckerhoff	Murray, UT
HDR, Incorporated	Salt Lake City, UT
Jacobs Engineering Group, Incorporated	Salt Lake City, UT
H.W. Lochner, Incorporated	Salt Lake City, UT
WCEC Engineers, Incorporated	Sandy, UT
URS Corporation	Salt Lake City, UT
JUB Engineers, Incorporated	Orem, UT

4.1.2 Survey Responses: Reported Advantages

The benefits of the CM/GC process reported in this thesis were gathered through a series of surveys distributed to contractors, owners, and design engineers with CM/GC experience. Respondents were asked specifically for benefits of the CM/GC process to the project. These

responses were grouped into categories: *Project Risk Management, Innovation, and Process Risk about Quality, Schedule, Cost, and Collaboration and Flexibility*. These categories were then further broken down based on the individuality of the responses. All corresponding benefits are captured in Table 4.

Table 4: All Listed Advantages of the CM/GC Process

Listed Advantages	
Best Value Selection Process	Minimized Change Orders and Added Scope
Enhanced Design through Constructability	Real Time Pricing and Value Engineering
Owner Design Control	Fair Market Value
Optimized Schedule	Open Book Accounting
Accelerated Start Dates	Collaboration and Flexibility
Shortened Design and Selection Time	Reduced Disputes
Reduced Public Impact	Third Party Coordination
Schedules Focused on Goals	Environment Supporting Innovation
Design Phase Savings	Improved Project Risk Management

The top ten benefits to the project of the CM/GC process, according to frequency are identified in Figure 8. Two similar lists from earlier research provided an interesting comparison, as well as, insight into the perspective gathered from the entire project team. The following paragraphs compare and contrast these findings.

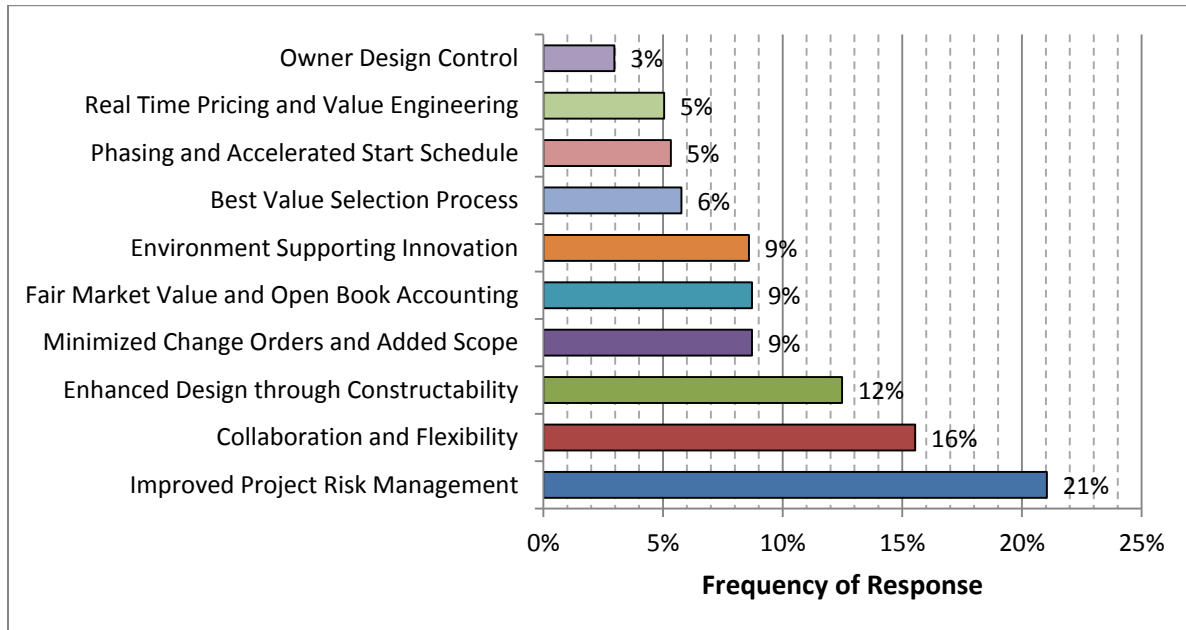


Figure 8: Top Benefits of the CM/GC Process by the Project Team

One study conducted in 2010 by the Transportation Research Board showcased the advantages of CM/GC delivery, based on the frequency of citation within 15 pieces of literature available at the time. The top five results included:

1. “The ability of the constructor to make substantive/beneficial input to the design
2. The enhanced ability to accelerate the project delivery schedule
3. Enhanced cost certainty at an earlier point in design than DBB
4. The ability to bid early work packages as a means to mitigate the risk of construction price volatility and accelerate the schedule
5. Owner control over the details of the design” (Gransberg and Shane 2010, 12).

A second study was conducted following an FHWA sponsored Peer Exchange, held in 2011. Researchers conducted a content analysis based on the presentations, panel discussion, and one state DOT interview, and reported the top seven benefits of CM/GC delivery as follows:

1. “The ability to fast-track
2. CM/GC design input
3. Early knowledge of costs
4. Ability to bid early work packages
5. Owner control of design
6. Flexibility during design/construction
7. Shared risk allocation” (Schierholz, Gransberg, and McMinimee 2011, 4).

In order to draw comparisons between the three lists, two principal differences should be noted, accounting for some of the disparities in the benefits given. First, respondents featured in the current study composed a broader group of the CM/GC team, experienced primarily in field practice as opposed to training or research, and including contractors and design engineers. Second, benefits within the three studies were not categorized identically and as such, any comparison is not exact. Finally, since responses to the first study were gathered, CM/GC practice has evolved, the pool of qualified respondents has grown, and individuals have gained more experience and better understand the advantages and disadvantages.

Despite these differences, some conclusions can be drawn by the comparison. All three analyses identified *Enhanced Design through Contractor Input or Constructability Review*, *Owner Control over Design*, and *Early Cost Certainty or Minimized Change Orders* as significant benefits. While benefits related to the project Schedule were listed by the current research, the *Ability to Fast-Track* the project or participate in *Early Work Packages* were given more often in the earlier studies. As the earlier studies were based mostly on the contribution of project owners, this indicated that schedule benefits were of more consideration to the owner.

Additionally, the top benefits in previous studies made no mention of risk management, innovation, or the selection process. This could be because the current research provided a more extensive variety of responses, or that items unmentioned or less frequently mentioned in previous studies such as risk management, innovation, or the selection processes and collaboration were benefits particularly relevant to contractors and engineers. These items may also be more essential to individuals with field-based CM/GC experience.

4.1.3 Advantages Specific to Project Roles

Unique to this thesis were survey responses gathered on the advantages specific to each party of the CM/GC project team. Respondents were asked to provide benefits of the CM/GC process specific to themselves, either as contractors, project owners, or design engineers. The five benefits most frequently cited for each project team role are found in Figures 9 through 11.

The responses provided additional insight into the differing needs of the project participants. Because *Cost Certainty* and *Minimized Change Orders* were listed in the two previous studies and by owners in the current research, it can be assumed that cost-related advantages were specific reasons that owners choose CM/GC delivery and remain a primary focus during delivery. The specific parties cited few advantages related to project schedule, implying that schedule benefits are less valued by individuals, or perhaps of more importance to upper management level owners as opposed to those involved mostly in field implementation. Contractors and design engineers listed the *Environment Supporting Innovation* as an advantage, supporting the idea that the innovative environment drew them to CM/GC delivery. Additional variances between the benefits reported by the project teams in this research and these three role-specific advantages are discussed more fully in sections 4.3 through 4.8.

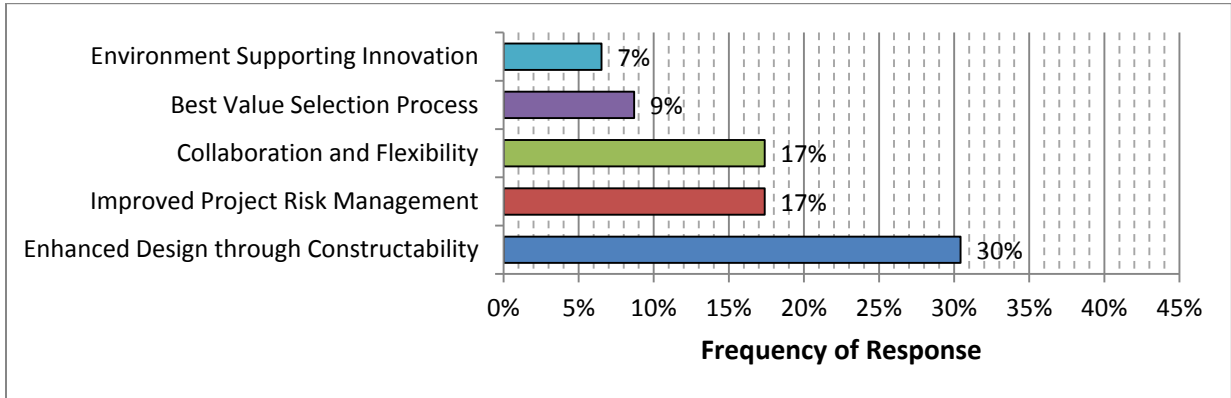


Figure 9: Top CM/GC Benefits for the Contractor

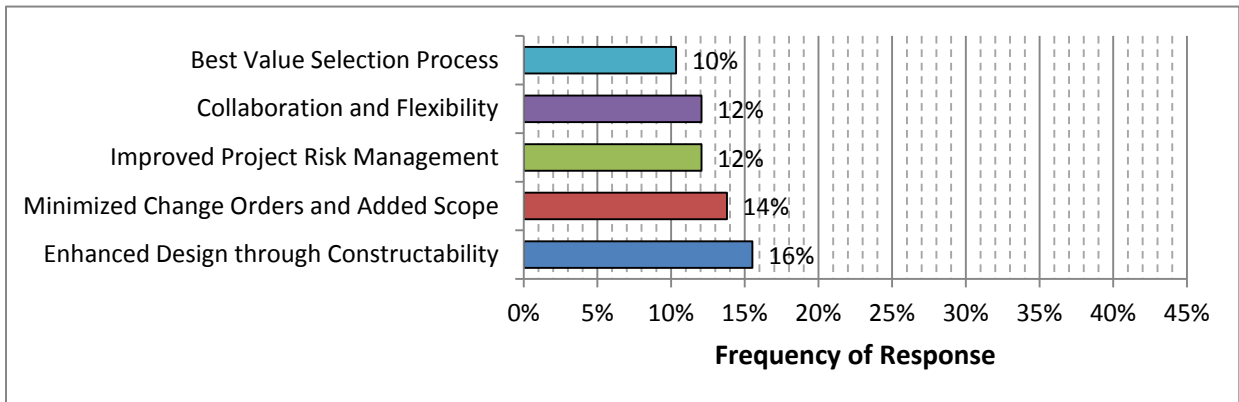


Figure 10: Top CM/GC Benefits for the Owner

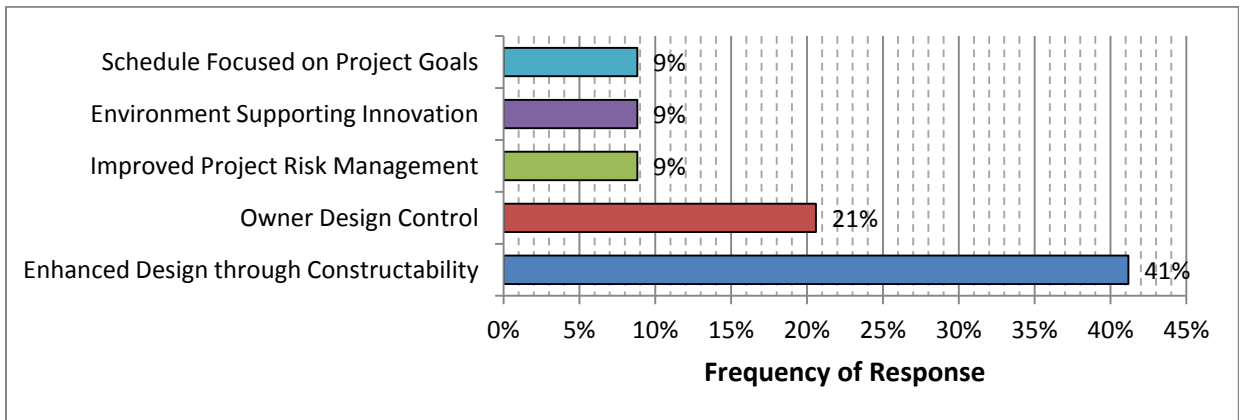


Figure 11: Top CM/GC Benefits for the Design Engineer

4.1.4 Survey Responses: Reported Disadvantages

Disadvantages of the CM/GC process to the project were gathered and grouped similarly to the benefit responses. These responses were grouped into categories: Project Risk Management, Innovation, and Process Risk about Quality, Schedule, Cost, and Collaboration and Flexibility. All identified disadvantages given are shown in Table 5.

Table 5: All Listed Disadvantages of the CM/GC Process

Listed Disadvantages	
Subjective Selection Process	Not Competitively Bid
Multiple Iterations of Changes	Lack of Change Orders
Too Late for GC Input	Qualified Staff Requirement
Questions Over Control	Open Book Accounting Impacting GC Profit
Added Phasing Effort	Lack of Collaboration and Disputes
Added Time in Procurement and Preconstruction	Transition in Negotiation
Accelerated Schedule Conflicts with ROW	CM/GC Learning Curve
Cost of Request for Proposal	Transparency in Innovation and Value Engineering
Added Preconstruction Cost	Not Suitable for All Projects

The top ten disadvantages of the CM/GC process to the project, according to frequency are listed in Figure 12, and discussed more in depth in Sections 4.3 through 4.8. Similar lists previously compiled also provided context for comparison and analysis.

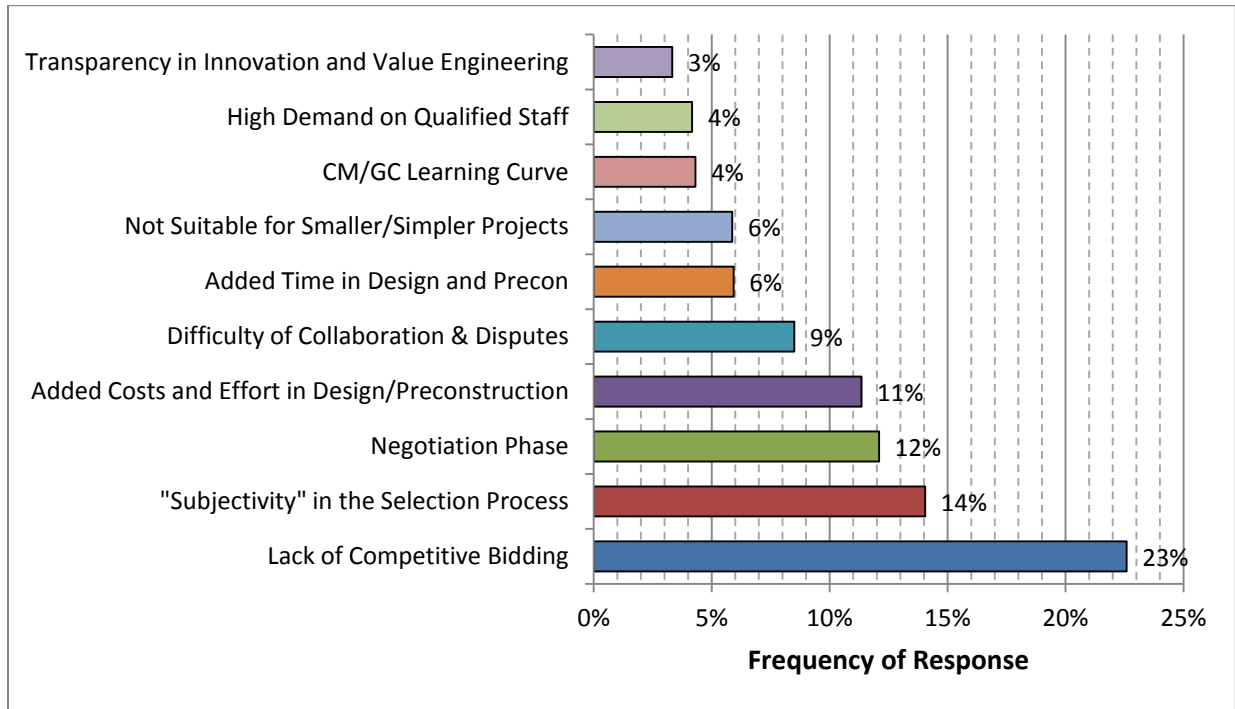


Figure 12: Top Disadvantages of the CM/GC Process by the Project Team

The top four most frequently cited disadvantages in the 2010 study of existing CM/GC literature included:

1. “Reconciling the conflict between the primary motivations of the [contractor] and the designer (i.e., cost)
 2. That the owner must still administer/coordinate both a design and a construction contract
 3. The final actual cost is not known until the GMP is established
 4. Agency personnel are trained to properly implement [CM/GC] project delivery”
- (Gransberg and Shane 2010, 13).

The second study based on presentations and discussions during a 2011 Peer Exchange also noted four “challenges” to CM/GC delivery:

1. “Training required for agency personnel
2. CM/GC and designer have different agendas
3. Requires different procurement culture
4. Actual cost is not known until GMP is set” (Schierholz, Gransberg, and McMinimee 2011, 4).

A wider variety of responses were gathered from this research. Two disadvantages cited in the 2010 study were particularly pertinent to the owner: administering multiple contracts and that the final cost is not known until the GMP is set after substantial design and preconstruction. These factors imply that contractors, owners, and design engineers, and those in management or in the field, face similar barriers to implementing CM/GC effectively.

4.1.5 Disadvantages Specific to Project Roles

Respondents were also asked to provide disadvantages of the CM/GC process specific to themselves, either as contractors, project owners, or design engineers. The five most frequently cited disadvantages for each project team role are found in Figures 13 through 15.

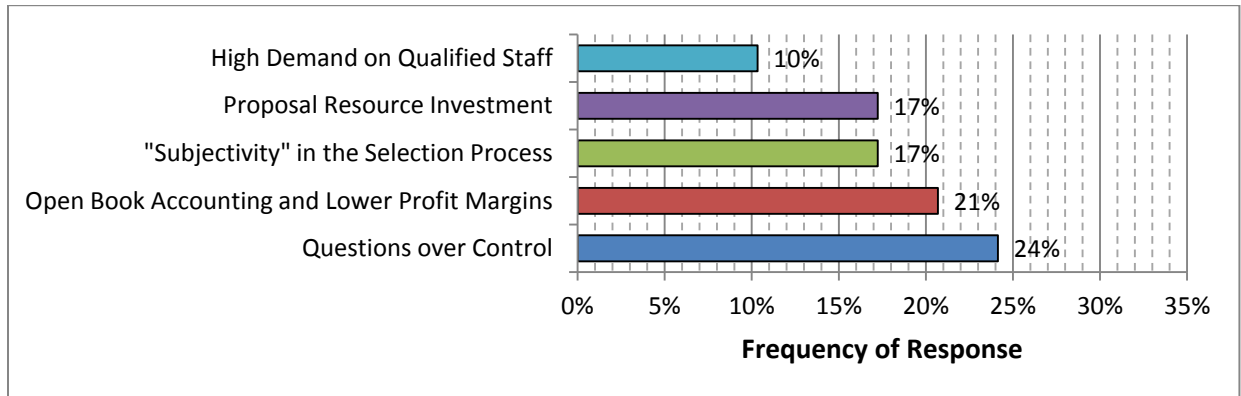


Figure 13: Top CM/GC Disadvantages for the Contractor

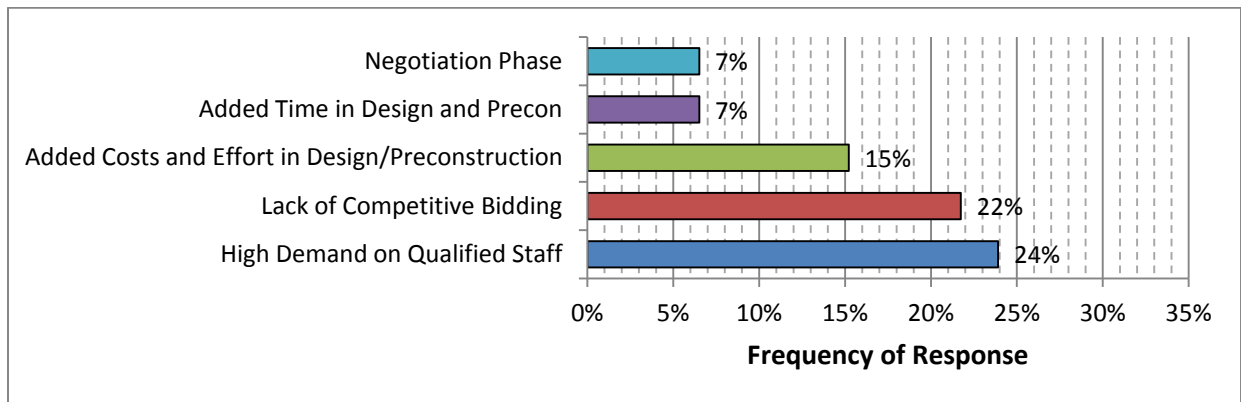


Figure 14: Top CM/GC Disadvantages for the Owner

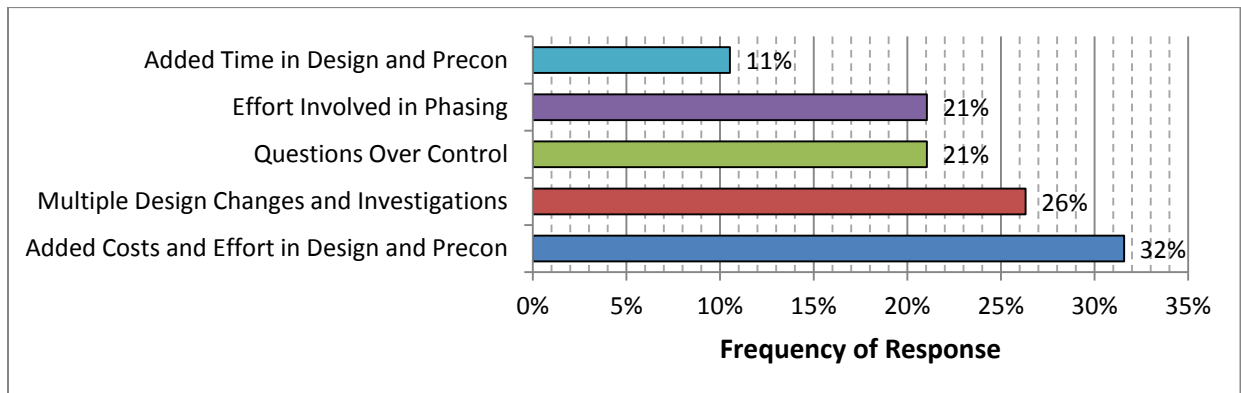


Figure 15: Top CM/GC Disadvantages for the Design Engineer

The disadvantages identified by the different project participants provided a number of insights into the processes that each part of the team saw as barriers to implementation. While many disadvantages to the process were similar to those identified in prior studies, disadvantages by project role were more varied. While responses on the *Lack of Competitive Bid* were absent with contractors and design engineers, they did mention *Subjectivity in Selection*, *Proposal Resource Investment*, *Transparency* and *Questions over Control* as specific barriers to them. This implies that the *Lack of Competitive Bid* is a disadvantage to the project and to the owner's ability to gauge value.

Additional variances between the benefits and disadvantages reported by the project teams in this research and these three role-specific disadvantages are discussed more fully in sections 4.3 through 4.8, based on the breakdown pictured in Figures 16 and 17. These figures are based on the weighted averages of the responses of contractors, owners and design engineer regarding the benefits and disadvantages of the CM/GC process *to a civil construction project*. Additionally, Figures 18 through 23 show the separated responses of contractors, owners, and design engineers regarding the benefits and disadvantages of the CM/GC process *to each party individually*. As appropriate, the discrepancies between the parties, seen in these latter figures, are discussed throughout the following sections, particularly emphasizing the differences in perception between contractors, owners and design engineers. First, Process Risk Management is discussed, with corresponding sections on Quality, Schedule, Cost, and Collaboration and Flexibility. These are followed by sections addressing the performance of CM/GC processes in Project Specific Risk Management and Innovation. Where applicable, corresponding disadvantages are noted and identified as barriers to implementation, with recommendations for improvement.

