Contract Administration Functions and Tools
for Design-Build and Construction Manager/General Contractor Project Delivery
in U.S. Highway Construction

by

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A Dissertation Presented in Partial Fulfillment
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ABSTRACT

The demand for new highway infrastructure, the need to repair aging infrastructure, and the drive to optimize public expenditures on infrastructure have led transportation agencies toward alternative contracting methods (ACMs) such as design-build (DB) and construction manager/general contractor (CM/GC). U.S. transportation agencies have substantial experience with traditional design-bid-build delivery. To promote ACMs, the Federal Highway Administration and the National Cooperative Highway Research Program (NCRHP) have published ACM guidance documents. However, the published material and research tend to focus on pre-award activities. The need for guidance on ACM post-award activities is confirmed in NCHRP’s request for a guidebook focusing on ACM contract administration (NCHRP 2016).

This dissertation fills the crucial knowledge gap in contract administration functions and tools for DB and CM/GC highway project delivery. First, this research identifies and models contract administration functions in DBB, CM/GC, and DB using integrated definition modeling (IDEF0). Second, this research identifies and analyzes DB and CM/GC tools for contract administration by conducting 30 ACM project case studies involving over 90 ACM practitioners. Recommendations on appropriate use regarding project phase, complexity, and size were gathered from 16 ACM practitioners. Third, the alternative technical concepts tool was studied. Data from 30 DB projects was analyzed to explore the timing of DB procurement and DB initial award performance in relation to the project influence curve. Types of innovations derived from ATCs are discussed. Considerable industry input at multiple stages grounds this research in professional practice.
Results indicate that the involvement of the contractor during the design phase for both DB and CM/GC delivery creates unique contract administration functions that need unique tools. Thirty-six DB and CM/GC tools for contract administration are identified with recommendations for effective implementation. While strong initial award performance is achievable in DB projects, initial award performance in this sample of projects is only loosely tied to the level of percent base design at procurement. Cost savings typically come from multiple ATCs, and innovations tend to be incremental rather than systemic, disruptive, or radical. Opportunity for innovation on DB highway projects is influenced by project characteristics and engaging the DB entity after pre-project planning.
DEDICATION

To Bethany, for your support and encouragement.
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CHAPTER 1
INTRODUCTION

1.1 Background

Many transportation agencies have turned to alternative contracting methods (ACMs) like design-build (DB) and construction manager/general contractor (CM/GC) to deliver capital improvement projects in a cost-effective and timely manner. FHWA refers to ACMs as innovations because they introduce advantages that design-bid-build (DBB) delivery does not offer such as contractor involvement during the design phase, optimizing schedule, cost and quality, and strategically dividing risk (FHWA 2017, 2018). While ACMs are delivery method innovations, they are also mechanisms to introduce innovations into the design and construction of projects. To optimize the use of ACMs, agencies need to identify and understand ACM contract administration functions and the tools that can be used to accomplish those functions. Tools are defined as a tactic or process, such as a document, event, or guidance that supports an agency in administering an ACM project (NCHRP 2016). Additionally, an ACM tool would not typically be used with DBB, or if it is, it has different roles, responsibilities, or timing in ACM projects that distinguish it from the tool as used in DBB. Examples of tools include: forms, checklists, spread sheets, agency guidelines to perform a task, flow charts, or meetings. This dissertation explores contract administration functions and tools for DB and CM/GC delivery of transportation projects.

1.2 Delivery Methods Defined

Project delivery methods have frequently been characterized by the type of relationship (contractual/non-contractual) between project stakeholders and timing of stakeholder involvement (design/construction) (Sullivan et al. 2017; DBIA 2015; Gransberg et al.
DBB is characterized by separate contracts for design and construction, with the contractor procurement occurring when design is complete. Similarly, CM/GC (sometimes referred to Construction Manager at Risk (CMAR)) has separate contracts for design and construction, where the construction contract is divided into two parts. Through an initial contract, the contractor is procured early enough to provide preconstruction consulting services during design, and through a second contract acts as general contractor if their construction price proposal is accepted. The designer and contractor have lines of communication but not contracts that tie them together. DB is distinguished by a single contract for design and construction. The designer and contractor share responsibility for design and construction and thus are highly motivated to communicate and collaborate regularly. (TRB 2009)

1.3 Three Research Gaps in ACM Contract Administration

Past research has indicated the need for organizational change to effectively administer ACMs (i.e., Minchin et al. 2014; Migliaccio et al. 2008; Pietroforte and Miller 2002; Molenaar and Gransberg 2001; Miller et al. 2000). Some agency ACM manuals also refer to the need for organizational change when implementing ACMs. For example, the ADOT DB Manual states “new paradigms are needed for technical leaders involved in a D-B project” (ADOT 2007). This refers to quick review times to accommodate the accelerated schedules frequently accompanying DB projects. It also refers to technical reviews focusing on the underlying goals of standards when reviewing innovations and determining whether the innovations achieve those goals rather than rigidly applying standards during technical reviews. The CDOT DB Manual refers to a revised and more efficient review process that includes over-the-shoulder reviews and task force meetings that help promote
“reviewers’ familiarity with the progress of the design and their ability to provide comments and feedback on an ongoing basis and not just when milestone submittals are made” (CDOT 2016). These examples illustrate that innovations in processes such as delivery methods give rise to changes in organizational structure such as roles and processes. The need for tools for ACM contract administration is further highlighted by the National Cooperative Highway Research Program in their call for a guidebook on ACM contract administration (NCHRP 2016). Thus, the first research gap is the need to identify the contract administration functions in ACMS. The second research gap is the need to identify a portfolio of ACM tools for contract administration functions with recommendations on applicability based on project complexity and size.

One specific tool used in DB delivery is the alternative technical concept (ATC) process. The project influence curve (Wang & Gibson 2002; CII 1995a, 1995b; Gibson et al. 1995) provides a lens from which to view the potential for ATCs to bring cost saving innovations to DB projects. The project influence curve suggests that greater cost savings would generally result when the contractor participates in the design process. However, the project influence curve also suggests that the typical timing of DB procurement in highway projects comes after a significant portion of the potential influence is past (after the perform pre-project planning phase). This research empirically tests the hypothesis that DB procurement with lower percent base design will generally achieve better initial award performance (agency estimate minus DB contract price) than DB procurement with higher percent base design. The third research gap is that the project influence curve has not been empirically tested in ACMS like DB.
1.4 Research Objectives, Methods, and Contributions

ACMs differ from DBB delivery, so different tools are needed for ACM contract administration. This dissertation uses three research objectives and multiple research methods that work together to provide a clearer understanding of tools for DB and CM/GC contract administration. These three research objectives are:

1. Model and compare DBB, CM/GC, and DB contract administration functions. (Chapter 2)
2. Identify and analyze DB and CM/GC contract administration tools. (Chapter 3)
3. Analyze alternative technical concepts (ATCs) (one specific tool used in DB delivery) to explore the relationship between percent base design and initial award performance considering predictions stemming from the project influence curve. (Chapter 4)

The relationship between these three research objectives is depicted in Figure 1.1.

![Fig. 1.1. Relationships between ACM Contract Administration Functions and Tools](image-url)
In Figure 1.1, contract administration functions are shown at the top. Contract administration is achieved through the execution of many functions. Research objective one seeks to identify these functions for DBB, CM/GC, and DB (chapter 2). Beneath contract administration functions are tools. Various tools are used to accomplish each function. Research objective two seeks to identify and analyze the tools for ACM contract administration (chapter 3). ATCs are a specific tool used to administer alignment on DB projects. Alignment refers to a shared understanding of project goals, scope, processes, and communication (NCHRP 2016). Research objective three seeks to analyze the relationship between percent base design and initial award performance (chapter 4). These three research objectives work together to explore contract administration at multiple levels.

1.4.1 Research Objective 1

The first research objective identifies the contract administration functions of DBB, CM/GC, and DB delivery and develops an integrated definition function (IDEF0) model of each that portrays a hierarchy of functions. IDEF0 modeling begins by interviewing industry professionals to uncover contract administration functions and their relationships. IDEF0 software is used to depict these contract administration functions and relationships in a hierarchical model. Models are verified through additional interviews with industry professionals. Final IDEF0 models are analyzed and compared; this highlight where DBB, CM/GC, and DB contract administration functions are similar and where they are different. Delivery methods are often compared based on contract relationships or timing of stakeholder involvement. In contrast, this dissertation delves into the underlying contract administration functions of these three delivery methods. The differences in contract
administration functions point to areas where tools unique to contract administration may be needed. More details about IDEF0 modeling are provided in Chapter 2.

This first research objective provides a macro view of project delivery. This research contributes to the construction engineering and management body of knowledge by identifying, structuring, and comparing contract administration functions across delivery methods. This research can help agencies make more informed decisions about selecting and administering contracting methods, especially as it relates to establishing the level of effort and skills needed for administering projects under various contracting methods. Additionally, these IDEF0 models provide a novel framework for future research on highway contract administration.

1.4.2 Research Objective 2

The second research objective identifies tools for ACM contract administration proven effective by transportation agencies and provides recommendation on appropriateness of each tool based on project complexity and size. The research method starts with reviewing state and agency ACM manuals and the ACM research literature to identify tools used in DB and CM/GC contract administration. Then case studies were conducted with state and federal highway project teams. The framework for these case study interviews is derived from the IDEF0 models developed while studying the first research objective. Industry professionals were surveyed and asked to rate each tool regarding appropriateness for project complexity and size. Additional agency interviews were conducted to determine the effectiveness of the guidebook presenting the tools. The large number of tools uncovered during the research was winnowed down to a shorter list of significant tools following the process outlined in Figure 1.2. First, a tool must meet the basic requirement
of a tool defined for this research, that is, it must be a tool not typically used in DBB, or a tool used in a unique way with ACMs. Secondly, the tool must be applicable to typical agency operations and not just idiosyncratic to a single agency. If tools are named differently, but are essentially similar in operation, then those tools are combined.

![Flowchart for Tool Selection](image)

**Fig. 1.2.** Process Flow Chart for Tool Selection
The second research objective provides a mid-level view of ACM contract administration by focusing on practical tools. This research contributes to the construction engineering and management body of knowledge by providing a comprehensive portfolio of tools for ACM highway projects that are field tested by transportation agencies along with recommendations on appropriateness for project complexity and size.

1.4.3 Research Objective 3

The third research objective looks at a specific tool used in DB delivery called alternative technical concepts (ATCs). ATCs are used to bring innovation and cost savings to a project. The project influence curve predicts that as percent base design at procurement increases, initial award performance will tend to decrease. Quantitative data was collected from 30 DB projects, including percent base design at time of procurement and initial award performance. Qualitative data on ATCs from a select group of projects was analyzed for types of innovation.

The third research objective provides a micro view of a specific tool used in DB, alternative technical concepts. This research contributes to the body of knowledge of construction project delivery by comparing DB highway project data to predictions stemming from the project influence curve. Results regarding timing of contractor involvement in design can assist decision makers in determining the suitability of a project for DB contracting and what level of base design to use in procurement.

The research methods for this dissertation are characterized by diverse input including: reviewing relevant literature, developing IDEF0 models, interviewing agency highway project teams, surveying industry professionals on the appropriate applications of
tools, collecting quantitative initial award performance, and collecting qualitative data on ATC innovations. These multiple points of input provide triangulation of the research results. Chapters 2, 3, and 4 provide detailed descriptions of the research methods applied for each research objective.

1.5 Dissertation Format

The three research objectives explored in this dissertation are related through the theme of contract administration functions. Each research objective is presented as a separate chapter in journal paper format; therefore, each chapter stands independently with its own abstract, introduction, literature review, research objective and methods, results, analysis, conclusion, and references. Although separate papers, these three research objectives come together as a cohesive unit to provide multiple perspectives and insights into DB and CM/GC contract administration functions and tools. Each of these papers has been submitted to a peer-reviewed journal.

Chapter two presents research objective one, the development of IDEF0 models that describe DBB, CM/GC, and DB contract administration functions and their relationships. Chapter three presents research objective two, the identification of DB and CM/GC contract administration tools with recommendations on their appropriateness based on project complexity and size. Chapter four presents research objective three, the analysis of the relationship between initial award performance and percent base design at DB procurement considering predictions derived from the project influence curve. Chapter five presents conclusions from these three research objectives. Contributions to the construction engineering and management body of knowledge are summarized. Also,
limitations of the research and recommendations for future research are noted. Appendices include the table of contents of the two NCHRP guidebooks on CM/GC and DB tools for contract administration that were offshoots of this research (NCHRP 2016).

1.6 References


Industry Institute, Source Document 105, Austin, TX.


CHAPTER 2

COMPARING CONTRACT ADMINISTRATION FUNCTIONS FOR
ALTERNATIVE AND TRADITIONAL DELIVERY OF HIGHWAY PROJECTS

2.1 Abstract

Agency roles and responsibilities for contract administration depend on the contracting method. The Federal Highways Administration (FHWA) has encouraged agencies to consider alternative contracting methods (ACMs) like design-build (DB) and construction manager/general contractor (CM/GC). There is a lack of information available to transportation agencies regarding the details of agency performed contract administration functions between ACMs and traditional design-bid-build (DBB) delivery. This research contributes to the existing body of knowledge of highway contract administration by revealing similarities and differences between agency performed contract administration functions across contracting methods through the development of integrated definition function models (IDEF0). These IDEF0 models depict the hierarchy of contract administration functions for DBB, CM/GC, and DB highway projects and reveal differences such as developing alignment, administering preconstruction services, managing work packages, and creating risk pools for additional scope. The findings can help agencies make more informed decisions about selecting and administering contracting methods, especially as it relates to establishing the level of effort and skills needed for administering projects under various contracting methods. Additionally, these IDEF0 models provide a novel framework for future research on highway contract administration.
2.2 Background

The United States has a long history of implementing DBB, including the establishment of the Interstate Highway system. The use of ACMs like CM/GC and DB has expanded in recent years (Minchin et al. 2014) as federal and state legislation has broadened to allow their use. The timeline of significant federal ACM legislation and initiatives is summarized in Figure 2.1. FHWA (2016) encourages the use of ACMs “to accelerate project delivery, encourage the deployment of innovation, and minimize unforeseen delays and cost overruns.” Not all states have used ACMs. By 2014, 35 states had some level of experience with DB and seventeen states had used CM/GC (FHWA 2018). The relatively new use of ACMs compared with DBB and the lack of comprehensive guidance on ACM contract administration led the National Cooperative Highway Research Program (NCHRP 2016) to initiate research for a guidebook on ACM contract administration. This research seeks to address the knowledge gap regarding the similarities and differences between DBB, CM/GC, and DB highway contract administration functions.

DBB separates the contractor from the design process, and the agency holds separate contracts for design and construction. CM/GC (sometimes referred to as Construction Manager at Risk (CMAR)) engages the contractor during the design phase through a preconstruction services contract. Similar to DBB, in CM/GC there are separate contracts for design and construction. When a price proposal is accepted, and construction begins, the CM/GC contractor switches to the role of general contractor. In DB, the agency holds a single contract for design and construction. (FHWA 2018; TRB 2009)
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<th>Year</th>
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<td>1987</td>
<td>Statute authorized by Florida to experiment with DB</td>
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<td>1988</td>
<td>Transportation Research Board (TRB) Task Force A2T51-Innovative Contracting Practices established</td>
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<td>1990</td>
<td>Special Experimental Project No. 14 (SEP-14)-Innovative Contracting encouraged states to test innovative contracting approaches such as DB and CM/GC</td>
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<td>1996</td>
<td>1996 Federal Acquisitions Reform Act (Clinger-Cohen Act) allowed DB to be used by federal agencies</td>
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<td>1998</td>
<td>Transportation Equity Act for the Twenty First Century (TEA-21) Section 1307(c) identified areas needing development for the implementation of DB</td>
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<td>2002</td>
<td>Federal Regulation Design-Build Contracting Final Rule 23CFR636 allowed DB</td>
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<td>2005</td>
<td>Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1503 broadened the use of DB</td>
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<td>2011-12</td>
<td>Every Day Counts (EDC) 1 Innovations included DB and CM/GC</td>
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<td>2012</td>
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<td>2013-14</td>
<td>Every Day Counts (EDC) 2 Innovations included DB and CM/GC</td>
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<td>2017</td>
<td>Federal Regulation CM/GC Contracting Final Rule 23CFR630 &amp; 635 allowed CM/GC</td>
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**Fig. 2.1.** Timeline of Significant ACM Legislation and Initiatives in the United States
Numerous research studies have compared the performance of contracting methods on highway projects (e.g., Tran, Diraviam, & Minchin 2018; Shrestha, O’Connor & Gibson 2012; FHWA 2006; Molenaar 2003). Yet these comparisons do not investigate the differences and similarities of contract administration functions nor their potential impacts on project delivery. Contract administration functions are the tasks agencies must do to fulfill their contract responsibilities and to facilitate project progress to completion.

The next section presents the research objective. Then a summary of state agency manuals and the research literature on ACMs is presented. Next, a process modeling method called integrated definition function modeling (IDEF0) is described followed by an explanation of the research methods. Then the results of IDEF0 modeling for DBB, CM/GC, and DB are shared as node indices and in IDEF0 hierarchy form. These models are from the perspective of contract administration functions performed by the agency. After that, the three IDEF0 models are analyzed and discussed. Conclusions are summarized at the end. IDEF0 models are included in the dissertation Appendices G-I.

2.3 Research Objective
The objective of this research is to identify the contract administration functions performed by agencies for DBB, CM/GC, and DB through hierarchical IDEF0 modeling based on input from industry professionals. No detailed models for the contract administration functions for these three delivery methods were found in the literature. Models of contract administration functions allow for in-depth analyses of similarities and differences across delivery methods. The detailed process models have practical applications in the staffing of projects. Agencies can consider the specific functions that are part of ACM project delivery as revealed in the IDEF0 models, and consider the skills needed by their staff to
perform those functions. Additionally, the IDEF0 models of contract administration functions can serve as a foundation for future research on delivery methods.

2.4 State of Practice: State Agency Manuals
Researchers and practitioners have shown a broad interest in alternative contracting methods. This section looks at the ACM manuals currently available in state transportation agencies. These manuals demonstrate the growing use of ACMs and the need to better understand how to successfully perform ACM contract administration.

Federal legislation (Moving Ahead for Progress in the 21st Century Act 2012) states, “Congress declares that it is in the national interest to promote the use of innovative technologies and practices that increase the efficiency of, construction of, improve the safety of, and extend the service life of highways and bridges” and goes on to cite DB and CM/GC contracting methods specifically. As the federal government has been encouraging states to implement ACMs, many states have responded by implementing ACMs and developing guidance manuals. Table 2.1 summarizes the manuals produced by state transportation agencies.

Table 2.1. ACM-related Manuals for State Transportation Agencies in the United States

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Total No. of complete manuals: 23 3 6 51

* related documents, not a complete guidebook  ** project specific documents
Most of these manuals include a section on the benefits of various delivery methods and considerations in the selection of a delivery method. However, the staffing, training, and tools to perform contract administration in ACMs is covered minimally or not at all in many manuals. Many of these manuals as well as researchers looking into ACMs have noted the need for a cultural or perspective change when an agency immersed in DBB begins to implement ACMs. Minchin et al. (2014) noted that for DB, “the approach to manage design activities is also uniquely different from traditional DBB delivery” and for CM/GC “It is very important for those considering implementing CM/GC to consider the cultural shift that has to take place if one (agency or individual) has never worked on a CM/GC project before.” This suggests that new processes suited for ACM contract administration are needed.

2.5 Literature on Alternative Delivery

The research on alternative delivery is rich in delivery method selection and project delivery performance, but there is a gap in the research on ACM contract administration for highway projects.

In the literature on delivery method selection, contract administration functions have either been overlooked or not directly linked to staffing needs. As early as 1985, nine criteria for project delivery selection were identified, including: time, certainty of time, certainty of cost, price competition, flexibility, complexity, quality, responsibility, and risk (NEDO 1985), but none of these criteria link directly to staffing variables. Over the years, researchers have used these criteria (e.g., Skitmore & Marsden 1998) and expanded on them (e.g., Luu et al. 2005; Gordon 1994). Gordon (1994) increased the number of variables to thirteen and grouped them into: project drivers, owner drivers, and market
drivers. While contract administration functions are not mentioned explicitly, Gordon (1994) did acknowledge the changing role and functions of an agency with different delivery methods when he stated, “Different contracting methods require different levels of involvement.” This need for agencies to implement changes in order to implement ACMs is referred to in the research literature as introducing a change in culture, philosophy, and practice compared to the traditional DBB (Minchen et al. 2014; Migliaccio et al. 2008; Pietroforte and Miller 2002; Molenaar and Gransberg 2001; Miller et al. 2000).

Researchers have developed various lists of criteria for project delivery selection. Alhazmi and McCaffer (2000) identified twenty-five client needs combined with a framework of project characteristics, market attributes, contractor needs, local construction regulations, client design organization, and client categories. Luu et al. (2005) grouped twenty-one project selection criteria into three categories: client characteristics and objectives, project characteristics, and external environment. Tran et al. (2016) focused on risk for delivery method selection variables of highway projects and identified multiple risks for DBB, CM/GC, and DB. Contract administration functions were not explicitly mentioned in any of these lists.

Tran et al. (2013) presented a selection matrix based on eight variables: delivery schedule, complexity and innovation, level of design, initial project risk assessment, staff experience/availability, level of oversight and control, and competition and contractor experience. This framework became the basis for Colorado’s Project Delivery Selection Matrix (CDOT N.D.). Alleman et al. (2017) summarized the selection criteria identified in twenty-two state ACM manuals. The variables most closely related to contract administration functions are: owner staff experience and availability (mentioned in ten
states), and level of oversight and control (mentioned in two states). The variables of owner staff experience/availability and level of oversight and control support the premise that the level of effort and skills for contract administration functions differ across delivery methods.

Research in ACM contract administration is limited. Processes like constructability which are used with ACMs have been researched (Trigunarsyah 2004; Fisher et al. 2000), but their work is not set in the context of ACMs. Researchers who have explored contract administration have typically focused on contract language, risks, and dispute avoidance (El-adaway et al. 2018, Chong et al. 2011) but this does not address the specific functions agencies perform to administer contracts. Others have described processes for contract administration (Phillips 1999; Thomas et al. 1980; Scott 1974) but these are not specific to ACMs. The limited reference to contract administration functions in project delivery selection and the absence of research on ACM contract administration points to a knowledge gap in highway contract administration.

2.6 Overview of Integrated Definition Function Modeling (IDEF0)

Integrated definition function modeling (IDEF0) is a graphical, hierarchical structure for modeling system functions and has been used widely in construction research (e.g., Anderson et al. 2015; Akinci et al. 2006; Erdogan et al. 2006; Fisher et al. 2000). IDEF0 graphically depicts relationships within and between hierarchical levels. IDEF0 modeling offers insight into the parts of a process and the connections between those parts. The IDEF0 model was selected for this research because it: 1) communicates functions graphically; 2) represents the detailed levels within functions through hierarchical modeling; and 3) was successfully applied to previous research in construction.
Practitioners and researchers have applied the IDEF0 technique to several construction research studies. Users of the family of IDEF models 0 through 5 include the US Air Force (NIST 1993; Mayer 1990), the US Department of Defense, and many corporations (KSBI N.D.a). The Minnesota Department of Transportation used IDEF0 modeling to deconstruct their departmental cost estimation and cost management processes (MnDOT 2008). IDEF0 modeling has been used successfully by researchers for modeling building design processes (Sanvido and Norton 1994), pre-project planning processes (Gibson et al. 1995), constructability review processes (Fisher et al. 2000), organizational change in construction companies (Erdogan et al. 2006), and project scoping processes for transportation projects (Anderson et al. 2015). Akinci et al. (2006) used the IDEF family of methods to model information flow on construction sites. The successful use of the IDEF family of models in construction demonstrates the relevance and value of this type of modeling.

IDEF0 models are composed of arrows and nodes. The left side of Figure 2.2 depicts the main components of an IDEF0 model. Functions are activities that transform inputs into outputs. Input arrows connect to the left of each node and represent data or objects that are transformed by the function. Output arrows connect from the right of each node and represent data or objects resulting from a transformation. Control arrows connect to the top of each node and represent conditions or constraints that impact transformations. Mechanism arrows connect to the bottom of each node and represent a means, such as a person or tool to perform a function.
Hierarchical levels can be depicted with IDEF0 modeling by linking subfunctions with functions. In Figure 2.2 the label A0 in the bottom right corner of the node indicates that this belongs to project A, at the top or zero level. The labels A1 and A2 indicate that these are subfunctions in level 1 (a single positive number after A). All inputs, controls, outputs, and mechanisms at the zero level must also be connected with one or more subfunctions in the first level and so on for each level/sublevel pair. If subfunction 1 had subsubfunctions, they would be labeled A11, A12, A13, and so on.

IDEF0 as a modeling tool has advantages and disadvantages (KSBI N.D.b). The advantages relate to its proven application and ability to describe in detail the activities of a system including inputs, controls, outputs, and mechanisms (ICOM). In IDEF0 terminology, activities are functions that transform inputs (e.g., contracts, scope changes, unforeseen conditions) into outputs (e.g., work packages, contract modifications), in the context of controls (e.g., standards and permits) and mechanisms (e.g., tools and resources). The hierarchical structure allows for additional levels of detail to suit the needs of a particular analysis. IDEF0 can be applied to “as-is” modeling of existing systems (which is the case for this study on delivery methods) as well as “to-be” modeling of systems under development. Additionally, models can be built from the bottom up, but be viewed from
the top down (starting with broad functions and drilling deeper to subfunctions). Disadvantages relate to the high level of detail and perceived sequence. In some situations, IDEF0 modeling can become extremely detailed, and might only be understandable to discipline experts and those involved in development of the model. Also, although IDEF0 is drawn from right to left with arrows linking various functions, it does not depict a time sequence. When IDEF0 is understood and applied appropriately, it has proven to be an effective tool for modeling system functions.

2.7 Research Method

The research methodology used to develop IDEF0 models that identify contract administration functions is summarized in five steps below. The DB model was developed first, followed by the CM/GC and DBB models. Seven industry professionals served as informants to develop the IDEF0 models. Table 2.2 summarizes the experience of the industry professionals.