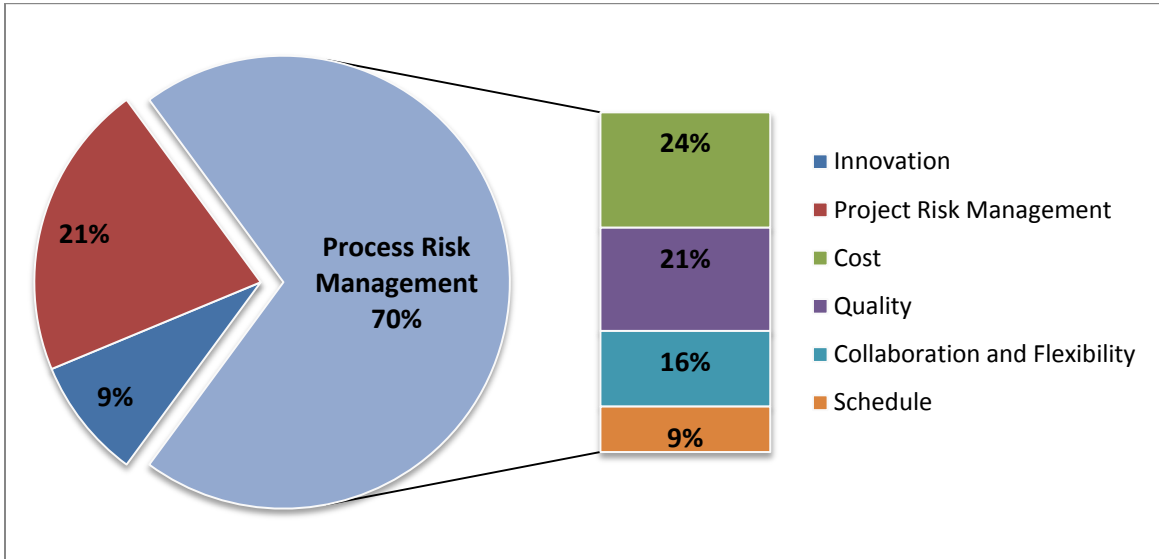


Figure 16: Benefits of the CM/GC Process by the Project Team

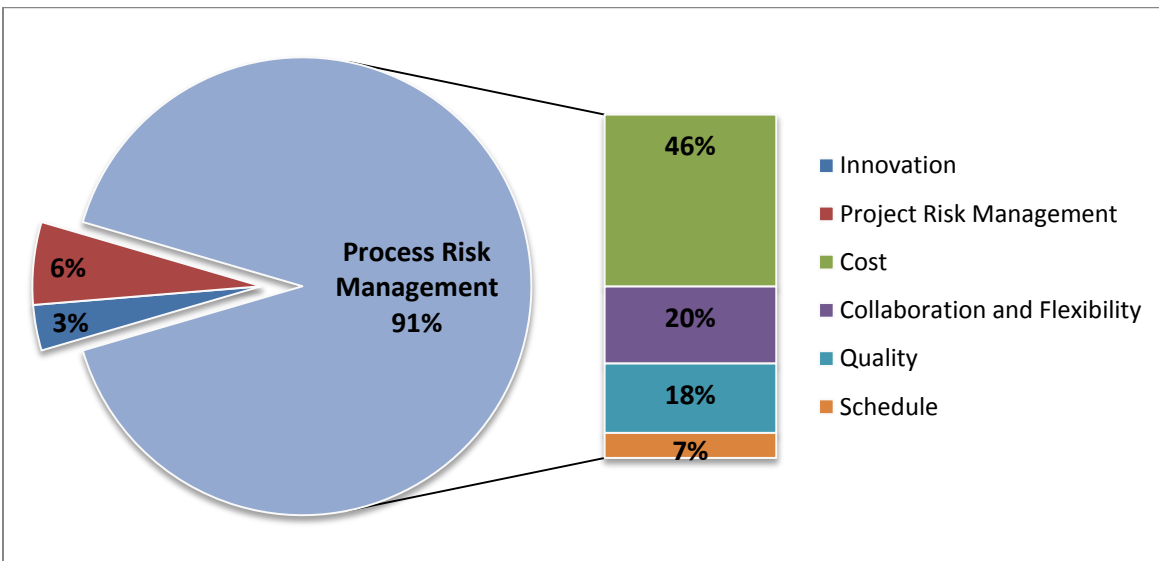


Figure 17: Disadvantages of the CM/GC Process by the Project Team

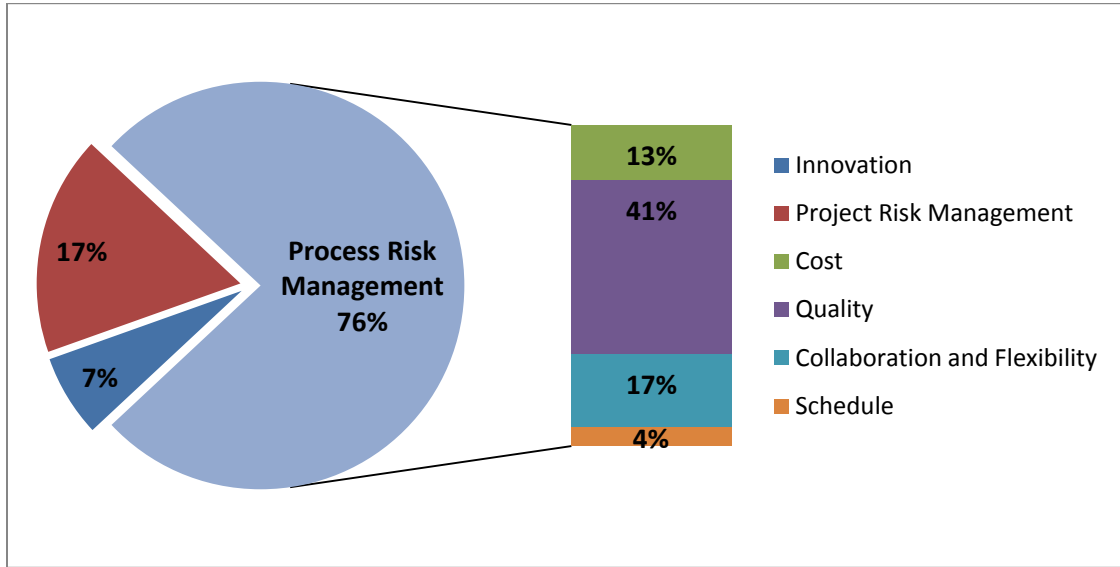


Figure 18: Benefits of the CM/GC Process to the Contractor

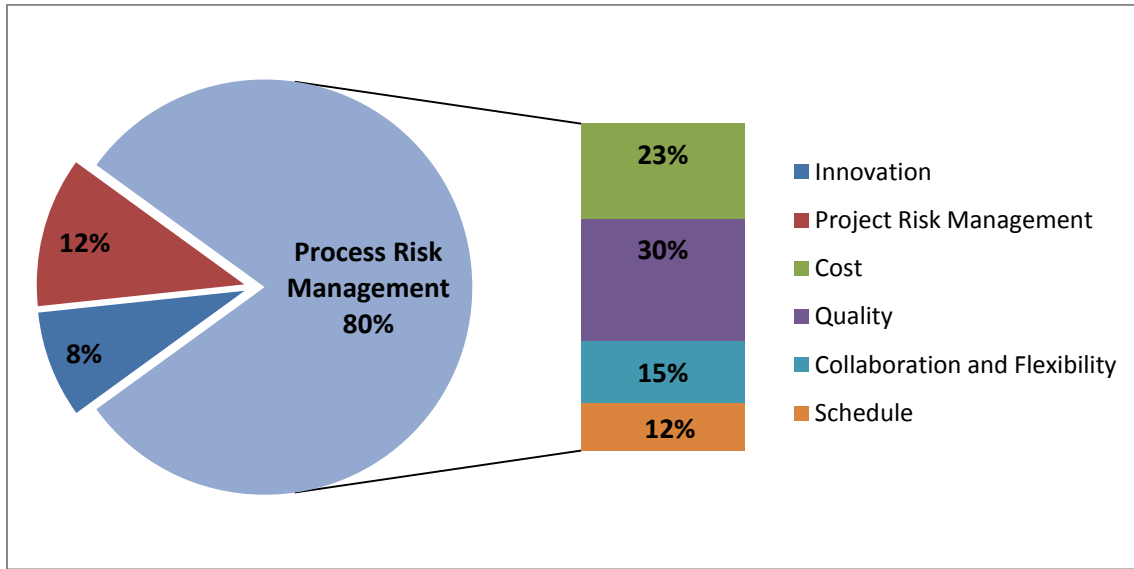


Figure 19: Benefits of the CM/GC Process to the Owner

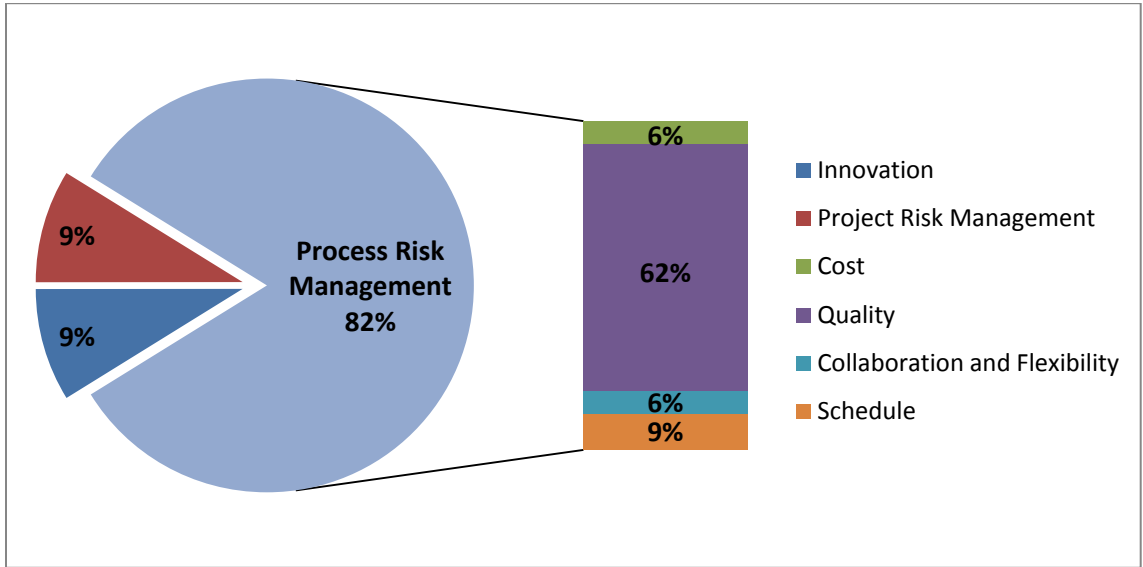


Figure 20: Benefits of the CM/GC Process to the Design Engineer

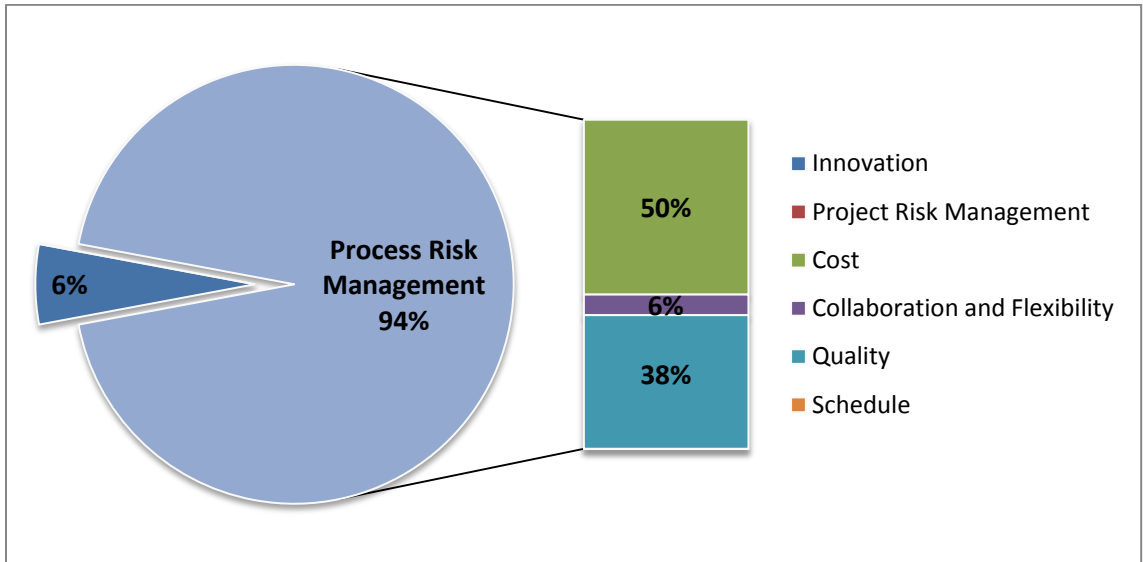


Figure 21: Disadvantages of the CM/GC Process to the Contractor

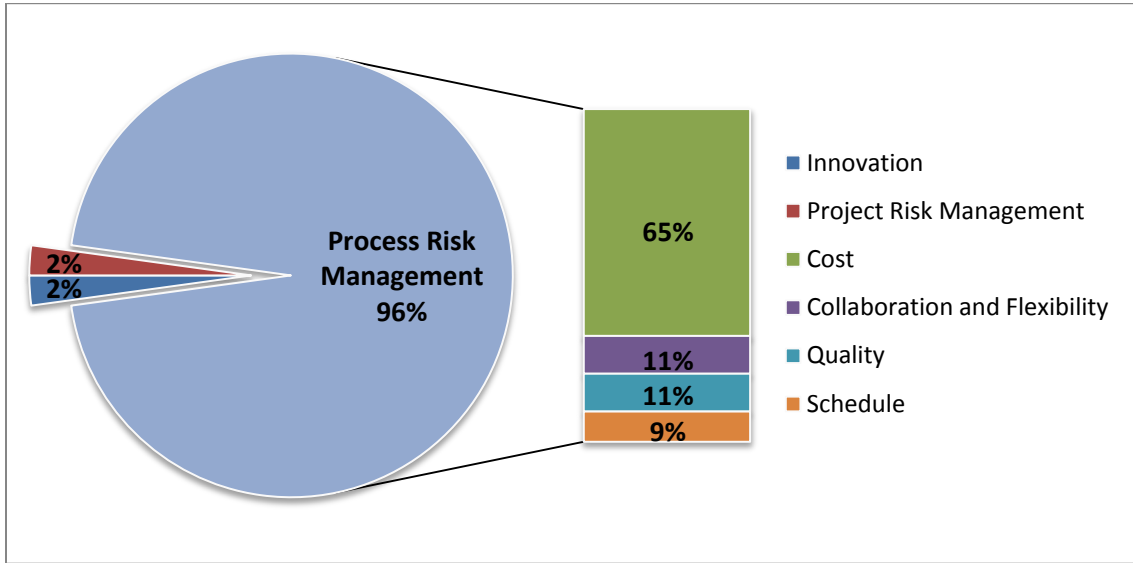


Figure 22: Disadvantages of the CM/GC Process to the Owner

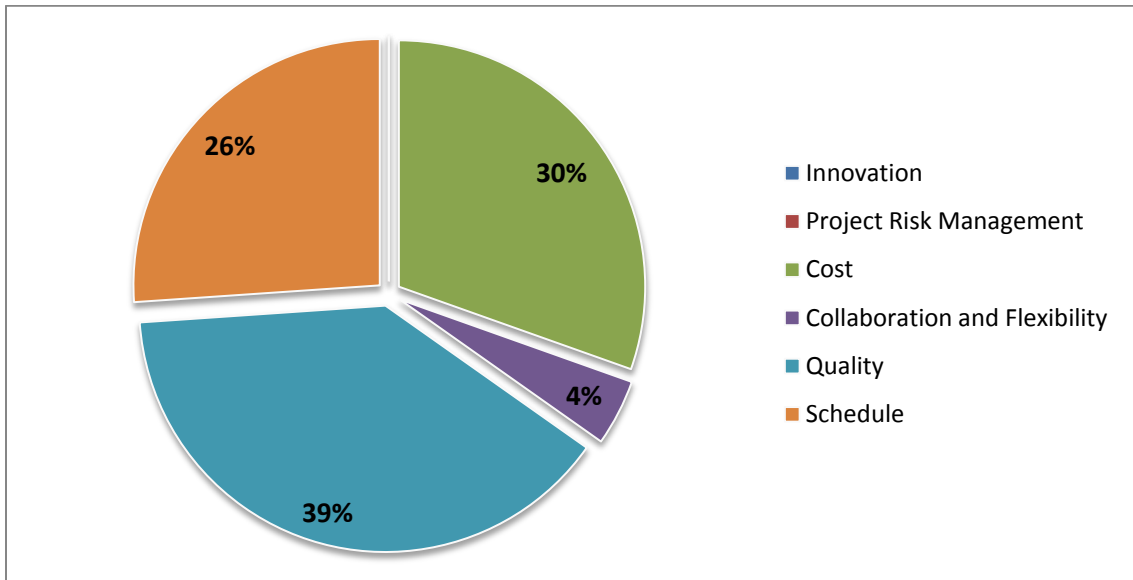


Figure 23: Disadvantages of the CM/GC Process to the Design Engineer

4.2 Management of Process Risk through CM/GC Delivery

Sections 4.2 through 4.6 contain a discussion of CM/GC practices that promote process risk management. Process risks can result in impaired quality, schedule delay and cost overruns. The manner in which process risk is resolved is often distinct to the project delivery method chosen. For example while all project delivery methods attempt to manage the risk associated with the cost of construction, cost control is handled differently in a CM/GC project than in a DBB project. Because “a construction project’s success can be measured by how its delivery method controls scope, costs, schedule, and quality” (Dodson 2013, 1), understanding CM/GC’s response to these process risks provides insight into its effectiveness. Section 4.3 addresses CM/GC process management of process risk related to quality, Section 4.4 addresses process risk related to schedule, Section 4.5 addresses process risk related to cost, and Section 4.6 addresses additional process risks related to team collaboration and flexibility.

As shown in Figures 16, CM/GC process risk management comprised 70% of all benefits given by the project team. Of this, cost-related benefits represented 24% of total benefits mentioned, quality-related benefits represented 21%, team collaboration-related benefits represented 16%, and schedule-related benefits represented the remaining 9%. As shown in Figure 17, of the disadvantages of the CM/GC process affecting the project, 91% of disadvantages given by the project team were related to process risk management. Of this, cost-related disadvantages represented 46% of total disadvantages mentioned, team collaboration-related disadvantages represented 20%, quality-related disadvantages represented 18%, and schedule-related disadvantages represented 7%.

Figures 18 through 20 show evidence of some differences between the perception the contractors, owners, and design engineers have of CM/GC benefits, as related to themselves

individually. Owners repeated cost benefits as 23% of total benefits, while engineers noted only 6% of benefits as related to cost. Design engineers noted more benefits related to quality, as indicated by 62% of their benefits. Owners repeated quality benefits as 30% of all benefits. In both instances contractor perceptions were between the owner and designer perceptions.

Figures 21 through 23 also demonstrate these discrepancies in the perceptions of disadvantages of the CM/GC process. Design engineers and contractors repeated quality disadvantages more often than did owners, a difference between 39% and 11%. Owners instead repeated cost disadvantages more often, as 65% of all disadvantages. Both contractors and design engineers repeated cost disadvantages less frequently, as 50% and 30% of disadvantages respectively. 26% of disadvantages noted by engineers related to project schedule. Fewer schedule disadvantages were repeated by owners, and contractors did not provide any schedule disadvantages to the CM/GC processes.

4.3 Process Risk Related to Quality

This section examines how CM/GC processes affect quality, especially emphasizing the relationship between design and quality. The most frequently repeated quality-related benefits listed by CM/GC project teams were: *Enhanced Design through Early Contractor Input on Constructability*, *Owner Control over Design*, and *Best Value Selection*. The disadvantages associated with quality that were most often cited included *Multiple Design Changes and Investigations*, *Questions over Control*, and *“Subjectivity” in the Selection Process*.

Management of quality-related risk is essential. The strong relationship between design and quality is the stem of multiple risks in highway construction. One example of risk is the result from selecting an inexperienced contractor that submitted the lowest bid, yet does not have

sufficient understanding of the design or company capability to provide a quality project. Another risk may result from the best effort design of engineers lacking the necessary construction field experience to know feasibly what can and cannot, or what should and should not be done on site during the actual construction of the project. Mistakes in design or items overlooked during the design phase, or misunderstood prior to procurement, also require emergency problem solving, often translating into costly changes affecting both budget and schedule. Along the same lines, a contractor with little confidence in the design provided will be more likely to assign high costs and contingencies to a project bid. Escalated costs and contingencies could lead to higher delivery costs to the owner.

When contractors, owners and design engineers were asked for the top advantages of the CM/GC process to the project, 21% of benefits given were related to improving project quality (see Figure 16). Quality-related benefits were also found to be the most often repeated benefit to the individual parties participating in the project. Benefits relating to quality comprised 62% of the benefits listed by the design engineer. Contractors and owners reported benefits relating to project quality as 41% and 31% of the total benefits, respectively (see Figures 18 through 20).

Additionally, nearly 92% of participants surveyed indicated that CM/GC processes enable them to improve project quality better than DBB processes. When compared to DB, over half of those surveyed noted that CM/GC processes better enabled the project team to deliver a high quality project than a typical DB project, and nearly the same amount stated that CM/GC processes enabled improving quality at least as well as DB processes. Thus, not only do quality-related benefits motivate project teams to participate in CM/GC projects, CM/GC processes better enable the delivery of high-quality projects. The results are graphically displayed in Figure 24.

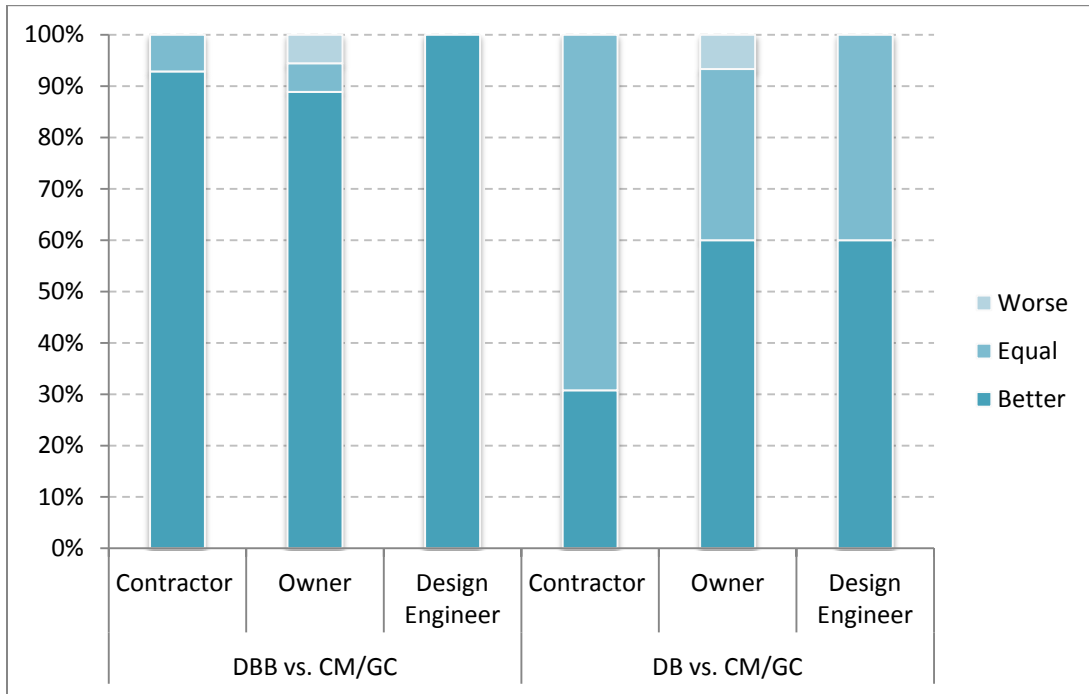


Figure 24: The Ability of CM/GC to Improve Project Quality

4.3.1 Enhanced Design by Early Contractor Input on Constructability

Enhanced Design through Early Contractor Input on Constructability was the third most mentioned benefit of the CM/GC process listed by experienced CM/GC project teams, repeated as 12% of total benefits (see Figure 8). Additionally, contractors, owners, and engineers each listed *Enhanced Design through Constructability* as the top benefit to each of them individually when participating in CM/GC projects (see Figures 9 through 11). Nearly 98% of the project team members surveyed indicated that CM/GC process enabled them to impact design and constructability better than DBB processes. Nearly half of contributors indicated that CM/GC processes allowed improved design and constructability over DB, and over 75% stated that CM/GC allowed the project team to impact design and constructability at least as well as DB.

Figure 25 shows the individual perceptions of CM/GC's ability to impact design and constructability, leading to the average values stated above.

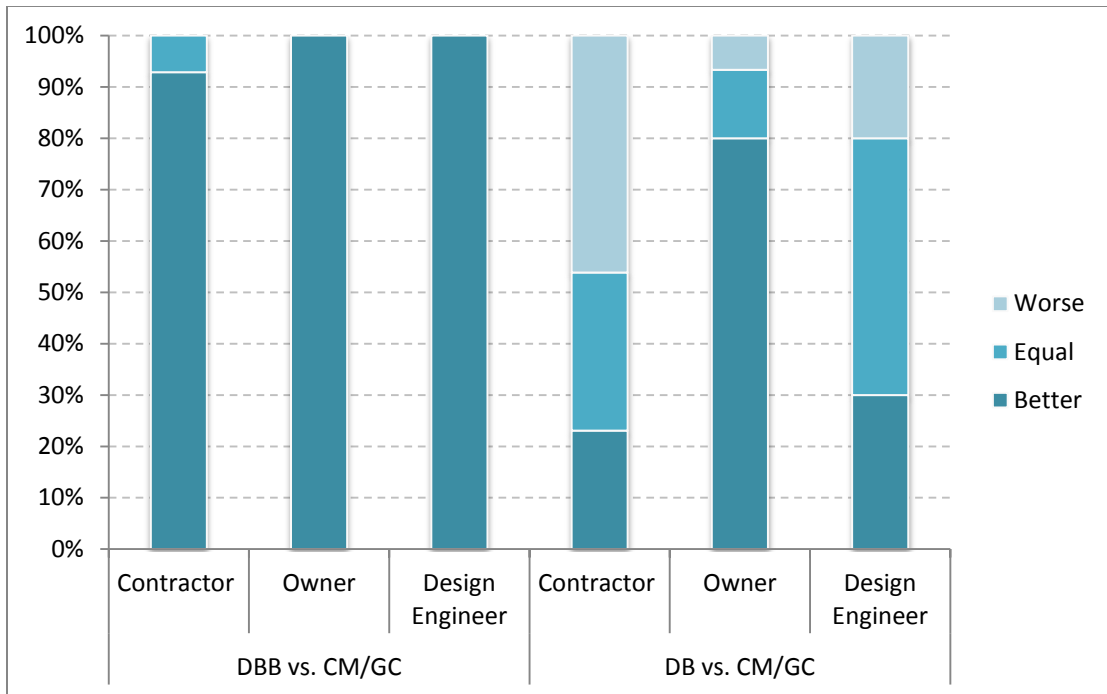


Figure 25: The Ability of CM/GC to Impact Design and Constructability

To better understand the implications of improved constructability in the CM/GC process, it is first important to understand CM/GC processes affecting constructability. Enhanced constructability, defined by the Construction Industry Institute as the “integration of construction knowledge and experience in planning, design, procurement, and construction phases of projects consistent with the overall project objectives,” is made possible through CM/GC by early contractor design input (Gransberg & Shane, 2010, 14). Under the CM/GC process, the contractor participates in constructability reviews of the design as part of the preconstruction services agreed to by contract. These early reviews of construction phasing,

material availability, and cost estimating reduce the “probable occurrence of change orders, project construction delays, and increased project costs due to contractor identification of these elements in the design phase instead of the construction phase” (Gransberg and Shane 2010, 14).

Improved constructability as a result of early contractor participation in turn yields:

- Minimized contract change orders and disputes,
- Reduced project cost,
- Enhanced project quality,
- Reduced project duration,
- Increased owner satisfaction, and
- Enhanced partnering and trust among the project team (Pocock et al. 2006).

Under the CM/GC process, design solutions are presented by the designer and evaluated by the contractor. “This continuous peer review helps reduce the errors in design and ensures unabated construction during installation (Alder 2012, 6).” Also, the contractor’s “continuous input on constructability issues allowed for customizing the design to match the contractor’s methods” (Alder 2012, A-33).

CM/GC delivery’s impact on constructability was mentioned frequently by survey participants, supporting the previous literature. Experienced project teams surveyed stated that the collaborative design effort resulted in a design that was “more aware of all components” of the project, including the owner’s intent and budget. The collaborating team gained “ownership of the plans and specifications” and a team understanding of project requirements and goals. The multiple perspectives found in the owner’s, designer’s and contractor’s teams helped to solve problems related to complex projects, such as staging, traffic control, and balancing the needs of

the owner with the contract price. Because of the collaboration owners were empowered to make “informed decisions” during both design and construction processes.

Participants mentioned that collaboration from the contractor in the design resulted in more complete subcontractor bids, a more “practical, efficient, and economical” design, and a smoother transition between design and construction. One contractor noted that being involved before the bid documents were complete. He was more able to give input on “materials and products that a contractor knows will work better than others.” Others listed “real world data for the project cost model, accurate constructability reviews,” risk and innovation tracking, and “phasing and sequencing determination” as the contractor’s contribution to meeting project objectives.

Engineers stated that CM/GC quality was improved by “another set of eyes” leading to a “higher quality finished product due to the level of effort and diverse input” and depth of planning improving the quality of execution. One engineer stated that the owner and contractor involvement allowed him to explore all options; for example, when planning for earthwork “the designer and contractor can work together on cut/fill balance, haul distances, production rates, use of different equipment, etc.” Each of these options reflected changes to price and schedule. Another said that a CM/GC design process gave him the “ability to capitalize on previous construction experience to optimize the project from a design and constructability perspective,” and that working with a contractor changed the way that he evaluated design issues in the future, “kind of like a lessons learned without waiting to see what went wrong.”

4.3.2 Associated Disadvantage: Multiple Design Changes and Investigations

One often repeated disadvantage given by design engineers as a drawback specifically to the designer was the *Multiple Design Changes and Investigations* common to the CM/GC design process. 26% of disadvantages named by design engineers were related to the changes typical to iteration in the design process (see Figure 15).

Engineers reported that the design process could take longer if not managed well because of the additional team members providing feedback and reviews. Participants stated this was more likely to be a problem when the contractor was brought later in the design effort, causing the design to be revisited and sometimes causing major changes. Contractors also noted that on some projects they were selected “too late to be truly effective” when most of the project had already been designed and the design team was already “set in their ways.” Another respondent also noted that changes in design effected the ability of the team to resolve right of way issues stating that the project team may not know “what ROW was needed until design was complete, and when design was complete and they were ready to construct,” the team had insufficient time to make ROW purchases.

Two implications can be drawn from this identified disadvantage. First, the multiple design changes and investigations can be a drawback to the project team. In order to take full advantage of contractor input, the contractor must be brought into the project as early as possible to be truly effective. Secondly, to avoid wasted time and effort in unnecessary changes and repetitive ‘what if’ scenarios, the design phase must be well managed with an owner able to make definitive decisions quickly.

4.3.3 Owner Control over Design

The risk of the owner losing control over the details of a project's design is a problem typically encountered in the DB delivery process, resulting from early delegation of project design details to the design-builder. Also, because the schedule and the budget are already fixed by contract, if unforeseen conditions or project requirements necessitate a change in scope or design, quality is the only remaining contractual element, that can suffer (Alder 2012). Two studies of alternative project delivery methods found that while owners used the DB process to effectively compress the schedule and control cost, DOTs were often reluctant to use DB project delivery because they lost control over the details of the design (Scott et al. 2006).

UDOT stated that CM/GC “places the owner in a better position to direct the team in a way that protects the owner’s interests” (Alder 2012, 10). CM/GC project teams repeated *Owner Design Control* as the final of the top ten benefits of the CM/GC process (see Figure 8). *Owner Design Control* was the second most mentioned benefit by design engineers as a benefit of participating in CM/GC projects (see Figure 11).

Experienced CM/GC project teams noted that owner control encouraged a designer to innovate with the contractor while still “maintaining the ability to provide preferences for the owner.” Even through the construction process, the owner potentially had better control, like in the bidding process where the owner was able to “audit subcontracts and the contractor’s budget.” Overall, CM/GC processes allowed the owner to “obtain the end product desired” while making decisions as informed by experienced contractors and design engineers.

Design engineers particularly noted that having a traditional contracting relationship directly with the owner was a specific benefit of the CM/GC process, stating that similar to DB, the team was able to “partner and work through issues” but also receive direction from the

project owner. One stated that because of this contracting relationship the emphasis in a DB project was “schedule and budget,” while in CM/GC “there was more emphasis on design accuracy and scope.”

4.3.4 Associated Disadvantage: Questions over Control

Both contractors and design engineers with CM/GC experience stated that *Questions over Control* was one of the top five disadvantages to each of their parties in the CM/GC process. Over 24% of drawbacks listed by contractors and over 21% of drawbacks listed by design engineers related to issues arising from questions of control in both design and construction (see Figures 13 and 15, respectively).

Contractors stated that compared to a DB experience, it was a disadvantage that they obviously held less control in the design. They shared that because of the design contract they were able to provide “recommendations and priorities” but they were not able to “influence them in a direct way.” Some mentioned that the “designer often controlled progress”, and that additionally, the owner’s internal specifications and processes, as well as Federal oversight, did not allow the implementation of many contractor ideas. Engineers alternately suggested that contractors in a CM/GC process potentially assumed an “owner” role, dictating the construction and controls approach. One stated that CM/GC processes led to the potential for a contractor to “lead designers to their advantage.”

In order to keep *Questions over Control* from becoming a barrier to implementation project teams must anticipate questions and make control clear. Successful implementation of CM/GC processes require strong leadership, empowered to make decisions. Control issues could be resolved by contract and by practice, with an owner that is involved in the details of project.

It would be helpful to establish by contract who controls the design schedule. In many cases it may be beneficial to delegate schedule control to the contractor because of experience. The owner must also investigate early on the agency's willingness to implement beneficial contractor ideas, even if it means adapting agency processes to gain the full benefit of contractor involvement.

4.3.5 The Best Value Selection Process

Best Value Selection was the seventh of ten top benefits of the CM/GC process as given by the CM/GC project team (see Figure 8). Owners mentioned *Best Value Selection* as a major benefit to themselves in a CM/GC process; 10% of the benefits listed by owners related to *Best Value Selection* (See Figure 10). Contractors also listed *Best Value Selection* as the fourth of the top five benefits to the contractor participating in CM/GC processes, as seen previously in Figure 9.

CM/GC selection processes were said to improve “quality and value by keeping focus on quality and value—not low bid (Ladino et al. 2008). Project teams were selected based on a technical proposal, which led to a more experienced, qualified team that was able to address the needs of complex project design and construction. The premise of this type of qualification based selection, as opposed to a selection based on price, was taught in a presentation given at the Annual Meeting of the Associated General Contractors of America; “When multiple prices are on the table, the owner is not in control; the price is” (Ladino et al. 2008).

Experienced project teams noted that the owner was able to select a contractor based on experience, fee, schedule, capability, and references “rather than just low bid.” Even contractors noted that the *Best Value Selection* process “weeds out poor performers.” One contractor with

significant CM/GC experience expressed the desire that every one of his jobs were CM/GC, stating that in CM/GC selection “you fight for the project and the best man wins.”

The qualification based selection noted by the participants allowed owners “to hire the best of the best and enter into construction with a higher level of partnership” and trust. Project owners were also “able to evaluate several approaches to the project,” even prior to selection. One participant mentioned that CM/GC processes regarding selection relieved the pressure of creating “a perfect plan” for the lowest bidder, and then later finding errors and cuts to quality.

4.3.6 Associated Disadvantage: “Subjectivity” in Selection

Alternately, the perception of “*Subjectivity*” in the Selection Process was the second most repeated disadvantage of the CM/GC process, as supported by the responses of CM/GC experienced contractors, owners and design engineers (see Figure 12). 17% of the disadvantages listed by contractors, as disadvantages to the contractor, were related to “*Subjectivity*” in the Selection Process (see Figure 13).

Even contractors with CM/GC experience stated that because the CM/GC selection process was based on subjective factors rather than quantifiable factors, it could become “a means to pick favorites” and that owners chose the general contractor “they have the best relationship with, not necessarily the one with the most experience or innovation.” The selection process was described as favoring “large organizations with greater staffing resources” and requiring experience “that can be hard to get” prior to winning a project. One participant mentioned that for his smaller firm it was “great to get [a CM/GC project], but tough to get one.”

Owners called the qualification based selection process “more subjective than low bid” and as such, expected that the results of the selection were more likely to be challenged. Owners

themselves noted that “fairness in selection” was an issue associated with CM/GC, and that the CM/GC selection process made it difficult for smaller general contractors to compete, even eliminating some.

Recognizing that any perception of impropriety should be addressed, representatives from UDOT were quick to defend its evaluation criteria. Proposers were scored for selection, based on specific categories including qualifications and experience of the project team, references, the proposer’s approach to the project (schedule, MOT, partnering, etc.), and risk and innovation management. Unlike other agency processes, UDOT selection processes also included the proposer’s “approach to price.” To avoid the perception of improprieties or favoritism in the case of the responding DOT, a technical evaluation team submits suggested proposals to an oversight committee anonymously for final selection (UDOT 2013).

In order to keep “subjectivity” in selection from being a barrier to CM/GC implementation, owners must specifically examine the agency’s specific selection process. In a document on Recommended Best Practices for the Use of Construction Management/General Contractor on Highway and Transportation Projects in the Public Sector, the AGC provided suggested procedures regarding the selection and evaluation processes to encourage “the greatest level of competition from the largest number of proposers” (AGC 2011, 3). The document stated that “transparency in the selection and clarity in how qualifications and proposals will be evaluated is essential” (AGC 2011, 3). Additionally, the AGC recommended that the agency carefully consider the qualifications of the owner’s selection committee and provides the following:

- Specific and objective evaluation criteria as described in the solicitation,
- Opportunities for proposers to respond to committee deliberations,
- A question and answer interview period,
- The elimination of significant anomalies in scores,
- Opportunity for evaluators to score proposals independently, and
- The disclosure of scoring documents following contract award (AGC 2011, 3).

In a second round of questioning, contributors were asked if the perception of “*Subjectivity*” in the Selection Process would be a barrier to implementation, keeping contractors from contributing in future CM/GC projects. Owners want to eliminate as much subjectivity as possible while giving their selection panel enough flexibility to select a contractor. Most participants noted that while subjectivity was an issue, it did not keep contractors from participating.

Multiple participants stated that increased understanding of the scoring system, criteria, and processes added legitimacy to the selection. Others asked to be de-briefed following the award of the contract, or open training sessions. The most repeated solution was to include a representative from the Association of General Contractors (AGC) and American Council of Engineering Companies (ACEC) on the selection committee to provide oversight maintaining the integrity of the process. Any favoritism or subjectivity in the process would thus be visible to outside participants. These individuals contribute value to the selection team and leave the selection process with a new appreciation of the efforts the department makes to eliminate subjectivity in the selection process.

4.4 Process Risk Related to Schedule

This section examines the effect of CM/GC processes on time, or the schedule of a project. The following benefits were repeated by experienced project teams and are discussed in the sections below: *Accelerated Selection* (mentioned only in existing literature or by DOT teams), *Accelerated Start Dates and Phasing Options*, and *Schedules Focused on Project Goals*. These following schedule-related disadvantages were most often given by project teams and are also discussed below: *Added Time in Procurement, Design and Preconstruction* and *Added Effort Involved for Phasing*.

Because most transportation projects involve disruption to the traveling public for significant periods of time, controlling schedule risk, as well as reducing design and construction timelines is critical in transportation projects (Ford et al. 2004). UDOT described their experience with CM/GC specific schedule risk reduction as follows:

“The CM/GC process has reduced the schedule for most projects. Part of the reason for this is the time saved in the design effort. The contractor’s participation helps to identify solutions quickly and speeds up the design process. Their participation also reduces the detail that must be communicated to the contractor in drawing specifications. CM/GC in general allows a project to begin at risk. One project began before the railroad right of way issues were cleared...By careful construction planning the railroad work was saved for last and right of way issues were cleared in time to complete the project on schedule...Phasing helps to reduce schedule time” (Alder 2007, 4-5).

Though less predominate than quality benefits, 9% of CM/GC process benefits gathered were related to the positive affect of CM/GC on the project schedule (see Figure 16). 15% of total benefits mentioned specifically by contractors as benefits to the project were related to the project schedule (see Figure 18). Also, 83% of the project team members surveyed indicated that the CM/GC process enabled them to control or shorten the project schedule better than the DBB process. However, approximately one-third of respondents indicated that, when compared

with DB processes, CM/GC processes were less likely to allow more control over the project schedule. Figure 26 shows the individual perceptions of CM/GC's ability to control or shorten project schedule, leading to the average values stated above.

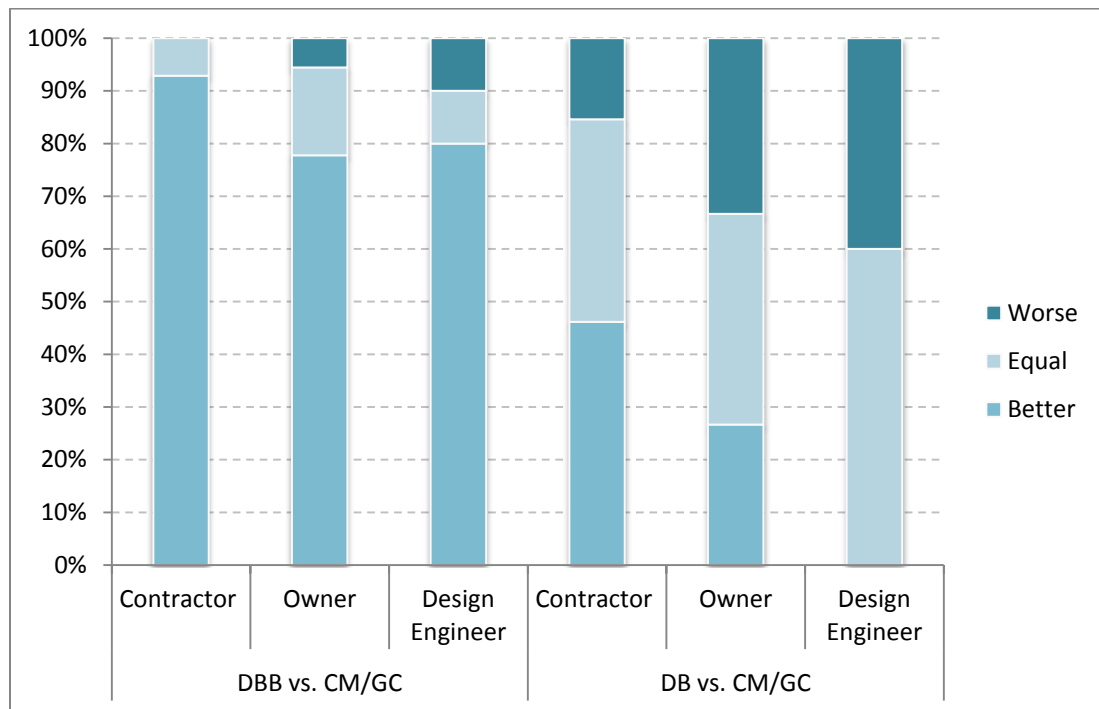


Figure 26: The Ability of CM/GC to Control or Shorten Project Schedule

4.4.1 Accelerated Selection

While the mention of *Accelerated Selection* within the current survey results was negligible, existing literature and lists of advantages noted earlier in this chapter merit further discussion. From the standpoint of the owner, CM/GC projects had the benefit of moving more quickly through the selection process than projects assigned to other delivery methods. Because a typical RFP for a DB project was often well over 600 pages for even simple projects, the time

involved in the owner's preparation of the RFP, in addition to the time required to solicit proposals based on a lengthy document, was usually between 6 and 8 months. The document length also led to a higher probability of the document containing multiple errors (Alder 2011).

An RFP for a CM/GC project was typically shortened to around 30 pages, with only 2 to 3 pages of project specific data. This reduced the preparation and selection time on the owner's side significantly, and the risk of error (Alder 2012). The procurement of the contractor typically took between 3 and 4 months for a CMGC project. In the case of extreme circumstances, such as UDOT's SR-14 emergency landslide repair, the selection of a contractor could also be accelerated to 2 months (Alder 2012). Accelerated project delivery also reduced the risk of inflation if the project were to span over multiple years. Owners claimed an additional benefit as follows: the entire project team was then held to a typically more aggressive schedule, even through the design and preconstruction phases (AGC and NASFA 2007).

4.4.2 Associated Disadvantage: Added Time in Procurement, Design and Preconstruction

Despite these owner-supported claims in previous literature, the sixth most common disadvantage of the CM/GC process as listed by contractors, owners, and engineers was the *Added Time in Procurement, Design, and Preconstruction* in the CM/GC process (see Figure 12). Owners and design engineers were especially vocal in listing this added time as a drawback to their party.

The owners and engineers surveyed stated that the "upfront time to get the contractor on board" as well as to hire consultants to perform independent cost estimates put the team at risk to delay the overall schedule. Also, multiple respondents continued that CM/GC was less likely to speed up the design phase. One noted that "in DB, one must put together the GMP and live with

it through design and construction, but work may start almost immediately upon submission of the proposal. In CM/GC, the proposal is submitted, then design and price are finalized, and then construction starts. Usually the sense of urgency attributed to DB is lacking from CM/GC.” Another indicated that pressure in the project schedule can place a strain on the CM/GC process.

In response to what may become a drawback of the CM/GC process, CM/GC project teams must take control of the schedule, especially during design, seriously. As was mentioned previously, it was suggested that design schedule control be delegated early by contract to one party, often the contractor, in order to introduce structure and urgency to the project’s design schedule.

4.4.3 Accelerated Start Dates and Phasing Options

CM/GC processes note significant benefits owing to the ability to optimize the schedule through phasing. A schedule is optimized by beginning design and construction activities as soon as they can technically be started, maximizing the number of parallel activities that occur in the schedule (Gransberg and Shane 2010, 15). Under CM/GC, dividing the project into phases allows the owner to overlap design and construction of different project phases and reduces the overall project time (AGC and NASFA 2007). Additional time can be saved as the integrated team makes itself responsible for identifying construction materials and equipment with long delivery requirements and assigning procurement of those long lead items to the contractor early on, or issuing early work packages before final design is completed (Gransberg and Shane 2010).

Benefits relating to *Accelerated Start Dates and Phasing Options* possible through CM/GC processes were the eighth most mentioned benefit to the project, related by contractors, owners, and design engineers (see Figure 8). Contributors stated that CM/GC schedule

performance was “improved by overlapping procurement and early work activities” with design. One project owner noted that many projects saved a construction season because the project team was able to begin before the design was complete. Participants also attributed expediting the schedule to early release construction packages with early and severable bid packages, and the phasing of challenging work elements, saying that this incremental way of building allowed flexibility to “design a little, and build a little.”

4.4.4 Associated Disadvantage: Added Effort Involved in Phasing

When questioned about the disadvantages to the CM/GC process specific to the design engineer, 21% of the disadvantages mentioned were related to the *Additional Effort Involved in Phasing* (see Figure 15). Phasing of the project was described as “difficult,” requiring additional effort to split the project into independent severable packages such as early grading and draining plans, or structures procurement packages.

Contributing engineers were asked if the typical iterations of changes would be a barrier to implementation, or keep design engineers from participating in future CM/GC projects. Responding engineers stated that this item would not keep engineers from participating. They stated that advantages of phasing were far greater, but might drive engineering fees a little higher. Some stated that they approved of phasing because it typically meant more work for the design consultant and provided the opportunity to maximize project funding. Engineers indicated that the barrier to implementation came when the engineer felt they were running out of budget and not getting construction plans done on time, because they were not prepared for the iterations of design and phasing. They stated that items identified up front and accounted for in the engineer’s schedule and budget.

Designers also stated that it was important to be cognizant of the time needed to provide benefit, recognizing the cost to benefit ratio of the phasing exercises. Designers were encouraged to ask ‘How much project value or schedule is saved by the contractor having the engineer execute multiple phasing scenarios to work through?’ to avoid getting trapped in multiple phasing options searching for the very best approach.

4.4.5 Schedules Focused on Project Goals

CM/GC processes allowing the project team to be focused on project goals were supported by literature and survey results. Unlike other delivery methods, the contractor can begin tailoring the construction schedule during the design phase, while the project’s needs are being recognized and addressed. Adjustments including special considerations for local government needs, minimizing traffic impact at specialized locations, and incorporating more public involvement have all been achieved. The allocation of any available float also becomes a project responsibility and topic of discussion, to be used as a benefit to the project team as a time cushion for those activities that need it most (Gransberg & Shane 2010, 58). Early schedule analysis, through selection and design, gives the owner another decision making tool when considering how construction will interfere with traffic or cause disruption to surrounding property owners.

Design engineers in particular noted that a *Schedule Focused on Project Goals* was a specific benefit of the CM/GC process to the design engineer (see Figure 11). One contributor mentioned that the “design schedule was typically more flexible, as the emphasis was on developing a good solution, not on meeting a specific deadline.” The deadline was instead replaced by project-specific goals. Respondents stated that CM/GC processes encouraged the

integrated team work together to define schedule critical items that would then drive early action items or contract phases. The schedule was described as more controllable, when compared to a DBB situation, and as benefited by the contractor's value engineering and innovations, focused specifically around project goals.

One example of CM/GC processes promoting problem-solving and allowing phasing was experienced by Oregon DOT in the \$160 million Sellwood Replacement Project currently under way in Portland (Gransberg 2013). When the initial CM/GC contract was awarded, the county did not yet have all the necessary funding available. Because a CM/GC preconstruction services contract obligates the owner only for the cost of that contract, the project was able to begin without having to wait for the full funding— a grant of approximately \$5 million. “After the initial constructability review, the CM/GC contractor suggested an alternative to building a temporary bridge to carry detour traffic during construction—jack the existing bridge over to temporary piers. This approach reduced the project cost by \$6 million and eliminated the need to obtain the grant before awarding the first construction package” (Gransberg 2013, 13).

4.5 Process Risk Related to Cost Control

The following section examines how CM/GC processes effect cost control. Benefits most often repeated relating to cost control discussed include: *Minimized Unplanned Change Orders and Extended Scope, Fair Market Value and Open Book Accounting, Real-Time Pricing and Value Engineering, and Design Phase Savings* (only mentioned in existing literature or by DOTs). Disadvantages discussed as mentioned by project teams relating to cost control include: *Open Book Accounting and Lower Profit Margins, Lack of Competitive Bidding, Proposal*

Resource Investment, Added Cost and Effort in the Design and Preconstruction Phases, and the High Demand of Qualified Staff.