Table 2.2. Summary of Experience of Industry Professionals Used in IDEF0 Modeling

<table>
<thead>
<tr>
<th>No.</th>
<th>Experience of Industry Professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Over 40 years of experience with federal and municipal projects in DBB &amp; ACMs</td>
</tr>
<tr>
<td>2</td>
<td>Over 38 years of experience in construction of DBB &amp; ACM heavy civil projects</td>
</tr>
<tr>
<td>3</td>
<td>Over 25 years of research experience and agency work in DBB &amp; ACMs</td>
</tr>
<tr>
<td>4</td>
<td>Over 22 years of experience with federal and municipal projects in DBB &amp; ACMs</td>
</tr>
<tr>
<td>5</td>
<td>Over 16 years of experience in consulting and public agency transportation projects in DBB and ACMs</td>
</tr>
<tr>
<td>6</td>
<td>Over 12 years of experience with federal and municipal projects in DBB &amp; ACMs</td>
</tr>
<tr>
<td>7</td>
<td>Over 10 years of transportation agency and research experience in DBB &amp; ACMs</td>
</tr>
</tbody>
</table>
The criteria for selecting informants was ten or more years of experience with delivery of federal or local transportation projects. The group of industrial professionals reflects agency, contractor, and researcher experience. Example IDEF0 models and further explanation of the hierarchical levels is presented in the next section called Resulting IDEF0 Models of ACM Processes.

2.7.1 Step 1 Identify Contract Administration Functions

Multiple in-depth interviews were conducted with one of the industry professionals. During a DB model interview, the researchers asked the industry professional to identify and describe activities a transportation agency performs to administer a DB contract (and agency activities for CM/GC during the CM/GC interview). The researchers probed for underlying activities to develop an understanding of the hierarchy of contract administration activities. Additionally, major controls that constrain a function were identified as well as the mechanisms, used to accomplish the function. Contrasts to DBB contract administration were also noted.

2.7.2 Step 2 Draft Preliminary IDEF0 Models

The data collected from the industry professional was used to draft a preliminary IDEF0 model using IDEF0 software with node and arrow syntax. The IDEF0 model contains multiple levels with lower levels linked to upper levels.

2.7.3 Step 3 Check Preliminary IDEF0 Models

Each of the preliminary IDEF0 models was shown to two or more industry professionals, including the industry professional involved in step one. The researchers and the practitioner reviewed together in detail each element of the model examining the contract
administration functions performed by an agency and how the functions are related. Feedback from the industry professional regarding additional details, clarifications, and adjustments were noted by the researchers. When feedback seemed specific to a particular project or organization, the researchers raised this point with the industry professional. Any idiosyncratic functions were left out of the models.

2.7.4 Step 4 Finalize IDEF0 Models

The industry professionals’ feedback was used to revise the IDEF0 model to produce a final version. A DBB IDEF0 model was developed based on the DB and CM/GC IDEF0 models and the contrasts to DBB identified by practitioners.

2.7.5 Step 5 Analyze IDEF0 Models

The IDEF0 models for DBB, CM/GC, and DB were compared at each of the hierarchical levels in the models and differences and similarities in contract administration functions were noted.

2.7.6 Summary of Model Validation

The credibility of process models is enhanced when content validity is increased, respondent bias is decreased, and generalizability is increased. Content validity is the extent to which a model captures the elements of the real process being modeled. Content validity of the IDEF0 model is increased through the input of industry professionals in identifying contract administration functions and in showing the relationships between contract administration functions within the models (Law and Kelton 2000). Content validity was further increased when the phases and functions from the model were used to structure thirty ACM case study interviews with ninety-one agency personnel from eighteen agencies (see Figure 2.3) for a National Cooperative Highway Research Program
study (NCHRP 2016). Agency personnel that were interviewed confirmed that the contract administration functions used to structure the interviews accurately identified the processes being used by their agencies though tools for performing those contract administration functions may have varied between agencies. Additionally, in all thirty interviews the functions from the IDEF0 models provided an effective framework for discussing the tools agency personnel use to carry out contract administration. Nevertheless, agencies may demonstrate unique organizational charts, project escalation ladders, or systems and software for project documentation, that can influence the way contract administration is performed.

Fig. 2.3. Geographical Distribution of Research Case Studies
Respondent bias was minimized by working with industry professionals who were knowledgeable about the process, and the input from multiple respondents helped prevent undue influence from individual bias. Generalizability was increased by involving multiple industry professionals from a variety of backgrounds including agency personnel, contractors, and researchers. When interviewing industrial professionals, they were asked to think of typical DBB, CM/GC, and DB projects which may preclude unique aspects of non-typical jobs that could reduce generalizability. These multiple validity and bias checks help confirm that the contract administration models are reasonable approximations to actual processes.

2.8 Resulting IDEF0 Models of ACM Processes

The IDEF0 models created for DBB, CM/GC, and DB are multiple pages each; therefore, this chapter is limited to showing the node indices and selected levels of the models (Figures 2.4-2.9). IDEF0 models are included in the dissertation Appendices G-I. These figures provide context for understanding the relationships between contract administration functions between hierarchical levels in a single model and comparisons across multiple models. All functions shown are functions performed by the agency. Functions performed by the designer and contractor are not explicitly shown. Later in the chapter, Table 2.3 shows a comparison of all contract administration functions across delivery methods.

Figure 2.4 shows the upper hierarchical level of the CM/GC IDEF0 model. A shadow around the box node indicates the presence of lower levels in the hierarchy, or what is referred to as a parent-child relationship. Many agency sub-functions occur in the levels lower than this first level. Figure 2.5 shows the next hierarchical level for the CM/GC IDEF0 model. This level reveals broad phases identified in this research for contract
administration, namely: alignment, design, preconstruction, construction, and closeout. The preconstruction phase occurs simultaneously with design and is identified as a separate phase in order to highlight the different contract administration functions the agency performs for the CM/GC contract. The DB IDEF0 model is similar at this level, except the role of administering preconstruction falls under the DB entity’s responsibility so a separate preconstruction phase is not included. The DBB model does not include the preconstruction phase but does include a design phase prior to contractor procurement. The model continues identifying agency contract administration functions for each of the phases. Figure 2.6 shows an example of the lowest hierarchical level in the CM/GC IDEF0 model, specifically agency functions for materials management.

![Diagram](image_url)

**Legend**

<table>
<thead>
<tr>
<th>A. CM/GC Contract</th>
<th>E. Project Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Design Contract</td>
<td>F. Contractor Performance</td>
</tr>
<tr>
<td>C. Agency Directed Change</td>
<td>G. Lessons Learned</td>
</tr>
<tr>
<td>D. Unforeseen Condition</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 2.4.** Level 0 of CM/GC IDEF0 Model of Agency Contract Administration
**Legend**

A. Design Contract  
B. CM/GC Contract  
C. Agency Directed  
D. Unforeseen Conditions Contract  
E. Quality Management Plan  
F. Cost Model Elements  
G. Preliminary Project Management Plans  
H. Preliminary Project Plans  
I. Design Completion Paperwork  
J. Environmental Restrictions  
K. Utilities and Permitting Restrictions  
L. Post Design Services Contract  
M. Work Package ‘n’ Released for Construction  
N. Interim Project Plans  
O. Design Contract Modification  
P. CM/GC Completion Paperwork  
Q. GMP ‘n’  
R. Final Project Management Plans  
S. CM/GC Construction Services Contract Modification  
T. CM/GC Input for Design  
U. As-Built Drawings  
V. Construction Completion Paperwork  
W. CM/GC Contract Modification  
X Complete Work Package ‘n’  
Y. Contractor Performance  
Z. Lessons Learned  
AA. Project Complete

**Fig. 2.5.** Level 1 of the CM/GC IDEF0 Model Showing the Main Post-award Phases
A. Final Project Management Plans
B. GMP “in”
C. Quality Management Plan
D. Work Package “in” Released for Construction
E. CM/GC Contract Modification
F. CM/GC Contract
G. Field Observations of Certifications
H. Material Samples
I. Testing Results
J. Material Non-Conformance Found
K. Reject Material
L. Approved Material for Installation
M. Material Dispute

Fig. 2.6. Level 3 of the CM/GC IDEF0 Model Showing Functions for Managing Materials under the Construction Phase

Another way to view the details of an IDEF0 model is to look at the node index. A node index is an outline format of the functions in the model. The node indices for DBB, CM/GC, and DB are shown in Figures 2.7-2.9. Figures 2.7-2.9 show the upper or “A0” level and the lower “A#” phase levels for DBB, CM/GC, and DB. When the triangles at the left side are pointed down, the level directly below that level is revealed in the node index. When the triangles are pointed to the right, this is an indication that there are lower levels for this node, but they are not displayed. Figures 2.7-2.9 clearly show that design
occurs before a contractor is procured in DBB, and preconstruction services is a separate phase in CM/GC only. The level below administer design is shown for CM/GC and DB, which are nearly similar at this level except for the negotiate post-design services function. A detailed comparison of the models is presented in the next section.

Fig. 2.7. Design-Bid-Build Node Index
Fig. 2.8. Construction Manager/General Contractor Node Index
2.9 Analysis of Results: Comparing Delivery Methods

A primary contribution of this research is a comparison of contract administration functions across DBB, CM/GC, and DB delivery methods. Similarities and differences between agency contract administration functions are shown in Table 2.3. A larger number of differences occur between DBB and ACMs than between CM/GC and DB. Levels within the model hierarchy are labeled top level, phase level, and lower level. Each level is discussed in turn below.
Table 2.3. A Comparison of Agency Contract Administration Functions across Delivery Methods

<table>
<thead>
<tr>
<th>Agency Contract Administration Function</th>
<th>DBB</th>
<th>CM/GC</th>
<th>DB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOP LEVEL-CONTEXT DIAGRAM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administer contract</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>PHASE LEVEL-MAIN PROCESSES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alignment phase</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Design phase</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Preconstruction phase</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction phase</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Closeout phase</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>LOWER LEVELS-SUB PROCESSES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alignment with agency, designer and builder</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduct kickoff meeting</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Administer team alignment meeting</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Align project plans</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Administer design</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure design compliance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Perform life-cycle cost analysis, value engineering, and/or sustainability measures</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage work package coordination</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Review design package</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Approve design invoice</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Manage design documentation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Enact a contract modification which impacts design</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Agency Contract Administration Function</td>
<td>DBB</td>
<td>CM/GC</td>
<td>DB</td>
</tr>
<tr>
<td>------------------------------------------------------------------</td>
<td>-----</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>Negotiate post design services</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Develop final plan package for bidding</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Administer CM/GC preconstruction**

<table>
<thead>
<tr>
<th>Activity</th>
<th>DBB</th>
<th>CM/GC</th>
<th>DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review CM/GC input for design</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review project management plans</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negotiate GMP (or CAP)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approve CM/GC preconstruction invoices</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enact preconstruction contract modifications</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage preconstruction documentation</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Administer construction**

<table>
<thead>
<tr>
<th>Activity</th>
<th>DBB</th>
<th>CM/GC</th>
<th>DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manage legal relations</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Manage public relations</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Manage materials</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Control and inspect work</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Review potential additional scope</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>• Review shared risk contingency with contractor</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Review agency risk contingency with contractor</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Execute supplemental agreements</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Resolve disputes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Measure progress and pay contractor</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Acquire project completion documentation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ensure as-builts are being developed</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
### Agency Contract Administration Function

<table>
<thead>
<tr>
<th>Function</th>
<th>DBB</th>
<th>CM/GC</th>
<th>DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administer closeout</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Conduct final inspection</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Review final turnover documentation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Review invoice for final payment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Review corrective action completion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Execute contractor release</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Conduct contractor evaluation and lessons learned</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Execute warranties</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Note:** Additional sub-levels are not shown when there are no differences between delivery methods.

#### 2.9.1 Top Level Comparisons

The top level of these IDEF0 model hierarchies is a single function that provides a context for the purpose of the model. For all three contracting methods the focus of these models is contract administration. These models do not address agency activities that occur prior to award of design and construction contracts. That is, preliminary planning or design that occurs prior to contracting with a CM/GC or DB is not included. The top level listed in Table 2.3 corresponds to the IDEF0 model for CM/GC depicted in Figure 2.2.

#### 2.9.2 Phase Level Comparisons

In these models, the level directly below the top level is called the phase level, which includes: alignment, design, preconstruction (for CM/GC only), construction, and closeout. The main difference when comparing delivery methods at this level is preconstruction,
which has contract administration activities in CM/GC only. DBB does not involve the contractor in design. In DB, the contractor is performing similar tasks that a CM/GC performs during preconstruction. However, in DB there is not a separate contract for preconstruction services, so the DB entity administers these functions instead of the agency. This does not preclude the agency from reviewing submittals and ensuring design compliance in the design phase. There are also differences in the alignment phase. For DBB, the agency can align with the designer during design, but must wait to align with the builder until the design is complete and a construction contract awarded. For DB, the designer and builder are coming to the project as one entity with one contract, so there is additional responsibility on the DB entity to establish alignment. In the construction phase, quality management and measurement and payment may be performed the same or differently in ACMs compared with DBB. This is discussed further in the description of the construction phase below. The phase level for CM/GC is depicted in Figure 2.3.

2.9.3 Lower Level Comparisons

In the IDEF0 models, a more granular look at contract administration processes is revealed as the hierarchy steps from the phase level to the lower levels. In the levels below the alignment phase, the contract administration functions for CM/GC and DB are similar in many ways; however, they both differ from DBB in that the contractor is brought into alignment during the design. In the levels below the design phase, the contract administration functions that differ are due to the early involvement of the contractor in design. For example, value engineering can look different in each delivery method. During design of a DBB, there is no builder under contract, so value engineering does not get the benefit of the contractor’s input until construction, and any cost savings are shared between
the agency and contractor. During CM/GC and DB design, the contractor is providing constructability input before design decisions are finalized, so there is no need for value engineering during construction. Also, work packages associated with fast tracking are a feature of CM/GC and DB. Furthermore, the agency needs to negotiate post-design services with the designer in both DBB and CM/GC, but not with DB. Moreover, in DBB, a complete set of project plans and specifications is required for bidding. In CM/GC and DB, the plans need to be developed to a state where there is enough information to build the project and fulfill requirements for record drawings, but not to competitively bid the entire project. However, in ACM projects, some work packages may require a detailed bid package with unambiguous interpretation to competitively bid the work among subcontractors. In each case the agency holds the contract administration function of managing design documentation, even though the level of design documentation might vary. Contract language and team alignment can help an agency manage design documentation.

The levels below the **preconstruction** phase is where the agency negotiates with the CM/GC to determine the construction price, often in the form of a guaranteed maximum price (GMP) or construction agreed upon price (CAP). In contrast, DBB is a low bid price, and DB can be low bid, qualifications, or a hybrid referred to as best-value. The preconstruction services are paid by the agency under a CM/GC preconstruction services contract. In DB, the proposal price includes contractor involvement in design, though it is not referred to as preconstruction services. In DBB, there are no preconstruction services since the builder has not been contracted when design is occurring.
In the levels below the **construction** phase, the agency performs many of the same contract administration functions in all three delivery methods. In contrast, when performance specifications are used with DB, the risk of any previously unidentified work required to achieve the original scope is carried by the DB entity. In contrast, for DBB and CM/GC, the agency may be responsible for work that was not identified initially and meets the criteria for additional scope. In the case when an agency decides to add scope beyond the original intent and goals of the project, the agency is responsible for the additional cost in all three delivery methods. All projects carry risk and it is helpful if the contract clarifies who is responsible for the various risks. In CM/GC, the agency and the contractor work together to identify risk and negotiate who is responsible for managing and paying for each risk through risk pools. DB contracts with a negotiated GMP may also involve discussions of risk and a negotiated assignment of risk (AASHTO 2005; Molenaar et al. 2000). In contrast, in DBB and non-negotiated DB, the contract may clarify how risk is handled for a project, but the risk allocation is decided unilaterally by the agency.

Some construction contract administration functions may or may not vary across delivery methods. For example, some agencies implement quality management in ACMs the same as for a DBB. However, on larger DB projects, some agencies are putting the DB entity in charge of quality control, and the agency performs statistically based sampling for verification. Measurement and payment is another example of a construction contract administration function that might be managed in CM/GC and DB just as an agency manages it in DBB with regular field measurement and reviews of pay applications. Alternatively, an agency may decide a project with a GMP or CAP does not need accurate
field measurements, and instead estimates the percent completion for work performed. The functions for managing materials in a CM/GC project is depicted in Figure 2.4.

In the lower levels of the closeout phase, contract administration functions for DB and CM/GC are similar to DBB. However, warranties are not typical of DBB, and when federal funding is involved, they are generally not used in CM/GC and DB either.

2.10 Discussion of Results

The comparison of DBB, CM/GC, and DB IDEF0 models of contract administration functions provides a window into the path for delivering a project from the agency’s perspective. If an agency has primarily been using one delivery method, seeing where contract administration functions are the same or different can help with deciding whether to use a different delivery method and how to prepare for implementing a different delivery method. This section discusses a few contract administration functions that differ depending on the delivery method. Some of these differences are caused by involving the contractor in design, while other differences relate to quality management and risk assignment. These differences suggest the need for training and organizational change.

Several ACM contract administration functions are distinguished from DBB due to contractor involvement in design (Touran et al. 2010; Miller et al. 2000). For example, in DBB administer alignment occurs with the agency and designer during design, and then again when the construction contract is awarded to a builder. In CM/GC and DB, alignment with the designer and builder occurs before a construction contract is awarded. During the case study interviews, some agencies said they were looking for innovation or cost savings by involving the contractor in design through a CM/GC or DB. This relates to the contract
administration functions review CM/GC input for design, and through alternative technical concepts which are proposed during DB procurement. The CM/GC and the DB perform constructability reviews and iterative budgeting and scheduling. They explore phasing and construction means and methods. This is built into the contracting method. Through the contract administration functions of ensuring design compliance and reviewing design package, the owner observes the impact of contractor involvement in design. The project influence curve (CII 1995) suggests that the earlier in the life of a project that ideas and changes are raised, the less costly they are to implement. Thus, involving the contractor in design through CM/GC and DB (Zhang et al. 2019) is thought to foster innovation and cost savings.

Quality assurance is important in every project regardless of delivery method. All three IDEF0 models (DBB, CM/GC, and DB) include the contract administration function monitor QA/QC. Although quality assurance is becoming the preferred term (Molenaar et al. 2010), most of the agency representatives from the case study interviews still used the term QA/QC. Most agencies have a long history with DBB and construction manuals that detail their quality processes (Molenaar et al. 2015; Anderson and Damnjanovic 2008; Ernzen and Feeney 2002). However, use of a DBB quality management system for an ACM can be problematic (Molenaar et al. 2010). In the agency case study interviews, agencies indicated they are holding to the agency standards of quality no matter how quality assurance responsibilities are divided. Quality management is important for design as well as construction (Molenaar et al. 2015). Contract administration functions like ensure design compliance and review design package convey the importance of quality in design. Contract administration functions like manage materials and control and inspect
work express the importance of quality in construction. During construction, quality sampling and testing may be performed by the agency (or agency’s consultant), or the contractor, or by a third-party hired by the contractor. Any of these methods can be used with any delivery method, however, the contractor or third-party methods are more common with DB. During the case study interviews, many agencies were reluctant to rely solely on the contractor or the third party hired by the contractor, so the agency was performing additional verification at additional cost to the agency. This suggests that agency inspection staff that is used to coordinating their own sampling and testing may need training on how reassigning this responsibility to the contractor changes their inspection role. Training will be discussed further toward the end of this section.

Every construction project holds risk (NCHRP 2009). Delivery methods approach the assignment of risk in various ways. In DBB, the construction contract is prepared by the agency and the agency assigns risk. The CM/GC IDEF0 model contains contract administration functions for review shared risk contingency and review agency contingency. These contingencies are risk pools established based on a risk analysis conducted during preconstruction. Thus, the agency and CM/GC are working together during the review CM/GC input for design to establish risk pools or contingency funds for construction. When a DB contract is negotiated, the DB entity performs a risk analysis and negotiates risk assignment with the agency. DB procurement with minimal base design introduces risk related to environmental permitting (AASHTO 2005). In a non-negotiated DB, the agency determines the risk assignment (Xia at al. 2012). Inconsistent application of contingencies has been noted as a problem in delivering transportation projects (Molenaar et al. 2010) and ACMs provide a context for communicating risk allocation. In
all delivery methods, the agency should work to get a strong understanding of project risk to be able to assign risk appropriately.

Effective project delivery requires effective training, experience, and appropriate organizational culture. Most transportation agencies in the US have a long history of DBB delivery. Agencies have design, construction, and procurement manuals which serve as resources for training along with guidance that is passed down informally. The need for training is consistent with the literature that notes a cultural, organizational, and process shift to implement ACMs (Minchen et al. 2014; Miller et al. 2000, Pietroforte and Miller 2002; Molenaar and Gransberg 2001). During the case study interviews, some agency representatives encouraged learning through reaching out to other states, asking questions, and participating in peer exchanges. Other agencies had training sessions for staff. Many agencies offered no formal ACM training. Agency use of CM/GC and DB is newer than DBB. Not all agencies have ACM manuals, and those that do are still developing and expanding their content. In these situations, outside resources and on-the-job training with experienced personnel can help agencies successfully implement ACMs. During the case study interviews, one agency representative advised, “Get familiar with contractor pricing, it’s different than agency bid history pricing” which emphasizes the different perspective and knowledge the agency needs when reviewing CM/GC construction cost estimates. Contractor involvement in design may trigger training for agency reviewers to be open to new ways of accomplishing project goals, the importance of meeting review deadlines, and focusing on ensuring design compliance. New ways of sharing responsibility for quality may require training for inspectors and a shift in culture to accept data from sources that are different from what was previously used. Training may be needed and processes
implemented for improved risk assessment and calculation of risk allowances or contingencies. For any delivery method, training and organizational culture can help reinforce agency processes and best practices for project delivery.

In summary, the results of this research provide a comparison of DBB, CM/GC, and DB contract administration functions through IDEF0 modeling that reveals many similarities and some important differences. A few important differences include contractor involvement during design, quality assurance, and risk assignment. Understanding the contract administration functions can help agencies understand the training, process changes, or organizational culture shifts that are needed for effective contract administration of ACMs.

2.11 Conclusion

This research contributes to the existing body of knowledge of highway contract administration by modeling and comparing contract administration functions performed by agencies for DBB, CM/GC, and DB. Previous comparisons of delivery methods focused on contract relationships and benefits of each delivery method. The IDEF0 models developed in this research provide a rich understanding of the contract administration functions through exploring their hierarchy and relationships between functions. Key parts of the model and node indices are included in this chapter while the complete multipage models are in the dissertation Appendices G-I. The model was tested using the input of industry professionals at various points in the model development process. By comparing contract administration functions across DBB, CM/GC and DB, this research can help inform agencies during the selection of delivery methods as well as with determining personnel needs and possible organizational or procedural adjustments within an agency.
The IDEF0 models of ACMs provides a point of departure from existing research in several areas. First, the existing research in the area of procurement and project delivery method selection has not been informed by a deep understanding of agency contract administration functions (Alleman et al. 2017; Tran et al. 2016; Tran et al. 2013; Luu et al. 2005; Molenaar and Gransberg 2001). Second, performance studies have compared delivery method outcomes, but the potential impacts of contract administration functions on performance outcomes has not been explored (Sullivan et al. 2017; Shrestha et al. 2012; Molenaar 2003; Molenaar et al. 1996). Thirdly, integrated project teams have been a focus of research, but without the context of contract administration functions (El Asmar et al. 2016; El Asmar et al. 2013; Elvin 2010; Pocock et al. 1996). Fourthly, cultural and organizational change for implementation of innovative processes has been researched, but this has not explored the implications of differing contract administration functions (Minchen et al. 2014; Migliaccio et al. 2008; Pietroforte and Miller 2002; Molenaar and Gransberg 2001; Miller et al. 2000). Fifth and finally, research on construction contracts have focused on contract language, disputes, and constructability but not ACM contract administration functions (El-adaway et al. 2018; Chong et al. 2011; Trigunarsyah 2004; Fisher et al. 2000; Phillips 1999; Thomas et al. 1980; Scott 1974). In all these areas - procurement and selection of delivery methods, performance studies, integrated project teams, culture and organizational change for ACMs, and contract administration – the IDEF0 models presented in this dissertation research stand as a point of departure and provide a framework to further explore each of these research areas.

The models focus on five phases: alignment, design, preconstruction (only for CM/GC), construction, and closeout. In alignment, CM/GC and DB differ from DBB by
bringing the builder into alignment during design. In design, CM/GC and DB are different from DBB in the way innovation and value engineering impacts the design process and how cost savings are allocated. Additionally, fast tracking can be employed with CM/GC and DB, which usually results in early work packages not associated with DBB. Also, project documentation for CM/GC and DB is developed to a point that the contractor can build the facility and the agency will have record drawings with adequate information, whereas in DBB, project documentation is developed for competitive bidding. In the preconstruction phase, the agency and the CM/GC are involved in an iterative and collaborative process to negotiate a contract price. In contrast, DBB is awarded to a low bidder. Additionally, DB can be awarded to a low bidder, a qualified bidder, or a combination of these in a best-value. In the construction phase, a key difference of CM/GC is the collaborative identification and allocation of risks and contingencies. DBB and DB may analyze risk, but with a less collaborative approach. Other contract administration functions during construction may or may not differ with ACMs. Quality control may reside with the agency as is typical with DBB, or it may be transferred to the contractor with the agency taking on a quality verification role. Furthermore, measurement and payment in ACMs may be the same as in DBB, or for CM/GC and DB projects the agency may approximate the amount of work installed for review and payment of invoices. In closeout, contract administration functions are generally the same for DBB, CM/GC, and DB; however, ACMs provide an opportunity for extended warranties. The differences between DBB and ACMs like CM/GC and DB largely rest on integrating the contractor in design, and deepening communication between the contractor and the designer and agency throughout the life of a project.
One limitation of this research is the models were developed from the perspective of the agency and agency contract administration functions. Future work could compare delivery methods from the contractor’s perspective or the designer’s perspective. Another limitation is that the modeling does not detail possible differences that project complexity or project size might introduce into contract administration. Future research could look at determining which contract administration functions contribute the most to project success for projects of various sizes and complexities. Additionally, future research could focus on other types of delivery methods, such as job order contracting, design-build-operate-finance-maintain, and integrated project delivery. This research provides a detailed contract administration structure that facilitates the exploration of these and other research endeavors to more effectively address the critical needs related to delivering highway infrastructure.