Cost-related risk played an important role in both CM/GC literature and current survey results. Risk associated with cost was summarized as follows: the price of any project at bid opening was seldom the final cost of the finished project. Unplanned change orders and bid item overruns often resulted in costs escalating beyond the project's original budget. Additionally, the unknowns and risks associated with a particular project might drive contractor pricing and contingencies higher than normal. Due to the CM/GC processes that affect design and schedule, and CM/GC's approach to risk management and innovation, CM/GC projects often resulted in cost savings and reduced the risk of exceeding the expected budget. While agencies with CM/GC experience do not claim that every CM/GC project shows cost savings, they do suggest that when finished projects are examined, the overall trend "shows significant savings" (Alder 2012, 14). UDOT reported that CM/GC is "approximately 10% more cost effective than traditional DBB projects" (Alder 2012, 4). The Department gave five primary factors that impact the cost of each project, stating that CM/GC takes advantage of four of the five factors.

1. "Innovation savings,
2. Risk management savings,
3. Construction process improvement savings,
4. Change orders and bid item overruns, and
5. Competitive bidding" (Alder 2012, 13).

UDOT's experience with the comparative cost of delivery methods, while considering the original bid, change orders or overruns, project enhancements, and innovation savings shown in Figure 27.

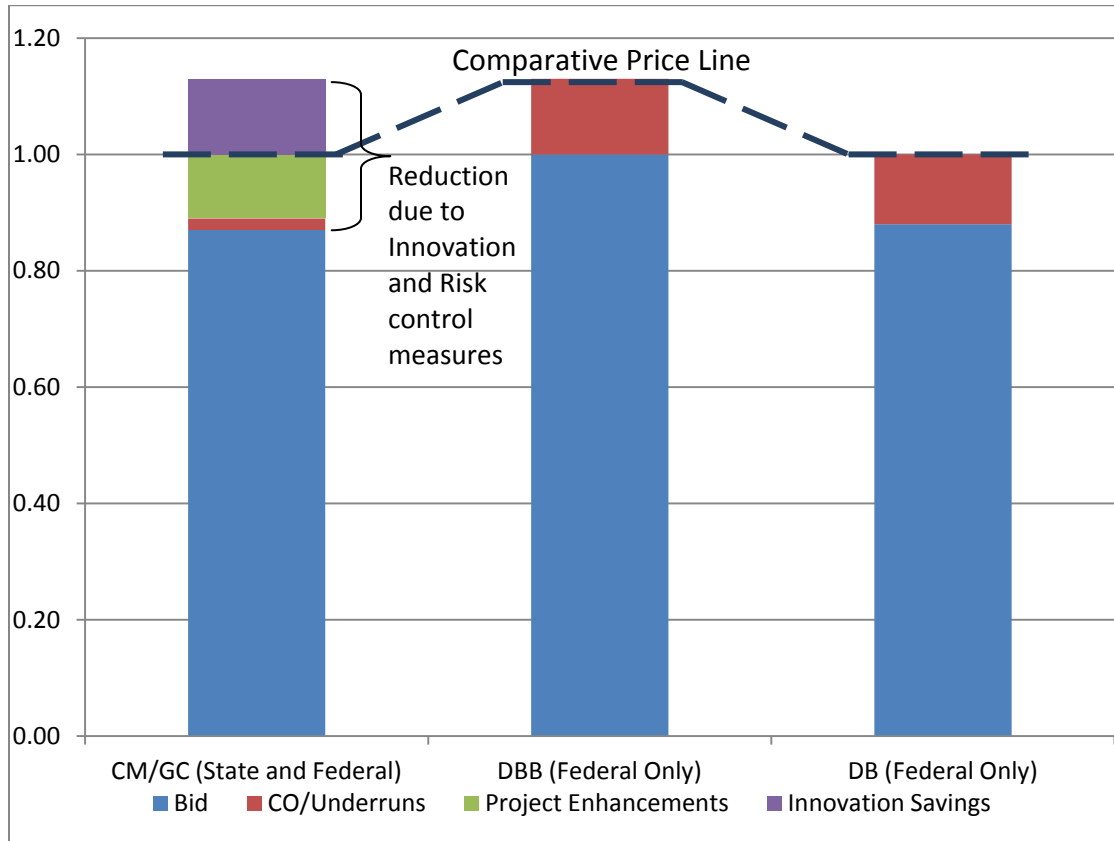


Figure 27: Comparison of Delivery Methods

Of all benefits listed by CM/GC project teams, those associated with cost were the most often mentioned by all parties coming to a total of 24% of all benefits (see Figure 16). Owners in particular noted that the benefits relating to cost control were particularly important for them. 24% of responses listed as benefits specifically to the owner were related CM/GC cost control processes (see Figure 19). When surveyed, 83% of the project team members indicated that CMGC processes enabled them to reduce the cost of construction better than DBB processes. Two-thirds of those surveyed indicated that CM/GC processes allowed the project team to reduce the cost of construction as well, or better than DB processes. Figure 28 shows the

individual perceptions of CM/GC's ability to reduce the cost of construction, leading to the average values stated above.

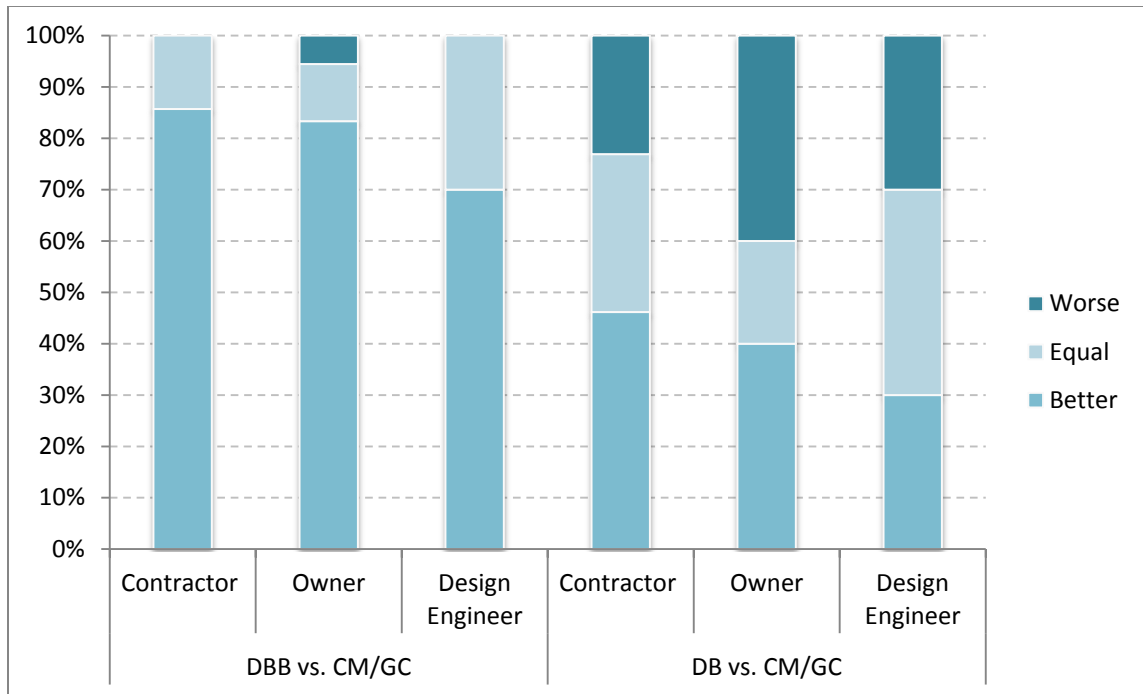


Figure 28: Ability of CM/GC to Reduce the Cost of Construction

However, equally predominate were the disadvantages related to CM/GC processes related to cost. Cost-related drawbacks comprised 46% of the disadvantages of the CM/GC process (see Figure 17). When questioned on the specific disadvantages of the process to their individual party, over 30% of engineer responses, 47% of contractor responses, and 60% of owner responses were related to CM/GC processes concerning cost (see Figures 21 through 23). A portion of these responses were related to the fact that one-third of respondents indicated that when compared with DB, CM/GC processes were less likely to allow reduction in the cost of construction or reduction of additional costs, such as those related to design and schedule. While

83% of project team members surveyed indicated that CMGC processes enabled them to reduce the cost of construction better than DBB, 22% of those surveyed indicated that CM/GC processes were less able than DBB processes to reduce additional costs related to construction. The difference between CM/GC performance with reducing the cost of construction and the additional costs related to construction are discussed in section 4.5.8.

4.5.1 Minimized Unplanned Change Orders and Extended Scope

A significant threat to any construction project is exceeding the project budget because of unplanned change orders and bid item overruns. This is true especially with DBB projects initially bid very competitively, while still remaining within the project budget. After the contract is accepted costs may escalate based on unaddressed design issues. “On almost all projects today, especially high-profile infrastructure projects, a key measurement of project success is cost growth and change management. How much additional money was required to cover the cost of quality overruns, changed conditions, incomplete or inaccurate plans, etc.” (Jackson and Bekka 2013, 18)? One of the most commonly mentioned benefits by the CM/GC project team members surveyed was the *Minimization of Change Orders* and associated *Extended Scope*, listed as the fourth of the top ten benefits (see Figure 8). 14% of owners specifically mentioned that the CM/GC processes leading to less change orders and added scope were of direct benefit to them (see Figure 10).

CM/GC processes supported the “reduction of scope and the reduction of material changes on the project” according to one CM/GC experienced contractor. Contributors to this research noted that the CM/GC processes in which the contractor provided reviews, assisted in developing the design, helped to isolate risk items, and thus, shared management “resulted in

more identification of issues up front and fewer change orders during construction.” During the CM/GC process, one participant noted that the owner had access to “iterative construction estimates as the design progressed to allow scope adjustment or risk sharing” and these processes helped to ensure that the project met the budget. This was particularly valuable to project owners, who stated that the budgets were “more easily managed” and that they were able to “provide more accurate information to the public about cost and schedule.”

The associated benefit was that with a reduction in changes and a known budget, the project team then stated they were able to “maximize the scope” and “add value to the project for the owner.” UDOT reported that “CM/GC projects had almost twice the savings in bid item underruns as DBB projects. These savings are evidence of project managers changing bid items during construction and replacing those bid items with project enhancements” (Alder 2012, 21). Because the savings in a CM/GC project could be tracked, state agency project managers could more effectively manage the project budget during the design and redirect innovation savings into project enhancements. This management technique uses project phasing to increase the scope thereby maximizing the overall value to the public. For this reason it was important to view change orders and overruns within CM/GC projects carefully. Not all change orders were unwanted. Using CM/GC, change orders often became a tool for the project manager to achieve the most benefit for the public with the established budget.

One contributor noted that the only change orders in the CM/GC process were typically used for the owner to add scope, and because the contractor had provided all alternates and pricing at the time of the bid, the owner had a “shopping list” complete with the “order of magnitude” indicating when they might be completed. Thus, the overall response of experienced

team members was that this, among other CM/GC pricing strategies, helped to “maximize scope delivery while minimizing the construction impacts.”

One tradeoff for the minimization of change orders by significant project team design investigation was no early cost certainty. The GMP was only established after all design investigations were finished, unlike DB where cost certainty was established around 30% design. This should not remain a barrier to implementation, given that CM/GC processes provide the mean for cost certainty without changes. CM/GC allowed the integrated team to design to a specific budget, especially with the appropriate use of a well-developed preconstruction cost model.

A preconstruction cost model, or a breakdown of the project’s scope of work in dollar terms, served to validate the owner’s budget. UDOT and UTA supported, by contract, the joint development of a preconstruction cost model before major design decisions are made (Gransberg and Shane 2010, 55-56). Although contractors had extensive experience with cost modeling, DOTs typically depend on bid tabulation-based estimating systems to perform an estimate after design. “Robust cost modeling actually drives design decisions and facilitates the value engineering process... it provides a foundation for scope creep and assisting design engineers’ understanding of the impact of design assumptions, such as factors of safety” (Gransberg and Shane 2010, 89-90). Agencies must develop understanding, expectation, and standardization of cost modeling to take full advantage of CM/GC cost benefits.

4.5.2 Fair Market Pricing and Open Book Accounting

The *Fair Market Value and Open Book Accounting* common to CM/GC processes was tied as the fourth most mentioned benefit to a CM/GC project given by the project team (see

Figure 8). This benefit was given as an advantage of the process to the project, but not specifically beneficial to any specific team member.

Participant responses indicated that CM/GC processes promoted “cost savings to the Department of Transportation” through “open book collaboration with all stakeholders in the process.” Project experience led some to say that CM/GC displayed a potential for a “lower overall cost” because the “scope can still be a bit unknown” and the project team can “work to a good price.” One contractor stated, “we get to negotiate a fair price for our work, instead of getting work only because we left something out of the bid like in DBB.”

4.5.3 Associated Disadvantage: Open Book Accounting and Lower Profit Margins

The prior advantage was alternately listed by some contractors as a disadvantage to them when participating in CM/GC projects. The actual *Open Book Accounting* nature of CM/GC contributing to *Lower Profit Margins* comprised 21% of all disadvantages given by contractors (see Figure 13).

Contractors noted that the “transparency” in CM/GC pricing strategies made CM/GC projects “less profitable” than other projects for them. In the CM/GC process, the markup was predetermined; the contractor “made less profit and relied solely on the fee.” Additionally, one contractor stated that on a CM/GC project “the intent was to remove risk and costs from the project.” On other projects “you might be able to win with some of that risk and find a good way or better way to accomplish it than the way it was estimated” and retain the savings. However, in the CM/GC process that savings is returned to the owner, and sometimes to the project. Other opportunities for the contractor to turn a profit, such as by self-performing work, must typically be “justified and compared to market rates” in a CM/GC project.

Contractors also reported that CM/GC pricing strategies often meant that the “owner had leverage on the contractor during price negotiation” and that “some owners could take advantage of the open book estimating approach, dissect the contractor’s cost estimate, and use it as a tool to beat down the price unfairly.” This practice is likely to lead to disputes, like those common to DBB.

Contractors contacted about transparency and decreased profit margins in second round questioning agreed that this concern was legitimate. Some stated that while the profit margins were lower, there was a corresponding drop in risk that justified the lower margin. Owners recommended that if the agency wanted a high quality contractor, they had to be willing to pay well for them. Thus, increased preparation of what to expect on the side of the contractor and appropriate investment on the side of the owner can contribute to mutual understanding.

4.5.4 Associated Disadvantage: Lack of Competitive Bidding

Overall, the most-often mentioned disadvantage of the CM/GC process as listed by contractors, owners, and engineers was that CM/GC projects are *Not Competitively Bid*. 23% of total disadvantages given were related to the *Lack of Competitive Bidding* (see Figure 12). 22% of owner responses particularly noted the non-competitive nature of CM/GC was a specific disadvantage for project owners (see Figure 14).

One contributing owner stated that in the CM/GC pricing process, “it’s hard for people to understand Fair Market Pricing compared to Low Bid pricing.” The CM/GC process gives the “perception that the competitive pricing aspect is eliminated, unlike DBB where low price is awarded the contract.” Another owner stated that “some critics from a traditional DBB

background feel low bid is the only way to get the right price” and do not believe owners get equal value through the CM/GC process.

Multiple participants stated that under CM/GC processes “the owner does not have the ability to be sure they have the most competitive price” and “are likely to pay more at least up front than if the project were low bid.” Because the project is only partially bid competitively prior to final design, “it is difficult to assure a true market value bid after completion of the design” and “unit prices appear high.” One stated that even the price proposal validated by an ICE consultant may be “reasonable, but not the cheapest.”

For agencies accustomed to low bid contracts, CM/GC bidding practices were described as “hard to set up.” Owners responded that the non-competitive process typically required additional or enhanced skill sets. The owner needed “a better knowledge of cost, and to be able to hold their ground in a bid opening.” One contractor noted that CM/GC bidding processes could be a disadvantage to the agency because under CM/GC the owner would “not get to take advantage of the low bid GC’s bidding mistakes.” These statements foster criticism of CM/GC processes relating to cost, deterring additional agencies from confidence in the delivery method.

In the case of non-competitive selection, multiple considerations should be recognized. First, UDOT claimed that while CM/GC does not get the benefit of competitive bidding, savings through competitive bidding were only “artificial and dependent on market conditions.” The premise was that in a tough economy, contractors cut the cost of delivering a project in order to stay in business by accepting lower profit and overhead percentages. UDOT claimed that these savings were “not due to a decrease in the cost of production and must be temporary if a company is to stay in business” (Alder 2012, 13).

Secondly, the AGC recommended that to minimize disadvantages related to the lack of competitive bid, the contractor be selected through a competitive Best Value Selection process, using qualifications and a price component as the determining factor. The ‘price’ was typically fees for preconstruction services and an overhead and profit factor to be applied to construction services) as the determining factors (AGC 2011). Oregon DOT used a “proposed fee percentage” as a scored category (Dodson 2013, 1). UDOT took it a step further using price as a selection criterion within their proposal.

A portion of the proposing entity’s score was based on a Price Submittal, the cost of construction for a specific list of items based on design, specification and information provided by UDOT, including direct costs, indirect costs, profit, overhead and risk. Another portion of the total score was based on the proposing team’s “Approach to Price,” or the proposer’s ability to provide an open book, detailed breakdown of costs. The department requested a description of the “fully-loaded” cost of items previously estimated in the Price Submittal showing labor, equipment, material, trucking, profit, etc, as typically supported by a detailed output of the proposer’s estimating software. This submittal allowed the department to assess the proposer’s ability to work in an open book environment with design entities and Independent Cost Estimators to reach a Targeted Maximum Price (UDOT 2013, 16-17). Throughout design, UDOT also used blind bid openings and state average pricing to gauge cost competitiveness. Agencies should consider their own procurement culture and selection criteria for opportunities to introduce fair market pricing checks or competition to selection and design decisions. These specific items regarding competitive and noncompetitive pricing must be understood if the CM/GC process is to be implemented successfully by other agencies.

4.5.5 Real Time Pricing Data and Value Engineering

Survey contributors stated that *Real Time Pricing and Value Engineering* was tied as the eighth of ten top benefits of the CM/GC process (see Figure 8). A major reason for selecting CM/GC project delivery was “to gain access to the contractor’s real time construction pricing data and have it available throughout the design process to assist in making cost driven decisions based on the best information possible” (Gransberg and Shane 2010, 56). Budget validation, as performed by the contractor, helped determine if the available funding could sufficiently cover the scope of work. Under CM/GC processes, the contractor’s real time construction pricing data was compared against the figures provided by the agency and designer, and against historical parametric cost factors. As a team they could then identify those features that appeared to be either underestimated or significantly overestimated. This approach facilitated recommendations based on experience, to resolve any issues identified (AGC and NASFA 2007). The owner could make informed decisions about design alternatives, considering real time effects on the budget, to “include the alternative, find a less expensive way of providing the alternative, reduce costs on the other aspects of the project, or select a less expensive alternative...thus, value engineering became a natural part of the design process” (Alder 2012, 7).

One contributing design engineer stated that “usually the designer has to create estimates using historic data, but contractors can provide more accurate real-time costs.” Another designer stated that this process made the design more cost effective. Other contributors shared that this “synergistic approach of having contractors providing a pricing control process into design” gave the team the ability to “compare options” and “make the most efficient decision.” This “real world data,” plus the contractor’s value engineering ideas were known by experienced team members to show cost savings to the agency, time savings, and to reduce risks.

4.5.6 Associated Disadvantage: Proposal Resource Investment

17% of disadvantages listed by contractors as a direct drawback of the CM/GC process for them were related to the *Proposal Resource Investment* common to the CM/GC process (see Figure 13). Understandably, because the assembly of the proposal is unique to the contractor's experience, this disadvantage was not listed by owners or engineers.

Despite RFP process benefits for owners mentioned earlier within this research as *Accelerated Selection*, many surveyed contractors described the CM/GC procurement process for them as “lengthy,” and the associated costs as “huge” and “far more costly than DBB.” One noted that the proposal process was “very time consuming between writing a proposal and estimating selected work” (typical in a UDOT RFP). Others mentioned the time and cost associated with interview preparation, publishing, and research. One contractor stated that “DBB is a much more efficient and concentrated effort” where “millions of dollars can be estimated in a short amount of time, while a CM/GC proposal for even small contracts can require much more time during the procurement process.”

One contractor called “the unrecoverable cost associated with technical and price proposals” CM/GC's largest problem, and shared his firm's experience with the process.

“Typical DBB pricing requires a Staff Estimator (100 hours), Chief Estimator (12 hours), and Project Manager (8 hours) for a total of 130 man hours allocated over two weeks in preparation and submittal. The approximate cost of the bid would be \$4,080 in labor and \$50 in printing, not reflecting payroll taxes, benefits, matching funds, or any mark ups for profit and overhead. A CM/GC Technical and price proposal requires eight weeks to complete, with a top heavy staffing commitment. Our last CM/GC proposal required a Chief Estimator (400 hours), Project Manager (80 hours), Staff Estimator (40 hours), Office Manager (30 hours) and an Office Clerk (12 hours) for a total of 562 man hours. The approximate cost of the CM/GC proposal was \$27,080 in labor, \$500 in printing, \$150 in binding, and \$50 in shipping.”

Citing similar costs in a DB process, this individual stated that as a small contractor, his firm could not afford to participate in alternatively bid projects like CM/GC or DBB, on a regular basis. Many contributors supported the assumption that smaller contractors were less likely to pursue CM/GC projects because of these associated costs and their unfamiliarity with the engineering proposal, requiring more than trade knowledge. Smaller firms were likely to have less marketing and technical resources to assemble a proposal for a qualified based selection process, described as a “paradigm shift” for those accustomed to a low-bid situation.

Contractors, even within larger organizations stated that the CM/GC selection process required preparations in order to participate. They recommended the creation of new divisions, or new groups charged with writing winning proposals, seeking out industry awards or employee experience in order to score well on CM/GC team requirements, working with other companies with prior CM/GC experience, and attending courses, training and lectures. One mentioned specifically recruiting individuals with CM/GC experience, and the purchase of software to assist in cost loading, conceptual estimating, and the open book process.

Those participants contacted with second round questions were quick to mention that while CM/GC proposals were more costly to assemble than DBB proposals, they were far less expensive than DB proposals. Also, contractors reported that they had a higher rate of winning CM/GC processes when compared to DBB projects. One noted that because the assembly of this type of proposal was a new arena for contractors, there was a level of discomfort that could only be overcome with project experience. Another stated that the large expense of the proposal was not required, because “a team is not judged on how pretty the proposal is, rather it’s judged by its content.” They also shared that a fair amount of work was required to assemble the initial CM/GC contract and bid documents, but after the initial investment assembly was minor. When

contractors understand the proposal assembly from this standpoint, it is seen as an investment in the future of the contractor. Minimal support was given to the idea of short listing contractors and offering a small stipend similar to DB.

4.5.7 Design Phase Savings

Though the mention of *Design Phase Savings* was negligible within the results of this research, according to cited literature, the risk of exceeding project budget was minimized under CM/GC processes by reducing the cost of project design, and thereby reducing the overall project cost. Researchers stated that through CM/GC processes the schedule of design was accelerated and the scope of the design was decreased resulting in time savings (Alder 2007). Time saved during design results in lower design fees to arrive at quality construction documents, improved by the involvement of the contractor. Because the contractor can control the level of detail required to get “biddable” subcontractor packages, the sum of the total design effort is less than that required to produce a full set of construction documents for a DBB project. UDOT calls this developing an appropriate design rather than a complete design (Alder 2007).

4.5.8 Associated Disadvantage: Added Cost and Effort in Design/Preconstruction Phase

Opposing the mention of *Design Phase Savings*, within the results of this research 15% of owners and 32% of engineers, respectively reinforced that especially to their individual party, this *Added Cost and Effort in the Design and Preconstruction Phases* was a significant drawback to the process (see Figures 14 and 15, respectively). One-third of respondents indicated that when compared with DB, CM/GC processes were less likely to allow reduction in of the additional costs, such as those related to design and schedule. 22% of those surveyed indicated

that CM/GC processes were less able than DBB processes to reduce additional costs related to construction. Figure 29 shows the individual perceptions of CM/GC’s ability to reduce additional project costs, leading to the average values stated above.