2.12 References


Anderson, S., Quiroga, C., Overman, J., Choi, K., Sahu, J., Kermanshachi, S., Goodrum, P., Taylor, T., and Li, Y. (2015). Effective project scoping practices to improve on-time and on-budget delivery of highway projects, NCHRP Project No. 08-88, Transportation Research Board of the National Academies, Washington, DC.


CHAPTER 3

CONTRACT ADMINISTRATION TOOLS FOR DESIGN-BUILD AND CONSTRUCTION MANAGER/GENERAL CONTRACTOR HIGHWAY PROJECTS

3.1 Abstract

Alternative contracting methods (ACMs) such as design-build (DB) and construction manager/general contractor (CM/GC) have been shown in some studies to offer cost and schedule advantages over design-bid-build. The Federal Highway Administration (FHWA) is promoting the use of ACMs and agencies are increasingly implementing ACMs. However, state agency ACM manuals and federal guidebooks tend to focus on pre-award activities. A need exists to provide guidance to agencies on how to effectively administer ACM post-award activities in order to realize their benefits. This chapter presents 36 tools for ACM contract administration that were collected from 30 project case studies with 18 transportation agencies involving 91 interviewees. Integrated definition (IDEF0) modeling was used to map and compare differences between delivery methods at the functional level whereas previous ACM models focus on contract relationships and lines of communication. This research contributes to the construction engineering and management body of knowledge by providing a comprehensive portfolio of tools for ACM highway projects that are field tested by transportation agencies along with recommendations on appropriateness for project complexity and size.

3.2 Background and Objective

Design-build (DB) and construction manager/general contractor (CM/GC) are referred to as alternative contracting methods (ACMs) in contrast to the traditional method of design-
bid-build (DBB). Academic literature commonly refers to ACMs in highway design and construction as project delivery systems. DBB is characterized by separate contracts for design and construction, with the contractor procurement occurring when design is complete. Similarly, CM/GC (sometimes referred to Construction Manager at Risk (CMAR)) has separate contracts for design and construction, with the construction contract being in two-parts. The contractor is procured early enough to provide preconstruction consulting services during design and acts as general contractor if their construction price proposal is accepted. DB is distinguished by a single contract for design and construction. (TRB 2009)

ACM projects have been implemented in the several countries including: Australia, Canada, England, Finland, France, Netherlands, New Zealand, Sweden, and the United States, among others (FHWA 2002; Pakkala 2002). Research into ACMs has tended to focus on procurement and performance. Procurement research addresses issues such as: procurement law, selection of delivery methods, and risk allocation (Alleman et al. 2017; Gransberg et al. 2013; Gransberg and Shane 2010; Migliaccio et al. 2010; Migliaccio et al. 2009; Molenaar et al. 2004; Molenaar and Gransberg 2001; Molenaar et al. 2000; Palaneeeswaran and Kumaraswamy 2000; Potter and Sanvido 1995). In comparison to DBB, ACM procurement emphasizes qualifications-based selection (QBS), or best-value that combines QBS with a technical and/or price proposal. Many researchers have compared the performance of some combination of DBB, CM/GC (or CMAR), and DB, projects for vertical construction (Shrestha and Fernane 2017; Chen et al. 2016; El Asmar et al. 2016; Hale et al. 2009; Rojas and Kell 2008; Molenaar, Bogus, and Priestley 2004; Ibbs et al. 2003; Konchar and Sanvido 1998; CII 1997; Bennett et al. 1996; Molenaar et al.
1996) as well as for horizontal construction (Tran, Diraviam, and Minchen 2018; Francom et al. 2016; WVDOH 2014; Shakya 2013; Shrestha et al. 2012; Goodrum, Uddin, and Faulkenberg 2011; WCEC 2010; FHWA 2006; Scott et al. 2006; Tom Warne & Assoc. 2005; Koppinen and Lahdenperä 2004; Molenaar 2003). Performance variables included measures of cost, schedule, owner satisfaction, and change orders. Sullivan et al. (2017) conducted a meta-analysis of 30 ACM studies from 1991 to 2013. They concluded that DB was most effective in controlling cost growth, DBB was least effective in controlling schedule variation, and DB was superior at delivery speed.

Amidst this research on ACM procurement and performance lies a research gap in ACM contract administration, specifically the tools used by agencies for ACM contract administration. This need is further verified by the National Cooperative Highway Research Program in their call for a guidebook on ACM contract administration (NCHRP 2016). In this research the term “tool” is defined as a tactic or process, such as a document, event, or guidance that supports an agency in administering an ACM project (NCHRP 2016). Tools may support contract administration in areas such as communication, collaboration, identification of issues or alternatives, analysis, decision-making, and quality management. Additionally, an ACM tool would not typically be used with DBB, or if it is, it has different roles, responsibilities, or timing in ACM projects that distinguish it from the tool when used in DBB. Examples of tools include: forms, checklists, spreadsheets, agency guidelines to perform a task, flow charts, or meetings. Tools can be contrasted to project goals, which define a desired result, and strategies, which provide broad guidelines for managing a project. Tools operate at the tactical level in support of the strategic level. At the time of this research, there is no widely available comprehensive
synthesis of existing agency tools for post-award contract administration of ACM projects. Post-award is defined here as the time the DB contract or CM/GC preconstruction services contract is signed and a notice to proceed (NTP) has been issued.

3.2.1 Research Objective

The objective of this research is to provide a portfolio of agency ACM tools that have been field tested by transportation agencies. Additionally, the portfolio of ACM tools offers guidance regarding the appropriateness of each tool for project complexity and size. This synthesis of tools provides a contribution to the construction engineering and management body of knowledge in the area of contract administration for ACMs, as well as a practical resource to transportation agencies.

The next section of this chapter reviews the state of practice and the existing research literature related to agency contract administration of ACM projects. This is followed by the research method section which presents the development of the integrated definition function (IDEF0) models of project delivery methods from the perspective of the contract administration functions performed by agencies. The IDEF0 models are included in the dissertation Appendices G-I. The results section compares the IDEF0 models of DBB, CM/GC, and DB, presents tools for ACM contract administration, and explains how agencies are implementing some of these tools. The discussion section presents four key objectives that the tools can be used for. Conclusions summarize the findings, reflect on limitations, and suggest future research.

3.3 State of Practice and Literature Review

The United States government encourages states to consider implementing CM/GC and
DB (FHWA 2016a-e; Moving Ahead for Progress in the 21st Century Act 2012). Some states have moved in this direction and developed their own ACM manuals. Meanwhile researchers continue to study varying aspects of ACMs. This section summarizes key findings on ACM contract administration from ACM guidebooks from FHWA and NCHRP, state ACM manuals, and published research.

3.3.1 State of Practice: Federal Guidebooks

The Federal Highway Administration (FHWA) has encouraged agencies to implement innovations like ACMs to improve the efficiency, safety, and the service life of highways and bridges (FHWA 2016a-e; Moving Ahead for Progress in the 21st Century Act 2012). However, until now, there has not been a comprehensive list, description, and guidance on tools for ACM contract administration. Tools for CM/GC have been identified through the Every Day Counts (EDC) initiative (FHWA 2016e), including pre-award tools such as: blind bid comparison, selection process interviews, and selection criteria weighting, and post-award tools such as: iterative pricing, open book accounting, and measuring and recording success (West et al. 2012). An NCHRP guide on quality assurance (Gransberg et al. 2008) identifies a few tools for DB contract administration, such as witness and hold points and over-the-shoulder design reviews, and points out the need for more tools for management of design quality. The NCHRP guidebook for alternative quality management systems (Molenaar et al. 2015) presents several quality-related tools that can be used on ACM projects. Co-locating and establishing expectations of all parties are also identified as tools for DB contract administration (FHWA 2006).

Federal publications have pointed out the need for more information on tools for ACM contract administration. An NCHRP study on construction manager-at-risk
(Gransberg and Shane 2010) points to a lack of tools for administering a GMP and discuss how CM/GC offers an “opportunity to explore innovation or technology” which emphasizes the difference between CM/GC and DBB and the need for unique tools for ACM contract administration. The DB effectiveness study (FHWA 2006, p.V-2) states, “Successful management of design-build may require a new approach to project administration by the contracting agency.” The DB effectiveness study suggests agencies consider possible changes to procedures for quality control, design review, and construction administration. To achieve the potential of ACMs, appropriate tools for the administration of post-award ACM services are needed.

3.3.2 State of Practice: Agency Manuals

In addition to federal guidance, some US states developed their own manuals to provide guidance for ACMs. A search for manuals from state agencies revealed 23 transportation agencies with DB manuals, three states with CM/GC manuals, six states with general ACM manuals. State manuals often refer to opportunities for innovation on a project as a criterion for selecting an ACM for project delivery. These existing manuals tend to focus predominantly on pre-award tasks like delivery method selection and procurement processes, and less on post-award contract administration. Most agency manuals refer to a change in culture, roles, and responsibilities with ACM. However, none of the agency manuals provide a comprehensive list of practical tools for ACM contract administration.

3.3.3 Research Literature

Similar to federal and state guidance, the existing ACM research literature refers to introducing a change in culture, philosophy, and practice compared to traditional DBB delivery (Minchen et al. 2014; Migliaccio et al. 2008; Pietroforte and Miller 2002;
Molenaar and Gransberg 2001; Miller et al. 2000). Some agencies suggest beginning with smaller, less complex projects to gradually learn and adapt to ACM processes (Seattle Department of Finance and Administrative Services 2011; Gambatese et al. 2002). The need for experience suggests that there are tools and processes unique to ACMs that promote success. The change that is sought is not limited to delivery mechanisms, but also includes cultural changes (Migliaccio et al. 2008; Molenaar et al. 2005). Cultural change can produce friction or confusion that impedes successful project delivery. In traditional DBB, the contractor and designer have not been required to work as an integrated team and Elvin (2010) notes that “failure in integrated practice is often the result of a clash between new methods and old principles.” Migliaccio et al. (2008) state that new practices and routines are needed for ACMs. New practices such as an early and active role of the contractor have the potential to increase innovation and teamwork in ACM projects (Minchen 2013). Miller et al. (2000) suggest that new tools will follow the emergent use of ACMs. Thus, the existing research points to a new culture and approach for ACMs, as well as the need for new tools for ACM.

Some post-award DB tools mentioned throughout the literature relate to: co-location, communication channels, partnering, third party coordination, constructability, risk allocation, quality management roles, alternative technical concepts, value engineering, and warranties (Gransberg and Loulakis 2012; Gransberg and Windel 2008; Gransberg et al. 2008; FHWA 2006; Ellis et al. 1991).

Gransberg and Shane (2010) summarize fifteen studies that identify the benefits of CM/GC. Other researchers have identified CM/GC post-award functions such as: fast-tracking, constructability input, early cost estimating, early work packaging, value engineering, and warranties (Gransberg and Loulakis 2012; Gransberg and Windel 2008; Gransberg et al. 2008; FHWA 2006; Ellis et al. 1991).
engineering, third party coordination, and risk sharing (Gransberg et al. 2012; Schierholz et al. 2012; Gambatese et al. 2002) but have not described tools for accomplishing these functions. An NCHRP guidebook on CM/GC (Gransberg et al. 2013) identifies tools for ACM contract administration including: open book accounting, cost model, independent cost estimate, contingencies for risk, and progressive target price. This literature shows that tools are being used in ACM contract administration and reinforces the need for a comprehensive list and a detailed description of tools for post-award ACM contract administration.

3.3.4 Research Problem

While a few states have extensive experience with ACMs, there are still many transportation agencies that lack guidance on how ACM contract administration functions performed by agencies differ from DBB, specifically, how roles and responsibilities may differ. Knowing about ACM contract administration functions and the tools used to preform those functions can inform agency decisions on staffing in terms of number of staff and the skills needed by staff to perform ACM contract administration effectively. The research literature and agency manuals point to a few tools for ACM contract administration, but no comprehensive list of ACM tools that have been field-tested by agencies currently exists at this time. The research presented in this chapter is part of a larger research project, NCHRP 08-104, A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Alternative Contracting Methods (NCHRP 2016). This research project involved professionals from over two dozen universities, transportation departments, contractors, and industry associations. The
NCHRP panel that guided the scope and reviewed the process and results consisted of 14 professionals from industry, transportation agencies, and academia.

3.4 Research Method

A six-step research methodology to identify, describe, and assess tools for ACM contract administration is summarized in Figure 3.1. Steps 1 through 3 comprise the data collection phase involving IDEF0 model development and case study interviews. Step 4 is the data analysis phase. Steps 5 and 6 comprise the testing phase where industry professionals provide recommendations on the appropriate applications of the tools.

In the first step, the agency manuals for project delivery and the research literature for ACM projects were reviewed for information on tools for ACM contract administration. This step and its results were discussed earlier in the chapter.

In step two, an integrated definition (IDEF0) model (Anderson et al. 2015; Akinci et al. 2006; KSBI N.D.) was developed to illustrate contract administration functions that agencies perform in DBB, CM/GC, and DB. IDEF0 modeling offers advantages such as the ability to communicate process functions graphically and to represent relationships between functions in a hierarchy. The several types of IDEF models numbered from 0 upwards offer a variety of uses including simulation, object-oriented analysis/design, and knowledge acquisition. However, IDEF0 is the most appropriate model due to its focus on process functions. Additionally, IDEF models have been used successfully in construction research (Anderson et al. 2015; MnDOT 2008; Akinci et al. 2006; Erdogan et al. 2006; Fisher et al. 2000; Gibson et al. 1995; Sanvido and Norton 1994; NIST 1993; Mayer 1990; KSBI N.D.). A portion of the CM/GC IDEF0 model is shown in Figure 3.2.
Figure 3.1. Research Steps for Developing a Portfolio of Tools for ACM Contract Administration

This level (A#) of the model shows five main contract administration functions. Functions are shown in the nodes. In IDEF0 terminology, activities are functions that transform inputs into outputs, in the context of controls (like standards and permits) and mechanisms (like
Legend

B. Design Contract  K. Utilities and Permitting Restrictions  S. CM/GC Construction Services Contract
B. CM/GC Contract  L. Post Design Services  Modification
C. Agency Directed  M. Work Package ‘n’ Released for Construction
D. Unforeseen Conditions Contract  N. Interim Project Plans  T. CM/GC Input for Design
E. Quality Management Plan  O. Design Contract  U. As-Built Drawings
F. Cost Model Elements  P. CM/GC Completion Paperwork  V. Construction Completion Paperwork
H. Preliminary Project Plans  R. Final Project Management Plans
I. Design Completion Paperwork
J. Environmental Restrictions

Fig. 3.2. Level 1 of the CM/GC IDEF0 Function Model Showing the Main Post-award Phases
tools and resources). Inputs are the arrows to the left of the nodes, outputs are the arrows to the right of the nodes. Controls are arrows above the nodes and mechanisms are arrows below the nodes. For simplicity, not all controls and mechanisms are shown in Figure 3.2. Below each node is another level (A##) of contract administration functions, and so on with additional levels until all contract administration functions are incorporated. The fully developed models are dozens of pages and are included in the dissertation Appendices G-I.

The IDEF0 modeling process draws on the experience of industry professionals ranging from 10-38 years with an average of 23 years of experience, as summarized in Table 3.1.

**Table 3.1. Summary of Experience of Industry Professionals used in IDEF0 Modeling**

<table>
<thead>
<tr>
<th>No.</th>
<th>Experience of Industry Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Over 40 years of experience with federal and municipal projects in DBB &amp; ACMs</td>
</tr>
<tr>
<td>2</td>
<td>Over 38 years of experience in construction of DBB &amp; ACM heavy civil projects</td>
</tr>
<tr>
<td>3</td>
<td>Over 25 years of research experience and agency work in DBB &amp; ACMs</td>
</tr>
<tr>
<td>4</td>
<td>Over 22 years of experience with federal and municipal projects in DBB &amp; ACMs</td>
</tr>
<tr>
<td>5</td>
<td>Over 16 years of experience in consulting and public agency transportation projects in DBB and ACMs</td>
</tr>
<tr>
<td>6</td>
<td>Over 12 years of experience with federal and municipal projects in DBB &amp; ACMs</td>
</tr>
<tr>
<td>7</td>
<td>Over 10 years of transportation agency and research experience in DBB &amp; ACMs</td>
</tr>
</tbody>
</table>

The IDEF0 modeling process started with DB. Two two-hour interviews were scheduled with one industry expert in order to uncover DB contract administration functions and associated inputs, outputs, controls, and mechanisms. The researchers used this
information to develop the DB IDEF0 model with the IDEF0 modeling software. This preliminary model was reviewed with the original industry professional and a second industry professional. The model was revised with their feedback. The researchers used the input gained from the DB modeling to prepare a CM/GC IDEF0 model. This preliminary CM/GC IDEF0 model was reviewed separately with two additional two-hour interviews with industry professionals. The model was revised with their feedback. During the interviews, the industry professionals frequently compared the contract administration functions for DB and CM/GC with DBB. Thus, the researchers used that information and their own experience with delivery methods to develop a DBB IDEF0 model. Further validation of the comprehensiveness of the contract administration functions included in IDEF0 models occurred when the contract administration functions from the models were shared with agency personnel (i.e. agency project managers, construction engineers, and alternative delivery administrators) during case study interviews; the interviewees confirmed the contract administration functions included in the models. IDEF0 models were compared. Similar upper level phases appeared in the CM/GC and DB models, including: administer alignment (shared goals, scope, communication, and processes), administer design, administer preconstruction (for CM/GC only), administer construction, and administer closeout. Under each phase there are functions that described contract administration tasks related to that phase. These phases and underlying functions formed the structure of the interview protocol.

In step three, case studies were conducted with transportation agencies. Fifty-six agencies throughout the US were contacted. Agencies included all fifty States, the District of Columbia, Puerto Rico, Colorado Bridge Enterprise, Colorado E-470 Tolling Authority,
FHWA Federal Lands Highway Central, and FHWA Federal Lands Highway Western. The researchers asked for nominations of current CM/GC and DB project teams that could be interviewed about tools for ACM contract administration. The following criteria were balanced during the selection of case studies: geographic diversity, variety of contract sizes, in-progress or recently completed projects, and a focus on highway projects such as roads and bridges, though in the small size category some intelligent traffic systems (ITS) and safety projects were included. From the 79 nominated projects, 30 case study interviews were conducted: 19 DB and 11 CM/GC interviews.

The interview questions followed the structure of the phases and functions identified in the IDEF0 models. Questions were asked about what tools were used effectively by the agency in each of these phases and how they were used. In these interviews, tools unique to ACM contract administration were sought. Through these 30 interviews, 66 preliminary tools for CM/GC and DB contract administration were identified. Every tool was used by the agencies on one or more projects.

In step four, the research team for the NCHRP 08-104 project narrowed the list of 66 potential tools to 36 by combining similar tools from different agencies and eliminating those that are not unique to ACM. The 36 tools included are considered to be “substantial,” meaning a tool that would be of regular use to an agency on a variety of CM/GC or DB projects. Out of the 30 tools that were combined or eliminated, sixteen tools were considered not distinctive enough to warrant their own tool descriptions but could be included as a variation of one of the substantial tools. For example, designating a DB champion, designating a document specialist, and setting time limits on reviews were placed under the tool that specifies roles and responsibilities. Fourteen tools were
eliminated from the list because they did not provide significant innovation or value or were too specific to a single agency to be widely used. For example, “a cover memo that provides context for reviewers of design packages,” and “a spreadsheet of contractor action items organized by project phase” were considered not substantial. A description of each tool was developed to explain the tool’s purpose, describe how to use it, and provide recommendations on when to use it. Since all the tools have already been field tested by agencies, the tool descriptions also include project examples of each tool. Brief tool descriptions are provided as supplemental materials in the Supplemental Data section for this chapter and the complete tool descriptions are available from the NCHRP 08-104 Guidebook (NCHRP 2016). Examples of four tools are included in the dissertation Appendices C-F.

In step five, a panel competitively selected for the NCHRP 08-104 Guidebook research (NCHRP 2016) was surveyed. The panel consisted of 16 industry professionals with over an average of 20 years of experience on multiple DBB and ACM highway projects from agencies, engineering and construction companies, and academia. A minimum of seven and a maximum of sixteen industry professionals reviewed each tool. The panel was provided a questionnaire that asked a series of structured questions on each of the 36 tools. Items related to project complexity and size are on the questionnaire.

Project “complexity within the field of construction is driven by the uncertainty of the disparate individual parts will interact” (Collins et al. 2016). In a review of the literature on complexity, 49 factors were identified (Collins et al. 2016). For highway projects, researchers have identified five categories of complexity that focus on the sources of complexity, including: technical, schedule, cost, context, and financing (Gransberg et al. 2016).
Size is related to complexity, as size relates the volume of work and the coordination between work elements (Lebcir and Choudrie 2011). The physical improvements found in a project’s scope of work is another way to categorize complexity (Anderson et al. 2006). Complexity categorization by physical improvements is the method used in this study due to its straightforward application by agencies who typically have well-defined scopes of work. The questionnaire provided definitions of complexity (see definitions in Chapter 3 Appendix A, Anderson et al. 2006) and size (less than $10M, between $10 and $50M, and greater than $50M). These project sizes are based on previous research (FHWA 2013; FHWA 2006). Project complexity is defined by project type (small, rehabilitation, major reconstruction, major new construction, and special situations) and location/site conditions (traffic flow, utility conflicts, terrain, environmental issues, level of public controversy) (Anderson et al. 2006). The panelists rated a tool’s appropriateness (yes, no, neutral) for complexity and appropriateness for size. Panelists could also provide open-ended comments on any tool. Open ended comments helped clarify and refine tool details. Additionally, panelists could opt out of answering for any tool they did not feel comfortable rating. From the combined panel ratings of tool appropriateness, tools that received less than 50% yes are categorized as not recommended. Tools that received greater than or equal to 50% and less than 80% yes are categorized as consider case by case. Tools that received 80% or greater yes are categorized as recommended.

In step six, two guidebooks for contract administration tools were developed as part of an NCHRP 08-104, one for CM/GC and one for DB (NCHRP 2016). These guidebooks serve as a portfolio of tools for agencies to use and adapt. Additionally, the guidebooks provide guidance on the underlying strategies and goals for tool implementation. A final
round of interviews was conducted with four ACM project teams from state transportation agencies. The guidebooks containing the tools were provided to these four agencies prior to the interviews. During the interviews, agencies were asked for feedback on the usefulness of tools and on the usefulness of the guidebook on selecting appropriate tools for various project phases, complexities, and sizes. Furthermore, the guidebooks for ACM tools for contract administration were approved by NCHRP (2016).

The research process for this study is characterized by diverse input through: the literature, IDEF0 model development, agency interviews, and reviews of tools by industry professionals. These multiple points of input provide triangulation of the research results.

### 3.5 Comparison of ACM Processes

The IDEF0 models for DBB, CM/GC, and DB were compared; similarities and differences between agency contract administration functions were identified. Table 3.2 summarizes the main differences in agency functions across delivery methods. These results show that there are more differences between DBB and the two ACMs than between CM/GC and DB. CM/GC shares similarities with DBB when it relates to the separate contracts for design and construction. For example, post-design services need to be negotiated by the agency in both DBB and CM/GC. CM/GC shares similarities with DB when it relates to involvement of the contractor during the design phase. Examples of contractor involvement during design include constructability reviews, pricing input, and scheduling input. Some functions occur only in CM/GC. For example, early work packaging can occur in CM/GC due to the contract arrangement. The procurement process in DBB limits early work packaging. In DB, the builder is already under contract and can fast-track a project without
Table 3.2. Agency Contract Administration Functions that Differ across Delivery Methods

<table>
<thead>
<tr>
<th>Agency Contract Administration Function</th>
<th>DBB</th>
<th>CM/GC</th>
<th>DB</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bid with 100% design</td>
<td>✓</td>
<td></td>
<td></td>
<td>VECPs can be used for modifications to technical requirements if the agency’s goals are still being met.</td>
</tr>
<tr>
<td>• Value Engineering with contractor during design</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Negotiate post-design services</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Preconstruction services provided by contractor such as constructability reviews, pricing, scheduling, innovation</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>DB performs similar services in the design phase, but it is not generally called preconstruction services.</td>
</tr>
<tr>
<td>• Negotiate construction price</td>
<td>✓</td>
<td></td>
<td></td>
<td>DB is commonly selected through a best-value or low bid process, rather than a negotiated price.</td>
</tr>
<tr>
<td>• Manage early work packages</td>
<td>✓</td>
<td></td>
<td></td>
<td>DB may fast track a project with construction work packages, but these often do not need to be negotiated with the agency.</td>
</tr>
<tr>
<td>• Control and inspect work: option for contractor to perform QC and agency to perform quality verification</td>
<td></td>
<td></td>
<td>✓</td>
<td>Not always implemented; considered more for large projects; some agencies reluctant to use this.</td>
</tr>
<tr>
<td>• Risk pools developed collaboratively with contractor</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Execute warranties</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Not widely used for DOT projects.</td>
</tr>
</tbody>
</table>

procuring early work packages. Additionally, contractor input during design in CM/GC can generate value engineering. Value engineering can occur during design and/or during construction, when it is usually referred to as a value engineering change proposal (VECP) with savings shared between the contractor and the owner. While VECP does not occur in
DB for modifications that fall within the contract requirements, a DB entity may propose a VECP that modifies technical requirements in the DB contract if it can show that the agency’s goals are still being met. In DBB, the agency would need to procure a contractor or engage uncompensated contractor participants for these services or rely on designers to perform value engineering without the benefit of the builder’s perspective. Risk pools are project funds set aside for risks that may materialize. The agency and contractor must agree to use these funds if needed. Risk pools can be created under any contracting method, but in CM/GC, the risk pools are developed through a collaborative process involving the agency and the contractor. The differences in contract administration functions between DBB and ACMs suggests that different tools will be useful or necessary to carry out those contract administration functions.

### 3.6 Resulting Tools for ACM Contract Administration

Table 3.3 presents the portfolio of tools for ACM contract administration which includes a descriptive name for each tool and recommendations on appropriate implementation. The first column provides the name of the tool. Tools are applicable to both CM/GC and DB unless otherwise noted in this column. The next group of five columns is the project phase. Checkmarks indicate all phases where each tool might be implemented. The next group of three columns indicates whether the tool is appropriate for a certain project complexity and project size. Level of appropriateness is indicated by a solid circle (recommended), a half circle (consider case-by-case) and an empty circle (not recommended). The tool portfolio is organized and presented according to the project phase when they are typically introduced (i.e., alignment, design, preconstruction (CM/GC only), construction, and closeout). For example, the tool *external stakeholder coordination* is suitable for both
CM/GC and DB since no specific contracting method is specified. Check marks in the alignment and design phases indicate that this tool can be implemented in these two phases. The half circles in the non-complex and under $10 M columns indicate that determining whether this tool is appropriate should be analyzed on a case-by-case basis. The solid circles in the moderately complex, complex, between $10 M to $50 M, and over $50 M columns indicate that this tool is recommended for these conditions. Brief tool descriptions are provided as supplemental materials in the Supplemental Data section at the end of this chapter; more extensive descriptions can be found in the two DB and CM/GC guidebooks prepared under the one project, NCHRP 08-104 (NCHRP 2016). Examples of four ACM tools are included in this dissertation Appendices C-F.

Table 3.3. Portfolio of tools used by agencies for CM/GC and DB contract administration

<table>
<thead>
<tr>
<th>Tools for CM/GC and DB contract administration (unless noted for one only)</th>
<th>Contract administration phase</th>
<th>Project complexity</th>
<th>Project size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alignment</td>
<td>Design</td>
<td>Preconstruction (CM/GC only)</td>
</tr>
<tr>
<td>1. Kickoff meeting</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Roles and responsibilities</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Glossary of terms</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Confidential one-on-one meeting (DB)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Tools for CM/GC and DB contract administration (unless noted for one only)

<table>
<thead>
<tr>
<th>Tools for CM/GC and DB contract administration</th>
<th>Contract administration phase</th>
<th>Project complexity</th>
<th>Project size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alignment</td>
<td>Design</td>
<td>Preconstruction (CM/GC only)</td>
</tr>
<tr>
<td>5. External stakeholder coordination plan</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>6. Regulatory agency partnering</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>7. Co-location of key personnel</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>8. CM/GC management fee table</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>9. ACM-specific partnering</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>10. Continuity of team members</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>11. FHWA involvement overview</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>12. Permit commitment database</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>13. Scope validation period (DB)</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>14. Discipline task force</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Independent party design review</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Cost savings matrix</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>17. Plan standards</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>18. In-progress design workshops</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>19. Deviations from agency standards</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>20. Over-the-shoulder reviews</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>22. Public announcements</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>23. Delegation of authority</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Tools for CM/GC and DB contract administration (unless noted for one only)</td>
<td>Contract administration phase</td>
<td>Project complexity</td>
<td>Project size</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Alignment</td>
<td>Design</td>
<td>Preconstruction (CM/GC only)</td>
</tr>
<tr>
<td>24. Cost comparison spreadsheet (CM/GC)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Cost modeling approach (CM/GC)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. CM/GC bid validation (CM/GC)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. Independent cost estimator (ICE) (CM/GC)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. OPCC process (opinion of probable construction cost) (CM/GC)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Risk pools</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>30. Dual construction engineering inspector (CEI) roles</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Contractor controlled QC testing</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32. Contractor involvement in establishing QC standards</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33. Incentive/disincentive program for superior quality</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34. Real-time electronic QM information</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35. Witness and hold points</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36. Payment checklist</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Note: ● = Recommended; ◐ = Consider Case-by-Case; ○ = Not Recommended
Three of the 36 tools are described here to provide background on how agencies are effectively implementing these tools for ACM contract administration. Each of these tools represents different phases during contract administration.

The first example tool is deviation from agency standards. This tool is applied in the design phase and/or the preconstruction phase. Instead of automatically following all standards, the project team evaluates project goals and project context, and when appropriate, suggests deviations from standards in order to better meet the project goals. This tool should not be used to avoid meeting functional, quality, safety or other agency standards. On federally funded projects, when state standards exceed federal standards, the state standards can be relaxed at the discretion of the state. However, federal standards must be met, or federal approval will be required for any deviations from federal standards. As the design team becomes thoroughly immersed in the project details, they can look for general standards that may not be meeting project goals efficiently. Then the project team considers alternatives to the standard and produces a cost-benefit analysis. A top alternative is presented to the agency as an alternative to the design standard. The agency has the authority to accept or reject the deviation from the agency standard. Deviations should result in a benefit for the agency and not just introduce a change for the convenience of construction. Minnesota Department of Transportation successfully saved $240,000 by allowing a cofferdam for bridge construction in the Mississippi River to be built to one foot above the 5-foot flood elevation instead of the standard one foot above the 10-foot flood elevation, with the contractor accepting the risk of flooding.

The second example tool is risk pools. This is a tool used to set aside funds for risks that may occur on a project. An agency risk pool will cover risks assigned to the agency
and a shared risk pool will cover risks shared by the agency and contractor. Risks associated with equipment and labor should be included in the contractor’s price proposal. Cost overruns and changes in scope are not covered by risk pools. The task of establishing risk pools helps a team consider how to avoid, mitigate, and eliminate risk early in design and can lead to cost savings during construction. Some project teams use a risk matrix (WSDOT 2018). The agency can also achieve cost savings on a project by accepting risk that is best handled by the agency which avoids a contractor marking up work to account for risk. Risk pools developed during the design phase are converted to force accounts in the construction contract. If a risk materializes, the risk pools/force accounts provide a way to pay for it without creating a change order. One project team identified project risks such as: ground water in excavations, difficult ground conditions for drilling soil nail walls, encountering boulders in excavations, delays in utility relocations, and early winter weather that delays paving. Each of these risks were analyzed and included in a risk pool.

The third example tool is open-book estimating. This tool is used for CM/GC throughout design, preconstruction, and construction. Estimating records during design and expense records during construction are made open to the agency for review. This tool helps the contractor demonstrate that they are applying fair market rates to the work. This review is important for a public agency to ensure that public funds are being used efficiently. Before the estimating process starts, the agency and contractor agree on profit margins for self-performed and subcontracted work. They also collaborate on dividing various costs into categories such as: direct costs, indirect costs, contingency, mobilization and demobilization, corporate overhead, escalations, and exclusions. One agency program manager viewed open-book estimating to be “synonymous with CM/GC” with the caveat
that the agency should only delve into a company’s estimating records further when it is needed to develop an understanding of the pricing. Additionally, agency personnel may not be familiar with reviewing categories such as indirect and direct costs and profit, so they need to be educated on what to expect to see in a contractor’s open books. This emphasizes the need to train agency personnel on tools for ACM contract administration. One agency program manager stated, “Problems arise when people are not familiar with the CM/GC processes and revert back to the traditional way of doing things.”

The wide variety of tools identified in this research shows the diversity of contract administration functions that agencies are called on to perform. Many of these tasks and the tools that support them can be grouped according to common goals agencies have for their projects. The next section will discuss these commonalities across tools.

3.6.1 Discussion of Findings

The primary result of this research is a comprehensive portfolio of tools for CM/GC and DB contract administration, field tested by transportation agencies, complete with recommendations on appropriateness for project complexity and size. The comparison of IDEF0 models for DBB, CM/GC, and DB was made using Table 3.2. The differences highlighted in Table 3.2 were further informed from descriptions of functions and tools provided by agencies during the case study. The researchers looked for patterns and identified four distinct objectives that many of the tools for contract administration address. The four objectives are: 1) tools that integrate the contractor in design; 2) tools that foster innovation and savings; 3) tools that foster price competitiveness; and 4) and tools that facilitate quality management. Many of the tools are intended to accomplish one or more of these objectives as shown in Table 3.4.
# Table 3.4. Objectives of Tools for CM/GC and DB Contract Administration

<table>
<thead>
<tr>
<th>Tools</th>
<th>Tools that integrate the contractor in design</th>
<th>Tools that foster innovation and savings</th>
<th>Tools that foster innovation and savings</th>
<th>Tools that facilitate quality management</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Kickoff meeting</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Roles and responsibilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Glossary of terms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Confidential one-on-one meeting (DB)</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. External stakeholder coordination plan</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Regulatory agency partnering</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Co-location of key personnel</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. CM/GC management fee table</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>9. ACM-specific partnering</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Continuity of team members</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>11. FHWA involvement overview</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>12. Permit commitment database</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>13. Scope validation period (DB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>14. Discipline task force</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>15. Independent party design review</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>16. Cost savings matrix</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Plan standards</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>18. In-progress design workshops</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Deviations from agency standards</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>20. Over-the-shoulder reviews</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Public announcements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>23. Delegation of authority</td>
<td></td>
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81
The first group of tools shares the objective of engaging the contractor in the design phase. The designer remains responsible for design, but the contractor offers their expertise and perspective to the design process through input on issues such as constructability, cost estimating, scheduling and phasing, maintenance of traffic, and means and methods. Contractor involvement in design also adds another layer of design quality control. With the contractor participating in in-progress design workshops and over-the-shoulder reviews, contractor questions that might appear as RFIs in DBB can be addressed during design instead of construction, and value engineering change proposals during construction are avoided since the contractor has the opportunity to provide that input during design.

The second group of tools shares the objective of creating innovation and savings. The tools that integrate the contractor into the design phase are also part of this group because they help establish an environment conducive to innovation and savings. Even before a contract is signed, DB entities are able to demonstrate their ability to innovate through the tool confidential one-on-one meetings where alternative technical concepts are presented.

The third group of tools are used with CM/GC; these tools tend to focus on keeping the
pricing competitive. An iterative process that provides a forum for discussion and clarification is intended to lead to an acceptable price proposal. The fourth group of tools shares the objective of quality management. For example, the tool contractor-controlled quality control testing is most commonly implemented with large, complex DB projects. To remain consistent with other NCHRP work, this research adopted the definitions for quality oversight, quality assurance, and quality control used in NCHRP Report 808 Guidebook on Alternative Quality Management Systems for Highway Construction (Molenaar et al. 2015). These tools allow the DB entity to perform QC activities in contrast to requiring the DB entity to hire an independent firm to perform QC. During the interviews some agencies expressed reluctance to assign the contractor this much responsibility for quality control, while other agencies are duplicating the quality control tasks or frequently performing quality verification. This finding suggests that there are improvements needed with quality control. One alternative is the tool dual construction engineering inspector roles which engages an independent firm conducting quality control, while the agency conducts quality acceptance through statistical sampling.

Some of the tools have multiple benefits. A tool that promotes communication may also help build alignment and trust and reduce uncertainty. For example, the tool confidential one-on-one meetings serve as a mechanism for communication, helps establish a foundation for alignment that can be built upon during the life of the project, and reduces risk for the contractor by clarifying what alternative technical concepts or innovations the agency is willing to consider. There are other tools that help reduce uncertainty while promoting communication and collaboration. For example, risk pools negotiated by the CM/GC and the agency clarify how unknowns will be paid for if they materialize. External
*stakeholder coordination plan* and *regulatory agency partnering* are tools that not only promote communication but also reduce the uncertainty of unexpected concerns or requirements being introduced by stakeholders late in the project. When risks are reduced, contractors tend to lower the contingencies in their pricing, which ultimately benefits the agency. A common thread for most of the tools is communication and a commitment to work together.

This research also revealed three gaps where additional tools for ACM contract administration are needed: 1) early work packaging; 2) training; and 3) closeout. During the case study interviews, agencies reported that early work packages prepared by the DB entity were so project-specific that generic tools were not applicable. However, agencies do have guidelines for approving early work packages, such as: packages are independent, severable, produce savings, and fit into the overall budget (Alleman et al. 2017). Additionally, agencies emphasized the importance of training to develop an organizational culture that supports the functions and goals of ACM delivery and clarifies new roles, responsibilities, and team interactions. There is also the need to train agency personnel to select tools for ACM contract administration. While agencies use meetings, memos, manuals, and other means to implement training, no training tools specific to ACM contract administration were identified in this research. Finally, agencies shared tools used during the closeout phase; but unlike the other phases, no tools were initiated in the closeout phase. Instead, the tools used in closeout are all initiated in earlier phases and carried through to the closeout phase. Tools used with DBB to collect lessons learned or document contractor performance were used by agencies on ACM projects; however, these tools are not included in the ACM tool portfolio because at this point they are not distinct for ACMs.
There may be an opportunity to develop tools specifically designed for the ACM closeout phase functions like ensuring development of as-built drawings.

In summary, this research results in a portfolio of tools for ACM contract administration. A theme that spans across all tools is enhanced communication and partnerships, both within the team and extending to stakeholders outside the core project team. The IDEF0 model process analysis revealed four contract administration objectives in ACMs, and the thirty case study interviews revealed tools that address each of these areas. The research identified ACM contract administration functions where new tools are needed such as administering early work packaging, training, and closeout.

3.7 Conclusion

This research contributes to the construction engineering and management body of knowledge on ACMs, and more broadly project delivery methods, in the area of contract administration by identifying ACM functions, and tools to accomplish those functions. Previous research and publications on ACM emphasize performance variations, goals and benefits of different delivery methods, selection criteria, and procurement best practices.

This dissertation provides research results on tools used by agencies to perform contract administration of ACMs and provides a point of departure from existing research in the areas of cultural and organizational change, performance of delivery methods, and integrated project teams. First, cultural and organizational change for implementation of innovative processes has been mentioned and studied by researcher (Minchen et al. 2014, Migliaccio et al. 2008, Pietroforte and Miller 2002, Molenaar and Gransberg 2001, Miller et al. 2000), but the identification and understanding of ACM contract administration tools
presented in this dissertation provide a new perspective from which to study change. Second, performance studies have compared delivery method outcomes (Tran, Diraviam, and Minchen 2018, Sullivan et al. 2017, Francom et al. 2016, Shakya 2013, Shrestha et al. 2012, Goodrum, Uddin, and Faulkenberg 2011, FHWA 2006, Scott et al. 2006, Tom Warne & Assoc. 2005, Koppinen and Lahdenperä 2004, Molenaar 2003, Molenaar et al. 1996), but the potential impacts of contract administration tools on performance outcomes has not been thoroughly explored. Thirdly, integrated project teams have been a focus of research, but without the context of contract administration tools (El Asmar et al. 2016, El Asmar et al. 2013, Elvin 2010, Pocock et al. 1996). In all these areas – culture and organizational change for ACMs, performance studies, and integrated project teams – the ACM tools presented in this dissertation research stand as a point of departure and provide specific lenses from which to study the interactions between agencies and contractors and the ways they impact ACM project outcomes.

The ACM tools also provide practical resources in addressing agency needs in contract administration. This research provides a portfolio of tools for CM/GC and DB contract administration that have been vetted by transportation agencies across the US. FHWA is promoting ACM, and more and more agencies are implementing ACMs. This research can benefit agencies with and without ACM experience by providing field-tested tools that are ready to use. Brief descriptions of the tools are provided in the Supplemental Data section at the end of this chapter. More extensive tool descriptions that include the purpose of the tool, when and how to use the tool, and agency examples of the tool in use is provided in NCHRP project 08-104 (NCHRP 2016). Recommendations on the appropriateness of the tools based on project complexity and size can also help agencies
effectively implement these tools. Examples of four ACM tools are in Appendices C-F of this dissertation. Experienced agencies can benefit by adding new tools to their portfolio. Less experienced agencies can accelerate their learning curve by leveraging the tools of experienced agencies. This comprehensive portfolio of tools for CM/GC and DB contract administration provides a much-needed resource that was not previously available to agencies.

These tools for ACM contract administration have been organized in a project chronological framework (alignment, design, preconstruction (CM/GC only), construction, and closeout), which was derived from IDEF0 models developed with input from industry professionals. Delivery methods are typically compared according to contract relationships (El Asmar et al. 2016; Konchar and Sanvido 1998). The IDEF0 models provide a structure for comparing delivery methods at a deeper level, the level of agency functions. The research approach discussed in this chapter yields new insights into the differences between ACMs and DBB. An analysis of the IDEF0 models reveals four objectives, namely: integrating the contractor in design, fostering innovation and savings, fostering price competitiveness in CM/GC, and facilitating quality management. Thirty case study interviews revealed ACM contract administration tools that address each of these four objectives.

The input of agencies, contractors, academics, and practicing engineers informed this research at multiple points, including: the development of the IDEF0 models of delivery methods, identification of tools for contract administration, and the recommendations for implementing those tools. Agencies can select tools confidently knowing that they have been used in the field on real projects and are not just theoretical
abstractions. One limitation of this research is the relatively small number of CM/GC transportation projects underway at the time this research was conducted. All known state and federal CM/GC road and bridge projects current at the time of this research study were included. However, there were no CM/GC projects under $10 million. As the number and variety of CM/GC projects expands, there will be more opportunities to study any additional tools used for their contract administration. Future research could look at what tools are not only appropriate for project complexity and size, but most effective for projects of various types and scope such as road, bridge, intelligent transportation systems (ITS), reconstruction, widening, or new construction. There are also opportunities to develop and pilot new ACM tools in the areas of early work packaging, quality management, and closeout. Finally, future work could weight the contributions of each individual tool towards project performance or provide a cost-benefit analysis for each tool. The portfolio of tools presented in this chapter serves as a strong foundation for future work on CM/GC and DB contract administration.

3.8 Appendix A: Definitions of Project Complexity

From Anderson et al. 2006.

Complex (Major) Projects

- New highways; major relocations
- New interchanges
- Capacity adding/major widening
- Major reconstruction (4R; 3R with multi-phase traffic control)
- Congestion management studies are required
• Environmental Impact Statement or complex Environmental Assessment required

**Moderately Complex Projects**

• 3R and 4R projects which do not add capacity
• Minor roadway relocations
• Non-complex bridge replacements with minor roadway approach work
• Categorical Exclusion or non-complex Environmental Assessment required

**Non-Complex (Minor) Projects**

• Maintenance betterment projects
• Overlay projects, simple widening without right-of-way (or very minimum right-of-way) take) little or no utility coordination
• Non-complex enhancement projects without new bridges (e.g. bike trails)
• Categorical Exclusion

Note: 3R = Resurfacing, Restoration, Rehabilitation; 4R = New Construction/Reconstruction

**3.9 Supplemental Data: Descriptions of Alternative Contracting Method Tools for Contract Administration**

1. **Kickoff Meeting**

This is a meeting where the project participants are introduced to the project and each other. Aspects relevant to an ACM project are discussed, including roles and responsibilities,
quality management processes, review processes, schedule, schedule of values, and payment processes.

2. **Roles and Responsibilities**

Clearly defining the roles and responsibilities of project participants in alternative contracting methods is a significant aspect of defining each participant’s expected scope of work. It could take the form of a table or a list.

3. **Glossary of Terms**

Definitions of terms related to ACM activities that helps facilitate communication by providing team members with a common vocabulary and understanding.

4. **Confidential One-on-one Meeting (DB)**

A confidential meeting between the agency and contractor during the Request for Proposals (RFP) stage, typically used for discussing Alternative Technical Concepts (ATCs).

5. **External Stakeholder Coordination Plan**

A plan that identifies which external stakeholders to involve at various project milestones to ensure that relevant information is conveyed to appropriate stakeholders and that stakeholder concerns are considered.

6. **Regulatory Agency Partnering**

A framework that brings together the project team and regulatory agencies to discuss alternatives and requirements prior to permit application in order to achieve a smoother permitting process.
7. Co-location of Key Personnel

Locating key personnel at the same facility during agreed upon phases of a project creates the opportunity for increased communication, improved project quality, greater efficiency, and enhanced project understanding.

8. CM/GC Management Fee Table (CM/GC)

A table that lists which costs are included and which costs are excluded from the CM/GC management fee used when preparing and reviewing cost proposals and invoices.

9. ACM-specific Partnering

A framework for aligning team members and other stakeholders on ACM project goals, issues, roles, and processes to enhance the delivery of the project.

10. Continuity of Team Members

Key team members from the agency and the contractor must remain involved throughout the design and construction phases to enhance project understanding, consistency, and communication.

11. FHWA Involvement Overview

This is a table or list that briefly describes the way that a project interfaces with the Federal Highway Administration (FHWA) on a federally funded project. This interface is often determined based on FHWA local division interests that are defined in Stewardship and Oversight agreements.

12. Permit Commitment Database

A summary of all commitments included in the permits and agreements, which helps the project team keep track of all commitments.
13. Scope Validation Period (DB)

A pre-determined period after contract award where the contractor can review all existing contract documents to identify any defects, errors, or inconsistencies. This allows the contractor to clearly identify and resolve any project scope issues that could result in disputes later.

14. Discipline Task Force

A group of individuals focused on developing design and construction plans and specifications for one specific discipline in a project while also ensuring coordination with other disciplines.

15. Independent Party Design Review

A design review that is performed by a third-party consultant that the agency hires. This can expand the access an agency has to resources and relevant expertise.

16. Cost Savings Matrix

A table listing the innovations or cost saving measures developed by the project team to enhance the project in a variety of ways such as cost and schedule. The table helps track innovative ideas, their impact on the project, who is responsible, and the status of the innovation.

17. Plan Standards

Adapting plan standards to the goal of developing plans and specification for building, rather than bidding. This recognizes that the contractor is involved in the design phase and has background knowledge of design intent.
18. **In Progress Design Workshop**
Meetings between the designer, the contractor, and the agency that take place throughout the design process to discuss and verify design progress. This can help streamline review of design submittals.

19. **Deviations from Agency Standards**
Instead of automatically following all standards, the project team evaluates project goals and project context and, when appropriate, suggests deviations from standards in order to better meet the agencies’ goals. Suggested deviations must go through a review and approval process.

20. **Over-the-shoulder Reviews**
Informal design reviews where designers and agency representatives discuss design assumptions, project constraints, and alternative design solutions prior to formal design submittals with a focus on assessing whether the designer is properly meeting the design requirements and design criteria of the contract. These reviews can also address whether approved design quality management plan activities are occurring.

Estimating records are kept by the contractor and made open to the agency for review and audit. This allows the agency to verify that competitive pricing is achieved during design.

22. **Public Announcements**
A communication that explains to the public what an ACM is, and the benefits it offers to a specific project.
23. Delegation of Authority
The agency delegates specific limits of authority in writing to the agency engineer managing the project enabling project decisions to be made quickly by personnel with project-specific knowledge, even when these decisions may increase the project budget.

24. Cost Comparison Spreadsheet (CM/GC)
A table that reports percent range deviations between the ICE estimate and the CM/GC estimate. These estimates are referred to as blind estimates because they are not revealed to the estimators, including the contractor, the ICE, the agency estimator, and/or the design consultant estimator.

25. Cost Modeling Approach (CM/GC)
A set of assumptions regarding construction means and methods that has been agreed to by the agency and the CM/GC. This is intended to produce uniformity of approach in estimating used by the CM/GC, independent cost estimator (ICE), agency, and designer.

26. CM/GC Bid Validation (CM/GC)
A process where the agency validates the CM/GC’s price proposal by comparing it with an independent estimate prepared by an ICE. The price comparison is performed using a cost comparison spreadsheet. A bid can be prepared for the entire project, an individual severable work package, or long lead-time procurement items.

27. Independent Cost Estimator (ICE) (CM/GC)
An independent consultant hired by the agency to prepare a production-based estimate that is used to compare with the CM/GC’s estimate, and/or the agency or designer’s estimate.
The ICE typically attends cost model review meetings and risk management meetings, so all estimates are based on the same assumptions.

28. OPCC Process (Opinion of Probable Construction Cost) (CM/GC)
An iterative procedure used to validate the CM/GC’s construction price at key milestones during the design process through approximately 90% design completion. The agency compares the CM/GC’s OPCC or construction estimate with the cost estimate prepared by the ICE, the agency estimate, and/or the designer’s estimate.

29. Risk Pools (CM/GC)
Project funds established as agency risk pools or shared risk pools to cover the cost when potential risks are realized. This is different than contractor risk for items such as equipment and labor availability, which is included in the price proposal. It is also different than cost overruns or scope changes which are handled through change orders to the contract.

30. Dual Construction Engineering Inspector (CEI) Roles (DB)
This is the use of two separate construction engineering inspectors (CEI) to inspect, test, and verify the quality of a project. One CEI role is hired by the constructing firm and is responsible for the quality management (quality control) of day-to-day operations. A second oversight construction engineering inspector (OCEI) role is provided by the agency to conduct audits with statistical sampling verification testing (quality acceptance).
31. Contractor Controlled Quality Control Testing

A process that includes contract clauses that offer the contractor the option of using their own personnel provided certain conditions are met. This has the potential of simplifying scheduling, reducing costs, and maintaining equivalent levels of quality.

32. Contractor Involvement in Establishing Quality Control Standards

A process where the agency judiciously considers alterations to its traditional specifications and testing requirements in order to customize and/or streamline quality control on projects, where appropriate, without sacrificing overall quality and still meeting the goals of the project. This is particularly useful in dealing with innovative or uncommon situations.

33. Incentive/disincentive Program for Superior Quality (DB)

A program to encourage superior quality performance by the contractor, thought it can also be used for safety performance, cost, environmental compliance, disruption to the travelling public, or other areas that align with the agency’s priorities.

34. Real-time Electronic Quality Management Information

A system for recording and accessing information. This may include uploading daily reports, and access to inspection checklists, statistical analysis and decision tools, integrated databases, and administrative tools.

35. Witness and Hold Points

Critical points during construction when inspection, testing, and verification by authorized agency personnel may need to take place before the next construction
activities can proceed. A hold point is linked to a specific construction activity, whereas, a witness point is linked to the entire construction project.

36. Payment Checklist

A list of tasks related to payment for construction and specifies which payment tasks are performed by the contractor and which are performed by the agency to help invoice preparation and review.

3.10 References


Anderson, S., Quiroga, C., Overman, J., Choi, K., Sahu, J., Kermanshachi, S., Goodrum, P., Taylor, T., and Li, Y. (2015). Effective project scoping practices to improve on-time and on-budget delivery of highway projects, NCHRP Project No. 08-88, Transportation Research Board of the National Academies, Washington, DC.


Construction Management Association of America (CMAA). (2012). *An owner’s guide to project delivery methods*, Mclean, VA.


CHAPTER 4

PROJECT INFLUENCE CURVE AND INITIAL AWARD PERFORMANCE IN DESIGN-BUILD HIGHWAY PROJECTS

4.1 Abstract

The project influence curve encapsulates the concept that planning efforts conducted earlier in a project can influence project success more than efforts undertaken later. Though front end planning efforts have been shown to influence project performance, the impact of contractor involvement through alternative delivery like design-build (DB) has not been tested empirically. The project influence curve seems to suggest that earlier contractor involvement in design should improve cost performance. The level of impact the timing of contractor involvement in design for a DB highway contract may have on initial award performance has never been tested. This research contributes to the body of knowledge of construction project delivery through the study of empirical data from 30 highway projects delivered under DB contracting where the base design provided by the owner at the time of procurement ranged from 10%-95%. The F-statistic indicates that this set of DB highway projects experienced a weak relationship between percent base design and initial award performance. This suggests that other variables are influencing initial award performance. Additionally, cost savings typically came from multiple alternative technical concepts (ATCs) rather than one ATC, and innovations tended to be incremental rather than systemic, disruptive, or radical.