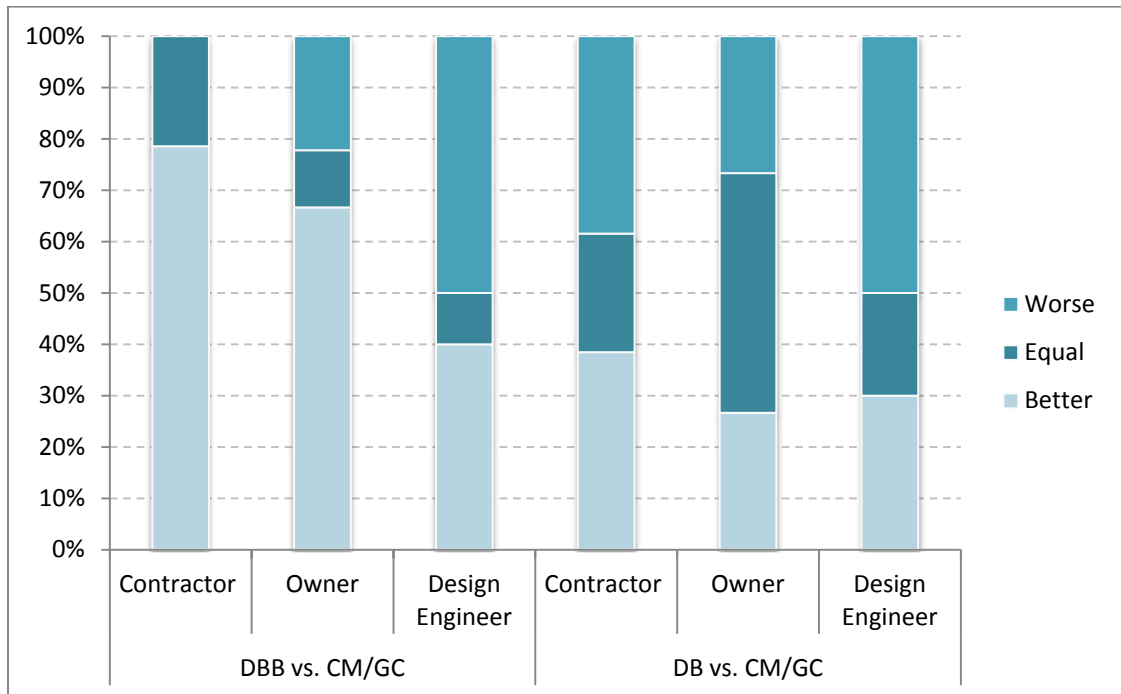


Figure 29: The Ability of CM/GC to Reduce Additional Costs

Participants listed the *Added Cost and Effort in the Design and Preconstruction Phases* as the fourth of ten most repeated disadvantages to the CM/GC process (see Figure 12). One owner summed up his experience with CMGC cost processes as follows:

“My experience has been that design costs are higher with CMGC rather than DBB. Selection of a contractor, more meetings to get everyone on board and share ideas, the number of attendees to meetings, and incorporating the contractor’s ideas into the plan set all add design cost and time to the project. On the other hand the benefit of reduced construction costs, fewer changes during construction, and possibly a reduced construction schedule (and user costs) can offset the higher design cost.”

Respondents supported these statements saying that the CM/GC process required “a lot more dedication and work for the project management teams,” “more management from the owner” and additional “up-front costs for preconstruction fees to the contractor and Independent Cost Estimator.” Another respondent added that while any additional costs should be offset by construction savings, the design costs are “more than traditional delivery.”

Given that the average fee for preconstruction services on highway projects is 0.8% of estimated construction costs one study concluded that the cost of preconstruction “is a reasonable investment that accrues tangible returns” (Gransberg and Shane 2010, 2). Supporting this premise, UDOT provided budgeting statistics for past CM/GC projects for agencies investigating the impact of CM/GC additional fees for future work as shown in Table 6.

Table 6: Budgeting Statistics for Some UDOT CM/GC Projects

Typical Services Cost (based on total project cost)	UDOT Average	Minimum	Maximum	Comment
ICE Cost	0.3%	0.1%	1.8%	This varies widely based on the overall size of the project. Generally the percentage is inversely proportional to the size of the project
Construction Management Services Cost	1.0%	0.2%	4.5%	The contractor's fee during the design phase is widely dependent on the services required by the team.
Preconstruction Services	7.2%	N/A	N/A	Projects with multiple contracts do not always distribute preconstruction services thereby making maximum and minimum estimates deceptive.
Notes: 1. Roughly 19 contracts investigated representing 12 projects. 2. All percentages based on Total Project Costs as reported in UDOT's EPM, Report 506 3. Only projects marked "Closed" were used in the analysis				

Beyond the perspective of the owner, engineers specifically stated that in a CM/GC environment, it was a challenge “to stay within the budget and on schedule as you investigate multiple options and develop concurrent designs before decisions are made” and that the additional team members involved in the project lead to probable increased time and costs from incorporating more comments. They also responded that the process required “extra time to meet and collaborate with the contractor during design” and that the additional time and costs created a “higher potential that the client will not pay for additional design efforts.” Contractors also mentioned more meetings and time spent traveling were a drawback of the process and that the preconstruction services fee provided by the agency “may not be adequate.”

This added cost and effort could easily become a barrier to implementation, especially for contractors and design engineers. In the case of additional contribution, meetings, travel, etc. it may require a culture shift and time for the project team to adjust to. In order to avoid design and preconstruction cost overruns and schedule impacts, both cost and schedule must be well managed, which may mean delegating that responsibility to the contractor, by contract. Also, during the proposal phase, both designers and contractors need to be aware of design and preconstruction costs when proposing a fee, either by past experience or by interaction with others with CM/GC experience.

4.5.9 Associated Disadvantage: High Demand of Qualified Staff

The *High Demand of Qualified Staff* in CM/GC projects was also repeated by contractors, owners, and engineers as a disadvantage of the CM/GC process (see Figure 12). Contractors named it as the fifth most mentioned disadvantage of the process for them particularly, listed as 10% of the total disadvantages (see Figure 13). The *High Demand placed on Qualified Staff* was

the most repeated disadvantage to the owner, given as 24% of all owner-specific CM/GC disadvantages (see Figure 14).

Survey contributors noted the difference in staffing requirements on CM/GC projects, saying that the process required more dedication, expertise and time from key individuals. One stated that “for key people it was a full-time job” while another stated that “often a project manager could only have this one project.” This process was particularly problematic for contractors. The commitment of key personnel early on the project presented an issue if the contractor was involved with multiple proposals at any given time.

Qualifications of the individuals involved also presented an issue. “Decisions must be timely and key personnel must have the authority to make key decisions” stated one CM/GC experienced contributor. Others noted that individuals participating in CM/GC projects must have “knowledge, experience and time to manage risks” and participate actively, as well as the ability to “make tough decisions,” or that the project would be at risk of losing money instead of saving it.

Contractors and design engineers particularly mentioned the “sizeable investment in key personnel time without comparable returns.” One designer stated that the “design service commitment can be lengthy, tying up key people and offering little return other than basic cost reimbursement.” Another contractor stated that because of the requirement on key personnel from the project manager down to the superintendent level, “the compensatory payments based on hours and wage rates do not sufficiently reflect the lost revenues involved on other projects which are competing or those same resource personnel.”

The demand of qualified staff presents a potential barrier to implementation for agencies and contractors new to the CM/GC process, or for smaller organizations without the necessary

personnel. Survey respondents with CM/GC experience indicated that because leadership, negotiation, risk assessment, estimating, and decision making skills are all necessary to the process, succession planning is important for CM/GC project participants. They suggested finding the right staff members that were willing to do smaller CM/GC projects allowed them to develop skills needed for larger CM/GC projects, creating a supply for a future demand. Respondents also recommended that agencies and organizations be selective in the CM/GC projects they choose, so as not to tie up qualified staff on negligible projects. This issue was said to alleviate over time as contractors hire more engineering, estimating, and participating members of their staff who work on multiple projects, each gaining a CM/GC resume.

A related disadvantage listed by participants was the learning curve associated with the CM/GC process. While important, this disadvantage is also temporary, because of the training resources available through FHWA and AGC implementation guides, existing literature, and the aid of DOT's currently utilizing CM/GC delivery.

4.6 Additional Process Risks: Collaboration, Flexibility, and Reduced Disputes

This section discusses CM/GC processes contributing to *Collaboration, Flexibility, and Reduced Disputes*. Associate disadvantages to be discussed include: the *Difficulty of Collaboration and Disputes*, and the *Negotiation Phase*. The presence of *Collaboration and Flexibility* in the CM/GC process was the second most named benefit given by experienced project teams, mentioned as 16% of total benefits (see Figure 8). Contractors and owners also named *Collaboration and Flexibility* as a top benefit to their party individually as well, named by contractors as 17% of all benefits and by owners as 12% of all benefits (see Figures 9 and 10, respectively). Over 80% of contributors also indicated that CM/GC process improved the team's

ability to adapt to changes in cost, scope or schedule better than DBB or DB processes. Figure 30 shows the individual perceptions of CM/GC’s ability to adapt to changes, leading to the average value stated above.

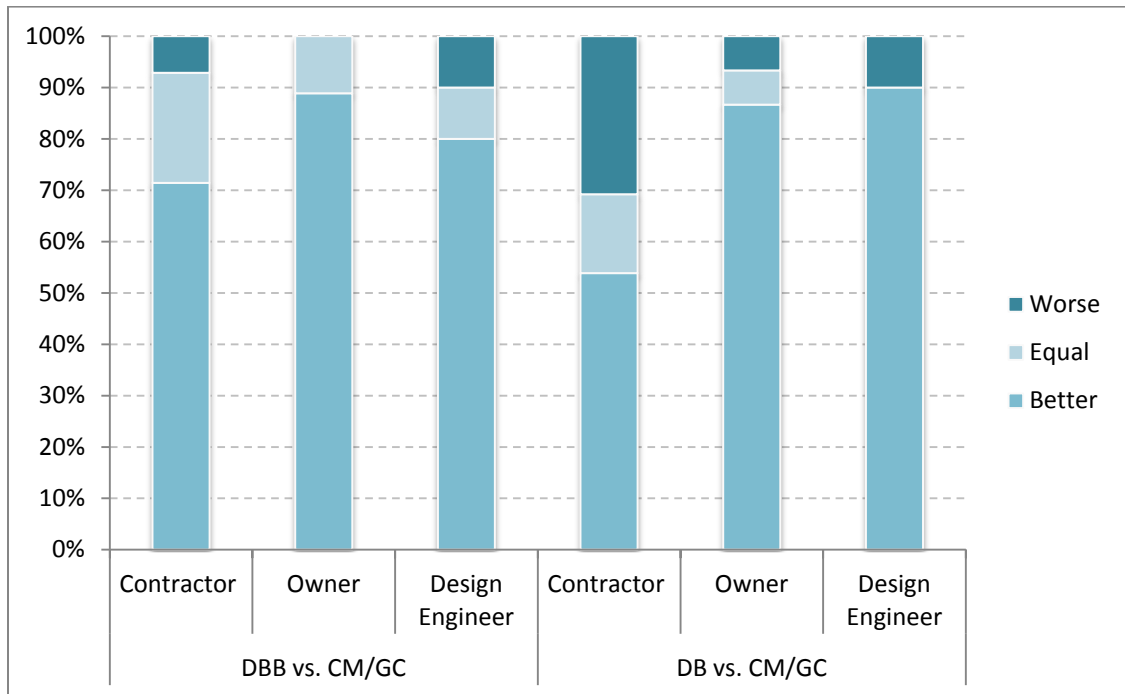


Figure 30: The Ability of CM/GC to Adapt to Changes

Through CM/GC, the owner benefited from the collaborative design team formed by both the designer’s and contractor’s teams. The collaborative approach of CM/GC also reduced risks to the owner. Under traditional delivery, the owner typically receives design input from the designer only. “Typically...the contractor is selected by a bid process near the end of the design phase. This is not a ‘truly collaborative environment’ where both the contractor and subcontractors feel invested in the project from their participation in the design phase” (AGC and NASFA 2007, 15). Selecting the contractor early, sometimes even before selecting the designer,

based on project needs “resulted in increased communication, more accurate pricing, and improved collaboration resulting in fewer change orders and claims” (AGC and NASFA 2007, 15). The CM/GC firm becomes an agent and ally of the owner through independent evaluation of project costs, schedule, and overall construction performance, including similar evaluation of changes (Strang 2002).

CM/GC project teams attributed the “collaborative and iterative” CM/GC process with reduced disputes, claims, and end of project issues, and the “synergy” typical in the process, allowing the contractor designer and owner to work as one team. Experienced contributors stated that the process allowed for the development of “trust early, and a focus on common goals” leading to problem solving of design issues before construction instead of during construction. Others noted that the collaborative environment created “an open communication venue” between the contractor, owner, and designer, and a dramatic reduction in miscommunication with widespread benefits.

The collaborative or “enhanced partnering” environment was also named as the basis for setting up good working relationships in the project. One respondent called it “amicable contracting” and another contractor noted that it helped him solidify relationships with the owner supporting future work. One responding contractor described the collaborative relationship during CM/GC projects in his experience as follows:

“An adversarial relationship can develop on traditional DBB projects, especially if there are multiple unexpected changes during construction. On a CM/GC project, the contractor has ownership in the plans because we’ve provided input into the project design. This eliminates the finger pointing and potential change orders during the construction process. Also, in a CM/GC contract the owner understands the risks that are accounted for in the contractor’s estimate and the risks that are not accounted for. Overall, it is a much more efficient and cost effective way to construct a project because of the openness and transparency during the pricing of the job.”

Respondents noted that the entire project team was more likely to “engage more fully in the project,” “take ownership in design when constructing” and “contribute to success in more areas.” They also noted that this collaboration promoted “flexibility of the owner to make adjustments to the scope as the project develops,” and that within the CM/GC process the project could have “more flexibility to change with the needs of the project and community, but still meet schedule and budget” requirements.

Flexibility is another associated advantage of CM/GC. CM/GC project delivery “provides for flexibility in the implementation of design changes late in the design process without impacting construction schedules and final delivery dates” (Gransberg & Shane 2010, 14). Flexibility in a project leads to a reduction of risk associated with strict budgets and schedules. In the CM/GC delivery method “there is much more flexibility and ability to handle the unexpected and there is a level of control over the design process that is not possible within an arrangement where the designer and constructor are contractually linked” (Ghavamifar and Touran 2009, 230).

The value of flexibility was evidenced in UDOT’s Mountain View Corridor project, explained more fully later within this chapter. Throughout the project nearly 150 agreements were required to handle approximately 500 individual conflicts. Because “29 cities, service districts, utility companies and third parties owned or had interests within or adjacent to the corridor...UDOT had to conduct extensive negotiations with landowners and utility companies. Again, [CM/GC] benefited this effort as it provided a much more flexible project delivery approach” (Jackson and Bekka 2012, 17). Measures which would have been extremely difficult within a different delivery method were made possible through CM/GC processes.

Over 90% of contractors, owners and design engineers contributing to this research indicated that in their experience, CM/GC processes generally had a positive effect on project relationships. Based on interviews conducted with project management teams involved in 22 Federal and State projects, UDOT project teams “agreed that the CM/GC process was a positive experience, that the project benefited from the CM/GC process, and that the team would prefer to continue working in this process” (Alder 2012, 10). One participant in this research stated that the “high levels of trust” present in CM/GC projects allowed the team to “explore design innovation and pricing strategies in an open environment,” and eventually provided “confidence for the owner that the team had delivered the highest possible value for the money.” Another stated that CM/GC allowed the project team to “fight the project problems and not each other.”

More effects of collaboration on project relationships shared by respondents included:

- Working toward common goals builds trust and reduces jobsite tension
- It allows more ‘cards’ to be laid out on the table, further instilling a level of trust
- Team unity develops better than other methods. Even with DB, there are some adversarial roles that aren’t present with CM/GC
- More face to face communication helps generate empathy for both sides

4.6.1 Associated Disadvantage: Difficulty in Collaboration & Disputes

Difficulty in Collaboration was the fifth most mentioned disadvantage by project teams, who stated that poor project relationships between a CM/GC team could potentially compromise the project (Figure 12). The collaboration necessary in a CM/GC project was said to require a “larger coordination effort” and because of the increased number of people involved, final decisions could be harder to achieve when “everybody has an opinion.” One respondent

explained that it sometimes seemed that “too many parties were involved; i.e. contractor, designer, sub-designer, owner, owner’s agent, public information specialists, etc.” Engineers specifically noted that this might mean “more reviewers to answer to and satisfy.”

Owners stated that CM/GC presented uncertainty about whether the selected design and contractor would work together as a team, and the difficulty in managing multiple contracts and multiple firms “with different values and perceptions.” One contributor stated that during design and preconstruction phases, traditionally trained DBB personnel “may be uncomfortable with the lack of structure (fully developed plans and specifications) and have difficulty leading resolution.” Also, a lack of collaboration in these early phases, especially in defining responsibility and risk ownership can make resolution difficult during the construction phase.

4.6.2 Associated Disadvantage: Negotiation Phase

Another disadvantage related to *Collaboration and Flexibility* given by experienced project teams was problems in the *Negotiation Phase* between the design and preconstruction Phase, and the Construction phase typical practiced in the CM/GC process. The third most often repeated drawback, responses relating to issues in the *Negotiation Phase* comprised 12% of responses given by CM/GC teams (see Figure 12). Owners specifically were prone to note difficulties in the *Negotiation Phase* as a drawback for project owners.

Experienced CM/GC project teams stated that the *Negotiation Phase* sometimes means a “drop off from design to actual construction”, and called negotiating to a fair price “difficult” and “cumbersome” with the “risk of not reaching an agreeable construction contract price.” The negotiations were also called an “uncomfortable process for an agency that typically used low bid processes,” also requiring additional team members and the anticipation of items like shared

savings clauses. One contractor noted that the drawback for him was that there was “no guarantee that the project would move into the construction phase” after significant resource investment in design and preconstruction.

Owners stated that the negotiation phase presented them with the potential difficulty of removing an uncooperative contractor after failed negotiations or once early packages had begun. One participant contributed that design could be “easily tied to a contractor and if the project was schedule critical,” it was often difficult to cut ties. The “owner must be willing to sever the contract if the contractor does not perform or if costs are unacceptable.” This could mean stopping construction, converting the project to DBB, and pursuing competitive bids.

One owner did note the flexibility of severing the CM/GC process and converting the project to DBB were advantages to the process as well. This insight can be particularly beneficial for owners; however, consideration must be taken for the possible delays associated with changing delivery methods during schedule-driven projects.

4.7 Management of Project Specific Risk through CM/GC Delivery

This section emphasizes the ability of CM/GC processes to promote the management of project specific risks. It also discusses projects best suited to CM/GC project delivery. One corresponding disadvantage is listed and discussed—that CM/GC may not be suited to small or simple projects. Project Risk Management benefits were grouped as they relate to *Risk Identification and Assessment, Risk Minimization and Management, Risk Retiring and Allocation*. Additional sections also discuss *Risk Tracking, Monitoring and Reporting, and Risk Sharing and the Sharing of Risk Savings*.

Improved Risk Management was the most repeated benefit of the CM/GC process by the project team, cited as 21% of total benefits mentioned by contractors, owners, and design engineers (Figure 8). It was listed by contractors as the second most repeated benefit to the contractors, as 17% of total benefits mentioned (see Figure 9). *Improved Risk Management* was the third most mentioned benefit to both the owners as stated by the owners and to the design engineers by the design engineers (see Figures 10 and 11, respectively). Additionally, nearly 98% of the project team members surveyed indicated that CM/GC process enabled the project team to minimize and manage risk better than DBB processes. Over 80% of those surveyed indicated that CM/GC process improved the team's ability to minimize and manage risk better than DB processes. Figure 31 shows the individual perceptions of CM/GC's ability to minimize and manage project risk, leading to the average values stated above.

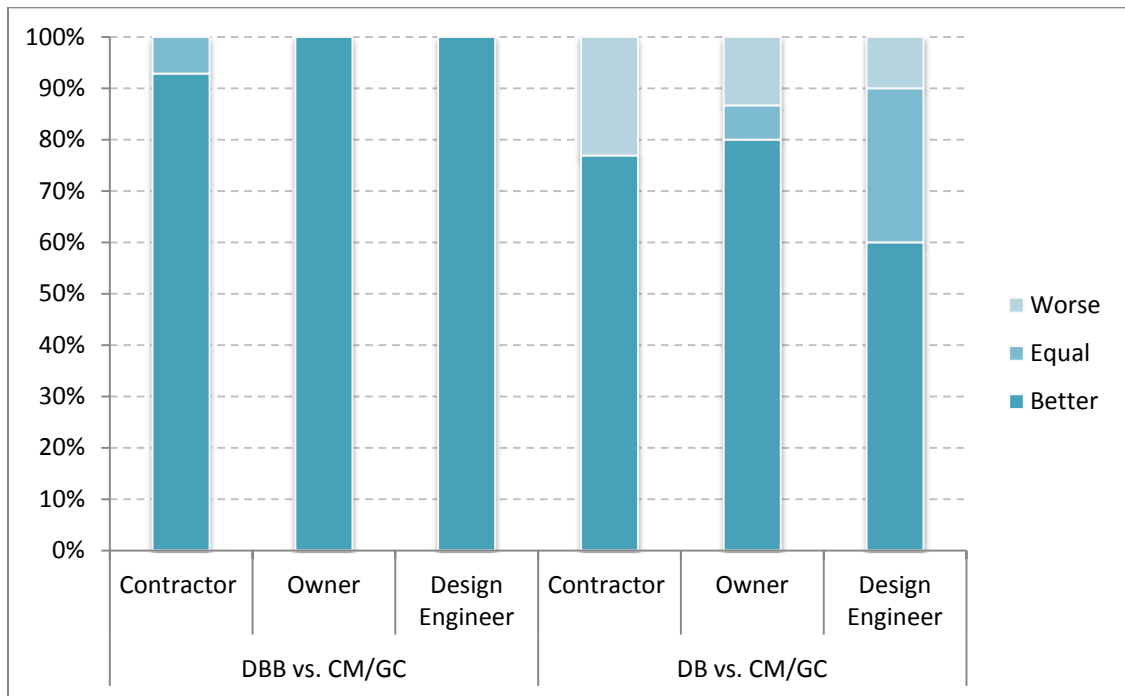


Figure 31: The Ability of CM/GC to Minimize and Manage Project Risk

4.7.1 Projects Best Suited for CM/GC Delivery

Improved project risk management is a primary reason agencies choose to delivery projects using CM/GC processes. This was supported by the responses of CM/GC experienced project teams consulted as part of this thesis. Researchers claim that CM/GC is “advantageous under the following constraints:

- The transportation infrastructure requiring immediate improvements;
- The design is technically complex, difficult to define at the early stages, subject to change, or requires the analysis of several alternatives;
- Coordination of external agencies is necessary, increasing concerns about cost overruns and the construction schedule; or
- The project is sequence-or schedule-sensitive” (Gransberg 2013, 11-12).

Project participants were asked to provide the types of projects that were best suited to CM/GC delivery. Their responses offered support for the argument for CM/GC as a valuable project risk management tool. Contributors stated that CM/GC was ideal for projects that the owner needed to keep control of, possibly where the owner was “under strict scrutiny,” and with a large dollar amount. Others mentioned the “potential for innovation,” or “fast-tracked” projects still in design infancy.

Most telling were the responses regarding risk-related project characteristics. Respondents stated that projects with “challenging construction constraints” and “atypical challenges” involving schedule, procurement, urban reconstruction, utility coordination, complex facilities or structure, geotechnical issues, political or stakeholder issues or difficult levels of traffic, among other challenges were appropriate for CM/GC delivery. CM/GC candidates were

described as “complicated, multi-disciplinary,” “cost-sensitive, time-impaired” and complex. Contributors often repeated the phrase “high risk” in association with CM/GC projects, including projects with multiple unknowns, risks that were difficult to quantify, and undefined or variable scope. One participant shared that CM/GC worked well for “complex projects where the owner...can’t frame a box around the problem for a traditional or DB delivery.” Another stated that if the project was motivated by speed, the owner may choose DB delivery, but “if you really need to get it right, you...go CM/GC.” Thus, the project characteristics that may pose a threat to project objectives under other delivery methods are the ideal characteristics for CM/GC delivery.

4.7.2 Associated Disadvantage: Not Suitable for Small or Simple Projects

The reverse side of this argument, particularly important for project owners, is that CM/GC delivery may be *Unsuitable for Small or Simple Projects*. This disadvantage tied for sixth in the list of top ten disadvantages to the CM/GC process (see Figure 12). CM/GC project teams stated that for projects described as low risk, “straightforward,” with “no sensitive community settings” and low dollar amount project value, CM/GC may not work as well or may have minimal benefit. This may mean more difficult implementation, or more coordination than should be necessary for a smaller project. One contributor stated that “small projects were not likely worth the outlay of time by the contractor” during the design. This may be a deterrent for agencies looking for reasons to implement CM/GC delivery. When CM/GC is considered as another tool for the correct project delivery job and not a ‘one size fits all’ delivery method, agencies should recognize the value for some projects through CM/GC delivery.

4.7.3 Risk Identification and Assessment

The following sections on *Risk Identification and Assessment*, *Risk Minimization and Management*, *Risk Retiring and Allocation*, and the *Sharing of Risk Savings* summarize the response of CM/GC processes to specific risk management, and current practices as identified by survey responses. Identification of project specific risk is the critical first step of effective risk management. The FHWA stated that when risks are “understood and their consequences are measured, decisions can be made to allocate risks in a manner that minimizes costs, promotes project goals, and ultimately aligns the construction team...with the needs and objectives of the traveling public” (Ashley, Diekmann and Molenaar 2006, 31).

The FHWA indicated that “people and the agency’s risk culture are the keys to continuous risk identification and management” (Ashley, Diekmann and Molenaar 2006, 13). Given this statement, CM/GC’s integrated team approach at project management provides an ideal setting for risk identification and management. Improving the information and “scope definition of areas fraught with uncertainty, such as underground conditions” was a key factor in order to decrease risk (Ghavamifar and Touran 2009, 230).

Based on the responses of contributing project team members, the collaboration of design and construction teams in risk identification was typical in CM/GC processes, and those processes lead to “fewer construction surprises.” One contributor stated that the shared identification process “results in more identification of issues up front and fewer change orders during construction.” Early identification also affected price, because when identification happens prior to pricing, “risk could be assigned so the contractor may not need to build risk into his price.” Within CM/GC processes project-specific risks were “better understood and planned for than in DBB,” and the risk levels were “more manageable than in DB.” The iteration of

design and risk analysis found in the CM/GC process also benefited the continuous identification of new risk. Typical risk identification and management processes are shown in Figure 32.

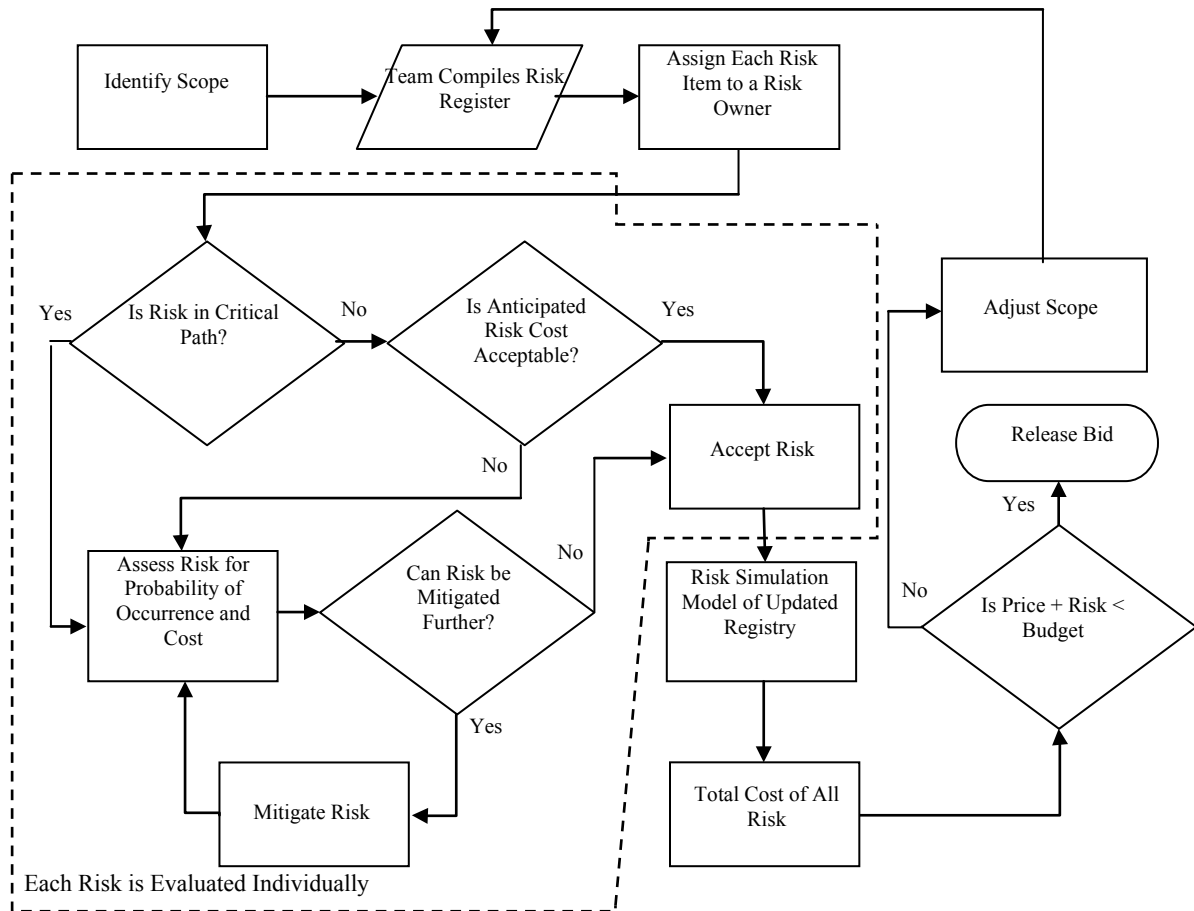


Figure 32: Typical Risk Process

4.7.4 Risk Minimization and Management

Following identification and assessment, CM/GC processes provide for improved risk minimization and management. The Department of Energy's (DOE) 2003 report on risk management practices emphasized that risk management is a team function. "This stems from

the pervasive nature of risk and the impact that risk-handling plans may have on other project plans and actions. In the aggregate, risk planning, assessment, handling, and monitoring affect all project activities and organizations” (Ashley, Diekmann and Molenaar 2006, 4). Certainly CM/GC processes provide the means for a team based approach at risk management, as opposed to paying one party to mitigate or manage all risk. This facilitated project cost savings, given that two recent studies showed that it was typically for contractors to add risk premiums between 8 and 20 percent to their contract with the owner (Zaghloul and Hartman 2003). Risk management is also often used as selection criteria. Proposing teams were required to identify possible risk factors associated with the project and provide a risk management strategy for handling project risk (UDOT 2012).

80% of responding team members agreed that CM/GC processes succeed in reducing the overall risk of construction, meaning that not only does CM/GC help project teams manage risk, but it also reduces the risk the team must manage. According to the responses of participants, this reduction comes as a result of:

- “Early and often” collaboration
- Identified and accounted for unknowns such as material supply, existing conditions, traffic impacts, weather delays, etc.
- All parties working together to “formulate plans and solutions quickly”
- Team discussion of risks
- The ability to “easily effect minor changes to design to avoid potentially damaging contract delays”
- Understanding constructability means and methods

4.7.5 Risk Retiring and Allocation

As a result of risk identification, assessment, and management, specific risk items can then either be retired or allocated to a specific party. Contributors to this research indicated that CM/GC processes often allowed the owner to maintain control of the risk, meaning that when the risk was retired, the related contingency could also be reallocated. The owner would then get a less expensive project unless the risks were actualized. The process also benefits the contractor because risk elements leading to lost product or time delays were often minimized, contributing to “a higher project profit margin.”

Construction risks significantly affected the final cost of a project. How these risks are allocated and managed has a direct bearing on the final total cost (Zaghloul and Hartman 2003). According to a recent investigation, “DBB places the majority of the project risk on the owner, whereas DB shifts most of the project risk to the contractor. CM/GC offers a more balanced approach to managing risk” (NCHRP 15-46 2014, 259). Based on this information and UDOT project experience, UDOT developed a “Risk Theory” graph, as shown in Figure 33. The stated premise is that CM/GC delivery enables the project team to “reduce risk” and “share the savings.”

In Figure 33, under DBB the owner retains a large majority of the risk because of his guarantee of the contract documents and the possibility of changes or overruns. In DB, the same amount of risk is present, but the majority is transferred to the contractor based on his lump sum bid to complete the specified project on time and at budget. Change orders and cost overruns remain high because of unknowns in the design and scope at cost certainty. UDOT’s theory states that under CM/GC project delivery, overall project risk is reduced by the integrated team approach. Also, the remaining risk is distributed to members of the project team best able to

handle it. Few change orders occur because of fewer design errors, and contractors “tend to fix things on their own instead of asking for more money” because of their design participation (Alder 2011b).

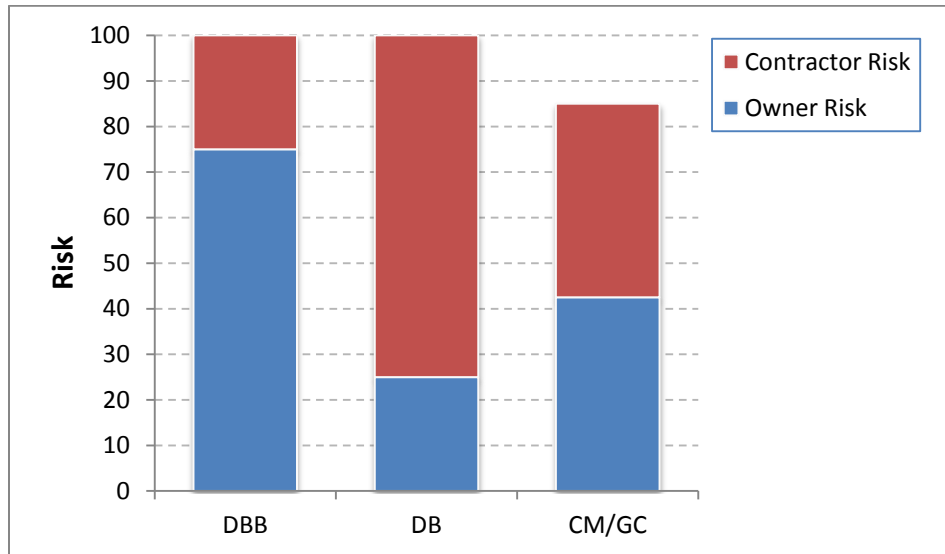


Figure 33: UDOT Risk Theory

When surveyed, 80% of project participants agree that CM/GC processes result in reduced risk. Participants were also asked to provide estimates of the amounts of risk each party holds under a DBB, DB, or CM/GC method. The results are shown in Figure 34. The results uphold UDOT’s risk theory that CM/GC delivery reduces overall risk and allows risk to be shared evenly between the owner and contractor. The results could be interpreted in two ways. Within CM/GC delivery, the owner and contractor divide risks equally between themselves, or within CM/GC delivery both owner and contractor divide responsibility for the management of all associated project risks. Figures 35 through 37 show the individual perceptions of contractors, owners, and design engineers.

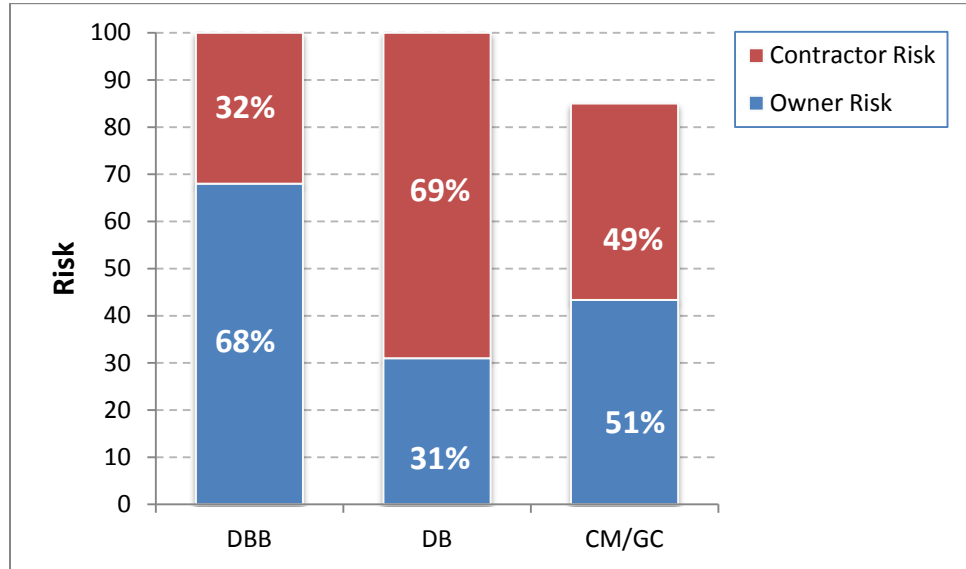


Figure 34: Typical Risk Sharing, All Parties

As seen in the figures, owners and engineers perceive more risk delegated to the owner in DBB delivery than do contractors. The perception between the parties were closer in the case of DB, and all parties perceived risk to be equally divided between owners and contractors, within one percentage point, in the case of CM/GC delivery.

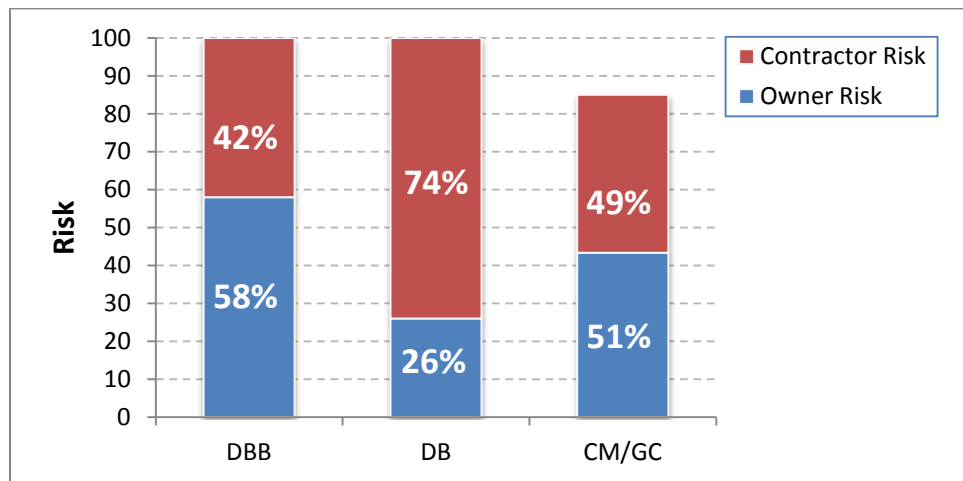


Figure 35: Typical Risk Sharing Perceived by Contractors

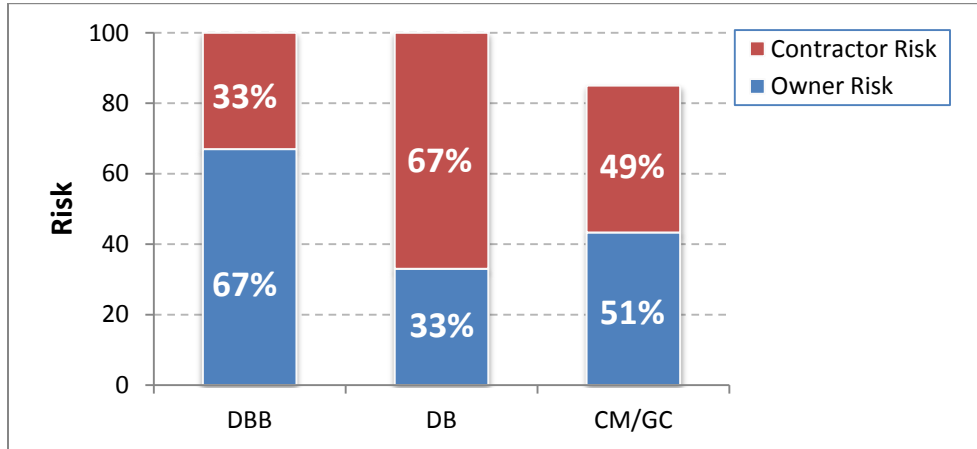


Figure 36: Typical Risk Sharing Perceived by Owners

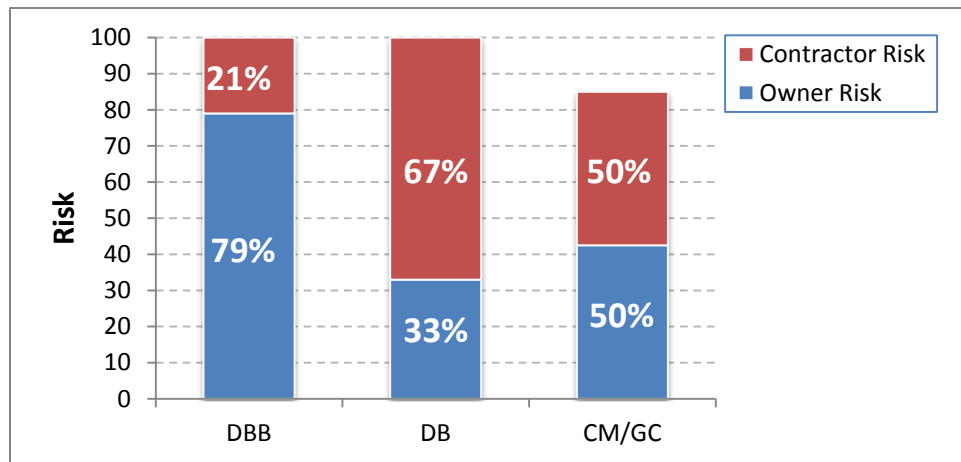


Figure 37: Typical Risk Sharing Perceived by Design Engineers

One respondent explained his experience with CM/GC risk ownership in this manner:

“Risk is divided into three areas—

1. Owner Risk—Risks the owner takes because it was completely out of the contractor’s hands such as scope changes, field directed changes, or a change in site conditions;

2. Contractor Risk—Risks the contractor managed because the contractor could control what he or she does in the field (relating to uncertainty in constructability or production); and
3. Shared Risk—Risks the owner and contractor shared due to some combination of characteristics of the work that can be controlled or are out of the contractor’s control. These risks and their impacts were negotiated, priced, and a sharing percentage was determined by the team collaboratively during pricing.”

The project-specific criteria for allocating risk and the cost to assume each risk item were decided through an iterative risk workshop—“a collaborative and mutual agreeable process.”

Multiple correspondents noted that “risk comes at a price” so the CM/GC processes aimed at eliminating or retiring risk through design investigation and iterative construction estimates served to also eliminate some contingency pricing, thereby reducing the overall cost of the project. One owner stated that the benefit of CM/GC risk processes was that as risk was continually identified and allocated, the price was further refined to avoid “surprises.”

The shared management of risk was a constant theme in responses from owners and contractors. One owner stated that “having the contractor perspective to... work as a part of the team to mitigate the risk was more effective than relying solely on the design consultant. By having the contractor produce a cost model with lump sum bid items, it often drove the discussion of who owns the risk and if the department was willing to pay the contractor to take that risk.”

One representative from the contractor’s side shared that in a CM/GC project, risks were less often seen as owner risk to be managed solely by the owner or as a contractor risk to be managed solely by the contractor. Instead, risks were seen as project risks to be managed by the

project team. Another contractor supported this view. He shared that in a DB project, the contractor felt the weight of being responsible for all project risk after entering into the contract. In the CM/GC process, the pressure of managing all project risk was removed. The contractor became part of the team responsible for finding solutions to project risk, instead of being solely responsible for risk problem-solving. It made the experience more acceptable to the contractor.

4.7.6 Sharing of Risk Savings through CM/GC Delivery

According to experienced CM/GC teams, the sharing of risk savings was “a complex issue” that varied from “contract to contract.” The AGC stated that “there are numerous ways to structure a shared savings provision, although the owner typically received the majority of any savings” (AGC 1991, 9). Most contributors to this research also indicated that under CM/GC processes risk savings returned to the owner, which in some cases benefit the project.

Risk savings were differentiated by those associated with the design phase and those associated with the construction phase. Participants shared that during the design phase, the integrated team worked to retire risks, to avoid risks entirely, and to mitigate the risks that could not be avoided. In CM/GC processes, the owner reimbursed both contractor and design engineer for the benefit of risk investigation during an iterative design process in an effort to reduce the cost the owner may eventually pay for realized risks. The owner’s investment in the design phase was, therefore, an investment in risk reduction.

If a risk was retired in design, when the contingency for the risk had not yet been included in the project’s GMP/TMP, the owner benefited from the risk savings of what the effect on cost or time would have been, had the risk occurred. One contributor said that these processes allowed the owner to pay for “actual conditions” instead of paying the contractor to

manage a risk that may or may not occur during construction. In this way, the owner, or the department, generally received the benefit of risk savings in the design phase.

During the construction phase, the sharing of risk savings was based on risk ownership and contingency ownership. Contributors indicated that the party that owned and held the contingency for the risk was the party that would benefit, or retain any unused contingency, if the risk was not realized. One participant stated that typically, the owner established a contingency account based on contractor and designer input to handle potential risks, “if those risks didn’t materialize the savings stayed in the owner’s budget.” In this way, the owner also generally received a majority of risk savings in the construction phase, if the owner had made the effort to hold the majority of contingencies, as was possible through CM/GC processes. Even with the owner held risk, the owner could consult the contractor, get a price from the contractor in case the risk occurred, and still hold the contingency to pay that price. This could be of benefit to the project, because those savings could then be reinvested into the project to build “more scope.”

CM/GC processes encouraging open-book accounting and transparency in the bidding process made owners aware of the risk priced into the contractor’s bid amounts. If the contractor were to take the ownership of the risk and take that risk into account in their pricing strategy, the contractor would then receive the benefit if the risk were not realized. CM/GC processes that allowed the owner to compare the engineer’s and contractor’s estimates at multiple phases during design help to “identify areas of the project where the contractor may be assuming a high degree of risk” (NCHRP 15-46 2014, 259). Discrepancies in these estimates prompt discussion between the project team about the mitigation of the risk factors, “reducing the risk and thus the cost” (NCHRP 15-46 2014, 259).

Some respondents also noted that although a majority of risk savings belong to the owner, both the contractor and owner could benefit indirectly from risk savings. One stated that through alternative pricing, the contractor could “cater the project to their expertise and maximize the cost benefit to the owner and themselves.” Some risk savings were also split when risks were identified and responsibility was shared during construction. Based on CM/GC team experience, the split was determined based on what the contractor was able to do to mitigate the risk and reduce the cost, ranging from 75% to the owner and 25% to the contractor to 50% each. The AGC states that this “sharing of savings between the owner and [contractor] could enable the parties to capitalize on performance variables that were unrecognized at the time of contract formation” (AGC 1991, 9).

Owner-dominance over the benefit of risk savings may be perceived as a barrier to implementation by contractors in the CM/GC process. One owner noted that while risk saving and open book processes were highly beneficial to the owner, “it was important to build trust in the [CM/GC] process, by recognizing that the contractor must make a fair profit on the project.” This participant also stated that “the hardest part was to reconcile ‘fair’ to all team players.” One author of CM/GC literature reported that “the vertical construction industry typically splits the savings below a given target cost as an incentive to keep costs down”...yet “the research found that a shared savings clause did not create a significant incentive for the CM/GC contractor and may add a layer of administration or account to produce auditable financial records of project costs” (Gransberg 2013, 14). This author additionally cited earlier research and interviews with case study contractors, confirming that “by far the most important incentive that an owner has is the promise of repeat work” (Gransberg 2013, 14).

Understanding risk savings sharing, profit margins, and any other perceived barriers to implementation, contractors within the scope of this study were asked which delivery method they preferred. While selection should depend on project characteristics and no delivery method is ideal, 73% of contractors stated they would prefer to deliver a project by CM/GC. One contractor involved in this research shared the opinion that while a contractor generally makes the most profit in a DB project, CM/GC was the best of option” from an integrity standpoint,” and “provided the greatest value to all parties.” Another said that while many contractors preferred DB in order to have more control of the project, the risk in a DB project was inherently higher. In his opinion, CM/GC was preferred from a risk standpoint.

4.8 Innovation through CM/GC Delivery

This section discusses CM/GC processes fostering innovation. Topics examined include: *Providing Incentive to Innovate, Supporting Application by Identification of Opportunities and Risks, Balanced Risk Distribution, the Ease of Standardization, and Savings through Innovation and Construction Process Improvement.* One disadvantage is also discussed: *Transparency in Innovation and Value Engineering.*

Respondents repeated the *Environment Supporting Innovation* as one of the top ten benefits of the CM/GC process to the project (see Figure 8). It was also given by both contractors and engineers as one of the top five benefits to their party when participating in the CM/GC process (see Figures 9 and 11, respectively). An overwhelming 98% of the participants surveyed indicated that CM/GC processes enabled them to contribute innovations better than DBB processes. Additionally, nearly half of respondents indicated that CM/GC and DB processes both allowed the contribution of innovations, and 33% of those surveyed indicated

under CM/GC processes, the team was better able to contribute to project innovations than in DB processes. The related disadvantage of *Transparency in Innovation and Value Engineering* was given, primarily by contractors, as the final of top ten drawbacks of the CM/GC process (see Figure 12). In comparing DB and CM/GC processes, the results show some contradiction between the perception of contractors, owners, and designers. However, at least 70% of all parties agreed that CM/GC processes enabled innovation at least as well as DB processes. These results were captured graphically in Figure 38.

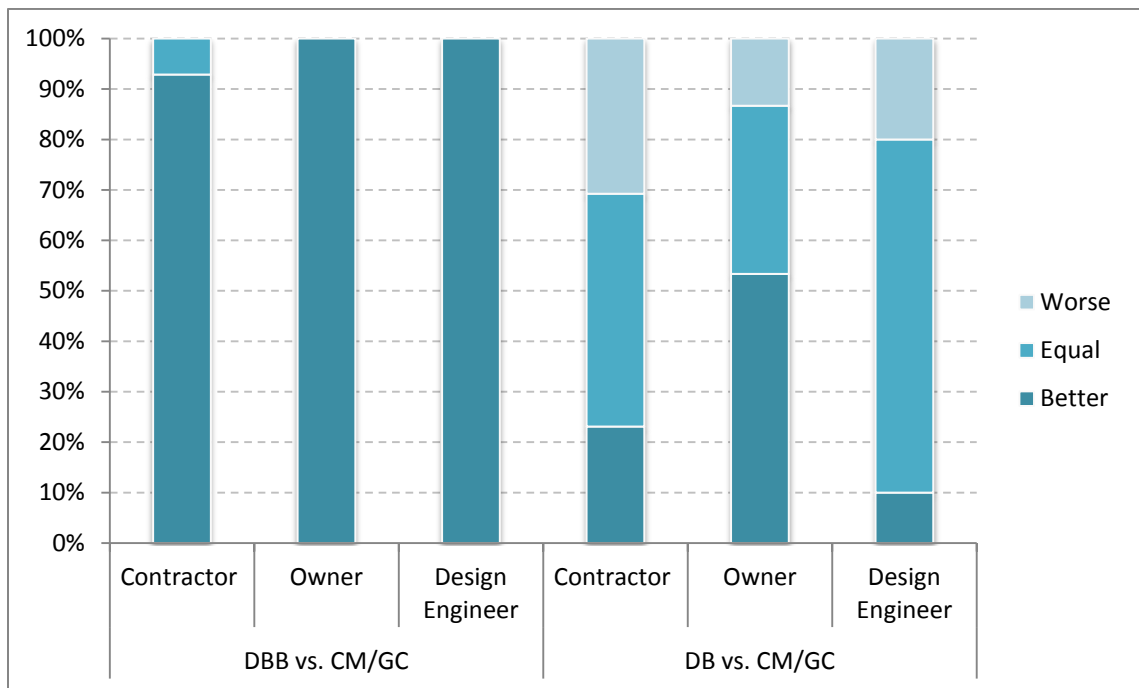


Figure 38: The Ability of CM/GC to Contribute Innovation

Innovation was one response to the risk associated with highway construction. This was evidenced by the problem-solving processes emerging recently in the highway construction industry, such as Advanced Bridge Construction (ABC), or other innovations based around

materials new to the highway industry. While the initial implementation of innovation often brought significant risk, that additional risk could potentially be offset by added cost and schedule savings. In CM/GC projects completed in Utah, UDOT reported that “innovations have produced a savings of 11% of the construction bid, by allowing the contractor to perform work more efficiently” (Alder 2012, 13).