4.2 Background

A possible cause for enhanced performance in alternative contracting methods (ACMs) like design-build (DB) is contractor involvement in design development. DB delivery
assumes that contractor involvement leads to innovation, which leads to lower initial award growth (and potential cost savings for the owner). Initial award performance is one measure of project cost performance and is the difference between the award cost and the agency estimate (FHWA 2018a; FHWA 2006; FDOT 2004). Figure 4.1 shows the relationship between agency estimate, initial award price, and actual project cost when there is positive growth.

![Figure 4.1. Performance Measures for Initial Award and Cost Growth](image)

Negative growth occurs when the initial award price or the actual project cost is less than the agency estimate. The agency estimate is considered a baseline in this measure.

Innovation is considered a key advantage of DB delivery, with alternative technical concepts (ATCs) used to promote innovation (NCHRP 2017; FHWA 2006). ATCs are used during procurement so that DB teams can demonstrate their ability to innovate. The selected DB team’s ATC innovations are incorporated into the DB contract and the contract amount reflects the savings from the approved ATCs. FHWA (2017) offers this definition of ATCs,

"Alternative Technical Concepts (ATC) are suggested changes submitted by proposing teams to the contracting agency's supplied basic configurations, project scope, design or construction criteria. These proposed changes provide a solution that is equal or better to the requirements in the Request for Proposal document. If the ATC concept is acceptable to the contracting agency, the concept may be incorporated as
The “equal or better” requirement is consistent with best-value and is fundamental to the ATC process. Nearly all state agencies that implement ATCs use the equal or better language (Gransberg et al. 2014). With an equal or better approach, agencies are seeking innovations and efficiencies that provide equivalent or better function and quality for less cost. ATCs seek to add value to a project similar to value engineering change proposals; however, ATCs are prepared before contract award (Molenaar et al. 2005).

The main steps in the ATC process are 1) the agency issues a procurement package with a base design and construction criteria, 2) the agency holds confidential meetings with proposers to review ATC proposals, and 3) the agency reviews final proposals that include approved ATCs and selects a winning firm. The confidential one-on-one meetings between the agency and a proposing firm helps reduce the risk for the proposer by vetting proprietary ideas which may deviate from standard practice or at least from the base design. Reducing risk can pave the way for innovation. Thus, a firm can include vetted ATCs in their project proposal with confidence that their proposal will not be rejected due to an innovative idea. If stipends are offered for DB proposals, then ATCs from the firms not selected for the contract can be available to the agency and the selected firm.

The percent base design to use for DB procurement varies on a case by case basis based on the specific characteristics of a project. Percent base design is defined as the level of design the agency provides at the start of procurement. Some transportation agencies have a target range for percent base design for DB procurement (i.e., WSDOT 10-15%; CDOT 30% or less; MoDOT 30%; NYSDOT 30%; CTDOT 60-70%). WSDOT chose to
deviate from their target percent base design on the SR520 Floating Bridge and took design to 60-95% in order to confirm proof of concept and reduce risk in the engineering and in the barging operations required for construction. One study showed base design for DB procurement between 15 to 50% for six transportation agencies (Molenaar and Gransberg 2001) and another study on 69 federally funded (Special Experimental Projects 14, or SEP 14) DB projects showed 0 to 85% (Molenaar et al. 2005). This aligns closely with a survey of 72 industrial construction projects with design completion ranging from 0 to 80% and an average of 30% (CII 2017). Factors that can influence the level of base design include 1) clarity of project goals and scope, 2) nature and complexity of the project, 3) the agency’s ability to convey the scope through performance criteria, and 4) the agency’s comfort level outsourcing design (Molenaar et al. 2005). Transportation projects have many elements and design will not be to the same level of completion for all elements. Some agencies define scope for various percentages of design completion (i.e., WSDOT 2018a). Agencies that implement base design above 30%, indicate that they are attempting to reduce risk and contingency pricing for risk by obtaining or preparing to obtain environmental, utility, and/or right-of-way clearance. For example, the TxDOT Design-Build Procurement Overview Manual (TxDOT 2017) states that some projects may want to “complete the environmental approval process and receive the necessary environmental approvals” prior to procuring a DB contract. One agency indicated that when a project interfaces with the railroad, their typical percent base design is increased to 30%. Setting percent base design is a balancing act of reducing risk, and the contingency pricing that goes with risk, and providing opportunity for innovation. Targeting a higher percent for base design may negate potential benefits of DB such as transferring risk (since many risks
have already been mitigated) and expediting delivery by overlapping activities. Additionally, in a recent study of front end engineering design, engineering design effort referred to as high maturity (based on 46 engineering elements) led to decreased cost change and better financial performance and customer satisfaction, but no impact to schedule or change order performance (El Asmar et al. 2018; CII 2017; Yussef et al. In press).

The use of ATCs is generally cost driven and the project influence curve predicts that costs are more easily influenced earlier in a project. CDOT (2014) states that ATCs “are a cost-oriented approach to providing complex and innovative designs” and “designer-builder collaboration and ATCs can provide a cost-efficient response to project goals.” Additionally, ATCs may provide other added-value benefits to areas such as schedule, safety, and maintenance. A gap in the research exists about whether potential benefits of ATCs may be impacted by percent base design.

If contractor involvement in design development can lead to innovation and low initial award growth, then the question is raised whether earlier involvement (lower percent base design) could result in even lower initial award growth. The theory behind the project influence curve (see Figure 4.2) suggests that it is easier to influence a project’s outcome earlier in the project life cycle when there are lower project expenditures (Gibson et al. 2006; Wang & Gibson 2002; CII 1995a; CII 1995b; Gibson et al. 1995; Gibson and Hamilton 1994; Paulson 1976). Gibson and Hamilton (1994) report as much as a 20% cost benefit between projects that do and do not execute pre-project planning well. Applying the project influence curve to DB suggests that the earlier a DB entity is involved in design development, the greater the cost savings.
Figure 4.2. Project Influence Curve (adapted from CII 1995b)

Figure 4.2 illustrates how project influence changes across the phases of a project. At the bottom of Figure 4.2, the phases for an industrial project typically seen with the project influence curve are labeled. Additionally, highway project phases (Antillon et al. 2016) are shown. In highway projects, planning can begin up to 20 years before construction; programming may include major environmental and interagency reviews; preliminary design is when the design of project elements is advanced to approximately 30%; and in final design, plans and specifications need for construction are prepared (Antillon et al. 2016; Anderson and Blaschke 2004). Figure 4.2 illustrates that the highest amount of influence occurs in the two earliest phases labeled perform business planning and perform
pre-project planning for industrial projects and planning, programming, and preliminary design for highway projects. The perform pre-project planning phase includes activities such as develop a project definition package and decide whether to proceed with the project (Gibson et al. 2006). The perform pre-project planning phase does not have a specific percent base design tied to it, rather, the intent of this phase is to develop strategy and understand risk so that an owner can make a go-no go decision about committing resources to move forward with the project. Researchers report an average of approximately 10% to 30% design completion on industrial projects at the end of the planning phase (El Asmar 2018; CII 2006; Gibson et al. 1995). Front end planning for infrastructure can help “in identifying and mitigating issues such as right of way concerns, utility adjustments, environmental hazards, logistic problems, and permitting requirements” (Bingham et al. 2011). DB procurement is initiated at the end of the perform pre-project planning phase (i.e, as seen in the TxDOT DB procurement timeline, TxDOT 2017). So according to the project influence curve, a majority of the opportunity to influence the project is already past. Some DB projects have shown strong initial award performance; however, the innovation and lower initial award that agencies may be expecting from the DB and ATC process may be overly optimistic considering that the DB entity is not typically engaged until after the perform pre-project planning phase.

4.3 Research Objective

A gap exists in the research regarding the influence of early contractor involvement during design and the impact on initial award performance. The theory of the project influence curve has not been empirically tested for highway projects using alternative contracting methods like DB. The theory of the project influence curve suggests that better initial award
performance would generally result when the contractor participates in the design process. However, the project influence curve also suggests that the typical timing of DB procurement in highway projects comes after a majority of the potential influence is past (after the perform pre-project planning phase). While front end planning in general has been well researched, little of this has targeted highway infrastructure projects (Bingham et al. 2011). The research in this dissertation diverges from existing research on front end planning by focusing on the contractor contributions to project development and the timing of contractor involvement. This research tests the hypothesis that DB procurement with lower percent base design will generally achieve a better initial award performance than with DB procurement at a higher percent base design. In order to make sense of initial award performance in a DB project, it is useful to look at the ATCs that are accepted, because ATCs are the mechanism by which the proposers introduce innovations that can lead to lower initial award performance. This research on percent base design at DB procurement makes a significant contribution to highway project planning for both agencies and DB entities. Agencies need to be fully informed as to how percent base design can influence initial award performance in DB procurement. This can help with appropriate project selection for DB contracting as well as with selecting the appropriate percent base design used in DB procurement. DB entities need to be fully informed as well, so that they can better plan on the level of effort required to advance the base design to a higher level of completion and to understand the potential for innovation as it relates to the percent base design.
4.4 Literature Review

Agencies seek strong initial award performance from the DB procurement process based on innovations brought forth through ATCs. ATCs are a primary tool for introducing innovation into a DB project. This section begins with a brief review of the literature on ATCs, followed by a summary of the background on innovation categories, innovation in construction, and innovation as a criterion for selecting a contracting method.

4.4.1 Alternative Technical Concepts

ATCs are a tool that agencies can use to derive best-value in a project by allowing DB proposers to consider innovative means, methods, and materials that draw from the proposers’ capabilities (MoDOT 2017). Gransberg et al. (2014) researched ATC practices in US transportation agencies through surveys, content analysis, and case studies. Their results confirm that ATC are more prevalent in DB than other delivery methods. They also report on changes agencies need to make in order to implement ATCs, such as allowing extra time during procurement for proposers to develop ATCs and time for the agency to review them. Additionally, their findings indicate that the vetting of innovative design proposals through the ATC process can help reduce the risk of the proposal being dismissed by the agency. They also noted that confidential one-on-one meetings operate best under well documented procedures such as confidentiality agreements. Their survey results indicated that 13 out of 20 agencies required ATCs to include an estimate of cost.

Gransberg et al. (2014) identified seven criteria for determining if a project might benefit from ATCs, including: 1) a strong correlation between design and construction means, methods, and equipment, 2) wide variation expected in the design in construction
shop drawings from different contractors, 3) potential benefits are expected to outweigh the potential costs agencies have for reviewing ATCs, 4) project permits allow latitude for alternatives, 5) if ATCs are not used the project is likely to generate contractor value engineering change proposals, 6) details such as maintenance of traffic and other non-permanent construction engineering are best decided by the contractor, and 7) the potential exists to mitigate risk through revisions to the base design. So, after an agency has selected DB delivery for a project, criteria like this can help agencies determine whether the ATC process is suitable for that DB project.

ATCs have been used with a variety of delivery methods, FHWA (2018a) reports that design-build best-value DB-BV (40 of 74 projects) employed ATCs more than design-bid-build (2 of 123 projects), construction manager/general contractor (0 of 34 projects), and design-build low bid DB-LB (2 of 38 projects). The use of ATC in DB-BV was primarily when complexity was high. The low use of ATC in DB-LB was attributed to small size and low complexity. The use of ATC with various contracting methods besides DB is documented in NCHRP Project 08-112 A Guidebook for Implementing Alternative Technical Concepts into Project Delivery Methods (Gransberg et al. 2018) where ATCs are identified as a risk management tool that can “help manage the cost, time, and performance risks associated with the quality of the construction documents and the ultimate constructability of the specific design solution articulated in the solicitation.”

In addition to federal manuals, some states have examined the performance of their own DB and ATC processes. In a review of DB project delivery, WSDOT (2016) reports that front end planning for DB projects prior to procurement will vary on a project by project basis. Tasks such as geotechnical or environmental investigations and third-party
coordination may need to be conducted by the agency in order to adequately define the project scope for DB procurement. The WSDOT (2016) report also suggests that the agency “be open to allowing changes in specification requirements in order to support innovation.”

ATCs have been used with other contracting methods besides DB. Research case studies performed on ATCs used with public private partnerships in highway projects (Jolley and Garvin 2014) revealed that cost savings were spread out over multiple ATCs, the limited procurement time limited the number of innovations that could be explored, and that ATCs were driven more by cost than by technical score. A secondary benefit of the ATC process was development of a shared understanding of project goals.

There is an abundance of research documenting best practices for ATC implementation. However, a gap exists in the research regarding the impacts of the percent base design at the time of DB procurement and the benefits achieved through ATCs.

4.4.2 Types of Innovation

DB is referred to as an innovative contracting method in comparison to the traditional design-bid-build (DBB) method of contracting (FHWA 2018b). To understand the types of innovations that can be derived from DB, a framework for innovation is needed. Innovation can be defined as the “actual use of a non-trivial change and improvement in a process, product, or system that is novel to the institution developing the change” (Slaughter 1998). In DB, the agency is looking for DB proposers to offer value-added improvements to a base design. A landmark framework for defining innovation was developed by Henderson and Clark (1990). They applied their work to the semiconductor
photolithographic alignment equipment industry. Their framework has two dimensions. The first dimension is the status of core concepts, whether they are reinforced or overturned. The second dimension is the linkages between core concepts and components, whether the linkages are changed or unchanged. The two aspects of these two dimensions identifies four types of innovation.

- Incremental innovation where core concepts are reinforced and linkages are unchanged.
- Modular innovation where core concepts are overturned and linkages are unchanged.
- Architectural innovation where core concepts are unchanged and linkages are changed. (The use of the term architecture refers to the notion of organizational structure and organizational knowledge.)
- Radical innovation where core concepts are overturned and linkages are changed.

Henderson and Clark show how incremental innovation disrupted product design, and this disruption in product design required a corresponding innovation in a company’s organizational structure and processes to adapt and stay competitive. Antillon et al. (2016) draw from multiple researchers (i.e., Sheffer and Levitt 2010; Taylor and Levitt 2004; Slaughter 1998) and rename Henderson and Clark’s four categories: 1) Incremental innovation, 2) Systemic innovation, 3) Disruptive innovation, and 4) Radical innovation. These labels will be use in this study.

Through case studies, Slaughter (1998) identifies idea generation, opportunity, and diffusion (communication about new applications) as necessary components for
innovation. Related to DB projects, this suggests that engaging the contractor in the design process may help idea generation, selecting projects with sufficient complexity may offer opportunity for innovation, and engaging proposers with experience constructing for other agencies may help idea diffusion.

Research on innovation in the construction industry suggests that existing features of the construction industry make it difficult for the construction industry to move beyond incremental innovations. For example, construction equipment improved only incrementally over a 30-year period (Arditi and Tangkar 1997). Diffusion of innovation in residential construction was limited due to industry fragmentation (Blackley and Shepard 1996) or the loosely coupled nature of the industry (DuBois and Gadde 2002). The discontinuity from one construction project to the next slowed learning (Gann and Salter 2000). The diffusion of energy efficiency was constrained to incremental innovation due to fragmentation in the industry (Lutzenhiser and Biggart 2003). Saenz de Ormijana and Rubio (2015) observed that only incremental innovation occurred on a small set of highway public private partnerships they studied. Although there are several types of innovations, these studies point to organizational constraints within the construction industry that seem to limit the construction industry to incremental innovation. This suggests that the DB contracting method and the ATC process may be generally constrained to generating incremental changes rather than systemic, disruptive, or radical innovations.

4.4.3 Innovation in Project Delivery Method Selection

Transportation agencies have a long history of delivering transportation projects using DBB delivery and more recently are exploring the use of ACMs like DB. The United States Federal Highways Administration (FHWA 2018b) in its Every Day Counts program
considers DB an innovation in delivering transportation projects and a tool to foster additional innovation. Some states have manuals, divisions, or teams that are referred to as innovative, i.e., Utah Innovative Contracting team (UDOT N.D.); CDOT Innovative Contracting Program (CDOT N.D.); MDOT Innovative Construction Contracting Guide (MDOT 2015); MnDOT Innovative Contracting Guidelines (MnDOT 2005); Caltrans Innovative Procurement Practices (Caltrans 2007); and FDOT Innovative Contracting Techniques (FDOT 2015). DBB is frequently referred to as traditional project delivery and ACMs like DB as innovative project delivery.

Innovation has been cited as a selection criterion for DB (i.e., FMI 2018; WSDOT 2017; GDOT 2014; Gransberg et al. 2013; FHWA 2006; Wyoming DOT 2002; Molenaar et al. 1999; CDOT N.D.). In a survey conducted by the FHWA (2006) about factors to consider in deciding whether to use DB, “opportunity for innovation” was ranked second, (4.6/6), only behind “urgency of project”. Furthermore, FHWA (2006) states, “One of the purported advantages of design-build project delivery is the opportunity to use more performance-based specifications to encourage greater innovation by the design-build team and focus on project performance results versus conformance with product specifications that may be outdated given the latest technology and research.” In DBB, innovative solutions can be explored prior to procuring a contractor. However, it is difficult to assess costs, benefits, and risk of innovation without input from the contractor that will be building the project. In DB, the contractor is selected in part on innovative ideas through ATCs. Alternative technical concepts is a key tool used during procurement that allows DB teams to exhibit their ability to innovate.
4.5 Research Method

This research tests the hypothesis that DB procurement with lower percent base design will generally achieve better initial award performance than DB procurement with higher percent base design. To test this hypothesis, data was collected from transportation agencies from around the United States. Contacts included agency personnel with titles such as: program manager, project manager, cost/risk estimating manager, engineering manager, principal engineer, and DB coordinator. Fourteen state agencies implementing DB delivery were contacted by phone and email. Seven of these provided data from one or more DB projects, for a total of 30 projects. These agencies provide a wide geographic representation of the United States including the northeast, southeast, east, mid-west, southwest, west, and northwest. Information requested included: percent base design, ATC descriptions, agency estimate, and DB contract price. The 30 projects include major roadway and bridge construction with total value of $6.4 billion. A description of the DB projects is provided in Table 4.1.

Table 4.1. Description of DB Highway Projects

<table>
<thead>
<tr>
<th>Description of Data</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of states</td>
<td>7</td>
</tr>
<tr>
<td>Number of DB projects</td>
<td>30</td>
</tr>
<tr>
<td>Range of percent base design</td>
<td>10%-95%, avg. = 34%</td>
</tr>
<tr>
<td>Range of DB price proposals</td>
<td>$2.2M-$1.09B, avg. = $213M</td>
</tr>
<tr>
<td>Total of all 30 DB price proposals</td>
<td>$6.4B</td>
</tr>
</tbody>
</table>
Initial award performance (see Fig. 4.1) is calculated as shown in the equation below.

\[
\text{Initial award performance} = \frac{\text{Contract proposal price} - \text{Agency estimate}}{\text{Agency estimate}} \times 100\%
\]

Some of the projects in this study were still under construction and therefore, an actual final project cost was not available. Some researchers have looked at cost growth between the contract price and the actual cost; however, results can become distorted if agency-initiated scope changes or change orders impact the actual cost. The use of initial award performance to measure the cost performance of DB is consistent with other research (FHWA 2018a; FHWA 2006; FDOT 2004). A statistical analysis of the data was performed using the F-test which is appropriate for determining if the proposed regression model is statistically different from the data (Neter et al. 1988). The null hypothesis predicts that there is no relationship between percent base design and initial award performance.

4.6 Results and Analysis

In this section, results are presented and quantitatively analyzed with statistics and qualitatively analyzed within the context of innovation levels, ATC processes, and agency estimating practices. The quantitative data for thirty projects including percent base design for DB projects at the time of procurement, the agency’s cost estimate, and DB contract proposal price, is summarized in Table 4.2.
Table 4.2. Summary of Highway Agency Estimate and DB Proposal

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>$85,229,751</td>
<td>-$18,367,649</td>
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</tr>
<tr>
<td>2</td>
<td>10</td>
<td>$177,299,000</td>
<td>$176,500,000</td>
<td>-$799,000</td>
<td>-0.45</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
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<td>$1,089,700,002</td>
<td>-$299,998</td>
<td>-0.03</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>$98,112,000</td>
<td>$109,177,109</td>
<td>$11,065,109</td>
<td>11.28</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>$106,693,600</td>
<td>$99,190,380</td>
<td>-$7,503,220</td>
<td>-7.03</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>$116,198,993</td>
<td>$109,177,109</td>
<td>-$7,021,884</td>
<td>-6.04</td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>$135,917,200</td>
<td>$129,749,000</td>
<td>-$6,168,200</td>
<td>-4.54</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>$241,539,794</td>
<td>$244,350,000</td>
<td>$2,810,206</td>
<td>1.16</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>$22,569,000</td>
<td>$14,553,000</td>
<td>-$8,016,000</td>
<td>-21.93</td>
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<tr>
<td>10</td>
<td>20</td>
<td>$30,000,010</td>
<td>$19,263,000</td>
<td>-$10,737,010</td>
<td>-35.79</td>
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<tr>
<td>11</td>
<td>20</td>
<td>$37,948,029</td>
<td>$34,450,000</td>
<td>-$3,498,029</td>
<td>-9.22</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>$106,000,000</td>
<td>$98,000,000</td>
<td>-$8,000,000</td>
<td>-7.55</td>
</tr>
<tr>
<td>13</td>
<td>20</td>
<td>$640,769,000</td>
<td>$586,561,000</td>
<td>-$54,208,000</td>
<td>-8.46</td>
</tr>
<tr>
<td>14</td>
<td>25</td>
<td>$51,540,170</td>
<td>$43,900,000</td>
<td>-$7,640,170</td>
<td>-14.82</td>
</tr>
<tr>
<td>15</td>
<td>25</td>
<td>$175,100,000</td>
<td>$107,500,000</td>
<td>-$67,600,000</td>
<td>-38.61</td>
</tr>
<tr>
<td>16</td>
<td>25</td>
<td>$231,000,000</td>
<td>$262,387,000</td>
<td>$31,387,000</td>
<td>13.59</td>
</tr>
<tr>
<td>17</td>
<td>30</td>
<td>$40,825,115</td>
<td>$41,965,000</td>
<td>$1,139,885</td>
<td>2.79</td>
</tr>
<tr>
<td>18</td>
<td>30</td>
<td>$62,000,000</td>
<td>$71,978,000</td>
<td>$9,978,000</td>
<td>16.09</td>
</tr>
<tr>
<td>19</td>
<td>30</td>
<td>$117,000,000</td>
<td>$110,994,000</td>
<td>-$6,006,000</td>
<td>-5.13</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>$205,000,000</td>
<td>$115,900,000</td>
<td>-$89,100,000</td>
<td>-43.46</td>
</tr>
<tr>
<td>21</td>
<td>30</td>
<td>$249,999,96</td>
<td>$155,500,001</td>
<td>-$94,499,995</td>
<td>-37.8</td>
</tr>
<tr>
<td>22</td>
<td>30</td>
<td>$422,064,082</td>
<td>$306,278,000</td>
<td>-$115,786,082</td>
<td>-27.43</td>
</tr>
<tr>
<td>23</td>
<td>60</td>
<td>$10,474,007</td>
<td>$10,474,007</td>
<td>$0</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>60</td>
<td>$195,061,391</td>
<td>$194,064,141</td>
<td>-$997,250</td>
<td>-0.51</td>
</tr>
<tr>
<td>25</td>
<td>60</td>
<td>$814,313,415</td>
<td>$810,583,415</td>
<td>-$3,730,000</td>
<td>-0.46</td>
</tr>
<tr>
<td>26</td>
<td>70</td>
<td>$40,800,000</td>
<td>$34,752,000</td>
<td>-$6,048,000</td>
<td>-14.82</td>
</tr>
<tr>
<td>27</td>
<td>70</td>
<td>$998,100,499</td>
<td>$943,557,999</td>
<td>-$54,542,500</td>
<td>-5.46</td>
</tr>
<tr>
<td>28</td>
<td>75</td>
<td>$2,750,002</td>
<td>$2,170,507</td>
<td>-$579,495</td>
<td>-21.07</td>
</tr>
<tr>
<td>29</td>
<td>75</td>
<td>$600,000,006</td>
<td>$367,330,000</td>
<td>-$232,670,006</td>
<td>-38.78</td>
</tr>
<tr>
<td>30</td>
<td>95</td>
<td>$29,321,810</td>
<td>$28,954,792</td>
<td>-$367,018</td>
<td>-1.25</td>
</tr>
</tbody>
</table>

Notes: 1 No ATCs approved; 2 No ATCs allowed; 3 Agency’s first DB

All but one of these agencies had delivered multiple projects with DB contracting. All but two of these projects had approved ATCs. For the projects studied, percent base design
ranges from 10% to 95%. DB initial award performance ranges from 43.5% under the agency estimate to 16.1% above the agency estimate. This range of initial award performance can be compared to what has been reported in other studies as summarized in Table 4.3. Initial award performance below 0% results when the initial award performance is lower than the agency estimate.

**Table 4.3.** Range of Initial Award Performance as Reported in Research

<table>
<thead>
<tr>
<th>Research</th>
<th>Range of initial award performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Design build program evaluation, Nov. 24, 2004 (FDOT 2004)</em></td>
<td>-56% to 87%</td>
</tr>
<tr>
<td>A design-build effectiveness study (FWHA 2006)</td>
<td>-41% to 23%</td>
</tr>
<tr>
<td><em>Alternative contracting method performance in U.S. highway construction</em> (FHWA 2018a)</td>
<td>-55% to 104%</td>
</tr>
<tr>
<td>This study</td>
<td>-43.5% to 16.1%</td>
</tr>
</tbody>
</table>

Additionally, 73% of the projects in this sample have percent base design at 30% or less, which suggests that these agencies are looking for innovation and cost savings through early engagement of the contractor during design. Agencies have different target percentages for base design. Agencies that have lower target percent base design tend to believe that more innovation and cost savings are possible with less design decisions defined. Other agencies target a higher percent base design in an effort to remove risks such as permitting and right-of-way acquisition. One agency representative stated, “In general, they like the 60% range for environmental documentation purposes. The 60% plans give them some confidence on the project impacts to environmental sensitive areas and corresponding documentation.” As noted in the Background section of this chapter,
base design can vary widely. In Europe, percent base design was pre-0% (for unsolicited proposals) to 100%, with a majority ranging from 10% to 50%. The United Kingdom was at the higher end from 30% to 80% (FHWA 2002). Thus, the percentages observed in this study are consistent with findings from other researchers.

Figure 4.3 shows a scatter plot of the percent initial award performance for DB projects at various percent base design. The two solid diagonal lines in Figure 3 create a theoretical funnel shape that indicate that the uncertainty of costs typically reduces as the project base design advances. A negative initial award performance indicates a cost proposal below the agency estimate. A majority of the projects in this data set fall below the zero initial line, which would be expected in a competitive procurement process. Generally, cost uncertainty diminishes as design progresses (Anderson et al. 2004). The Association for the Advancement of Cost Estimating International (AACE) developed a cost estimating classification system (AACE 2011) that shows how estimate accuracy is expected to increase as project definition increases (Table 4.4). The five-tiered classification system was developed for engineer, procure, and construct (EPC) delivery in the process industries, but its basic principles are applicable broadly to construction. The AACE cost estimating classification system provides a low and high range for estimate accuracy.

The DB process also creates a unique situation where the engineer’s estimate is based on the percent base design at procurement and the DB proposers estimate is based on a design that is more advanced than the base design. DB proposers will advance the base design to a level where they have confidence in their cost proposal. Because of this, it is expected to see variation between the agency estimate and the DB proposal price.
Table 4.4. Cost Estimate Classification Matrix for Process Industries (adapted from AACE 2011)

<table>
<thead>
<tr>
<th>Estimate Class</th>
<th>Project Phase</th>
<th>Percent Base Design</th>
<th>Expected Cost Estimate Accuracy Range</th>
</tr>
</thead>
</table>
| Class 5        | Early Perform Business Planning | 0%-2%               | L: -20% to -50%  
|                |                        |                     | H: +30% to 100%               |
| Class 4        | Perform Business Planning | 1%-15%              | L: -15% to -30%  
|                |                        |                     | H: +20% to +50%               |
| Class 3        | Perform Pre-Project Planning | 10%-40%            | L: -10% to -20%  
|                |                        |                     | H: +10% to +30%               |
| Class 2        | Early Execute Project   | 30%-75%             | L: -5% to -15%  
|                |                        |                     | H: +5% to +20%               |
| Class 1        | Execute Project         | 65%-100%            | L: -3% to -10%  
|                |                        |                     | H: +3% to +15%               |

Note: Ranges are typical, and can be influenced by many variables.

Likewise, it is expected to see deviations between the lowest cost proposal and the other proposals. One project in this data sample had a 17% difference between the low and high proposals. Additionally, agencies may have different approaches or process that can influence the engineer’s estimate, such as accounting for inflation, or including calculated contingencies for analyzed risks. Furthermore, the percent base design leaves some design questions unanswered, introducing uncertainty. Estimating unique elements in a project will have more uncertainty that estimating elements that are commonly built. The procurement time for DB is limited, which can impact the level of uncertainty. The initial award performance of the 30 projects studied generally fall within the percentages established in the AACE estimate classifications. This indicates that the data follows typical expectations for estimating accuracy.

The project data has been plotted in Figure 4.3 in order to understand how initial award performance may be impacted as the percent base design increases. There are
twenty-five projects (83%) with DB contract price proposals equal to or lower than the agency estimate (solid dots), and five projects (17%) with DB contract price proposals higher than the agency estimate (open dots). The project influence curve predicts gradually higher initial award growth as percent base design increases. A strong relationship between percent base design and initial award performance is not evident with this set of projects, as the slope of the trend line is relatively flat. Additionally, the small \( r^2 \) value of 0.003 is consistent with visual inspection of the dispersed data points in the scatter plot in Figure 3. The \( r^2 \) value of 0.003 indicates that virtually none of the variance in initial award performance is attributable to the percent base design. For an F-test with one in eight degrees of freedom, the p-value is 0.782. This is greater than a standard probability of 0.5, so the null hypothesis cannot be rejected. That is, for this data the relationship between percent base design and initial award performance is not statistically significant. Design and construction of highway projects are complex; each project has unique characteristics and takes multiple years to design and construct. So, it is not expected that percent base design would be the only or even the main contributor to initial award performance.
Note: Solid black dots represent projects with contract price proposals equal to or lower than the agency estimate.

Solid gray dots represent projects with contract price proposals equal to or lower than the agency estimate where no ATCs were accepted.

Open dots represent projects with contract price proposals higher than the agency estimate.

Figure 4.3. Percent Initial Award Performance for DB Highway Projects across Percent Base Design.
The initial cost performance in dollars that corresponds to projects with varying percent base design is shown in Figure 4.4. The DB contract initial award performance is scattered more below the agency estimate than above for this set of projects. It is expected that higher value projects have the potential for higher dollar savings; however, some projects with similar agency estimates are seeing variable initial award performance. For example, two similar size projects started DB procurement with 15% base design, one project with an agency estimate of $98M had initial award growth of +$11M, and another project with an agency estimate of $106.7M had an initial award growth of -$7.5M. This
is an $18.5M swing that must be accounted for by something other than percent base design.

The project with the greatest dollar amount saved at initial award is the same as the project with the best percentage initial award performance. This project had a scope of work that involved a 1,500 ft. long, 2-lane flyover bridge. Designing and building a flyover bridge has many complexities that lends itself to innovation. Nine ATCs from the winning proposal were accepted by the agency on this project. Base design documents were at 30%. The four top ATCs included 1) reduced lane taper that reduced the impact on wetlands, 2) reuse of existing ITS conduit resulting in less impact to the community, traffic, and the environment, 3) combining exits to increase safety and reduce earthwork by 100,000 CY, and 4) narrow mainline lanes to promote better transition to an urban section and reduce wetlands impacts. These ATCs can be considered innovations to the specific base design provided by the agency, but from a broader perspective of the transportation industry, they can be considered efficiencies or improvements rather than innovations since these ATCs are not novel to the transportation sector. A second project with strong initial award performance had a scope of work including four reversible managed lanes and six managed lane interchanges. Fifteen ATCs were accepted. Base design was at 70%. The top ATCs included 1) remove certain shoulder breaks on managed lanes, and 2) alternative alignment for managed lanes. These ATCs also reflect efficiencies or improvements rather than pure innovations. Additionally, these ATC examples reinforce the notion that initial award performance on DB proposals come from multiple ATCs, rather than just one large innovation (Jolley and Garvin 2014).
In addition to looking at how initial award performance varies with percent base design, it is important to consider the level of innovation occurring to obtain low initial award growth. ATCs may be introducing common design, material, or process changes that save money (efficiencies) or they may fundamentally alter design, materials, or processes in a way that adds value (innovation). Of the thirty projects studied, descriptive information for 63 ATC on 16 projects was collected. Applying the innovation framework of incremental, systemic, disruptive, and radical (Antillon et al. 2016), all the ATCs in this group of projects were identified as incremental by the authors. Some ATCs were documented by the DB proposer as having been used on previous projects or as common practice in other regions, indicating the diffusion of these innovations. Other ATCs could be described as project efficiencies or improvements rather than true innovations that introduce novel changes.

The researchers analyzed the ATCs that were collected. Three categories of efficiencies were identified in the 63 ATCs: design (46), process (10), and materials (7). An example of a design ATC includes moving a roundabout to reduce right-of-way impacts. The increase in material cost may be offset by a decrease in total construction time. An example of a process ATC includes bolting field splices instead of welding in order to decrease construction time and traffic impacts. An example of a material ATC includes using number 57 stone for backfill because it can be placed in larger lifts and reduce time during limited work windows for accelerated bridge construction. These last two ATCs provide examples of how saving construction time can lead to cost savings.

The ATC process has a structure that tends to drive DB proposers toward incremental innovation rather than higher levels of innovation. The time allotted to develop
ATCs is limited, which motivates DB proposers to look for simpler incremental innovations that they can research and develop within that limited time frame (Jolley and Garvin 2014). This may also encourage the diffusion of ideas across agency boundaries where DB proposers can introduce ideas that they have used successfully in other regions. Diffusion is a key characteristic of innovation as noted by Slaughter (1998). Additionally, the “equal or better” criteria that many agencies use in determining whether to approve an ATC is intended to focus ATC innovation on function rather than cost, but the selection process may counteract this when it weights the cost proposal. This serves to keep DB proposers focused on incremental innovations and cost savings at the project level, rather than systemic, disruptive, and radical innovations.

Agency estimates are used as benchmarks for measuring cost growth; however, agency estimates may not be consistent across agencies or even across projects within a single agency. It can be challenging for an agency to develop preliminary cost estimates for a project when the project is early in design. Factors that influence estimating can be categorized as internal to the agency or external to the agency (Anderson 2004). Some internal factors include error and omissions from poor estimating, historical bid database features, and inconsistent application of contingencies. The difficulty of estimating public infrastructure projects has been previously documented (Flyvberg et al. 2003; US GAO 2003). Agencies may take different approaches to estimating (US GAO 2003) accounting for design, right of way acquisition, and inflation in different ways. For example, WSDOT has an extensive process for risk-based estimating (WSDOT 2018b) which may add cost to an estimate in order to account for risk. WSDOT’s risk-based estimating may lead to higher estimates than other agencies (Hill 2016).
Another possible factor influencing initial award growth is the uniqueness of each construction project (Ellis et al. 1991). Some factors that can impact initial award performance (Wang & Gibson 2008) include: project goals and stakeholders; site conditions such as soils, weather, and utilities; economic conditions such as the labor market, materials prices, competitiveness, and contractor capabilities; and regulatory environment including national and local regulations. One-off projects limit the opportunity for systemic, disruptive, and radical innovation because the conditions change project to project. This individualized nature of projects is often considered by agencies in the project delivery selection process. Projects with multiple constraints and limited opportunities for innovation may not be the best candidates for DB contracting. For example, CDOT considers a project’s potential for cost savings and innovation in the delivery method selection process (CDOT 2014), in order to select DB contracting for projects that allow DB entities to distinguish themselves with innovative ATCs that lead to strong initial award performance. The reasons for selecting DB delivery for projects may vary. Some projects may have a priority on cost savings through innovation, while other projects may prioritize best-value, accelerated schedule, or bundling multiple related projects.

Yet another factor that may influence initial award performance on a DB project is an agency’s level of tolerance for deviations from their standards and processes. One agency may require work to be accomplished according to the agency’s documented standards. Alternatively, another agency may be open to considering ATCs that use standards from other agencies. Flexibility occurs when an agency is open to deviating from the agency’s standards when it is demonstrated that project goals and quality can still be
met. In an agreement between FHWA and MoDOT (FHWA-MoDOT 2013) flexibility in applying standards is encouraged in order to maximize innovation. Similarly, in a review of WSDOT practices (WSDOT 2016), prescriptive requirements are noted as limiting opportunity and innovation.

4.7 Conclusions

The project influence curve suggests that the earlier a contractor is brought into the design process, more innovation and better initial award performance will be achieved. Actual data indicates a more nuanced interaction than what the project influence curve suggests. This dissertation research on the relationship between percent DB base design and initial award performance provides a point of departure from existing research in a number of areas. First, the existing research on front end planning has focused on the various elements of planning on how they benefit a project (El Asmar et al. 2018; Bingham et al. 2011; CII 2006, 1995a, 1995b; Gibson et al. 2006; Wang and Gibson 2002; Gibson and Hamilton 1994; Paulson 1976; Yussef et al. in press). Effective front end planning has been shown to improve costs by as much as 20% (Hamilton and Gibson 1994). However, front end planning research has not looked at how contractor involvement in DB highway project development may impact innovation and cost savings. Second, integrated project teams have been researched, but without the context of contract administration functions (El Asmar et al. 2016; El Asmar et al. 2013; Elvin 2010; Pocock et al. 1996) but the value teams bring to a project has not been compared to the project influence curve. Thirdly, the process and performance of DB and ATCs have been researched (Gransberg et al. 2018; FHWA 2018a, 2006; NCHRP 2017; Gransberg et al. 2014), but the relationship between ATCs, innovation, cost savings, and percent base design in highway project has not been
studied in depth in relationship to the project influence curve. Fourthly and finally, innovation and innovation in construction has been researched (Antillon et al. 2016; Saenz de Ormijana and Rubio 2015; Sheffer and Levitt 2010; Taylor and Levitt 2004; Lutzenhiser and Biggart 2003; DuBois and Gadde 2002; Gann and Salter 2000; Slaughter 1998; Arditi and Tangkar 1997; Blackley and Shephard 1996; Henderson and Clark 1990), but past research has not explored DB highway projects for relationships between innovation, initial award performance, percent base design, and types of innovation. In all these areas – front end planning, integrated project teams, DB and ATCs, and innovation – the research results presented in this dissertation stand as a point of departure and provide a deeper understanding of where the ATC process in DB highway projects fits into the theory of the project influence curve.

The research in this dissertation contributes to the body of knowledge on alternative delivery methods by testing with empirical data whether design-build highway projects tend to follow the initial award performance predictions of the project influence curve. The data from the 30 highway projects included in this study point to cost savings for the transportation agency as indicated in 25 projects (83%) with a contract price less than or equal to the agency estimate. However, the relationship between percent base design and initial award performance is not statistically significant. DB procurement occurs at the end of pre-project planning, where the project influence curve suggests that the ability to financially influence a project has diminished greatly. While savings can be significant with early procurement of a DB entity, this study suggests that there may be other circumstances that mitigate potential savings. Agencies and researchers need to be careful not to be overly optimistic about the amount of innovation and initial award performance
that DB procurement and the ATC process can generate. Agencies can use the results of this research to inform the decision of what percent base design to use when procuring a DB contract. Agencies should consider that the more detailed design required to reduce uncertainties (i.e., environmental permits, right-of-way acquisition, utility relocation) may also be reducing the opportunity for innovations and initial award performance. Projects should be analyzed on a case-by-case basis to determine if they are appropriate for DB delivery and what percent base design to choose to optimize innovation, cost savings, and risk.

In this study, it was observed that ATCs are primarily incremental innovations or cost efficiencies instead of systemic, disruptive, or radical innovations. Innovations that DB proposers have used in other jurisdictions demonstrates how the ATC process can help the diffusion of innovation. Ideas that are common and do not rise to the level of innovations that are placed into ATCs in order to save costs or accrue other benefits can be considered efficiencies or improvements rather than true innovations. This study identified three categories of ATCs: design, process, and materials. Agencies may want to describe their base design so as to allow as much flexibility in these areas as possible. Future research could explore these three categories of ATCs and explore which types of ATCs are most beneficial to different types of highway projects.

Other factors in addition to percent base design may be at work influencing initial award performance. One of these factors may be that DB procurement occurs after pre-project planning where a majority of influence lies. This observation has not been widely noted in the agency manuals or research literature on DB. Additional factors that may influence initial award performance include: the accuracy of agency estimates, the
uniqueness of construction projects, difficulty documenting lessons learned in a retrievable way and sharing institutional knowledge, selecting DB delivery for projects that can benefit from innovation, and the agency’s openness to deviating from their own standards. Future research could explore these areas and their relationship to DB initial award performance.

The structure of the ATC process tends to reinforce incremental innovation or cost efficiencies instead of systemic, disruptive, or radical innovations. DB proposers have limited time to prepare ATCs. Stipends generally do not fully cover the expenses for pursuing advanced innovations. Due to economic reasons and time constraints, proposers may be more likely to focus on less complex, incremental innovations. Selection of a winning DB entity often includes a weighted price component that reinforces incremental innovations at the project level and initial award performance for the specific project, but not systemic, disruptive, or radical innovations.

Despite these limitations, agencies are realizing benefits from DB delivery and the ATC process. Ideas are being diffused across agency boundaries. Multiple ATCs can contribute to initial award performance rather than just one large innovation. ATC meetings can foster team alignment, communication, and trust. In the future, agencies should look for ways to incentivize systemic, disruptive, and radical innovations in addition to incremental innovations.

Future research can address some of the limitations of this study. One limitation is that only cost savings were studied, not other potential benefits such as improved schedule, improved safety, reduced traffic impacts, and reduced environmental impacts. Another limitation is that this research did not account for how the type of project (i.e., widening for express lanes, vs. road and bridge improvements) may influence the type of innovations.
generated. Also, this study is limited by the number of projects studied. In the future, a larger sample of projects could be studied as the number of agencies and highway DB projects expands. This study compared contractor proposal price and agency estimate, but did not have sufficient information to compare these to actual final cost of the project.

As more agencies start to implement DB and expand their use of DB, it is predicted that innovation diffusion between transportation agencies will accelerate. It can be imagined that at some point in the future, basic incremental innovations will be widely diffused, and initial award performance may taper off. This may not occur as readily or as quickly in the building sector, because the number of owners in the building sector is much larger than the number of state transportation agencies. This research provides empirical data on percent base design and initial award performance for DB highway projects and compares it to predictions from the project influence curve. This research serves as a starting point for researching other factors that influence enhanced design-build performance.

4.8 References


CHAPTER 5

CONCLUSION

This chapter summarizes the research presented in this dissertation, describes research contributions, reviews limitations of the research, and discusses recommendations for future research. This research contributes a new way to view DBB, CM/GC, and DB delivery by focusing on contract administration functions modeled with IDEF0. Furthermore, this research contributes the first comprehensive presentation and analysis of contract administration tools for DB highway projects. Finally, this research contributes to the understanding how predictions from the project influence curve may be applied to DB highway projects. Together, these contributions provide a macro, mid-level, and micro view of contract administration (Fig. 1.1).

5.1 Summary of Research

This dissertation has three objectives:

1. Model DBB, CM/GC, and DB contract administration functions. (Chapter 2)
2. Identify and analyze DB and CM/GC contract administration tools. (Chapter 3)
3. Analyze alternative technical concepts (ATCs) (one specific tool used in DB delivery) to explore the relationship between percent base design and initial award performance considering predictions stemming from the project influence curve. (Chapter 4)

Research findings from these three research objectives are summarized next.
5.1.1 Summary of DBB, CM/GC, and DB IDEF0 Model Research

The IDEF0 models developed in this research provide a rich understanding of contract administration functions through exploring their hierarchy and relationships between functions. Key parts of the model and node indices are included in the body of this dissertation while the complete multipage models are included in Appendices C-F. The model was tested using the input of industry professionals at various points in the model development process. The models focus on five phases: alignment, design, preconstruction (CM/GC only), construction, and closeout. In alignment, CM/GC and DB differ from DBB by bringing the builder into alignment during design. In design, CM/GC and DB are different from DBB in the way innovation and value engineering impacts the design process and how cost savings are allocated. Additionally, fast tracking can more easily be employed with CM/GC and DB, which can result in contractor early work packages not associated with DBB. Also, project documentation for CM/GC and DB is developed to a point that the contractor can build the facility and the agency will have record drawings with adequate information, whereas in DBB, project documentation is developed for competitive bidding. In the preconstruction phase, the agency and the CM/GC are involved in an iterative and collaborative process to negotiate a contract price. In contrast, DBB is awarded to a low bidder. Additionally, DB can be awarded to a low bidder, a qualified bidder, or a combination of these in a best-value award. In the construction phase, a key difference of CM/GC is the collaborative identification and allocation of risks and contingencies. DBB and DB may analyze risk, but with a less collaborative approach. Other contract administration functions during construction may or may not differ with ACMs. Quality control may reside with the agency as is typical with DBB, or it may be
transferred to the contractor with the agency taking on a quality verification role. Furthermore, measurement and payment in ACMs may be the same as in DBB, or for CM/GC and DB projects the agency may approximate the amount of work installed for review and payment of invoices. In closeout, contract administration functions are generally the same for DBB, CM/GC, and DB; however, ACMs provide an opportunity for extended warranties. The differences between DBB and ACMs like CM/GC and DB largely rest on integrating the contractor in design and strengthening communication between the contractor and the designer and agency throughout the life of a project.

5.1.2 Summary of DB and CM/GC Tools for Contract Administration

This dissertation provides a portfolio of DB and CM/GC tools for contract administration that have been vetted by transportation agencies across the United States (see Table 2.3). This comprehensive portfolio of tools for DB and CM/GC contract administration provides a much-needed resource that was not previously available to agencies. Recommendations on the appropriateness of the tools based on project complexity and size are reported and can help agencies effectively implement these tools. These tools for ACM contract administration have been organized in a project chronological framework (alignment, design, preconstruction (CM/GC only), construction, and closeout), which was derived from IDEF0 models developed with input from industry professionals. Tool descriptions and recommendations can be seen in their entirety in NCHRP Report 08-104 (NCHRP 2016).

An analysis of the ACM tools reveals four objectives, namely: integrating the contractor in design, fostering innovation and savings, fostering price competitiveness in CM/GC, and facilitating quality management. Thirty case study interviews revealed ACM
contract administration tools that address each of these four objectives. The input of agencies, contractors, academics, and practicing engineers informed this research at multiple points, including: the development of the IDEF0 models of delivery methods, identification of tools for contract administration, and the recommendations for implementing those tools. Agencies can select tools confidently knowing that they have been used in the field on real projects.

5.1.3 Summary of the Timing of DB Procurement and the Project Influence Curve

The project influence curve suggests that the earlier a contractor is brought into the design phase, the more innovation and lower initial award growth will be achieved. The relationship between percent base design and initial award performance was studied in 30 design-build highway projects. In this sample set, 25 projects (83%) showed positive performance where the contract price at time of DB award was less than or equal to the agency estimate. This demonstrates the potential value DB delivery can bring to highway projects. Additionally, the F-statistic indicates that the relationship between percent base design and initial award performance is not statistically significant. This suggests that there are other factors impacting cost savings in DB highway projects. It was also observed that ATCs are primarily incremental innovations or cost efficiencies instead of systemic, disruptive, or radical innovations. Furthermore, examples of innovations diffusing across agency boundaries was observed, which is one characteristic of innovations. Finally, the primary categories of innovations identified in the sample are: design, process, and materials.
5.2 Summary of Contributions

This dissertation expands the knowledge about ACM contract administration in highway projects. First, it provides comprehensive modeling of DBB, CM/GC, and DB contract administration functions. Second, it provides a comprehensive portfolio of 36 DB and CM/GC tools for contract administration with recommendations on appropriateness for project complexity and size. Thirdly, it provides empirical evidence from DB highway projects that suggest a more nuanced look at the project influence curve when applied to percent base design and initial award performance.

5.2.1 Contributions from Models of Contract Administration Functions

This dissertation contributes to the existing body of knowledge of highway contract administration by modeling and comparing contract administration functions for DBB, CM/GC, and DB delivery. The IDEF0 models of ACMs provide a point of departure from existing research in a number of areas. First, the existing research in the area of procurement and project delivery method selection has not been informed by a deep understanding of agency contract administration functions (Alleman et al. 2017; Tran et al. 2016; Tran et al. 2013; Luu et al. 2005; Molenaar and Gransberg 2001). Second, performance studies have compared delivery method outcomes, but the potential impacts of contract administration functions on performance outcomes has not been explored (Sullivan et al. 2017; Shrestha et al. 20012; Molenaar 2003; Molenaar et al. 1996). Thirdly, integrated project teams have been a focus of research, but without the context of contract administration functions (El Asmar et al. 2016; El Asmar et al. 2013; Elvin 2010; Pocock et al. 1996). Fourthly, cultural and organizational change for implementation of innovative processes has been researched, but this has not explored the implications of differing
contract administration functions (Minchen et al. 2014; Migliaccio et al. 2008; Pietroforte and Miller 2002; Molenaar and Gransberg 2001; Miller et al. 2000). Fifth and finally, research on construction contracts have focused on contract language, disputes, and constructability but not ACM contract administration functions (El-adaway et al. 2018; Chong et al. 2011; Trigunarsyah 2004; Fisher et al. 2000; Phillips 1999; Thomas et al. 1980; Scott 1974). In all these areas - procurement and selection of delivery methods, performance studies, integrated project teams, culture and organizational change for ACMs, and contract administration – the IDEF0 models presented in this dissertation research stand as a point of departure and provide a framework to further explore each of these research areas.

The IDEF0 models also provide a unique perspective in addressing agency needs in contract administration. Previous comparisons of delivery methods focused on contract relationships and benefits of each delivery method (Sullivan et al. 2016; Gransberg et al. 2006; Konchar and Sanvido 1998). For example, DBB is described as having separate contracts with the designer and the builder where the designer and builder have loose lines of communication during construction. The comparison of contract relationships in delivery methods has served the industry well in terms of considerations of risk and responsibility. However, agencies have an important need to understand what functions they need to perform, and the type of skills and level of effort required to perform those functions to administer a given type of contract. The IDEF0 models of DBB, CM/GC, and DB begin to inform this need. For example, with ACMs, the agency needs to help bring the builder into alignment with the owner and designer’s understanding of goals, scope, processes, and communication. Another example is an agency’s need to manage contractor
work packages produced by the design team in ACMs that are fast tracked. In contrast, typically, DBB does not produce multiple contractor work packages for construction. Better understanding of the contract administration functions that an agency needs to perform with ACMs will help an agency better plan staffing for ACM projects. Additionally, understanding of ACM contract administration functions can help an agency with possible organizational or procedural adjustments that may be needed within an agency to perform functions that may differ from the traditional ways of doing business with DBB delivery. This is especially helpful for agencies or agency personnel without much experience with ACM contract administration.

5.2.2 Contributions from DB and CM/GC Tools for Contract Administration

This dissertation also contributes to the existing body of knowledge of highway contract administration by providing a portfolio of 36 DB and CM/GC tools that have been field tested by transportation agencies. This portfolio of ACM tools provides a point of departure from existing research in the areas of cultural and organizational change, performance of delivery methods, and integrated project teams. First, cultural and organizational change for implementation of innovative processes has been mentioned and studied by researcher (Minchen et al. 2014; Migliaccio et al. 2008; Pietroforte and Miller 2002; Molenaar and Gransberg 2001; Miller et al. 2000), but the identification and understanding of ACM contract administration tools presented in this dissertation provide a new perspective from which to study change. Second, performance studies have compared delivery method outcomes (Tran, Diraviam, and Minchen 2018; Sullivan et al. 2017; Francom et al. 2016; Shakya 2013; Shrestha et al. 2012; Goodrum, Uddin, and Faulkenberg 2011; FHWA 2006; Scott et al. 2006; Tom Warne & Assoc. 2005; Koppinen
and Lahdenperä 2004; Molenaar 2003; Molenaar et al. 1996), but the potential impacts of contract administration tools on performance outcomes has not been thoroughly explored. Thirdly, integrated project teams have been a focus of research, but without the context of contract administration tools (El Asmar et al. 2016; El Asmar et al. 2013; Elvin 2010; Pocock et al. 1996). In all these areas - culture and organizational change for ACMs, performance studies, and integrated project teams – the ACM tools presented in this dissertation research stand as a point of departure and provide specific lenses from which to study the interactions between agencies and contractors and the ways they impact ACM project outcomes.

The ACM tools also provide practical resources in addressing agency needs in contract administration. In the portfolio of ACM tools, guidance is offered regarding the appropriateness of each tool regarding project phase, complexity, and size. This provides a practical resource for transportation agencies to consider when planning ACM projects.

5.2.3 Contributions Regarding the Timing of DB Procurement and the Project Influence Curve

This dissertation also contributes to the existing body of knowledge on alternative delivery methods for highway projects by demonstrating with empirical data that a nuanced application of the project influence curve is required in DB highway projects. Overlaying the DB procurement phase on the project influence curve reveals that DB procurement falls at the end of the pre-project planning phase (Fig. 4.2). This closer look at the project influence curve suggests that a majority of the potential influence for the project has passed by the time a DB highway project goes to procurement.
This dissertation research on the relationship between percent DB base design and initial award performance provides a point of departure from existing research in a number of areas. First, the existing research on front end planning has focused on the various elements of planning on how they benefit a project (El Asmar et al. 2018; Bingham et al. 2011; CII 2006, 1995a, 1995b; Gibson et al. 2006; Wang and Gibson 2002; Gibson and Hamilton 1994; Paulson 1976; Yussef et al. in press). Effective front end planning has been shown to improve costs by as much as 20% (Hamilton and Gibson 1994). However, front end planning research has not looked at how contractor involvement in DB highway project development may impact innovation and cost savings. Second, integrated project teams have been researched, but without the context of contract administration functions (El Asmar et al. 2016; El Asmar et al. 2013; Elvin 2010; Pocock et al. 1996) but the value teams bring to a project has not been compared to the project influence curve. Thirdly, the process and performance of DB and ATCs have been researched (Gransberg et al. 2018; FHWA 2018a, 2006; NCHRP 2017; Gransberg et al. 2014), but the relationship between ATCs, innovation, cost savings, and percent base design in highway project has not been studied in depth in relationship to the project influence curve. Fourthly and finally, innovation and innovation in construction has been researched (Antillon et al. 2016; Saenz de Ormijana and Rubio 2015; Sheffer and Levitt 2010; Taylor and Levitt 2004; Lutzenhiser and Biggart 2003; DuBois and Gadde 2002; Gann and Salter 2000; Slaughter 1998; Arditi and Tangkar 1997; Blackley and Shephard 1996; Henderson and Clark 1990), but past research has not explored DB highway projects for relationships between innovation, initial award performance, percent base design, and types of innovation. In all these areas – front end planning, integrated project teams, DB and ATCs, and innovation – the research results
presented in this dissertation stand as a point of departure and provide a deeper understanding of where the ATC process in DB highway projects fits into the theory of the project influence curve.

Agencies as well as researchers need to moderate their expectations about the amount of innovation and initial award performance that ATCs for DB proposals can generate. Agencies can use the results to inform project delivery method selection. Agencies should recognize that the more detailed design required to reduce uncertainties (i.e., environmental permits, right-of-way acquisition, utility relocation) may also be reducing the opportunity for innovations and cost savings. Projects should be analyzed on a case-by-case basis to determine if they are appropriate for DB delivery and what percent base design to choose to optimize innovation, cost savings, and risk management. DB entities need to be fully informed as well, so that they can better plan on the level of effort required to advance the base design to a higher level of completion and to understand the potential for innovation as it relates to the percent base design. Additionally, it was also observed that ATCs are primarily incremental innovations or cost efficiencies instead of systemic, disruptive, or radical innovations. In the sample of projects studied, the diffusion of innovation across agency boundaries was observed, which highlights the ability of ATCs to bring new knowledge to bear on a project. However, agencies should be aware that DB delivery leans toward incremental innovations and consideration should be given on how to open DB procurement to systemic, disruptive, and radical innovation. Many ATCs in the sample set revolved around design, process, and materials. To optimize innovation, agencies may want to describe their base design to allow as much flexibility as possible in these areas.
5.3 Limitations of the Research

The uniqueness of highway projects generates some limitations in this research. Limitations are related to modeling orientation (this research used the perspective of the agency), variables studied, data availability, and variations in agency processes like cost estimating.

5.3.1 Limitations of the Research on DBB, CM/GC, and DB IDEF0 Models

The development of the IDEF0 models for DBB, CM/GC, and DB delivery were done from the perspective of the agency, with a focus on contract administration functions. This is an important view to take on managing project delivery, but it is not the only view. There are other functions that designers and builders perform in order to make a project successful which the IDEF0 models in this research do not address. Additionally, input for the IDEF0 models did not distinguish for project characteristics like project type, complexity, or size which may limit its generalizability. Despite these limitations, the multiple industry professionals involved in the research were able to agree that the models provided an accurate representation of agency contract administration functions.

5.3.2 Limits of Research on DB and CM/GC Tools for Contract Administration

The portfolio of DB and CM/GC tools is based on 30 case studies; however, none of the projects in the case study included CM/GC highway projects under $10 million. To obtain the best cross section of CM/GC projects, all known state and federal CM/GC road and bridge projects current in the United States at the time were included in this study. Additionally, recommendations for the appropriateness of tools regarding project complexity and size were based on the experience of industry professionals and not from
actual performance measurements. The validity of the recommendations is strengthened by incorporating several perspectives in the survey of recommendations, including agency, contractor, and academic personnel with experience in ACMs.

5.3.3 Limits of the Research on the Timing of DB Procurement and the Project Influence Curve

The DB percent base design and initial award performance study was limited by the data that was collected and by the nature of highway projects. The percent base design is an estimated percentage with some elements of a project being more or less designed than the average percent. Thus, two projects at any given percent base design may not have exactly the same percent design completed on a specific element. A quantitative analysis was conducted using percent base design and initial award performance. Other potential benefits such as schedule, safety, traffic impacts, and environmental impacts were not part of the analysis unless they had a cost impact to the project contract. Some agencies require the proposers to estimate the cost savings of ATCs, while other agencies specifically prohibit the valuation of ATCs so that the evaluation of ATCs will be on technical merit only. When ATCs are not monetized, then the cost savings seen in proposals is only indirectly linked to ATCs. Another limitation is that this research did not account for how the type of project (i.e., widening for express lanes, vs. road and bridge improvements) may influence the type of innovations or cost efficiencies. Additionally, the results of this study are influenced by the thirty projects studied. However, these thirty projects came from seven agencies from different regions of the United States which helps ameliorate potential bias of any one project or agency.
5.4 Recommendations for Future Research

This dissertation research provides a springboard to other research opportunities with practical implications on how transportation infrastructure is delivered. A fuller understanding of how contract administration functions and tools impact project performance is needed. The use of IDEF0 modeling and the in-depth analysis of one tool demonstrated in this research provides a roadmap of how additional research can be approached.

5.4.1 Recommendations for Future Research on DBB, CM/GC, and DB IDEF0 Models

This research produced detailed IDEF0 models of DBB, CM/GC, and DB contract administration functions that can facilitate further research on the delivery of highway infrastructure. Future research could look at determining which contract administration functions contribute the most to various measures of project success for projects of various sizes and complexities. Future research could apply a similar modeling process to detail the contract administration functions of other types of delivery methods, such as job order contracting, design-build-operate-finance-maintain, and integrated project delivery. The IDEF0 models developed for this dissertation focus on the perspective of the agency and the contract administration functions performed by the agency. Future research could model delivery methods from the contractor’s or designer’s perspective, or from a combined stakeholder perspective.
5.4.2 Recommendations for Research on DB and CM/GC Tools for Contract Administration

This research also produced a portfolio of DB and CM/GC tools for contract administration with recommendations regarding project complexity and size. Future research could look at what tools are most effective for projects of various types and scope such as road, bridge, intelligent transportation systems (ITS), reconstruction, widening, or new construction. Additionally, research could explore whether ACM tools used in highways are applicable to buildings and infrastructure. Future research could seek to weight the contributions of individual tools towards project performance or provide a cost-benefit analysis for each tool. There are also opportunities to develop and pilot new ACM tools in the areas of contractor early work packaging, quality management, and closeout.

5.4.3 Recommendations for Research on the Timing of DB Procurement and the Project Influence Curve

This research also analyzed DB delivery considering predictions from the project influence curve, specifically the relationship between percent base design and initial award performance. Further research could broaden the sample size and parse out differences between project work scopes such as road, bridge, intelligent transportation systems (ITS), reconstruction, widening, or new construction. Future research can also explore how various project characteristics relate to innovation and cost savings. This research identified design, process, and materials as areas for innovation. These categories can be used to further explore patterns of where innovation can occur. Incremental innovation was the predominant innovation discovered in this research. Future research could explore the
limitations to higher levels of innovation such as systemic, disruptive, and radical innovations, and probe ways to overcome those limitations.

This research provides a macro view of ACM contract administration functions, a mid-level view of ACM contract administration tools, and a micro-view of the tool alternative technical concepts for DB delivery. This research focuses on practical needs faced by transportation agencies and provides much needed guidance on ACM tools that agencies can employ to perform ACM contract administration functions. This research also highlights the potential and the limitations for innovation in DB highway project delivery.

5.5 References


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Construction Management Association of America (CMAA). (2012). An owner’s guide to project delivery methods, Mclean, VA.


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APPENDIX C

DB TOOL: CONFIDENTIAL ONE-ON-ONE MEETING
**Confidential One-on-One Meeting**

A meeting held with the agency and contractor during the Request for Proposals (RFP) stage, typically used in discussing Alternative Technical Concepts (ATCs).

**What is it?**

A confidential one-on-one meeting is a conference between the agency and the contractor in which the contractor presents potential ATCs. The agency then provides general feedback as to whether the ATC will be considered during the proposal process. Although this tool is implemented prior to contract administration, it is an important tool for establishing a foundation of alignment that the project team can further build upon throughout design and construction.

**Why use it?**

Confidential one-on-one meetings allow contractors to present potential ATCs. These help facilitate alignment of contractor proposals with the agency’s project goals. The confidentiality of the meeting is necessary to facilitate innovation and open communication. Additionally, the contractor saves resources by not pursuing ATCs of no interest to the agency.

The potential benefits include innovate design solutions, more constructible project designs, more appropriate risk allocation, and enhanced value engineering.

Confidential one-on-one meetings guide the contractor to a better understanding of project characteristics including, but not limited to; the agency’s project specific goals, potential project risks, and what type and magnitude of innovations the agency is interested in considering. These meetings aid the agency in understanding what ATCs they are likely to receive from proposers, such as different methods of construction based on experience or equipment, standardized design elements to eliminate waste, and design or processes to permit winter work. This allows the agency to recognize if additional clarifications are required for proposers, prepare potential RFP amendments, and assists the agency in the eventual determination of “equal or better,” which is pivotal in the ATC process. Confidential one-on-one meetings allow both parties to clearly express ideas and constraints. They also can create alignment between the agency and the contractor. These meetings can initiate the foundation of trust and demonstrate an agency’s desire for innovation and willingness for collaboration.

Confidential one-on-one meetings address the alignment, scope and construction efficiency strategies. The scope strategy includes a clear understanding of responsibilities and the alignment build toward productive
relationships as team members fulfill their responsibilities. The discussion of ATCs in one-on-one meetings will almost always result in more efficient means and methods of construction.

**When to use it?**

The confidential one-on-one meetings are used during the procurement phase, typically for projects in which ATCs are being considered. Agencies normally only have one meeting per contractor, though some require one meeting and then provide as many meetings as desired by the contractor.

**Table C1.** Recommended uses for confidential one-on-one meetings

<table>
<thead>
<tr>
<th>3 Confidential one-on-one meetings</th>
<th>Contract administration phase</th>
<th>Project complexity</th>
<th>Project size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alignment</td>
<td>Design</td>
<td>Construction</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

● = Recommended; ⚫ = Consider Case-by-Case; ○ = Not Recommended

Confidential one-on-one meetings are part of the larger ATC process as shown in Figure C1 below. This figure gives a visual representation of when the confidential one-on-one meetings should be held in relation to the entire ATC process.
Note: ATCs are presented in the confidential one-on-one meetings.

Figure C1. ATC Process (Modified from National Cooperative Highway Research Program Synthesis 455)
How to use it?

The Request for Qualifications (RFQ) and RFP should include guidelines for confidential one-on-one meetings. To execute these meetings the agency must acquire a meeting space of sufficient size to fit all attendees, and one that is equipped to allow presentation of potential ATCs. Attendees can include a facilitator familiar with the process (usually from the agency), agency representatives involved with procurement and future contract administration, and people of specialties that may be impacted by the ATCs presented (e.g., environmental officer, structural engineer, designers). All attendees should be invited in advance. The specialty representatives may attend via phone or online conferencing if they are not located locally.

Confidentiality of these meetings is critical. All agency attendees should be notified that no information from an ATC meeting is to be shared and all documentation, including any notes and meeting minutes, are not to leave the meeting. These rules should also be reiterated at the initiation of the meeting. When the contractor presents potential ATCs, the agency should only comment on the ability of the agency to consider the ATC presented; no RFP clarifications, ATC guidance, or ATC rating discussions should occur. Having the meeting in a third-party location is suggested, but not required, as it may further encourage open discussion and collaboration.

Synthesis of examples

The general meeting agenda is as follows:

1. Introduction
   a. Ensure confidentiality
   b. Review flow and duration of meeting
   c. Review types of questions that should be asked
   d. Review agency allowed responses
2. Contractor presentation of ATC
3. Agency response to ATC
   a. Cannot be entertained
   b. Can be entertained
   c. Requires more clarification (Attempt to resolve all clarifications during meeting if possible)
4. Loop 2 and 3 until all ATCs have been presented
Example 1

**MD 404 – US 50 to East of Holly Road Project, Maryland State Highway Administration (MD SHA)**

This project used confidential one-on-one meetings to review ATCs developed by the design-build team proposers. Guidelines for these meetings were presented in the project RFP.

**2.08.02 Pre-Submittal Requirements**

**2.08.02.1 Mandatory One-On-One Meetings**

The Administration will require mandatory one-on-one meetings with the Reduced Candidate List (RCL). The purpose of these meetings will be to discuss issues and clarifications regarding the RFP and/or the Proposer’s potential ATC submittals. The Administration reserves the right to disclose to all Proposers any issues raised during the one-on-one meetings, except to the extent the Administration determines that, in its sole discretion, such disclosure would impair the confidentiality of an ATC or would reveal a Proposer’s confidential business strategies. Each meeting will be held independently with each Prospective Proposer on the RCL.

The one-on-one meetings are subject to the following:

a. The meetings are intended to provide Proposers with a better understanding of the RFP.

b. The Administration will not discuss any Proposal or ATC with any Proposer other than its own.

c. Proposers are not permitted to seek to obtain commitments from the Administration in the meetings or otherwise seek to obtain an unfair competitive advantage over any other Proposer.

d. No aspect of these meetings is intended to provide any Proposer with access to information that is not similarly available to other Proposers, and no part of the evaluation of Proposals will be based on the conduct or discussions that occur during these meetings.

The Administration reserves the right to disclose to all Proposers any issues raised during the one-on-one meetings which require addenda to the RFP. The Administration, however, will not disclose any information pertaining to an individual Proposer’s Proposal, ATCs, or other technical concepts to other Proposers.
Example 2

**Wellwood Avenue over Route 27 Project, New York State Department of Transportation (NYSDOT)**

The RFP for this project contained detailed descriptions of confidential one-on-one meetings. These guidelines can help set expectations about the meetings and consistency in executing the meetings.

**A9.0 ONE-ON-ONE MEETINGS**

Prior to and/or after submission of Proposals, the Department may conduct One-on-One meetings with Proposers as described below. If One-on-One meetings are held, they will be offered to each Proposer. The Department reserves the right to disclose to all Proposers any issues raised during One-on-One meetings. However, the Department will not disclose to other Proposers any information pertaining to an individual Proposer’s technical concepts, Proposal or ATCs. The Department will hold One-on-One meetings on matters it deems appropriate.

**A9.1 MEETINGS DURING PROPOSAL PERIOD**

If the Department decides that One-on-One meetings should be held, they will be held between the Department and each Proposer. The period indicated in this ITP Appendix A for these meetings is subject to change. Specific meeting dates will be confirmed in advance of each meeting by the Department to each Proposer’s Representative. At least five (5) business days prior to the first scheduled meeting each Proposer may submit suggested agenda items for each One-on-One meeting to the Department’s Designated Representative. The Department will advise the Proposer of the location, final agenda, and the protocol for the meeting at least two (2) business days before the meeting. ATCs may be discussed at One-on-One meetings. Each Proposer may request One-on-One meeting(s) with the Department to discuss general concepts for potential ATCs or obtain preliminary feedback from the Department, to be held prior to the ATC submittal deadline. Should a One-on-One meeting be scheduled with a Proposer, the Department will offer the opportunity for a One-on-One meeting with the other Proposers. The Department may also schedule One-on-One meetings with any Proposer that has submitted ATC(s), to allow the Department to fully understand the ATC(s) and to request clarifications. At any meeting, the Department may seek clarifications regarding previously submitted ATCs. If a Proposer requests additional meetings, or if the Department considers it desirable or necessary to schedule additional meetings, the Department may, in their discretion, schedule any such additional meetings. The Department may, in its sole discretion, issue one or more Addenda to address any issues raised in the One-on-One meetings.

**A9.2 POST-PROPOSAL MEETINGS**
The Department does not currently anticipate the need for post-Proposal discussions, but reserves the right to enter into discussions and request revised Proposals. If interviews or presentations occur, Proposers shall not modify their Proposals or make additional commitments regarding Proposals at such meetings. The Department anticipates engaging in limited negotiations with the selected Proposer prior to Contract award regarding such matters as are deemed advisable for negotiations by the Department. The selected Proposer shall have no right to open negotiations on any matter that has not been raised by the Department.

A9.3 STATEMENTS AT MEETINGS

Nothing stated at any meeting will modify the Instructions to Proposers or any other part of the RFP unless it is incorporated in an Addendum or, in the case of an ATC, approved in writing.

Example 3

Minnesota Department of Transportation (MnDOT) Design-Build Manual

MnDOT uses confidential one-on-one meeting to enhance communication and build alignment. MnDOT’s D-B Manual provides guidance on conducting confidential one-on-one meetings.

One-on-one meetings between (MnDOT) and design-build teams are used to improve communication during the procurement process. The primary purpose of these meetings is to allow design-build teams to discuss potential ATCs and Pre-Accepted Elements (PAEs) with MnDOT prior to making a formal submittal. This minimizes effort on both MnDOT and design-build firms drafting ATCs and PAEs that have a limited chance of being approved.

The one-on-one meetings should not be used to discuss clarifications or have the design-build teams gain additional insight into the process. Clarification questions need to be submitted to MnDOT in writing via the clarification process.

The number and frequency of the one-on-one meetings will depend on the size and complexity of the project. The Project Manager (PM) and Design-Build Project Manager (D-BPM) will jointly determine the number and frequency. Each design-build team will be offered the same one-on-one opportunity.

Listed below are the procedures and protocols for conducting one-on-one meetings. This procedure outlines the one-on-one meeting process with design-build teams.

1) The PM will schedule all one-on-one meetings. MnDOT staff should be limited to the PM, D-BPM and a select group of key experts. On full federal oversight projects, the PM will invite the Federal Highway Administration (FHWA) to all one-on-one
meetings. The size of the MnDOT staff (total) should be limited to three or four individuals. Design-build teams may ask for key experts to attend certain one-on-one meetings to discuss draft ATC or PAE concepts.

2) The content of the one-on-one meeting are confidential to each design-build team and should not be discussed with other design-build teams.

3) The PM will instruct the teams that the purpose of the one-on-one meetings are to provide D-B teams an opportunity to discuss draft ATC or PAE concepts.

4) After a team discusses the draft concept, the PM will inform the team if the ATC/PAE has potential to be accepted or if MnDOT will not entertain that concept.

5) If a team asks clarification questions beyond those related to an ATC or PAE, the PM will not answer the question and will inform the team that the question needs to be submitted as a written clarification.

6) No formal meeting minutes will be taken.

7) Do not provide any handouts.

8) If design-build teams provide handouts, return all handouts to them at the conclusion of each meeting.

Example 4

Vermont Agency of Transportation (VTrans) Alternative Technical Concepts Document

VTrans alternative technical concept document provided guidance on how confidential one-on-one meetings should be conducted for their projects. In addition, it provided guidance on scheduling the meeting in advance and how the time during the meeting should be allocated.

VTrans may conduct confidential One-on-One ATC Meetings with each Bidder to discuss proposed ATCs as determined during the Conceptual and Detailed ATC Submittal. The purpose of the One-on-One ATC Meetings are to provide each Bidder with an opportunity to informally discuss potential ATCs and obtain preliminary feedback from VTrans.

At least five (5) working days before the scheduled One-on-One ATC Meeting the Bidder shall submit the following information to the VTrans point of contact in electronic format:

- A list of personnel that will be attending the One-on-One ATC Meeting and their function on the Design-Build Team (No more than five members may attend the meeting).
- A specific meeting agenda presented in outline format. The meeting agenda must be specific in identifying all topics of the meeting which are intended to be presented and/or discussed.
- A list of specific questions pertaining to the ATCs. Bidders must submit a list of specific questions which will be discussed at the One-on-One ATC Meeting.
If Bidders are presenting a PowerPoint, one (1) CD copy shall be left with VTrans. Bidders shall use their own equipment for the presentation.

Each team will be contacted in advance by the VTrans POC to schedule their One-on-One ATC Meeting on the date set forth in the RFP.

Meeting Schedule (Conceptual ATCs):
The One-on-One Conceptual ATC Meeting for each Bidder will be 1 hour and 45 minutes in length.

- 45 minutes for presentation of submitted conceptual ATCs and questions/discussion.
- 30 minutes Break for VTrans internal discussion.
- 30 minutes for VTrans feedback and general ATC discussion.

Meeting Schedule (Detailed ATCs):
The One-on-One Detailed ATC Meeting for each Bidder will be 2 hours in length.

- 1 hour for presentation of submitted conceptual ATCs and questions/discussion.
- 30 minutes Break for VTrans internal discussion.
- 30 minutes for VTrans feedback and general ATC discussion.

Meeting Guidelines
VTrans will not discuss with any Bidder the contents of any ATCs other than its own. Bidders shall not seek to obtain approval from VTrans in the meetings or otherwise seek to obtain an unfair competitive advantage over any other Bidder. Bidders are prohibited from discussing any ATCs with VTrans personnel or VTrans consultants outside of the confines of the One-on-One ATC Meetings.

Discussions during the One-on-One ATC Meeting will solely focus on ATCs presented and the manner in which they may affect the Base Technical Concept. Any general clarifying RFP questions should be submitted to the POC as described in the RFP.

VTrans reserves the right to change or clarify the RFP based on information or issues raised during the One-on-One ATC Meetings.

No electronic recording of any kind will be allowed during the One-on-One ATC Meetings.

One-on-One ATC Meeting Attendees
Bidders attending the meetings shall have the proper expertise and authority to present ATCs and answer VTrans’ ATC questions. Persons attending the One-on-One ATC Meetings will be required to sign an acknowledgment of the foregoing rules and identify all participants. The Bidder shall bring the signed form to their meeting. All participants must attend in person – conference calls will not be permitted.
VTrans meeting attendees may include Technical Evaluation Committee (TEC) members, representatives from VTrans Attorney General’s Office, Federal Highway Administration, as well as any appropriate technical experts.

References


A portfolio of ACM tools can be found in two in press publications from NCHRP (project 08-104), A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Construction Manager/General Contractor Delivery and A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Design-Build Delivery.
Continuity of Team Members

Key team members from the agency and the contractor must remain involved throughout the design and construction phases to enhance project understanding, consistency, and communication.

What is it?

D-B projects can take advantage of collaboration to seek efficient and innovative design and construction solutions. Collaboration is enhanced when trust exists, and trust is built through ongoing relationships. By keeping key team members involved during design and construction, project knowledge and communication channels are leveraged for efficient project management.

Why use it?

Continuity of team members can help a team avoid misunderstandings and mistakes since key team members have a strong knowledge of project background and decisions, and the intent behind those decisions. Continuity of team members creates ownership and understanding of design intent. Replacing a key member of the team during construction can lead to situations where past design decisions are re-discussed because of a lack of history and knowledge with the project. Additionally, if unexpected conditions occur in the field, the response to those decisions may not be consistent with the project intent. This can happen when new team members have not been fully immersed in the project from the design phase.

Potential benefits include schedule acceleration and construction input in design to encourage constructability, innovation, and risk mitigation.

Continuity of team members addresses both the alignment strategy and design quality strategy. Key team members develop relationships through the life of the project which fosters alignment. The quality of preconstruction services is enhanced when team member involvement is consistent.

When to use it?

The continuity of key team members should begin in planning and through project closeout. The larger and more complex a project is, the more potential benefit there is from fostering continuity in the team members.
Table D1. Recommended uses for continuity of team members

<table>
<thead>
<tr>
<th>Continuity of team members</th>
<th>Contract administration phase</th>
<th>Project complexity</th>
<th>Project size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alignment</td>
<td>Design</td>
<td>Construction</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

● = Recommended; ▲ = Consider Case-by-Case; ○ = Not Recommended

**How to use it?**

Assign team members in planning and design that will continue their involvement with the project through construction and closeout. This is true of D-B and design staff as well as agency staff. Although many agencies include statements about retaining key personnel, these requirements can sometimes be difficult to enforce. There are times when team members cannot be assigned to a project, like when a project is delayed and personnel are reassigned to other projects. During a project, a team member might be promoted, become ill, resign, or retire. In these situations, assigning new team members is unavoidable. Every effort should be made to assign personnel with appropriate qualifications and to provide briefings for new personnel so they understand and are knowledgeable about project background. Bringing new lead construction personnel on during construction puts them at a disadvantage because they do not have history with the project and they lack an understanding of how risks have been assigned and mitigated. Without this background knowledge, they may default to treating risk like they would for a design-bid-build project, instead of the way the D-B team has agreed to approach the risk. It is important for agency personnel to have continuity on a project as well. An agency should think through the ramifications of assigning an agency staff member primarily to a designated project in order to provide team continuity. This can take an agency staff member away from other assignments and commitments that will need to be covered by others.