Traditional delivery methods were less likely to provide support for non-conventional construction solutions. UDOT called CM/GC “the ideal delivery method to use when a project contains opportunities and risks that are best addressed through innovations” (Alder 2012, 7). The work of the project team and environment created by a CM/GC approach facilitate innovation in a way other project delivery methods do not. An integrated CM/GC team was in a better position to identify opportunities and risks to be addressed by an innovation, and to identify risks that could threaten a suggested innovation. CM/GC also allowed the owner to distribute and balance the risk of innovation between the project team members (Alder 2012). The FHWA also stated that the CM/GC delivery process fosters innovation. According to the FHWA Every Day Counts Initiative, CM/GC’s “collaborative process encourages both contractors and project owners to look at all options including using and innovative techniques or approaches that reduce time and cost—for example, use of Self-Propelled Modular Bridge Transporter (SPMT) bridge moves and slide-in bridge technologies” (FHWA 2012).

The following sections provide insight into current CM/GC practices promoting innovation, as supported by project team interviews conducted for this research.

4.8.1 Providing Incentive to Innovate

According to participant responses, CM/GC promotes innovation by providing the project team with incentive to innovate. Innovation in CM/GC processes begins during the selection phase. UDOT's Request for Proposal states that the CM/GC process is "intended to...apply innovation" and that it reduces "the cost of construction and provide[s] the best value to the public" (UDOT 2013). The RFP requires that the proposing contractor use the proposal to discuss the process "[the proposer] will use to...apply innovation during the design phase," "how [the proposer] will track and report...innovation savings" and "how the proposer will support the team during pre-construction and construction activities to achieve a favorable cost, including ways to bring the project costs down and on a schedule that is better than traditional projects" (UDOT 2013). Proposers are also asked to identify innovations that assist in achieving the goals of the project, and to provide their past performance "in providing innovation in construction projects in similar size and complexity" (UDOT 2013), as well as how that performance will benefit the current project. Those innovations are scored by an evaluation team without knowledge of the proposer's identity before analyzing the proposals. Surveyed owners participating in this research shared that encouraging the contractor to "think outside the box" and provide innovative solutions based on the premise that they are "king for the day" during the bid process...allowed the owner to evaluate several approaches to the project prior to selection."

The incentive of the project team to innovate continued through the design phase. In traditional delivery a contractor was responsible to complete construction work associated with the project according to the design, schedule, and budget requirements set forth in the contract documents. As such the contractor had little incentive to provide additional innovation. Because CM/GC processes involved the contractor in the creation of the contract documents, the

contractor was better able to contribute early to the development of innovations. The project team's responsibility over design, means and methods provided an atmosphere encouraging innovation.

One contributor shared that in DB projects the contractor directed designers under their direct contract to design what met the program but also fit within the contractor's budget. This typically meant what benefitted the contractor most and protected the contractor's profit margins within every line item. The contractors put pressure on the designers to provide what was asked for and usually not what was possible. In CM/GC the idea was to present innovation and value engineering ideas, exploring what was possible and not just what was expected or typical. Another respondent stated that in CM/GC projects, contractors were motivated to innovate during the design phase in order to drive costs down so that the owner could award the construction phase.

4.8.2 Supporting Application by Identification of Opportunities and Risks

Survey contributors stated that the environment created by the CM/GC process supported the application of innovations by the identification of project-related opportunities and risks. A CM/GC project relies on the design engineer, a sophisticated owner, and the contractor, each with proven experience in the highway construction industry. Participants of this research stated that this system, where the contractor provides input into the design, helped maximize the innovative capacity from all involved parties. Owners, designers and contractors have expertise in their unique industry and experience base. According to participants, all team members were brought to a unique project in a way that they were able to maximize the innovative nature of the

project and the team. The process promoted brainstorming, interaction between parties, and teamwork for positive winning solutions.

Contributors to this research also indicated that common goals encouraged innovation. Within CM/GC projects, each had a knowledge of and responsibility over meeting the specific project goals. All ideas to deliver the project within the project constraints were developed by the team and pursued to either adopt the innovation or reject it based on the common goals of the project. The project goals were more likely to be the team's common goals. This "increases the likelihood that the team will discover unforeseen risks and identify opportunities to enhance the project goals. Having the contractor on the design team accelerates the development of innovative approaches to risk or opportunity" (Alder 2012, 7).

Because of the expertise of the integrated project team and their ability and responsibility to identify opportunities and risk, a CM/GC project owner could direct the team to apply an innovation with the confidence that the innovation would succeed. Each member of the team had the opportunity to identify areas of concern before the plans were complete. These concerns could then be addressed through sufficient investigation and proper detail. The owner then addressed risk based on the contractual agreements between parties (Alder 2012). Because a thorough investigation had been conducted by the project team, team members were more familiar with the risk and more willing to accept their portion of risk associated with implementing an innovation. Additionally, because the contractor was selected before the design was completed, the designer was able to tailor the design to the contractor's strengths, specific experience, methods, and techniques to accommodate both innovation and smooth project delivery (Gransberg & Shane, 2010).

Participants also stated that CM/GC provided the ideal environment to apply new technologies. In this process, innovations and new technologies were based on owner preferences. One shared that CM/GC was a “great opportunity for the owner to try something new that it wants to implement” and that the process allowed the owner to “try new technologies with contractor input” and “innovate solutions to complex problems with the contractor that will actually build the project.” One designer that participated in UDOT’s 4500 Bridge Reconstruction project stated that “having the contractor on board early was a huge benefit due to the unique nature of the project and the newness of the technology. It was essential to have the general contractor and SPMT (self-propelled modular transports) contractor involved in design” (Mike Arens, Alder 2012, A-38). One study emphasized that the commitment of both contractor and designer to a high degree of collaboration, possible within this process, was “especially vital” when using CM/GC to implement new construction technologies (Gransberg and Shane 2010, 1).

4.8.3 Balanced Risk Distribution

Current research results indicated that CM/GC processes foster innovation through a balanced risk distribution. One contributor stated that “CM/GC creates a collaborative effort between the owner and the contractor that can spur innovation through the sharing of risk.” Innovations are typically only implemented if the contractor, or one of the other parties involved, is willing to accept all risk if the innovation were to fail. An integrated, experienced project team inspires a greater level of confidence that an innovation supported by designers, engineers and contractors can be successfully applied. This partnering allows the team to introduce innovations safely. One contributor shared that “the collaboration that occurred between the

owner, contractor and designer allowed each partner to communicate their own perspective on a wide range of risks.” As the other partners begin to understand and trust each other through this open process, they are more able and “willing to offer innovative ideas that may meet all requirements. They are also more apt to buy into ideas” they had a role in developing.

After risks were identified by the project team, CM/GC enabled the owner to consider the risk associated with applying an innovation, and delegate responsibilities and risk ownership. UDOT described this benefit as follows:

“By using the contractor as part of the design team, the owner has a greater ability to identify unforeseen risks. For example, if a traditional project discovers a risk that invalidates a portion of the contract, there is no incentive for the contractor to help resolve the issue once contract documents have been awarded. Thus deviations from the contract documents result in increased costs because the owner takes all the risk for undiscovered conditions. CM/GC utilizes the contractor to resolve challenges during design when the cost for delay is minimal. In this way the contractor takes a proactive role in addressing risks, and absorbs a fair portion of that risk” (Alder 2012, 8).

4.8.4 Ease of Standardization

The ease of standardizing innovation from CM/GC to other delivery methods was another survey-supported CM/GC process. New techniques and technologies now becoming standardized in the highway industry were initially implemented on CM/GC projects (FHWA 2013). These technical innovations produce a direct benefit to the project as their application helps achieve specific project goals. These innovations also produce a benefit to future projects, as their successful implementation is repeated and becomes standardized across delivery methods (Alder 2012). “Insights, innovations, and lessons learned through the process are at the owner’s disposal and can be applied to future projects regardless of delivery method” (Alder 2011).

Respondents stated that CM/GC provided the best setting to experiment with technical innovations. Through CM/GC, the team shared risk and allowed the free exchange of information required to learn about technical innovations. Contingency costs were reduced and all members of the team gain valuable experience that could be transferred to other projects as well as other delivery methods.

The mobilization of bridges on UDOT's I-80 Reconstruction project provided an ideal example of this benefit. The contractor recommended that all bridges be built at one location, a 'bridge farm' and transported into place. "Building bridges offsite, and moving them into place, resulted in bridge replacement that was accomplished in days. Every aspect of construction of bridge decks off site and installing was an innovative process. This led to an overall savings of at least one year as opposed to a standard DBB project" (Alder 2012, A-36). Mobilizing a bridge costs more than onsite construction; however, the User Cost savings (\$122,000,000) from "tremendous remediation and MOT costs" at multiple bridges, far exceeded the mobilization cost. UDOT used CM/GC to learn how to move large structures so that this method could be achieved through DB and DBB methods" (Alder 2012, 20).

4.8.5 Savings through Innovation and Construction Process Improvements

Contributors indicated that CM/GC processes promoting innovation and construction process improvements typically result in significant savings. One participant shared that "the value of CM/GC lies in the innovations contractors propose to save money." Because the contractor on a CM/GC project spent time developing the final project design and assuming a significant degree of ownership in the project, this motivated the contractor to provide innovation

and improve construction processes on the project. The result was a “better project for less cost to the owner via innovation,” as given by one contributor.

UDOT claimed that CM/GC produces its greatest savings through project team innovations that address risk—particularly those risks associated with the duration of the project’s construction phase, and thus impacting the public. UDOT reported that CM/GC projects cost “about 15% less than DBB and 23% less than DB owing to the innovations of a collaborative team effort and risk management” where the owner gets to keep the savings (UDOT 2012).

According to the participants of this research, in CM/GC projects “the contractor’s means and methods can be maximized into the design.” Also, “the plans and specifications can be tailored to contractor’s unique capabilities, benefiting constructability and costs.” Cost savings were seen as the contractor contributed to the modification of the design, enhancing constructability. Cost savings were also evident when the project could be delivered to the public early, because innovation and improved construction processes resulted in a reduction in the overall time of the construction phase.

4.8.6 Associated Disadvantage: Transparency in Innovation and Value Engineering

Survey participants noted one disadvantage associated with innovation: the *Transparency necessary for Innovation and Value Engineering* (see Figure 12). Each team member must be assured of the other’s transparency for the CM/GC process to be effective. Issues could arise because CM/GC processes relied “heavily on trust and fair dealing on all sides, which can be difficult for those raised in the DBB world.” One owner stated that it was a challenge to get the design team to participate actively in innovation or “to think outside the box.”

Some owners were concerned with the possibility that the selected contractor may knowingly hold back information. Contractors presented the concern that any innovation in means and methods, under CM/GC processes would be shared with the owner, as opposed to a DBB situation where the contractor would own the innovation. Contractors also stated that the innovative processes required that they “give away all value engineering ideas.”

Experienced team members were asked to respond to this possible barrier to implementation in a second round of questioning. While the owner typically benefits from innovation savings in the selection and design phases, contractor-led innovation savings during the construction phase would typically be split with the contractor. Participants were asked if some contractors might be unwilling to provide innovations upfront knowing that they may not win the project, or may not benefit from innovation savings until the construction phase. Contributors responded that they had not often encountered transparency as an issue.

Because the selection process is highly competitive, the contractor needs to include their innovations and value engineering ideas in the proposal if they want to be seriously considered for the project. Also, because innovations often focus on means and methods that are difficult to transfer between contractors, contractors are at little risk of losing the value of an innovation to a competitor. By disclosing innovations contractors demonstrate their understanding of the project and how well they’ll partner with the agency if awarded the project. In order for the project to be successful, all stakeholders must become part of the project team, working toward project goals. One contributor offered the reminder that the owner must be willing to pay the contractor well in order to develop the relationship of trust necessary for CM/GC projects.

4.9 Case Study—Mountain View Corridor

This section examines the result of CM/GC processes promoting risk management and innovation used during a recent UDOT civil construction project. These processes have been explained in greater detail in sections 4.3 through 4.8. Rather than provide a step-by-step guide on CM/GC practices, this section provides a CM/GC project case study to show the results of CM/GC risk management and innovation practices.

The Mountain View Corridor (MVC) is a planned freeway, transit and trail system along the western edge of Salt Lake County in Utah, intended to serve 13 municipalities. UDOT is implementing MVC in phases, the first of which was recently completed. UDOT opted to deliver the first phase of the MVC project by CM/GC, making it UDOT's largest CM/GC project to date (Jackson and Bekka 2013). The large dollar amounts on the MVC project made the results of innovative and proactive risk management processes more perceptible.

The MVC project presented specific challenges to UDOT and the project team. Beyond the typical complexity and high dollar amount in a transportation project of this size, the project included major utility relocations that were unresolved before selection of contractor, and complex right-of-way acquisition, evidenced by 275 individual parcels in conflict at an estimated cost of \$212M. The CM/GC delivery method provided an “ideal framework” for innovative and “CM/GC’s progressive and collaborative features provided the balance between realizing the contractor’s innovation and the owner maintaining control over the process” (Jackson and Bekka 2013, 19).

4.9.1 MVC Risk Management Practices

The input of the integrated project team in risk management through appropriate risk assessment and allocation, and quantified by simulation models, made risk management effective on the MVC project. Risk management processes corresponded with MVC's project four pricing milestones. CM/GC gave the team the opportunity to visit and revisit cost at each milestone, decreasing risk and cost. At each milestone the team held a risk workshop corresponding with that phase in design. The first milestone and risk workshop was conducted when the design was approximately 30% complete, the second at 50% design completion, the third at 75% and the fourth at 90%.

At each risk workshop, the integrated team conducted a risk assessment with the goal of recognizing the significant risk challenges to the project and initiating an appropriate management response (Ashley, Diekmann and Molenaar 2006). Based on agreed quantities, the team discussed "every possible good or bad thing that could happen to change the pricing" (UDOT 2009). Each risk item was assigned a percentage based on the team's perception that it might actually occur. The team also discussed what the impact of each risk item would be on cost and schedule. The compilation of these risk items became the risk register.

Based on the risk register, simulation models were used to find the effect of multiple uncertainties on a quantity of interest, such as total project cost or project duration. These simulation models, or Monte Carlo models, use random number generators to draw samples from probability distributions. They can determine risk effects for cost and schedule models that are too complex for common analytical methods, incorporating the risk knowledge of the project team for both cost and schedule risk events (Ashley, Diekmann and Molenaar 2006).

Simulation models also facilitate sensitivity analysis, allowing the team to see the impact of specific risk events on the project cost and schedule (Ashley, Diekmann and Molenaar 2006, 24). In the MVC project, corresponding curves were developed through Monte Carlo simulation to identify the probability of finishing the job at a certain cost. The curves, as seen in Figure 39, were “useful for determining project budgets and contingency values at specific levels of certainty or confidence” (UDOT 2009).

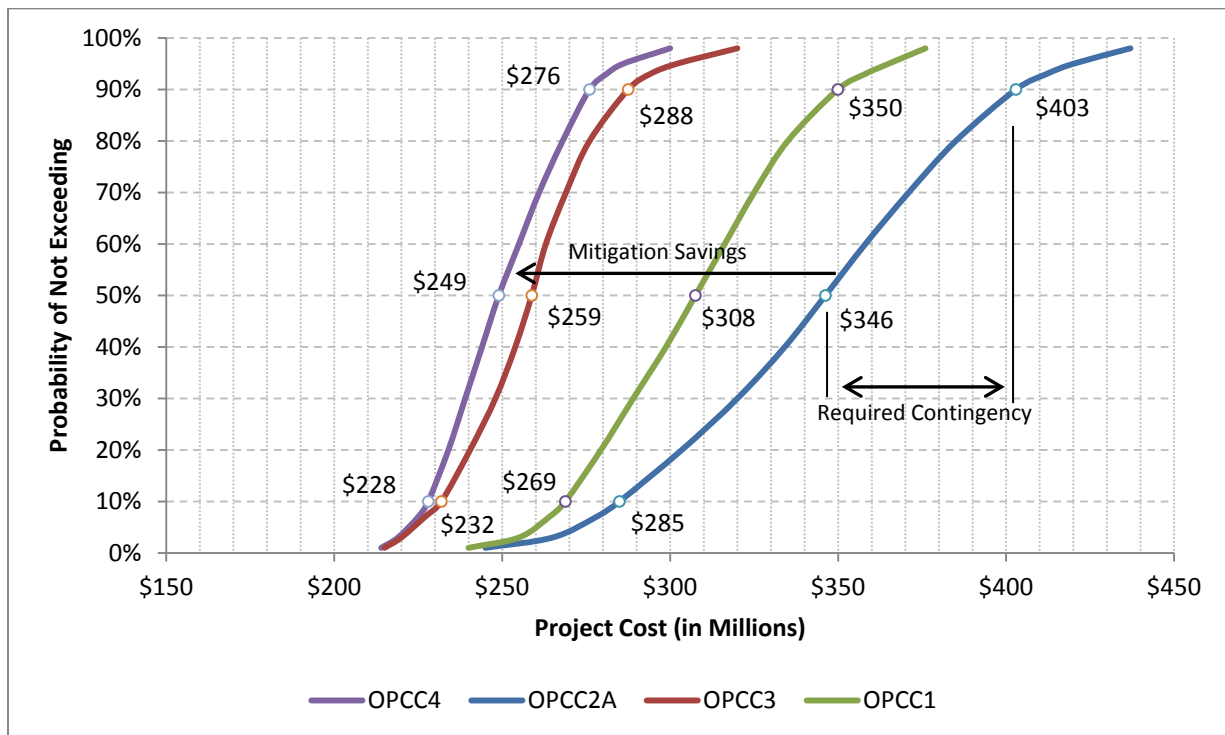


Figure 39: Risk Curves on the Same Contract after Four Risk Registers

At calculation of the first risk register curve the project had a 90% probability of finishing within a cost of \$350 million, therefore \$350 million was set as the project budget. The contractor was selected and incorporated into design and constructability reviews, as well as risk

discussion. In Figure 39, the green curve labeled OPCC1 (Opinion of Probable Construction Cost 1) corresponds with 30% design and the first risk workshop.

The team continued to identify, assign and retire risks, and the corresponding risk register and curves were updated quarterly. “As risk was retired, contingency was retired in kind” (NCHRP 15-46 2014). When the project was priced at 75% design, a number of risks had been retired and the contractor had introduced several innovations. The probable cost began to fall as risks were retired, shown in the Figure 39 on the red curve. At 90% the probable cost had dropped to \$276 million. Figure 39 calls this \$127 million Risk ‘Mitigation Savings.’

Figure 40 shows the difference in required contingency for the project at each milestone, each of which generated an Opinion of Probable Construction Cost (OPCC). After the contractor became involved in the project, between OPCC1 and OPCC2A, the contingency fund increased. The owner stated this increase was expected because designers tend to estimate risk more conservatively than contractors. After the contractor was brought on board and the two sides began working together to mitigate risk, uncertainty fell quickly by over \$29 million (UDOT 2009). The savings in contingency alone for the project was 13%.

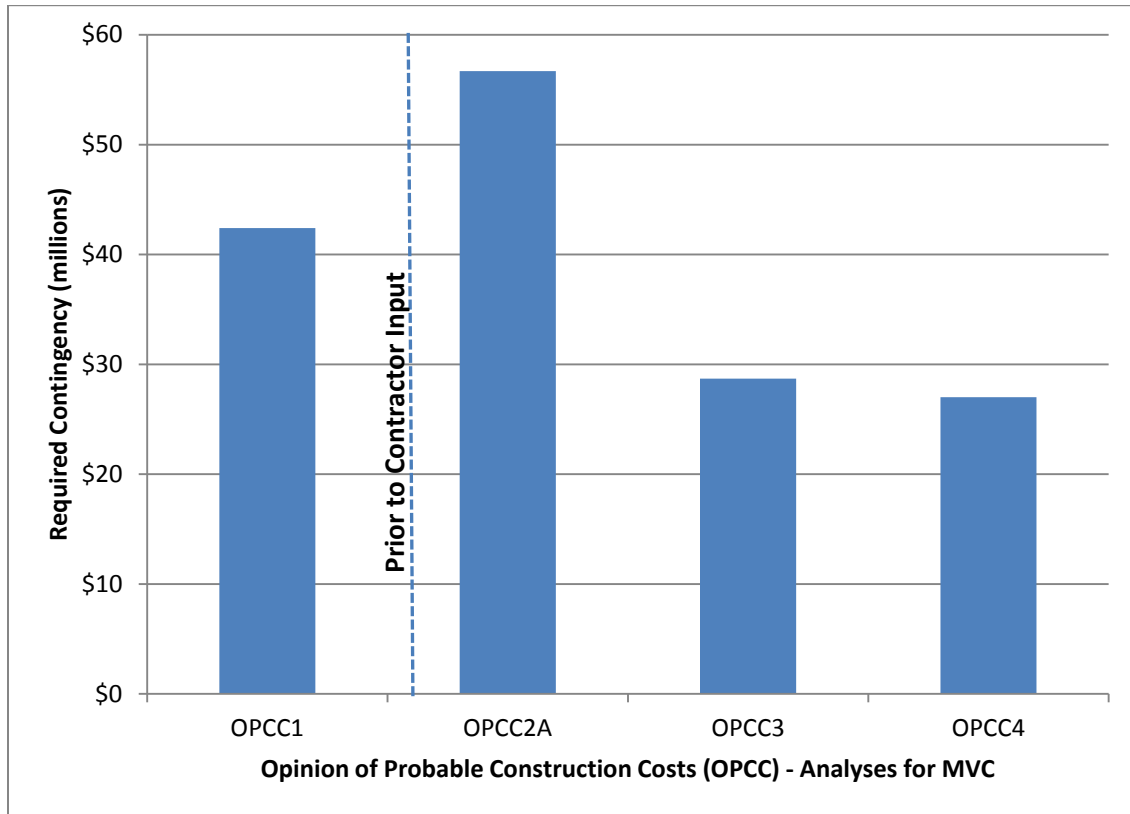


Figure 40: MVC Contingency Reduction Due to Risk Mitigation

One additional insight on MVC risk management results shows the comparable value of CM/GC process and DB processes. Figure 41 shows the engineer's initial estimate to build the project at roughly 30% design completion, seen in the first bar. The bar corresponds to the end of the preliminary engineering when the design has sufficiently developed to acquire right-of-way and to begin the environmental permitting process. This is also the point at which a DB project is typically bid.