**Synthesis of examples**

An agency should first consider which team members they will be dedicating to a project. The time commitment should be estimated, and other responsibilities adjusted to allow the team member to fulfill their role throughout the entire project. If an agency expects the contractor to maintain continuity of team members, this should be clearly communicated.
in the contract. The roles where continuity is expected should be identified and the process to replace these people should be described. The project team should plan for onboarding new team members during the project, whether these are subcontractors or replacements of key personnel. Onboarding should provide an overview of project scope, goals, decisions, roles and responsibilities, and project issues and challenges.

Example 1

US 60 (Grand Ave.) and Bell Road Interchange Project, Arizona Department of Transportation (ADOT)

This D-B project specifies in the Request for Proposals (RFP) that changing key personnel is not allowed between the submittal of qualifications and the D-B proposal, unless a formal request is submitted and approved.

Changes in Proposer’s Organization or Key Personnel

Proposers are advised that, in order for a Proposer to remain qualified to submit a Proposal after it has been placed on the shortlist, unless otherwise approved in writing by ADOT, Proposer’s organization and Key Personnel as identified in the Statement of Qualifications (SOQ) must remain intact for the duration of the procurement process through award of the Design-Build Contract. Accordingly, following submittal of the SOQs, the following actions may not be undertaken without ADOT’s prior written consent:

a) Deletion or substitution of a Proposer team member identified in its SOQ;
b) Deletion or substitution of Key Personnel identified in its SOQ;

Should a Proposer wish to make such a change, it shall notify ADOT and request its consent in writing and shall provide, for any new or substitute team member or personnel, the same information required under the Request for Qualifications (RFQ) for such team member or personnel had it, he or she been part of the Proposer team as of the SOQ submission. If a Proposer wishes to delete a team member or change Key Personnel, the Proposer shall provide ADOT with information establishing that the Proposer remains qualified for shortlisting as contemplated under the RFQ. Any such request shall be sent via E-mail or in writing addressed to ADOT’s Authorized Representative described in this Section. For a change in Key Personnel, the request shall be accompanied with the same information as requested under RFQ for Key Personnel.

If the Preferred Proposer requests any such change, or any change in any other team members or personnel identified in its Proposal, after evaluation of Proposals and before execution of the Design-Build contract, it shall submit such information as may be required by ADOT to demonstrate that the proposed deletions, substitutions and changes meet the RFP criteria and would not change the outcome of the Proposal rankings.
ADOT intends to respond to requests for changes within the reasonable time period. ADOT is under no obligation to approve requests for changes in the Proposer’s organization, Key Personnel or other identified personnel, and may approve or disapprove in writing a portion of the request or the entire request in its sole discretion. Any such change made without the written consent of ADOT may, at ADOT’s sole discretion, result in the Proposer being disqualified.

Example 2

Lahaina Bypass 1B-2 Project, Hawaii Department of Transportation (HDOT) & Federal Highway Administration – Central Federal Lands Highway Division (FHWA-CFLHD)

For this project, language about retaining key personnel is included in the design-build contract. Proposers were required to identify key personnel in the response to the RFQ.

**Key Personnel, Subcontractors and Outside Associates or Consultants**

In connection with the services covered by this contract, any in-house personnel, subcontractors, and outside associates or consultants will be limited to the key individuals or firms that were specifically identified and agreed to during the RFQ submittal process. The Contractor shall obtain the Contracting Officer’s written consent before making any substitution for these designated in-house personnel, subcontractors, associates, or consultants.

Example 3

MD 404 – US 50 to East of Holly Road Project, Maryland State Highway Administration (MD SHA)

For this D-B project, language about retaining key personnel is included in the Request for Proposals (RFP). Unapproved changes in key personnel is not allowed. When personnel continuity cannot be achieved, guidance on approved replacements is provided.

**Design Personnel Identified in Proposal**

The designer and design subcontractors shall utilize the key personnel identified in their Statement of Qualification (SOQ) to manage the project and supervise engineers and technicians in completing the design in a timely manner to permit construction activities. Changes in key staff identified in the SOQ must be approved in writing by the Administration, and replacement personnel must have equal or better qualifications than the key personnel identified in the proposal. The format for replacement staff resumes must be in the same format as required for the SOQ including requirements thereof.
Administration shall be the sole judge as to whether replacement staff members are acceptable.

**Construction Personnel Identified in Proposal**

The Design-Build Team, all key staff and construction-related key personnel, and all other Major Participants identified in the proposal shall be utilized in the same manner and to the same extent set forth in the Statement of Qualifications (SOQ) and for the duration of the project. Changes regarding the Design-Build Team shall not be allowed. Changes regarding key staff, construction-related key personnel and all other Major Participants require prior written approval by the Administration. Requests for such changes must be submitted to the Administration in writing and replacement personnel must have equal or better qualifications than the key personnel identified in the SOQ. The format for replacement staff must be the same format as required for the SOQ including the requirements thereof. The Design-Build Team acknowledges that any such changes are for the convenience of the Design-Build Team alone and shall not increase the Design-Build Team’s Price or change the project schedule. The Administration will approve such requests only if it determines that such change will not detrimentally affect the long-term quality, durability, maintainability, timeliness of the Work.

**Example 4**

**Route 8 in Bridgeport Bridge Rehabilitation Project, Connecticut Department of Transportation (CTDOT)**

This project utilized continuity of team members, and the requirements were described in the project RFP as seen below.

**Summary of the Design-Build Proposal Process**

In its SOQ, each Proposer identifies Key Personnel that it has assigned or will assign to the Project, stating the specific role that each person would play in the Project work. Those identifications will be deemed a binding commitment that if the Proposer should receive the Contract, those identified “team members” will, in fact, play the designated roles in the Project design construction. Proposers are precluded from substituting, replacing, or removing any of the Key Personnel without written consent of the Department to do so. If a Proposer believes that a substitution for any identified Key Personnel is warranted at any time (due to an intervening event), the Proposer shall notify the Department in writing, providing details of the proposed change and the reasons for it. The Department shall not withhold such consent unreasonably. Proposed substitutions for each identified Personnel shall have equal or better credentials than the Personnel that they would be replacing. Should the substituted Personnel, in the opinion of the Department, prove to not meet or exceed the experience and training that the original team member possessed, the
Evaluation Committee may reevaluate the Proposer’s Qualifications score accordingly, if the substitution is proposed before the award of the Contract.

Example 5

Texas Department of Transportation (TXDOT)

The TXDOT design-build agreement template has a table for identifying key personnel and assigning liquidated damages when an agreed upon person is not placed.

**Table D2. Key Personnel Change Liquidated Damages**

<table>
<thead>
<tr>
<th>Position</th>
<th>Key Personnel Change Liquidated Damages (per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>Construction Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>Design Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>Independent Quality Firm Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>Professional Services Quality Services Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>Environmental Compliance Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>Safety Manager</td>
<td>$[●]</td>
</tr>
<tr>
<td>[revise and insert others as applicable]</td>
<td>$[●]</td>
</tr>
</tbody>
</table>

*Note:* As deemed compensation to TxDOT for Losses described in Section 8.3.1 of the General Conditions, DB Contractor agrees to pay to TxDOT the following Key Personnel Change Liquidated Damages amounts in accordance with such section, for each day that the relevant Key Personnel role is not filled by an approved individual:

References

Connecticut Department of Transportation (ConnDOT), *Rehabilitation of Bridge Nos. 03761, 03762, 03764, & 03765 Route 8 in Bridgeport*, October, 2014 [Online]. Available:


A portfolio of ACM tools can be found in two in press publications from NCHRP (project 08-104), A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Construction Manager/General Contractor Delivery and A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Design-Build Delivery.
APPENDIX E

CM/GC OR DB TOOL: DELEGATION OF AUTHORITY
Delegation of Authority

This is an action taken by the agency to empower the agency engineer in charge of a project to make project decisions that often have an impact on the project budget.

What is it?

The agency delegates authority, with specific limits, in writing to the agency engineer managing the project. This enables some project decisions to be made quickly by personnel with specific project knowledge, even when these decisions may increase the project budget.

Why use it?

The authority to execute agreements and increase the budget up to a designated amount is placed in the hands of the agency engineer in charge of the project. By delegating authority, the project team has confidence that project decisions will be made in a timely fashion so that schedule commitments can be met. Decisions made by those familiar with a project can avoid unintended consequences which sometimes arise when decisions are made from those not involved day-to-day in a project.

Potential benefits include schedule acceleration, the ability to fast track, and owner control of design.

Delegation of authority addresses the scope strategy and the design quality strategy. Clarity in responsibilities is part of the scope strategy, and delegation of authority clarifies the responsibility of making timely decisions belongs to the agency engineer. Knowing that the agency engineer has this responsibility encourages the D-B to raise questions because they know that they are speaking with the decision makers.

When to use it?

A memo delegating authority and specifying authority limits should be written at the end of the procurement process. The authority granted is in effect from design through closeout. This tool is recommended for projects of all sizes and complexities.
Table E1. Recommended uses for delegation of authority

<table>
<thead>
<tr>
<th>Alignment</th>
<th>Contract administration phase</th>
<th>Project complexity</th>
<th>Project size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design</td>
<td>Construction</td>
<td>Closeout</td>
</tr>
<tr>
<td>Alignment</td>
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<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Delegation of authority</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
</tr>
</tbody>
</table>

● = Recommended; ● = Consider Case-by-Case; ○ = Not Recommended

How to use it?

Often an agency selects an alternative delivery method because they want the project to have an accelerated schedule. To keep the project team advancing the project, project decisions must be made quickly. Agencies often have an extended process for approving agreements and allocating additional funds. Delegation of authority to the agency engineer managing the project creates a streamlined process.

Synthesis of examples

The delegation of authority should occur before it is needed, typically at the time of notice to proceed. Extent and limitations of the authority should be clearly stated. The person given authority should be supported by upper management to use that authority. Some agencies associate the delegation of authority with their change order process, but it should be thought of as a broader authority that can address design exceptions and other agreements.

Example 1

St. Louis District Safety Project, Missouri Department of Transportation (MoDOT)

This design-build project included 31 improvements across two counties. To help the Department of Transportation (DOT) remain nimble in responding to project team requests, the Missouri Highway and Transportation Commission delegated authority to the DOT project director to execute agreements that were beneficial to the project. This gave the D-B team confidence that project issues would be handled expeditiously by a knowledgeable DOT staff member. The contents of the memo delegating authority is shown below.
SUBJECT: Delegation of Authority to [name], Project Director for the St. Louis District Safety Improvements Design-Build Project in Franklin and St. Charles Counties.

The Missouri Highways and Transportation Commission at its August 2013 meeting delegated to the Chief Engineer position or his designee to approve and execute documents and expend funds on their behalf for the following items, except that any change resulting in the expenditure of 2 percent over the project costs will be presented to the Commission.

- **Escrow of Bid Documents** – Approve authority to execute agreements, affidavits, and related documents and expend funds for costs associated with the escrow of bid documents on the project.
- **Agreements** – Approve authority to execute agreements with local governments including other entities for cost-share, enhancements, use of property, environmental mitigations, utilities, etc. on the project, subject to approval as to form by Chief Counsel’s Office and Commission Secretary attestation.
- **Railroad Agreements** – Approve authority to execute agreements pertaining to railroads, subject to approval as to form by Chief Counsel’s Office and Commission Secretary attestation.
- **Construction Change Orders** – Approve authority to approve construction change orders on the project.
- **Consulting Engineering Services** – Approve authority to execute contracts for engineering services needed subject to approval as to form by Chief Counsel’s Office and Commission Secretary attestation.
- **Other** – Approve Authority to expend funds for the project, as well as approve, execute, sign, and seal project specific documents.
- **Design Exceptions** – Approve authority to sign design exceptions specific to the design of the project currently delegated to the State Design Engineer and the State Bridge Engineer, subject to consultation with the department’s technical experts.

References


A portfolio of ACM tools can be found in two in press publications from NCHRP (project 08-104), *A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Construction Manager/General Contractor Delivery* and *A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Design-Build Delivery*. 
APPENDIX F

CM/GC TOOL: RISK POOLS
**Risk Pools**

A risk pool is a fund set aside to cover risks that may occur on a project.

**What is it?**

Risk pools are project funds established as agency risk pools or shared risk pools. This is different than contractor risk for items such as equipment and labor availability, which is included in the price proposal. It is also different than cost overruns or scope changes which are handled through change orders to the contract.

**Why use it?**

Risk pools are the basis for establishing planned force accounts in the construction contract that can pay for risks that materialize during construction. It places the responsibility for risk in the hands of the party most able to manage the risk. Contractors typically add a contingency on activities that carry unusual risk. It encourages the project team to avoid, mitigate, and eliminate risk, thus keeping project costs lower. It also keeps project costs lower by avoiding contractor contingencies in price proposals to cover risks that the contractor is not best able to manage. Risk pools developed during design are converted to planned force accounts in the construction contract. The agency force accounts and shared force accounts serve as mechanisms for paying for work associated with risks that occur during construction Risk pools are a mechanism for quantifying risk and assigning risk. Risk pools provide a source of funds to pay for risks that occur without having to develop a change order to the contract.

The potential benefits from risk pools include cost savings and shared risk allocation.

Risk pools address alignment strategy, preconstruction services quality strategy, and construction efficiency strategy. Discussing risks promotes productive relationships associated with alignment. Allocating risk establishes responsibility which is associated with scope. Minimizing contingency pricing promotes construction efficiency.

**When to use it?**

Risk pools are developed during design and can be used during construction.
Table F1. Recommended uses for risk pools

<table>
<thead>
<tr>
<th></th>
<th>Contract administration phase</th>
<th>Project complexity</th>
<th>Project size</th>
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<tr>
<td></td>
<td>Alignment</td>
<td>Design</td>
<td>Preconstruction</td>
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<td>27 Risk pools</td>
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<td>✓</td>
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</tr>
</tbody>
</table>

● = Recommended; □ = Consider Case-by-Case; ○ = Not Recommended

How to use it?

The project team identifies, analyzes, and assigns risks to the party best able to manage those risks. Risk registers and risk management plans are other tools used to manage risk. Throughout the project the project teams regularly review risks and seeks for ways to avoid, minimize, or eliminate risk. Construction risks may be assigned to the agency, the contractor, or shared between the two. The potential cost of dealing with a risk if it materializes is estimated and funds are set aside in risk pools to cover potential risks. The agency checks the contractor’s pricing for all risk items with an estimate from an Independent Cost Estimator. A contractor’s internal risk, such as labor and equipment availability, is not included in the risk pools. The risk pools developed during design are changed to planned force accounts for construction.

Synthesis of examples

Agencies that implement risk pools should document the process for developing risk pools in the CM/GC Manual or other guidance documents. Guidelines for developing risk pools typically address the following:

- Guidance about when work items should be considered as part of a risk pool versus other forms of risk management methods (e.g. contractor contingency)
- When is a risk covered exclusively in the agency’s own risk pool and when is a risk covered in a shared risk pool
- Process for estimating the dollar amount to be set aside in the risk pool(s)
- Guidance on how shared savings should be split between agency and CM/GC
- Process for converting risk pools to force accounts
- Guidance for approving payment out of the risk pool.
Risk pools should be implemented in conjunction with risk analysis procedures.

**Example 1**

*I-70 Vail Underpass Project, Colorado Department of Transportation (CDOT)*

This project followed the CDOT CM/GC Manual guideline on how to develop risk pools. Some of the risks identified were impacts to paving due to early winter weather, difficult ground conditions for soil nail drilling, ground water in excavations, encountering boulders during excavation, delays in utility relocations performed by others, etc.

**Allocate the Risk**

Once a risk has been identified and quantified, it is assigned to either CDOT or the Contractor. The goal is to assign the risk to the party who is best able to control the risk. Risks can be allocated solely to the Contractor or CDOT, or they can be shared. Risk is accounted for in three ways: (1) risk that is allocated to the Contractor is included within the Contractor’s bid items; (2) risk that is allocated to CDOT is accounted for in the CDOT Risk Pool; and (3) risk that is to be shared is accounted for in the Shared Risk Contingency Pool. Additionally, risk for minor overruns and Contract changes are addressed by a CDOT Risk Pool similar to Design-Bid-Build (D-B-B) Force Accounts. Minor Contract Revisions (MCRs) for CM/GC projects can usually be significantly less than for traditional D-B-B as a result of the risk mitigation process and cost allocation to risk pools. The Contractor and CDOT develop risk pools for risks that need to be addressed through the CDOT Risk Pool or Shared Risk Contingency Pool by following four steps:

1. The CM/GC Contractor submits drafts of the items, including estimates for those items, to be covered by Minor Contract Revisions (MCRs), Overruns, CDOT Risk Pools, and Shared Risk Contingency Pools for CDOT review and acceptance.
2. The CM/GC Contractor submits drafts of the definitions for Shared Risk Contingency Pools for CDOT’s review and acceptance.
3. The CM/GC submittals are reviewed by CDOT, with technical input from the Design Consultant and cost validation from the Independent Cost Estimator (ICE).
4. Once accepted, CDOT adds the items and definitions to the Risk Register as a Project Special Provision for team review, acceptance, and signing.

**Monitor and Control the Risk**

…During the Construction Phase, CDOT and the Contractor monitor contingencies and the Risk Pools to ensure that the established Risk Pools are adequate for the actual realized project risks.

**CDOT Risk Pool**

The CDOT Project Manager should consider taking ownership of the risk if CDOT has a better opportunity to manage the risk than the Contractor or if the risk is completely beyond the
control of the Contractor (e.g., weather, changes in site conditions, etc.). The CDOT Project Manager may also consider taking ownership of the risk if he or she believes the probability of the risk occurring is less than the Contractor’s assessed probability. For example, a Contractor is including a high contingency in a bid item to cover the cost of potential weather delays that could increase the rental costs for a specialty piece of equipment. CDOT may decide to take that risk and include this price within the CDOT Risk Pool. If the weather delay occurs, CDOT is responsible to pay the Contractor. However, if the weather delay does not occur then CDOT has saved the contingency cost without sharing the cost savings with the Contractor.

**Shared Risk Contingency Pool**

The Shared Risk Contingency Pool is often the best tool for managing project risks that have a high amount of uncertainty, along with a high likelihood of occurring, but still have the potential for the Contractor to control. Typically, these items are identified and proposed by the Contractor who submits a plan to CDOT for review and approval. The potential amount of the shared risk is defined in the Risk Register along with a payment specification (a Project Special Provision). If the risk is encountered during construction, the Contractor is paid per the agreed-to payment specification. However, if the entire estimated risk is not recognized, CDOT and the Contractor share the savings as identified in the Risk Register. Typically, Shared Risk Contingency Pools are split equally, but the amounts could vary if either CDOT or the Contractor is assuming more risk. Ultimately this is part of the negotiation and how CDOT plans to manage the risk. CM/GC Project Special Provisions are required to contractually define shared risks.

The motivation for using the Shared Contingency Risk Pool is that it provides an incentive for the Contractor to control risk and maintain good production methods during construction. Under D-B-B or D-B project delivery methods, the savings of unrealized risks are kept entirely by the Contractor. Shared Risk Pools allows CDOT the ability to recover a share of the unrecognized risk and collaboratively assist with controlling the risk when possible. However, to ensure fair pricing, the ICE is heavily relied upon to review all unit item costs and total estimated costs associated with any Contractor-proposed shared risks. If the Contractor and CDOT cannot agree to an appropriate shared risk item price or total amount of the pool, the CDOT Project Manager may decide to accept the risk entirely into the CDOT Risk Pool.

**Establishing Dollar Amounts for the Risk Pools**

There is no standard formula to establish the dollar amounts to include in the risk pools for identified risks. The CDOT Project Manager must use some judgment and work collaboratively with the Contractor and the ICE to include sufficient funds to cover the likelihood of the risks occurring without overestimating the contingency such that it falsely limits the budget available for the project’s intended scope of work.
To provide guidance to CDOT Project Managers, one way of viewing a simplified approach to risk allocation is to review the probability that a risk may occur. Generally, if the probability of a risk occurring is high, the entire amount of the risk should be considered for the risk pool. If both CDOT and the Contractor are in agreement that the probability of a risk is low, it is often accepted entirely by one of the parties or alternatively included in the risk pool with a reduced amount (relative to its probability of occurrence). Challenges occur, however, when CDOT and the Contractor are not in agreement on the probability of the occurrence of the risk. An approach for the CDOT Project Manager to consider is to accept the risk into the CDOT Risk Pool when the Contractor considers the probability of the risk occurring to be higher than CDOT’s assessment. Otherwise, from CDOT’s perspective, for shared risks, the Contractor can receive additional compensation for avoiding risks that are unlikely to occur.

The Risk Matrix can be an effective tool to assist in these discussions and in establishing appropriate amounts to include in the risk pools. The risk matrix should show the probability of the risk occurring and the total maximum cost impact if the risk does occur. To establish the contingency, a weighted average or expected value of the risk is then obtained by multiplying the probability of the risk occurring by the cost impact.

Contractors that routinely deal with risk may have more detailed methods involving complex simulations or other risk management informational systems. In these circumstances, the CDOT Project Manager must collaborate with the Contractor to understand the approach and methods used in the risk analysis.

**Force Accounts for CDOT Risk Pool and Shared Risk Contingency Pool**

Once the project moves into the Construction Phase, the previously established CDOT Risk Pool and Shared Contingency Risk Pool become planned Force Accounts.

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**Example 2**

*Arizona Department of Transportation (ADOT) Construction Manager at Risk (CMAR) Process Guide*

The ADOT CMAR Process Guide describes how to develop fixed, open, and provisional allowances to cover risk. If a contractor requests a change order for work, ADOT considers whether the work could be considered unforeseen even with the contractor’s early involvement in the design phase.

**GMP (Guaranteed Maximum Price) Allowances**

There is a risk associated with the CMAR Contractor establishing maximum prices (for example, where subterranean features cannot be determined in advance, or where alternatives have not been selected by the Department). The CMAR Contractor can propose guaranteed maximum price (GMP) allowances. The allowances establish the type
and amount of risk the Department and CMAR Contractor have assumed in agreeing to the GMP. In addition, the Department (documented by written consent) and the CMAR Contractor will agree upon the type of allowance and the terms and conditions regarding use of the GMP allowance.

When establishing allowances, the CMAR Contractor must provide the Department adequate justification for the allowance. The allowance(s) will be used only for the work that the allowance was negotiated to cover. Each allowance is item specific. Allowance monies are not interchangeable and belong to the Department if not used.

There are three types of allowances:

- **Fixed Allowance:** A fixed allowance establishes the upper limit the Department will pay for the corresponding item of work. For example, if there is a fixed allowance for 1,000 linear feet of saw cutting, the Department will pay the CMAR Contractor up to 1,000 linear feet of saw cutting above the quantity designated in the GMP Item Schedule for saw cutting.

- **Open Allowance:** An open allowance designates that there is no upper quantity limit for the corresponding item of work. The Department will pay for all approved quantity increases for each corresponding item in excess of the GMP Item Schedule. For example, if there is an open allowance for geotextile and the Department directs the CMAR Contractor to place more geotextile than what is shown in the GMP Item Schedule, the Department will pay the CMAR Contractor for the full amount placed.

- **Provisional Allowance:** A provisional allowance is for alternative work. For example, the Department has not completed a Joint Project Administration (JPA) with a local government to replace ADOT chain link right-of-way fence. The quantities are known. The decision hasn’t been made whether chain link, wrought iron or block will be used. The Cost Model will include an item for chain link right-of-way fence, but two provisional allowances are set up, one for each type of replacement. (Another method would be to use the Provisional Allowances as a premium per foot for the selected upgrade.)

**References**


A portfolio of ACM tools can be found in two in press publications from NCHRP (project 08-104), A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Construction Manager/General Contractor Delivery and A Guidebook for Post-Award Contract Administration for Highway Projects Delivered Using Design-Build Delivery.
APPENDIX G

IDEF0 MODEL OF CM/GC DELIVERY
Fig. G1. Administer CM/GC Contract

(These models are intended to be viewed in a format larger than 8.5” x 11”.)
Fig. G2. Administer CM/GC Contract (A0)
Fig. G3. Administer Alignment between CM/GC, Designer and Owner (A1)
Fig. G4. Align Project Plans (A13)
Fig. G5. Administer CM/GC Design (A2)
Fig. G6. Ensure Design Compliance (A21)
Fig. G7. Administer CM/GC Preconstruction Services (A3)
Fig. G8. Administer CM/GC Construction (A4)
Fig. G9. Manage Materials (A43)
Fig. G10. Control and Inspect Work (A44)
Fig. G11. Review Potential Additional Scope (A45)
Fig. G12. Execute Supplemental Agreements (A46)
Fig. G13. Measure Progress and Pay Contractor (A48)
Fig. G14. Administer CM/GC Closeout (A5)
Fig. G15. Conduct Final Inspection (A51)
Fig. G16. Review Final Turnover Documentation (A52)
APPENDIX H

IDEF0 MODEL OF DB DELIVERY
Fig. H1. Administer DB Contract

(These models are intended to be viewed in a format larger than 8.5” x 11”.)
Fig. H2. Administer DB Contract (A0)
Fig. H3. Administer Alignment between Design-Builder and Owner (A1)
Fig. H4. Align Project Plans (A13)
Fig. H5. Administer DB Design (A2)
Fig. H6. Ensure Design Compliance (A21)
Fig. H7. Administer DB Construction (A3)
Fig. H8. Manage Materials (A33)
**Fig. H9.** Control and Inspect Work (A34)
Fig. H10. Execute Supplemental Agreements (A35)
Fig. H11. Measure Progress and Pay Contractor (A37)
Fig. H12. Administer DB Closeout (A4)
Fig. H13. Conduct Final Inspection (A41)
**Fig. H14.** Review Final Turnover Documentation (A42)
APPENDIX I

IDEF0 MODEL OF DBB DELIVERY
Fig. II. Administer DBB Contract

(These models are intended to be viewed in a format larger than 8.5” x 11”.)

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Fig. 12. Administer DBB Contract (A0)
Fig. 13. Administer Alignment between DOT Team (A1)
Fig. 14. Finalize Project Plans (A13)
Fig. 15. Administer DBB Construction (A2)
Fig. I6. Manage Materials (A23)
Fig. 17. Control and Inspect Work (A24)
Fig. 18. Execute Supplemental Agreements (A25)
Fig. 19. Measure Progress and Pay Contractor (A27)
Fig. I10. Administer DBB Closeout (A3)
Fig. I11. Conduct Final Inspection (A31)
Fig. 112. Review Final Turnover Documentation (A32)