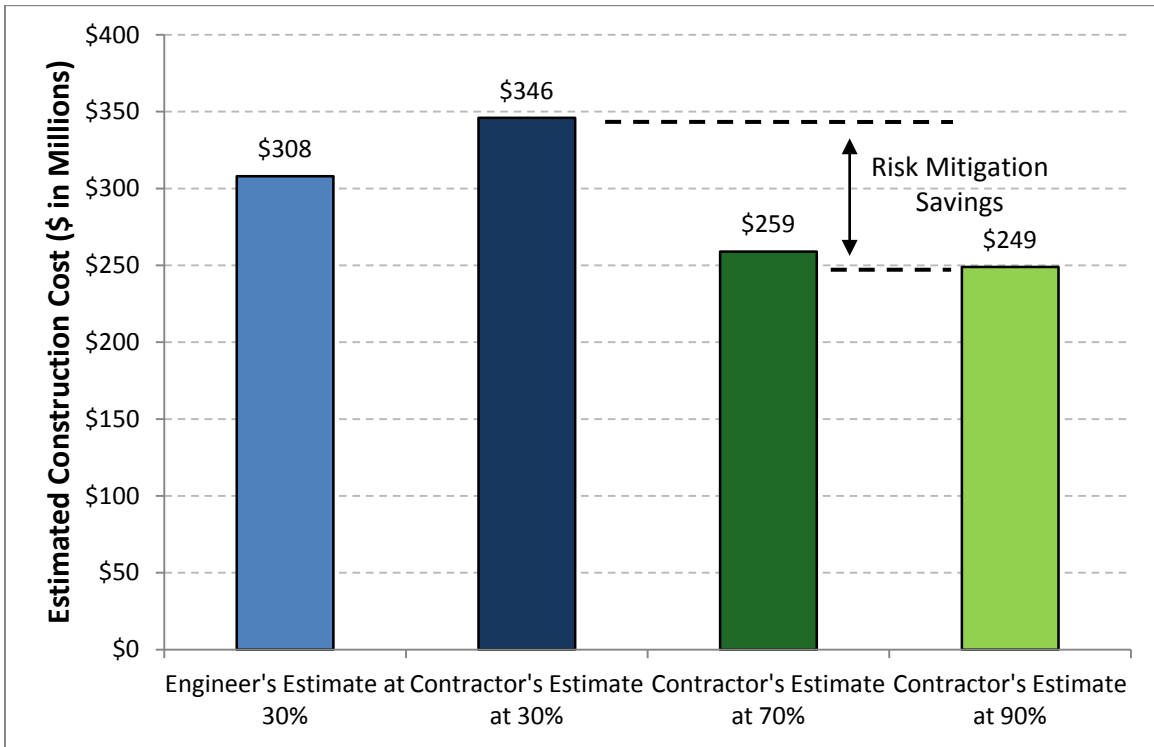


Figure 41: MVC Risk Mitigation Savings

The second column, labeled as the Contractor’s Estimate at 30%, shows the contractor’s initial estimate to construct the project based on plans at 30% design completion. Therefore \$346 M would have been the contracted construction cost to UDOT for the MVC project if the project had been delivered by DB. At this point, the difference between the engineer’s and contractor’s estimate showed how the contractor priced the risk of the project, at \$38 million. The design process then advanced, and the team was involved in risk minimization and mitigation as well as early packages to lock in prices. The result was a risk mitigation savings of almost \$100 million, attributable to the contractor’s involvement in the design process. The figure “demonstrates the benefit of involving the contractor in the design process before the contract cost is fixed” (Gransberg 2013, 12).

4.9.2 Innovation Processes

Innovative processes enabled by CM/GC delivery contributed to the cost savings discussed previously. Many innovations were naturally produced as a result of risk management. A formal innovation process was also conducted during the OPCC design and risk workshops (UDOT 2009).

The MVC project used a process called Decision Analysis by Ranking Technique (DART), to encourage the entire project team to be responsible for innovation. The associated software tracked the affect of any change on the design, construction schedule, and construction to tell the team whether the cost for changing design, delaying construction and changing construction cost will be greater than or less than the benefit of the innovation or change (NCHRP 15-46 2014, 52). Overall, the team proposed 55 total innovations, 14 of which were incorporated into the final design (UDOT 2009). The DART process on MVC showed \$25 million in savings from team member innovations, all saved prior to construction benefitting the owner and/or project (NCHRP 15-46 2014). “After all was said and done, the process to review risks every quarter that included risk registers, DART, risk assignment, and risk retirement allowed UDOT to save and set aside about \$117 million. All of this money was used to extend the contract” (NCHRP 15-46 2014, 52).

4.9.3 Project Results and Cost Savings

Cost reduction was perhaps the “most significant achievement” attained through the [CM/GC] process on MVC (Jackson and Bekka 2012, 18). The construction cost was reduced throughout the project by approximately \$100 million, or roughly one-third of the initial construction estimate over a 10-month period, as an iterative process. These price saving

included both “risk reduction and the innovations implemented to reduce these risks” (Alder 2012, 23). The following were some of the largest cost-reduction measures:

- “\$25 million saved through design analysis and construction innovation (DART),
- \$12 million saved in cost reduction in utility relocations,
- \$6 million saved in indirect cost attributable to schedule compression, and
- \$9.5 million saved attributable to elimination of a rail bridge” (Jackson and Bekka 2012, 18).

As a result of the processes used on the MVC project, the project team was able to:

- Extend the project limit from 9 miles to 15,
- Reduce the overall estimated construction cost from \$346 million to \$249 million,
- Mitigate risk and reallocation \$43 million in contingency budget to purchase right-of way- and build more of the project,
- Shave a year from the construction schedule by designing, acquiring right-of-way, and building simultaneously with no delays to the critical path (Jackson and Bekka 2013).

“As MVC experience shows, when the CM/GC delivery method is enhanced with processes such as active risk management...the outcomes are robust” (Jackson and Bekka 2013, 19). Figures 42 and 43 show the results.

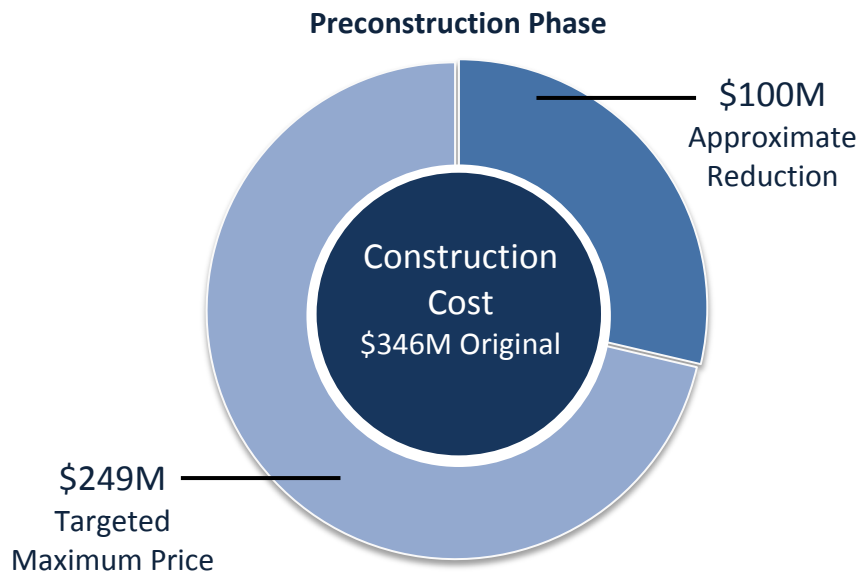


Figure 42: MVC Reduction in Overall Estimated Construction Cost

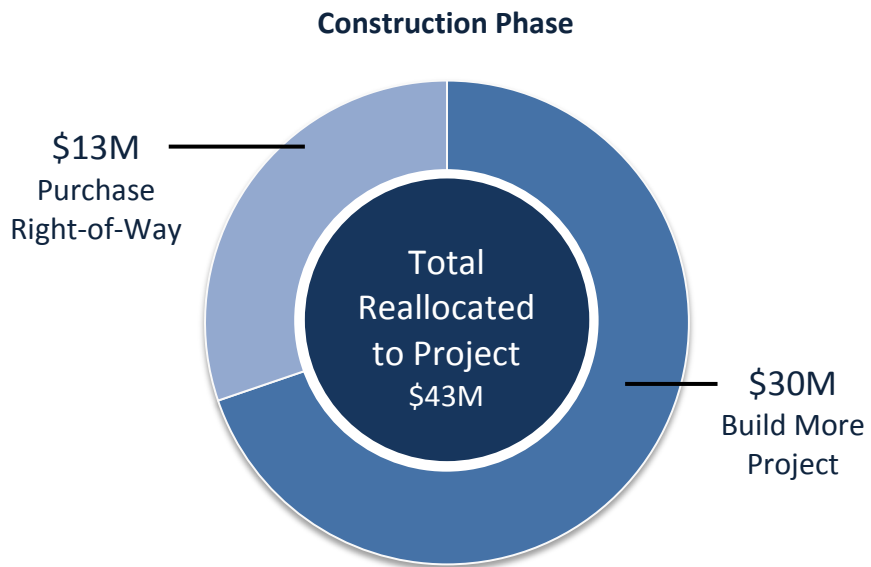


Figure 43: MVC Reallocated Risk Contingency Budget

5 CONCLUSIONS

5.1 Conclusions

Based on the findings and critical evaluation of the research performed in this thesis, CM/GC furnishes an attractive option for public agencies to deliver their projects in a manner that is less adversarial and more constructive by involving the contractor during design. The owner does not have to relinquish control of the details of the design to be able to accelerate the schedule or see the benefits of real-time cost estimating data. There are documented cost and schedule benefits with no degradation in quality.

Barriers to the implementation of CM/GC delivery do exist and keep some agencies and contractors from participating. While CM/GC delivery is not appropriate for all projects and is not infallible, the disadvantages and barriers noted in the previous chapter are not fatal flaws. Many barriers to implementation are mostly perceptual. Additionally, experienced teams identified few disadvantages to the process associated with either risk management or innovation. Most respondents supported the idea that the benefits of the CM/GC process, particularly those relating to risk management and innovation, outweigh the disadvantages and offered strategies for overcoming barriers to implementation.

As CM/GC becomes more common, so do CM/GC experienced contractors. Because the delivery method requires a large contribution in construction management from the general contractor, this delivery method may not be suitable for all contractors. Yet many who see an

opportunity in CM/GC are in the position to take that advantage of a profitable market sector. Contractors willing to adapt to the changes in the civil construction industry and provide the level of service required for CM/GC projects experience the benefits noted in this document. Of those involved in this research, the vast majority of contractors were pleased with the CM/GC experience and results.

This document provides an overview of CM/GC benefits, barriers to implementation and processes. It is recommended that interested agencies consult DOTs with CM/GC experience for the appropriate training resources. The following sections provide conclusions about CM/GC process's effectiveness in managing process risk, project specific risk, and innovation.

5.2 **Process Risk**

CM/GC processes promote quality, schedule and cost benefits. Through enhanced design by early contractor input on constructability, improved owner design control, and best value selection processes, CM/GC processes support improved quality. Project team members indicate that CM/GC processes enable them to improve project quality better than DBB processes. When compared to DB, over half of those surveyed noted that CM/GC processes better enabled the project team to deliver a high quality project than a typical DB project, and nearly the same amount stated that CM/GC processes enabled improving quality at least as well as DB processes. Thus, not only do quality-related benefits motivate project teams to participate in CM/GC projects, CM/GC processes better enable the delivery of high-quality projects.

One of the most highly mentioned benefits was the enhanced design through contractor input promoting constructability. Contractors, owners, and engineers agree that CM/GC processes supporting constructability was the top benefit to each of them individually. This

constructability review is compared to a built-in risk management process. Project team members stated that CM/GC process enabled them to impact design and constructability better than DBB processes. Nearly half of contributors indicated that CM/GC processes allowed improved design and constructability over DB, and over 75% stated that CM/GC allowed the project team to impact design and constructability at least as well as DB.

CM/GC processes promote schedule-related benefits through accelerated selection, accelerated start dates and phasing options, and encouraging schedules focused on project goals. 83% of those surveyed indicated that the CM/GC process enabled them to control or shorten the project schedule better than the DBB process. “Given the rapid current urgency being imparted on the rapid renewal of deteriorating bridges and roads and the emphasis given in the EDC program... schedule risk is now the DOT’s top priority” (Schierholz, Gransberg, McMinimee 2011, 8). These schedule benefits are closely linked to the capability of the project team, and each team member’s ability to make decisions efficiently. However, one-third of respondents indicate that, when compared with DB processes, CM/GC processes were less likely to allow more control over the project schedule.

CM/GC projects benefit from minimized unplanned change orders, extended scope, fair market pricing and open book accounting. The CM/GC timeline also allows the team to design to a meet a specific budget, with the aid of real-time pricing and value engineering. For this practice to be effective, the team must take advantage of the entire team’s participation and expertise concerning materials, methods, sequence, procurement, lifecycle, maintenance, etc. 83% project team members indicated that the effective use of CMGC processes enabled them to reduce the cost of construction better than DBB processes. Two-thirds of those surveyed indicated that CM/GC processes allowed the project team to reduce the cost of construction as

well, or better than DB processes. Over 80% of contributors also indicated that CM/GC process improved the team's ability to adapt to changes in cost, scope or schedule better than DBB or DB processes.

5.3 Project Risk

Risk management processes made possible through the CM/GC delivery method are the most noted benefit of CM/GC. According to experienced industry leaders, CM/GC processes enable the project team to minimize and manage risk better than DBB processes. Additionally, over 80% of those surveyed indicated that CM/GC process improved the team's ability to minimize and manage risk better than DB processes. Characteristics that may pose a threat to project objectives under DBB or DB delivery are described as ‘Best Suited’ for CM/GC delivery. Therefore, projects that include high risk, complexity, large dollar amounts, variable or undefined scope, in urban areas, with multiple stakeholders are the best candidates for CM/GC delivery.

Under CM/GC processes, the integrated team aides in the identification and assessment of risk and allows risk to be delegated to the most capable party. Because contractor input is offered prior to the price being fixed, the risk savings benefit the project unlike other delivery methods. According to the perception of experienced team members, CM/GC processes decrease overall project risk and allow that risk to be shared equally between the owner and contractor. While this perception is not quantified, the perception contributes to industry practices, especially cost. As shown by the MVC project case study, “when the CM/GC delivery method is enhanced with processes such as active risk management...the outcomes are robust” (Jackson and Bekka 2013, 19).

In order to experience the full benefit of risk management under CM/GC delivery, best practices encouraged the continual monitoring and reporting of risk. The FHWA states that “a successful risk monitoring and updating process will systematically track risks, invite the identification of new risks, and effectively manage the contingency reserve. The system will help ensure successful completion of the project objectives. If documented properly, the monitoring and updating process will capture lessons learned and feed risk identification, assessment, and quantification efforts on future projects” (Ashley, Diekmann and Molenaar 2006, 40). Experienced team members state that if the team does not have a meaningful, measurable system in place to track and report risk and innovation savings, it is difficult to identify the savings, the practices that led to them, and how to repeat them.

5.4 Innovation

The CM/GC process fosters innovation by providing the team with an incentive to innovate, supporting the application of innovation through the identification of opportunities and risks, and balanced risk distribution. These processes result in innovations that can be transferred between delivery methods and standardized for ultimate cost savings. The promotion of innovation is one of the top five reasons that contractors and engineers participate in CM/GC projects. According to experienced CM/GC team members, CM/GC processes enabled them to contribute innovations better than DBB processes. Additionally, nearly half of respondents indicated that CM/GC and DB processes both allowed the contribution of innovations, but 33% of those surveyed indicated under CM/GC processes, the team was better able to contribute to project innovations than in DB processes.

However, in order to experience the full benefit of the innovation possible through CM/GC processes, agencies must consider their own innovation culture. Multiple contractors stated that department processes suppressed innovations they provided. In successful applications of CM/GC agencies provided flexibility. The agencies delegated responsibility for particular risks and innovations according to which party was most capable of managing the risk effectively. Their owners were encouraged not to think of the plans as unchangeable, but instead to think in terms of the goals that specific provisions were intended to meet. With this in mind the team was free to propose alternative means of meeting the project goals that reduced, or eliminated the risk and promoted innovation.

Interested agencies must question if they are prepared to accept innovative ideas even if the proposed concepts have never been used on its projects in the past (NCHRP 15-46 2014). If the agency is generally unreceptive of change, the CM/GC processes may be of less value. Agencies must also be willing to reimburse the contractor well for the innovative contribution to the project to encourage the necessary transparency.

5.5 Differences in Individual Participant Motivation

Based on the findings of this research, quality-related benefits such as enhanced constructability, owner design control, and best value selection were more of a motivation to participate in CM/GC projects for both contractors and design engineers than for owners. Owners were more likely motivated by cost-related advantages or disadvantages.

5.6 Recommendations

In summary, it is recommended, as part of a long-term implementation strategy, that capable agencies champion the use of CM/GC project delivery for pilot projects and develop performance metrics to evaluate the results compared with similar projects using the traditional low-bid only procurement. The intent is not to advocate the use of CM/GC as the ideal project delivery method or the default for all civil construction projects, but rather to demonstrate that it has been implemented successfully by DOT's and offers valuable benefits. While CM/GC delivery is not a one-size-fits-all solution, it provides a good solution for promoting contractor input benefitting the owner, risk management, and innovation. Agencies and organizations investigating implementation are advised to seek out training and suggested improvements from experienced parties, such as those found in Section 4.5.6.

5.7 Suggested Research

The research in this study provides a basis for implementation based on benefits and best practices of CM/GC delivery in civil construction. However, the U.S. highway and transportation construction industry as a whole has relatively little experience with non-traditional procurement. More research is needed if the highway industry expects to change from the general low-bid processes that are currently within use in the industry. The primary need for future research involves measurement of CM/GC projects by considering performance measures and measurement metrics at the national and state levels. Baseline metrics are necessary for individual evaluation of the projects.

As more projects are completed in the highway sector, more project performance data will become available and more objective project selection models can be developed. The

wealth of data from DOT's with growing CM/GC project experience makes this goal increasingly possible. Measuring the performance of these projects will help determine the cost, schedule, or quality implications of the delivery method more precisely. Compiled data will allow agencies to make informed decisions.

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APPENDICES

APPENDIX A. CM/GC EXPERIENCED CONTRACTOR SURVEY

CM/GC-Experienced Contractor Survey

CM/GC Advantages and Disadvantages

1. What are the top three advantages of the CM/GC project delivery process?

2. What are the top three advantages to the contractor from CM/GC project delivery?

3. What are the top three disadvantages of the CM/GC project delivery process?

4. What are the top three disadvantages to the contractor from CM/GC project delivery?

Contractor Role & Responsibilities Using Different Delivery Methods

These questions are aimed at understanding how a contractor's roles, responsibilities, and project experiences vary in a CM/GC project as opposed to a DBB (Design Bid Build) or DB (Design Build) project.

5. How is the contractor's experience different when participating in a CM/GC project as opposed to a DBB project?

6. How is the contractor's experience different when participating in a CM/GC project as opposed to a DB project?

Rank the following contractor roles and responsibilities in order from 1 to 5, 1 being where the contractor spends the most time and effort, 5 being where he or she spends the least time and effort.

CMGC-Experienced Contractor Survey

7. Typical Design Bid Build Contract

	1	2	3	4	5
Design Review/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Planning/Coordination Meetings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actual Construction/Supervision	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation/Problem Solving for Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pricing/Cost Control/Value Engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="text"/>				

8. Typical Design Build Contract

	1	2	3	4	5
Design Review/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Planning/Coordination Meetings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actual Construction/Supervision	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation/Problem Solving for Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pricing/Cost Control/Value Engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="text"/>				

9. Typical CM/GC Contract

	1	2	3	4	5
Design Review/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Planning/Coordination/Meetings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actual Construction/Supervision	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation/Problem Solving for Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pricing/Cost Control/Value Engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="text"/>				

Contractor Perception of CM/GC

CMGC-Experienced Contractor Survey

10. In a CM/GC project, is your ability as a contractor to improve these areas worse, equal, or better than in a DBB project?

	worse	better	equal
Reduce Cost of Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Additional Costs (design, time, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact Design/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide Improved Project Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control/Shorten Schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Public Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute Innovations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimize and Manage Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adapt to Changes in Cost, Scope, Schedule, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third Party Coordination (utilities, municipalities, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. In a CM/GC project, is your ability as a contractor to improve these areas worse, equal, or better than in a DB project?

	worse	equal	better
Reduce Cost of Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Additional Costs (design, time, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact Design/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide Improved Project Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control/Shorten Schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Public Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute Innovations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimize and Manage Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adapt to Changes in Cost, Scope, Schedule, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third Party Coordination (utilities, municipalities, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

CM/GC-Experienced Contractor Survey

12. Given the choice, would you as the contractor prefer to deliver a project by DBB, DB or CM/GC?

13. What types of projects are best suited for CM/GC project delivery?

14. What adaptations or preparations did your company make in order to participate in CM/GC projects?

15. How are project relationships affected (positively or negatively) by CM/GC processes?

Risk Minimization & Management

16. Is overall project risk reduced by CM/GC project delivery?

17. In your opinion, what percentage of project risk do the owner and contractor bear individually under the three project delivery methods?

	Owner	Contractor
DBB	<input type="text"/>	<input type="text"/>
DB	<input type="text"/>	<input type="text"/>
CM/GC	<input type="text"/>	<input type="text"/>

18. Are there any risks that are specific to CM/GC projects? What are examples of CM/GC specific-risks?

CMGC-Experienced Contractor Survey

19. How are risk savings shared between the contractor and owner following risk reduction?

20. Does CM/GC promote innovation? How?

21. In your opinion, will the heavy civil arena trend toward more project delivery through CMGC in the future?

22. Additional Comments about CMGC Project Delivery:

APPENDIX B. CM/GC EXPERIENCED OWNER SURVEY

CM/GC-Experienced Owner Survey

CM/GC Advantages and Disadvantages

1. What are the top three advantages of the CM/GC project delivery process?

2. What are the top three advantages to the owner from CM/GC project delivery?

3. What are the top three disadvantages of the CM/GC project delivery process?

4. What are the top three disadvantages to the owner from CM/GC project delivery?

Team Perception of CM/GC

5. In a CM/GC project, is the project team's ability to improve these areas worse, equal, or better than in a DBB project?

	worse	better	equal
Reduce Cost of Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Additional Costs (design, time, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact Design/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide Improved Project Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control/Shorten Schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Public Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute Innovations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimized and Manage Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adapt to Changes in Cost, Scope, Schedule, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third Party Coordination (utilities, municipalities, etc)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

CM/GC-Experienced Owner Survey

6. In a CM/GC project, is the project team's ability to improve these areas worse, equal, or better than in a DB project?

	worse	equal	better
Reduce Cost of Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Additional Costs (design, time, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact Design/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide Improved Project Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control/Shorten Schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Public Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute Innovations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimize and Manage Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adapt to Changes in Cost, Scope, Schedule, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third Party Coordination (utilities, municipalities, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. Given the choice, would you as the owner prefer to deliver a project by DBB, DB or CM/GC?

8. What types of projects are best suited for CM/GC project delivery?

9. How are project relationships affected (positively or negatively) by CM/GC processes?

Risk Minimization & Management

10. Is overall project risk reduced by CM/GC project delivery?

CM/GC-Experienced Owner Survey

11. In your opinion, what percentage of project risk do the owner and contractor bear individually under the three project delivery methods?

	Owner	Contractor
DBB	<input type="text"/>	<input type="text"/>
DB	<input type="text"/>	<input type="text"/>
CM/GC	<input type="text"/>	<input type="text"/>

12. Are there any risks that are specific to CM/GC projects? What are examples of CM/GC specific-risks?

13. How are risk savings shared between the contractor and owner following risk reduction?

14. Does CM/GC promote innovation? How?

15. In your opinion, will the heavy civil arena trend toward more project delivery through CM/GC in the future?

Owner-CM/GC Relationships

16. How has contractor involvement in past projects contributed to project success?

17. Did the specific characteristics of a company, or specific skills of a team member impact project success? How so?

CMGC-Experienced Owner Survey

18. Additional Comments about CMGC Project Delivery:

APPENDIX C. CM/GC EXPERIENCED DESIGN ENGINEER SURVEY

CM/GC-Experienced Design Engineer Survey

CM/GC Advantages and Disadvantages

1. What are the top three advantages of the CM/GC project delivery process?

2. What are the top three advantages to the designer from CM/GC project delivery?

3. What are the top three disadvantages of the CM/GC project delivery process?

4. What are the top three disadvantages to the designer from CM/GC project delivery?

Role & Responsibilities Using Different Delivery Methods

These questions are aimed at understanding how roles, responsibilities, and project experiences vary in a CM/GC project as opposed to a DBB (Design Bid Build) or DB (Design Build) project.

5. How is the designer's experience different when participating in a CM/GC project as opposed to a DBB project?

6. How is the designer's experience different when participating in a CM/GC project as opposed to a DB project?

Team Perception of CM/GC

CMGC-Experienced Design Engineer Survey

7. In a CM/GC project, is the project team's ability to improve these areas worse, equal, or better than in a DBB project?

	worse	better	equal
Reduce Cost of Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Additional Costs (design, time, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact Design/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide Improved Project Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control/Shorten Schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Public Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute Innovations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimized and Manage Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adapt to Changes in Cost, Scope, Schedule, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third Party Coordination (utilities, municipalities, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. In a CM/GC project, is the project team's ability to improve these areas worse, equal, or better than in a DB project?

	worse	equal	better
Reduce Cost of Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Additional Costs (design, time, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact Design/Constructability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide Improved Project Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control/Shorten Schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce Public Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute Innovations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimize and Manage Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adapt to Changes in Cost, Scope, Schedule, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third Party Coordination (utilities, municipalities, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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CM/GC-Experienced Design Engineer Survey

9. Given the choice, would you as the designer prefer to deliver a project by DBB, DB or CM/GC?

10. What types of projects are best suited for CM/GC project delivery?

11. What adaptations or preparations did your company make in order to participate in CM/GC projects?

12. How are project relationships affected (positively or negatively) by CM/GC processes?

Risk Minimization & Management

13. Is overall project risk reduced by CM/GC project delivery?

14. In your opinion, what percentage of project risk do the owner and contractor bear individually under the three project delivery methods?

	Owner	Contractor
DBB	<input type="text"/>	<input type="text"/>
DB	<input type="text"/>	<input type="text"/>
CM/GC	<input type="text"/>	<input type="text"/>

15. Are there any risks that are specific to CM/GC projects? What are examples of CM/GC specific-risks?

CMGC-Experienced Design Engineer Survey

16. Does CM/GC promote innovation? How?

17. In your opinion, will the heavy civil arena trend toward more project delivery through CMGC in the future?

18. Additional Comments about CMGC Project Delivery: