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Indefinite Delivery/Indefinite Quantity project selection framework using stochastic techniques

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Indefinite Delivery/Indefinite Quantity project selection framework using stochastic techniques

by

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NOMENCLATURE

AFCAP	Air Force Contract Augmentation Program
AGC	Associated General Contractors
ARTBA	American Road & Transportation Builders Association
CCI	Construction Cost Index
CMGC	Construction Manager/General Contractor
CMR	Construction Manager at Risk
DBB	Design-Bid-Build
DB	Design-Build
DoD	Department of Defense
DOT	Department of Transportation
ECI	Early Contractor Involvement
FAR	Federal Acquisition Regulation
FHWA	Federal Highway Administration
IDIQ	Indefinite Delivery/Indefinite Quantity
KPI	Key Performance Indicator
MATOC	Multiple-Award Task Order contract
MCCI	Multi-Level Construction Cost Index
MnDOT	Minnesota Department of Transportation
NCHRP	National Cooperative Highway Research Program
NZTA	New Zealand Transport Agency
ROUT	Robust Regression and Outlier Removal
RMP	Risk Management Plan
SCIRT	Stronger Christchurch Infrastructure Rebuild Team

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ABSTRACT

The use of Indefinite Delivery/Indefinite Quantity (IDIQ) contracting by state transportation agencies for the procurement of repetitive construction and maintenance services has been growing during the last few years. An IDIQ contract is a multi-project, multi-year mechanism to permit an agency to essentially hire a contractor on a stand-by/as-needed basis to provide a specified set of construction services. A study conducted for the development of the National Cooperative Highway Research Program (NCHRP) Synthesis 473: *IDIQ Contracting Practices* found that at least 32 departments of transportation (DOT) are using IDIQ contracts for the procurement of construction and/or maintenance projects. As part of the development of Synthesis 473, surveys were sent to all state DOTs asking about their IDIQ contracting practices, their perceived benefits and drawbacks, and the challenges faced during the implementation of this alternative contracting method. The analysis of survey responses showed that state transportation agencies are satisfied with the benefits they are obtaining from IDIQ contracts, but they do not know whether or not they are paying a premium for its benefits. A close look at the issue revealed that the agencies do not have the tools to reliably quantify the cost implication of using IDIQ contracting. This dissertation constitutes the first research initiative intended to address this issue through the development of an IDIQ project selection framework based on the comparison between the estimated costs for a given project if procured under IDIQ versus the costs if traditional Design-Bid-Build (DBB) techniques are used.

The proposed framework combines a qualitative assessment of a candidate project's scope with a stochastic analysis of its construction costs. Once a transportation project's scope is deemed a suitable candidate for IDIQ contracting (qualitative assessment), the final decision is made using a comparison between the estimated cost of the IDIQ project and its cost if procured through traditional DBB methods (stochastic analysis). Thus, the decision making framework proposed in this study provides public transportation agencies with a tools to both identify and justify delivering a given scope of repetitive work using IDIQ based on the agency's perception of a reasonable cost for the benefits offered by IDIQ contracting. This dissertation also describes research efforts conducted to identify

opportunities to improve IDIQ contracting procedures currently in use by state DOTs to increase budget control and optimize project construction costs. It should be noted that many of the findings of this research have already been implemented by the Minnesota DOT and are currently in use in the field.

CHAPTER 1
INTRODUCTION

Government contracts are notorious for needing excessive amounts of time to be developed, advertised, and awarded (Chan and Young 1995; Ahadzi and Bowles 2004). Combining the serial nature of the highway construction procurement process with regulations that mandate full and open competition and the tyranny of the fiscal year funding system, creates an environment that leads to the inefficient use of available public capital and a potential to restrict the amount of needed construction and maintenance that can be accomplished in any given year (Gransberg et al. 2015a). From a typical DOT perspective, the crux of the issue is the pre-contract where a design must be developed and advertised for bids. "Excessive time during the pre-contract stages [may] result in huge cost overruns after award" (Ahadzi and Bowles 2004). Thus, employing an alternative contracting method that allows the DOT to reduce the number of times it has to design, advertise, and award a construction contract for a project type that is known will be repeated frequently over the course of a given fiscal year accrues the benefit associated with a single procurement period and reduces transaction costs for both the DOT and the contracting community (Dixon et al. 2005). IDIQ is just such an alternative contracting method.

Indefinite Delivery/Indefinite Quantity (IDIQ) contracting practices were first used by the newly organized General Services Administration (GSA) by the Federal Property and Administrative Service Act of 1949. The implementation of these innovative contracting techniques was motivated by a longstanding need to accelerate the acquisition of supplies and services recurrently procured by federal agencies (GAO 1979; Matchette and Danis 1995; US Congress 1951). This method began to be accepted by state and municipal agencies in states like Florida, New York and Missouri around 2005. A number of studies have been initiated by the Congressional Budget Office on the variations of IDIQ in response of repetitive protests claiming contracting agencies were using it to circumvent competitive bidding regulations (Sandner and Snyder 2001). The lack of public confidence in IDIQ and other streamlined contracting approaches led the Congress to enact the Federal Acquisition Streamlining Act (FASA) in 1994, which regulates the use of federal funds with these contracting techniques, making them more transparent, efficient, and competitive (Sandner and Snyder 2001; US Congress 1994).

Unfortunately, the lessons learned from federal IDIQ experience are not fully transferable to state public owners due to the differences between federal and state contracting regulations as well as the diversity found among the 50 states' procurement cultures. Therefore, state departments of transportation (DOTs) have been compelled to individually develop their own IDIQ contracting programs within their current practices, unique requirements and preferences, and applicable state regulations (Rueda and Gransberg 2014a).

As usually occurs with the implementation of any new practices in any type of business or organization, the decision to start using non-traditional contracting methods commonly places DOTs into a challenging process, during which these agencies have to face the risk of the unknown. IDIQ contracting is just one of the many alternative contracting techniques that have arisen during the last few decades as result of the inadequacy of traditional Design-Bid-Build (DBB) contracts to cope with the tight deadlines and budgets of today's construction environment. "The difficulty that [state transportation agencies] face then is how to choose between the more traditional approach and an alternative contracting strategy for a specific contract" (Molenaar et al. 2014). The study conducted for the development of the National Cooperative Highway Research Program (NCHRP) Synthesis 473 (Gransberg et al. 2015a) found that for DOTs, the selection of projects for IDIQ contracting is primarily based on the scope of the projects. As general rule, all projects involving recurrent construction and maintenance services are suitable for IDIQ contracting. However, by using this rule as the one and only criterion for the selection of projects to be performed using this alternative contracting method, state transportation agencies may be ignoring the cost implications of using IDIQ techniques, hindering their ability to obtain the best value for money from their infrastructure construction and maintenance investments.

NCHRP Synthesis 473 also found three principal factors that motivate the use of IDIQ contracts by DOTs; 1) the reduction of project delivery periods, 2) the greater flexibility in quantity and delivery scheduling, 3) and the suitability of this contracting approach to respond to emergencies (Gransberg et al. 2015a). Likewise, this report mentions two main disadvantages pointed out by DOTs; 1) the lack of experience of agencies and contractors on IDIQ contracting and 2) the limited ability to conduct complete planning, programming, and budgeting procedures at the contract level. An important observation regarding the benefits and drawbacks perceived by state DOTs in the use of IDIQ contracts was the fact that IDIQ construction costs were not classified as an advantage or a disadvantage by the respondents to the Synthesis 473 survey. It could be inferred from this observation that DOTs believe that either the cost of using IDIQ is roughly the same as the cost of using a traditional contracting approach or that if the cost of IDIQ contracts is higher, the extra cost is justified by the benefits received by these agencies. However, a deeper look into this issue found the problem is rooted in the facts that DOTs do not have the tools necessary to quantify the cost implication of using IDIQ contracting, and the literature contains very little authoritative research on estimating IDIQ costs. Although most alternative contracting methods are reported to produce “positive results by those who used them, more implementation experience is needed within the transportation industry to determine if they are truly cost-effective in meeting cost performance targets” (Anderson and Damnjanovic 2008).

The main contribution of this dissertation is an IDIQ project selection framework that includes expected construction costs as a selection criterion. In addition to a qualitative analysis of scopes of potential project candidates, this framework includes a comparison between the estimated stochastic cost of these projects if procured under IDIQ and their costs if traditional DBB techniques are used. The framework presented in this dissertation was specifically developed for the IDIQ contracts awarded by the Minnesota DOT (MnDOT), but it could be adapted to other agencies. This framework required the creation of multiple nonlinear regression models to estimated unit prices, for the pay items most commonly used by MnDOT in its construction projects based on a frequency analysis of bid quantities. The analysis used MnDOT historical bid data from all projects awarded by MnDOT between January 2008 and April 2015, which included 1,713 DBB and 33 IDIQ contracts.

Additionally, the dissertation analyzes the major aspects affecting construction costs in IDIQ contracts and identifies/proposes effective practices to optimize costs and minimize cost uncertainty. The major cost-related aspects studied in this dissertation are as follows:

- Early contractor involvement (ECI) and potential effects of increasing integration among different parties involved in the contract, which was analyzed through the comparison of a major IDIQ contracting program implemented by the US Department of Defense

(DoD) and the highly integrated collaborative alliancing agreement used in Christchurch, New Zealand, for reconstruction activities after the earthquakes of 2010 and 2011;

- Price escalation over time, which involved the evaluation of the performance of twelve different construction cost indexes (CCIs) in relation to their ability to track changes in construction prices over time; and
- Effective risk management strategies, including practices to reduce the probability of occurrence of some cost-risk events and the mitigation of their impact if they actually occur.

Content Organization

This paper-based dissertation consists of the compilation of four archival journal publications reporting the findings of research efforts conducted on different IDIQ contracting areas. The papers are strategically interconnected to provide the proper foundation and understanding required to develop the major contribution of this dissertation: an IDIQ project selection framework using stochastic techniques.

Chapter 2 furnishes the reader with the background information and relevant terminology necessary to understand the content of the subsequent chapters. Likewise, this chapter explains the facts and issues that motivated this study and clearly defines the problem statement that frames the research efforts behind this dissertation.

Chapter 3 gives and overall description of the methodology and research plan designed and implemented for the development of this dissertation, including a description of the process used to validate the IDIQ project selection framework. More detailed information about the methodology and research tools used in each the publications compiled in this dissertation is presented in their respective chapters (Chapter 4 – 7).

Chapter 4 corresponds to the first paper of this dissertation. This publication makes a comparison between two similar multi-billion contracts, both of them involving a fixed group of contractors competing for multiple projects during a given period of time. The first is the US Air Force Contract Augmentation Program IV (AFCAP IV), a worldwide multiple award IDIQ contract awarded by the Department of Defense (DoD), and the second contract is termed the Stronger Christchurch Infrastructure Rebuild Team (SCIRT). SCIRT comprises a collaborative alliance agreement signed by various public owners and contractors for the reconstruction of public infrastructure damaged by the Canterbury earthquakes of 2010 and 2011 in New Zealand. The main difference between these two contracting methods lies in the level of integration among the parties involved in the contract. This paper presents a systematic comparison of these two contracts on five different aspects, including two aspects with a direct impact on construction costs: ECI and incentive/disincentive provisions. The other three comparison aspects are general procurement and administration procedures, dispute resolution aspects, and documented advantages. The analysis of the strengths and weaknesses of each of these two case studies was used by the authors to identify opportunities of improvement in both contracting methods, including opportunities to optimize IDIQ construction costs.

The Chapter 5 paper presents a statistical analysis on the performance of twelve existing CCIs in relation to their ability to track changes in construction prices over time. The analysis was conducted to determine the most suitable CCI for price adjustment and estimating purposes in MnDOT's IDIQ contracts. However, the analysis determined that the general principles and assumptions associated with the development, maintenance, and use of these indexes make traditional CCIs unsuitable to be used at the project level in IDIQ contracts. Therefore, an alternative construction cost indexing system was designed to overcome the drawbacks found during the analysis of the existing CCIs. The proposed indexing system is called Multi-level CCI and is described in detail in Chapter 7.

Chapter 6 holds the third paper of this dissertation, which describes the use of several risk management strategies as part of a two-phase risk analysis framework for IDIQ contracts. Phases 1 and 2 of the framework correspond to risk planning and monitoring/control, respectively. The effective risk management strategies in this framework are intended to address eight different possible risk situations commonly found in IDIQ contracts that have the potential of affecting final construction costs.

The last article of this dissertation is in Chapter 7. This paper contains the main contribution of this dissertation: the stochastic IDIQ project selection framework. The proposed framework consists of two parts: an initial qualitative assessment of candidate projects based on the scope of work and a quantitative analysis and comparison of stochastic cost estimates considering the use of IDIQ or DBB techniques for the same specific scope of work. This comparison considers several case scenarios for different distributions of work among various contract periods. The results of all case scenarios is presented to decision makers as a matrix to facilitate the interpretation of the results.

Chapter 8 consolidates the conclusions and limitations of the research articles presented in Chapters 4 to 7 and analyzes them as a whole. Finally, Chapter 9 summarizes the most important contributions that have resulted from the research efforts and presents recommendations for future research to improve the IDIQ project selection framework described in Chapter 7 as well as other aspects of IDIQ contracting.

CHAPTER 2
BACKGROUND AND MOTIVATION

This chapter presents and analyzes information obtained through a comprehensive literature review on topics related to this study. The main purpose of this chapter is to complement and support the information and findings presented in the research articles comprised in Chapters 4 to 7. This chapter provides the reader with a better understanding of the principles of IDIQ contracting and defines some key terms used throughout this presentation. Some of the information and concepts discussed in this chapter are contained in research reports and articles associated with previous research projects in which the author has participated. This chapter begins with a section summarizing NCHRP Synthesis 473 *Indefinite Delivery/Indefinite Quantity Contracting Practices* (Gransberg et al. 2015a), which describes the IDIQ contracting practices used by DOTs across the country and was used as the foundation for this dissertation. Furthermore, this chapter describes the main reasons that motivated the research efforts documented in this dissertation and the problem statement framing this study.

Background

NCHRP Synthesis 473 – IDIQ Contracting Practices

The point of departure for this study was the NCHRP Synthesis 473: *IDIQ Contracting Practices* aimed to compile and evaluate effective IDIQ practices implemented by state DOTs across the country. The main objective of the synthesis is to "identify and synthesize current effective practices that comprise the state-of-the-practice related to the use of IDIQ contracting by public transportation agencies for highway design, construction, and maintenance contracts" (Gransberg et al. 2015a). The synthesis report covers concepts and practices of IDIQ contracting associated with following three main aspects:

1. Legal and contractual issues
2. Procurement policies and procedures, and
3. Contract administration procedures.

Information contained in the report was gathered from the literature and a formal content analysis of IDIQ procurement documents, policy and procedure manuals from 32 different state DOTs, two local transportation agencies, and 20 federal agencies. Additionally, the analysis about legal and contractual issues in IDIQ contracts was conducted using 76 legal cases. This analysis was focused on identifying trends in court decisions under different types of conflicts and common sources of disputes between contract participants.

One of the most important sources of information used in the development of the NCHRP Synthesis 473 were survey responses submitted from 43 DOTs (84% response rate) and 18 general contractors doing business in different parts of the country. This information was supplemented with four face-to-face structured interviews with general contractors and case studies on IDIQ contracts awarded by the Florida, Minnesota, Missouri, and New York State DOTs and the Central Federal Lands Highway Division.

"This study found that IDIQ techniques increase agency capabilities to quickly procure a wide range of recurrent construction and maintenance services" (Gransberg et al. 2015a). IDIQ contracting proved to be a versatile procurement tool with the ability to be combined with different project delivery methods and contracting approaches to address the particular needs of each project. "With an appropriate selection of contracting procedures, agencies could successfully execute IDIQ contracts for almost all types of projects typically procured by state DOTs" (Gransberg et al. 2015a).

Much of the information presented in the following sections of this chapter were obtained through the literature review, surveys, and interviews conducted for the NCHRP Synthesis 473. It should be noted that the author of this dissertation was the Co-Principal Investigator and co-author of Synthesis 473.

IDIQ Contracting

The Federal Acquisition Regulation (FAR) IDIQ contracting mechanism that "provides for an indefinite quantity, within stated limits, of supplies or services during a fixed period" (FAR 2005). While this definition applies specifically to federally-funded projects, it seems to be accepted by state agencies across the country with one slight difference. The decision on whether or not to establish "stated limits" on the quantities of work to be ordered under an IDIQ contract is optional at the state-level, and depends on either regulatory constraints or agency's preferences. Thus, this study defines IDIQ as contracting approaches that involve the procurement of an indefinite quantity of supplies and/or services on as-needed basis using individual orders over a fixed period of time. The unique configuration of IDIQ contracts allows public owners to "reduce the need to conduct multiple procurement actions to deliver technically similar, repetitive projects to a single transaction" (Gransberg et al. 2015a).

IDIQ Terminology and Key Definitions

One of the major issues faced by the author when gathering information about current IDIQ contracting practices used by DOTs across the country was the lack of consistency in the terminology used by these agencies to refer to IDIQ contracts and the work orders issued under them. Several of these terms and their definitions are referred in the NCHRP Synthesis 473 (Gransberg et al. 2015a). The absence of a standard terminology has slowed the evolution of IDIQ contracting practices at the state level by hindering the ability of state transportation agencies to exchange experiences and lessons learned among them. For example, before the publication of the NCHRP Synthesis 473, the Florida DOT did not know that its 6-year-old Push-Button contracting program was similar to the Job Order Contracts the New York State DOT has been awarded by about a decade; therefore, the Florida DOT had not considered the possibility of evaluating the more mature set of contracting practices used by the New York State DOT to improve its own contracting procedures given that it was unknown that both programs were based on the fundamentals of IDIQ contracting.

Figure 1 presents the different terms found by the NCHRP Synthesis 473 to refer to IDIQ contracts. Even though some of these terms are slightly different from each other, all of them meet the following definitions at the contract and project level (Gransberg et al. 2015a):

- IDIQ: Type of contract that provides for an indefinite quantity of supplies and/or services whose performance and delivery scheduling is determined by placing work orders with one or multiple contractors during a fixed period of time.
- Work Order: Every project to be executed within an IDIQ contract is developed under the issuance of a work order. A work order becomes the contract document that determines location, contract time, and scope of work. Moreover, a work order outlines all required pay items, quantities, and unit prices (MnDOT 2014). Also termed Task, Job, or Service Order.

FIGURE 1 IDIQ terminology.

Based on the previous definitions, it can be said that IDIQ is a general concept that covers all terms in Figure 1. The terms in this figure have been either defined in the Federal Acquisition Regulation (FAR), used by other authors, or used by some state transportation agencies to refer to variations of IDIQ contracts with restrictions either in scope, size, and/or number of contractors. Table 1 presents definitions given to some of the contracts contained in Figure 3. It is important to understand that these definitions are merely common descriptions for these terms and do vary among agencies; however, all meet the generic definition for IDIQ stated above.

TABLE 1 IDIQ Terminology – Definitions

Term	Definition
Delivery Order Contract	Contract for supplies whose performance and delivery scheduling is determined by placing delivery orders with the contractor or contractors during a fixed period of time (FAR 2005).
Task Order Contract	Contract for services whose performance and delivery scheduling is determined by placing task orders with the contractor or contractors during a fixed period of time (FAR 2005).
Job Order Contract	Contracts for construction services whose performance and delivery scheduling is determined by placing work orders (task, delivery and/or job orders) with the contractor or contractors during a fixed period of time (Farris 2002).
On-Call Contract	Contract that involves a group of undetermined or predetermined small projects usually related to professional/engineering services, which are requested by issuing task orders (UDOT 2010). Some state DOTs also use this term to refer to construction and maintenance/repair contracts (Maine DOT 2011; TDOT 2010).
Push-Button Contract	Contract with a predetermined scope of work to be performed by the contractor pursuant to the agency's issuance of work orders, which specify location, project description and amount of work required (FDOT 2012).

Figure 2 presents a classification of work orders and IDIQ contracts in accordance with the different types of work and services furnished by each of them. The terminology in Figure 2 is used in this dissertation unless the author is referring to a particular agency, in which case the agency's corresponding terminology is used. The terminology and classification of different types of IDIQ contracts illustrated in Figure 2 is based on two main aspects: the distinction as outlined by the FAR for supplies (delivery orders) and services (task orders) (FAR 2005), and the wide use of the term "Job Order" for construction services (which may include supplies and services) (Farris 2002; Rueda and Gransberg 2014a).

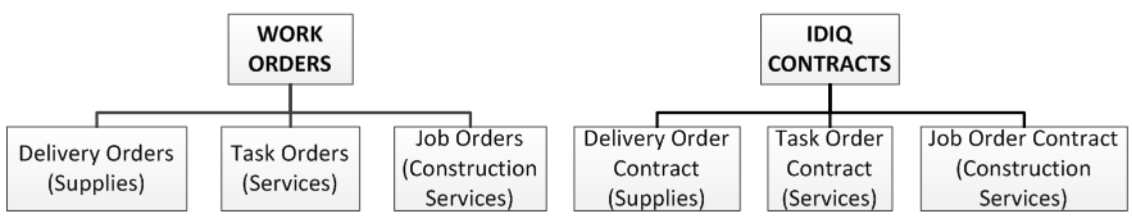


FIGURE 2 Work order and IDIQ contract classification scheme (Rueda and Gransberg 2014a).

IDIQ Generic Models

Three different IDIQ contracting models used by public owners have been found during a previous research conducted by the author for the development of the MnDOT IDIQ Implementation Guide (MnDOT 2014). These models are classified in accordance with the number of contractors selected to participate in the contract and the expected number of work orders to be issued (Rueda and Gransberg 2014a). This classification is illustrated in Figure 3, which also highlights the three different IDIQ contracting models. Furthermore, Table 2 illustrates the structure of each contracting model and describes the most appropriate conditions for successfully using each of them.

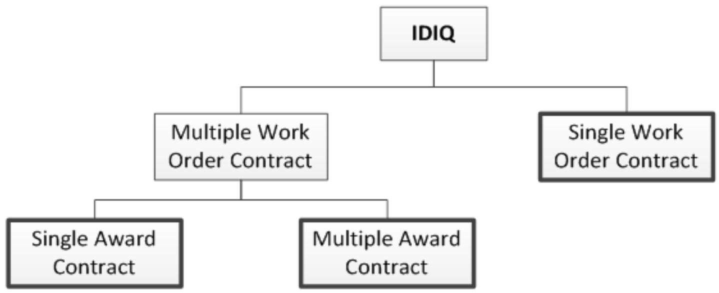
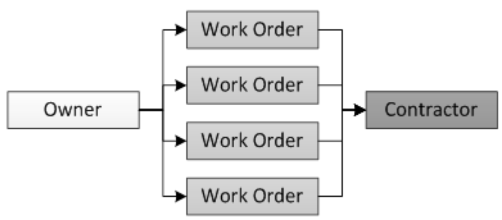
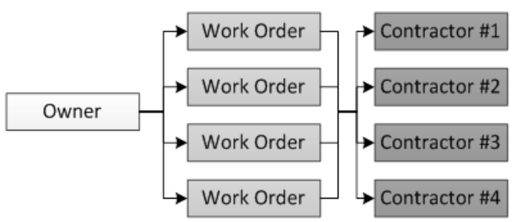


FIGURE 3 Generic IDIQ contracting models (Rueda and Gransberg 2014a).

The FAR establishes a clear preference for multiple award IDIQ construction contracts over a single award approach for federally funded projects (this preference does not apply to architectural/engineering (A/E) services) (FAR 2005). The preference for multiple award IDIQ contracts is due to the fact that this type of contract seems to represent more benefits for agencies as a consequence of the highly competitive environment (GAO 1979; OFPP 1997). However, some authors and agencies agree that this is not always the most appropriate approach (DoD 1999), which seems to be the case of state transportation agencies. For most DOTs a single award approach "seems to better fit their procurement methods and limited resources, and even with less apparent benefits, DOTs have perceived an opportunity to improve their contracting practices" (Rueda 2013) by executing single award IDIQ contracts.

TABLE 2 IDIQ Contracting Models Structure and Typical Use (Gransberg et al. 2015a)

IDIQ Model	Diagram	Typical Contract Characteristics
Single Work Order Contract		• When the agency foresees a future necessity which most likely will be fulfilled with one work order, but cannot fairly determine the total quantity of resources that will be ultimately required and/or the final delivery schedule. • Often used for emergency stand-by services, like hurricane debris removal.
Single Award Contract		• For repetitive tasks or services contained in a **narrow scope of work**, allowing a certain degree of uniformity among work orders; • When **only one contractor** has the capabilities to perform all work orders to be issued under the IDIQ contract; **or** • When the agency considers that the ultimate number of work orders to be issued under the IDIQ contract **will not justify** award multiple contractors.
Multiple Award Contract		• For repetitive tasks or services contained in a **broad scope of work**, making it hard to determine a typical composition of work orders; • When **more than one contractor** has the capabilities to perform all work orders to be issued under the IDIQ contract; **and** • When the agency considers that the number of work orders to be issued under the IDIQ contract will justify award multiple contractors.

IDIQ Advantages and Disadvantages

One of the objectives of the NCHRP Synthesis 473 was to understand the reasons that motivate DOTs to implement IDIQ contracting. DOT survey participants were provided with a list of potential benefits offered by IDIQ contracts and were asked to select those benefits (all that apply) that they consider their agencies are receiving from the use of this alternative contracting method. Figure 4 shows the responses to this question.

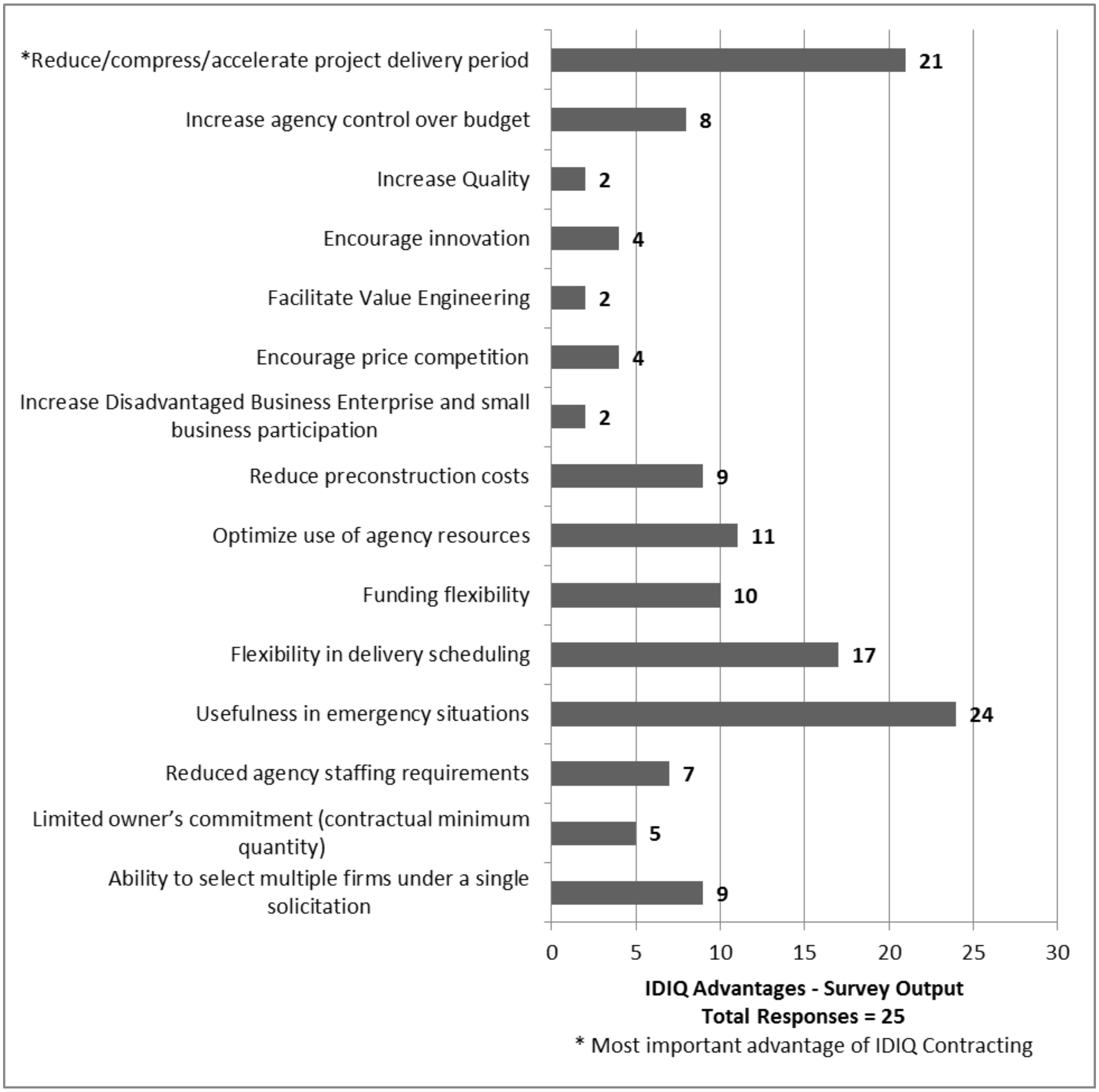


FIGURE 4 IDIQ advantages – survey output.

Nearly all the DOTs (24 out of 25) recognized that IDIQ techniques provide a quick response during emergency situations. However, when survey participants were asked in a separate question to indicate the single most important benefit of IDIQ contracts, most of them selected acceleration of the project delivery period, followed by flexibility in delivery scheduling (see Figure 5). The difference between the responses illustrated in Figures 4 and 5 is explained by the fact that the ability to effectively use IDIQ contracting for emergency situation is mainly due to the reduction of project delivery periods and the flexibility in delivery scheduling.

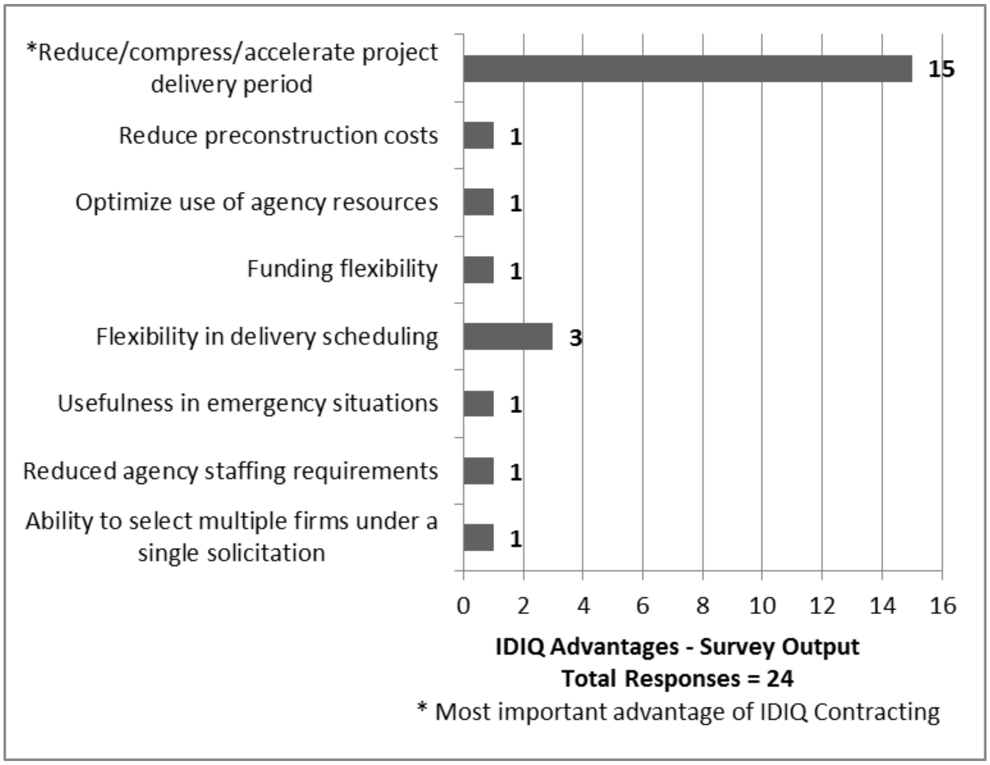


FIGURE 5 IDIQ most important advantage for DOTs.

Figures 4 and 5 show a wide range of benefits perceived by DOTs in the use of IDIQ contracting. However, these figures do not show the relationship between these benefits and the contracting practices adopted by these agencies. For example, agencies that selected as an advantage the ability of IDIQ contracts to award multiple contractors under a single solicitation (see Figure 4) may be those that are either currently using multiple award IDIQ contracts or considering this alternative. Different procurement policies and procedures offer different sets of benefits for public owners. A cross-reference analysis of the information collected from the literature review, the results of the content analysis on IDIQ contract documents, and the information shown in Figures 4 and 5 reveal three different levels of advantages related to IDIQ generic models presented in Table 2. Table 3 shows the three levels of benefits, indicating those attributed to each model. This table also shows how a public owner would benefit as it moves from a single work order approach to a multiple award IDIQ contracting model. It is important to note that the one advantage that single work order and single award contracts have over multiple award IDIQ contracts is the reduced administrative effort for coordinating and supervising a single contractor versus multiple contractors. Therefore, agencies awarding contracts to single contractors would require fewer resources to manage these contracts, an important distinction in the current environment of shrinking DOT staffs (Molenaar and Yakowenko 2007; Touran et al. 2009).

TABLE 3 Contracting Advantages of Each IDIQ Model (Rueda and Gransberg 2014a)

Multiple Award	Single Award	Single Work Order	Advantages
	Single Award	Single Work Order	• Owner only has to deal with one contractor
Multiple Award	Single Award	Single Work Order	• Owner can keep lower inventory levels • Flexibility in quantity and delivery scheduling • Supplies and services are ordered when they are really needed • Agencies commit only for a minimum or no amount of work to be ordered • Owner can direct shipments directly to the users
Multiple Award	Single Award		• Shorter project delivery period • Lower preconstruction costs • Allows contractor involvement in preconstruction activities • Fast use of year-end funding • Lower cost in future issuance of work orders • Useful contracting option during emergencies • Increase quality and timeliness of delivery
Multiple Award			• Reduce potential for graft and corruption • Highly competitive • Lower bid prices • Larger participation of small-size and disadvantaged business

This study also found two main disadvantages in IDIQ contracts regardless of the model used. As occurs with most alternative contracting methods, the first disadvantage is related to the lack of knowledge and experience of state agencies and contractors to plan, execute, and administer IDIQ contracts (Farris 2002). The second disadvantage is a consequence of some of the benefits mentioned above. In order to obtain increased flexibility in quantity and delivery scheduling and the possibility of assigning funds on a work order basis, public owner must sacrifice their ability to conduct the traditional planning, programming, and budgeting procedures for each individual work order project in the IDIQ contract.

IDIQ Types of Work

The research efforts comprised in this paper are mainly intended to get a better understanding of IDIQ construction and maintenance contracts as well as to optimize planning, contracting, and contract administration procedures in this type of contracts. In spite of the fact that the NCHRP Synthesis 473 found several state transportation agencies using IDIQ techniques for the acquisition of design services, contracts for these types of services are not included in the scope of this dissertation. Table 4 presents a list of different construction and maintenance services found in the literature and provided to DOT survey participants to classify the types of work they perform via their IDIQ contracts.

TABLE 4 IDIQ Types of Work – Construction and Maintenance

Construction Services	Maintenance Services
• Hazardous waste treatment, mitigation, removal • Erosion control/stormwater mitigation • ADA-related improvements (sidewalk ramps, etc.) • Bike lanes, sidewalks, transportation enhancement projects • Roadway safety improvements • Environmental mitigation • Resurfacing • Landscaping • Traffic signalization	• Bridge repair/preservation • Drainage maintenance • Pavement markings • Roadside safety hardware repair/preservation (e.g., guardrail, impact attenuator repair) • Roadway repair/preservation • Rest area improvements

Motivation

The use of IDIQ contracting by state DOTs for the procurement of repetitive construction and maintenance/repair services has been growing during the last few years (Gransberg et al. 2015a). Currently, there are at least 32 DOTs using IDIQ contracts for the procurement of construction and/or maintenance projects (Gransberg et al. 2015a). Previous research conducted on the use of IDIQ contracting has revealed that the principal reason that has led state DOTs to incorporate the use of IDIQ contracting into their procurement practices is the reduction of project delivery periods, following by a great flexibility in quantity and delivery scheduling, and the ability to provide quick response before, during, and after emergency situations (Gransberg et al. 2015a). It should be noted that the literature does not cite potential construction cost savings as a potential benefit, as is the case for other forms of alternative contracting methods like design-build and construction manager/general contractor (Anderson and Damnjanovic 2008; Molenaar and Gransberg 2001), nor is it cited as a disadvantage. It seems that construction cost savings perceived by DOTs are either not substantial. On the other hand, IDIQ construction costs may actually increase, but the logistical and operational benefits obtained are worth the extra costs. Based on comments collected from DOT project engineers and contractors during the face-to-face interviews conducted for the development of the NCHRP Synthesis 473, the author could identify three different lines of thought in regard to public owners cost implications of using IDIQ contracting:

1. Those who think that the possibility of performing work in more than one project should work as an incentive for contractor to submit lower bid unit prices;
2. Those who consider that this incentive may be lost by a high level of uncertainty inherent to IDIQ contracts, resulting in higher price proposals; and
3. Those who think that this alternative contracting approach has the potential to reduce project costs, but it is actually increasing construction prices as a result of a poor implementation by public owners.

The fact remains that formal research supporting or opposing any of these opinions is almost nonexistent, making the work associated with this dissertation both valuable and timely, given the recent interest shown in expanded use of alternative contracting methods, triggered by the FHWA Every Day Counts Program (Mendez 2010).

Problem Statement

The increasing number of alternative project delivery methods and contracting approaches in the transportation construction industry is improving the contracting capabilities of state transportation agencies, but it is also bringing new challenges and demanding additional skills from those is charge of selecting the contracting method to be used on a specific project. “To overcome the shortcomings of vital resources, state transportation agencies are adapting by using alternative delivery methods and contracting strategies to design and build major road infrastructure projects. The difficulty that STAs face then is how to choose between the more traditional approach and an alternative contracting strategy for a specific project” (Molenaar et al. 2014). One of these alternative contracting strategies is IDIQ contracting.

The ability to consolidate multiple repetitive projects into a single solicitation, as well as the need for greater flexibility in the procurement of some types of construction services, have triggered the rapid growth in the number of IDIQ contracting programs among DOTs during the last few years (Gransberg et al. 2015a). Regardless of the benefits provided by IDIQ contracts, these agencies are aware that this is not always the most suitable contracting approach. Due the small size and low complexity of typical IDIQ projects executed by DOTs, the potential use of IDIQ contracting usually competes with traditional DBB techniques. Thus, a major issue faced by IDIQ users, and one addressed in this dissertation is *how to decide whether to use IDIQ or a traditional DBB contracting approach for a given project or group of projects*.

More specifically, this dissertation addresses an issue that is not only confined to IDIQ contracts. It is the lack of mechanisms to formally determine the cost implications of alternative contracting methods. “[B]ecause no adequate and systematic methods exists to evaluate how project delivery methods and contracting approaches have impacted costs, it is difficult to validate the financial impacts of their use” (Walewski 2001). Current methods used by state transportation agencies for the selection of suitable projects for IDIQ contracting are mainly based on the scope of the projects (Gransberg et al. 2015a). Almost any group of projects that involves repetitive tasks is a good candidate for IDIQ contracting (FAR 2005).Thus, by disregarding the cost-related consequences of this decision, under some circumstances, these agencies may be unwittingly overvaluing the benefits offered by IDIQ contracting by paying unreasonably high construction prices than those that would be obtained using traditional DBB low bid procedures. To address this issue, this dissertation presents an IDIQ project selection framework that combines current scope-based selection techniques with a stochastic cost analysis of the projects under consideration. The framework was developed and validated via the methodology described in the following chapter (Chapter 3 – Research Methodology and Validation).

CHAPTER 3
RESEARCH METHODOLOGY AND VALIDATION

This chapter presents an overall description of the methodology followed in the academic publications in Chapters 4 to 7 and the validation process designed to evaluate to performance of the proposed IDIQ project selection framework. Detailed information about the methodology and research tools used in this study is provided in the methodology sections of the articles compiled into this dissertation. Since this study is based on previous findings obtained from the NCHRP Synthesis 473, there is a section in this chapter that describes the research approach and tools used for the development of this synthesis.

Research Methodology

Figure 6 shows the research methodology followed in study comprised in this dissertation. The study began with a supplementary literature review aimed to collect either new knowledge or any additional information missed or not available when conducting the NCHRP Synthesis 473. Given that the IDIQ project selection framework developed in this study relays on the performance of construction cost estimates for both IDIQ and DBB techniques, the next step in this study was to analysis different aspects and contracting practices that might help DOTs to increase budget control and optimize construction costs.

Subsequently, the process for the development of the IDIQ project selection framework was divided into a qualitative and a quantitative part. The qualitative part identifies and proposes effective IDIQ contracting practices, analyzes current IDIQ contracting techniques, and identifies any improvement opportunities that may help to optimize IDIQ construction costs. On the other hand, during the quantitative part, the author developed construction cost prediction models for IDIQ and DBB projects, allowing a comparison of expected construction costs between these contracting methods. The decision making framework delivered as a result of this study offers the possibility of comparing construction costs for IDIQ and DBB considering several different distributions of work among various contract periods. The quantitative part of this study was be conducted for a case study agency; the Minnesota Department of Transportation (MnDOT). Prediction models were be built and validated using MnDOT historical bid data for all project awarded between January 2008 and April 2015.

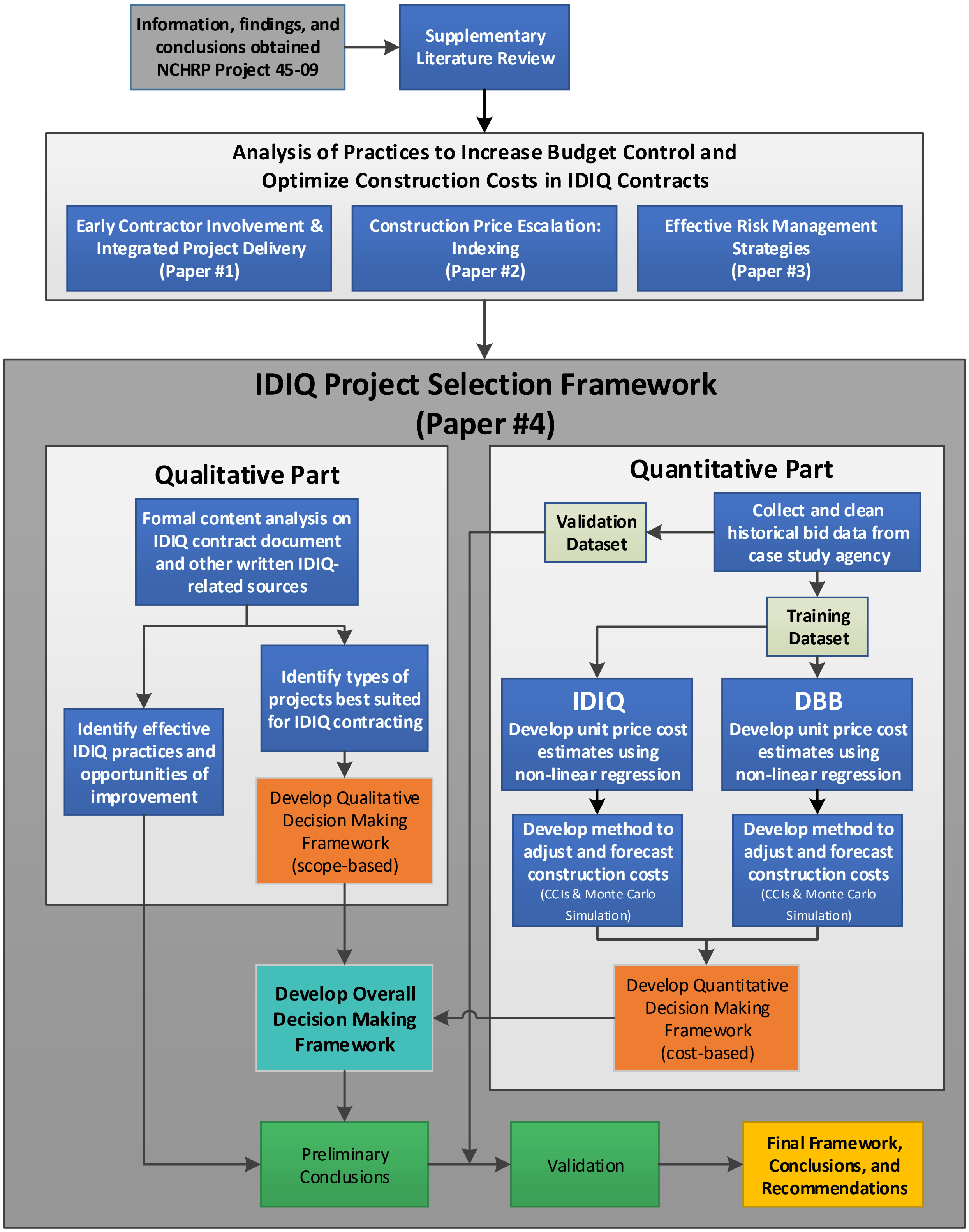


FIGURE 6 Research methodology and validation.

The findings and observations obtained from the qualitative and quantitative procedures were analyzed together to create and overall decision making framework, including an initial qualitative assessment (scope-based) for the pre-selection of IDIQ candidates, and a subsequent quantitative analysis (cost-based) of these candidates.

This chapter of the dissertation also includes a further description of two research methods that are not fully explained in the academic publications presented in the following chapter. The the modified Z-score and the robust regression and outlier removal (ROUT) method are two outlier detection approaches used at different stages during the analysis of MnDOT historical bid data.

Modified Z-Score Method

The modified Z-score method is used in an effort to remove unit prices related to unbalanced bids that could compromise the integrity of the study. Unit prices are considered to be unbalanced when "each bid item…fails to carry its proportionate share of the overhead and profit in addition to the necessary costs for the item. The results are understated prices for some items and enhanced or overstated prices for others" (Manzo 1997) Unbalancing is triggered by the owner overstating the bid quantities (Gransberg and Riemer 2009) and is so common that any research involving the use of DOT bid tabulation data must remove potentially unbalanced unit prices from its sample or risk unintentionally skewing the output (FHWA 1988).

The Modified Z-Score method was selected based on the fact that the use of the mean and sample standard deviation to detect and remove outliers in numerical data-sets (commonly used to handle outliers) may not be appropriate for small samples. This is due to the fact that these two indicators may be highly affected by one or few extreme values (Seo 2006). It is important to remember that the sample sizes subjected to this method are driven by the number of bidders in a single project that ranges from 2 to 6 on most MnDOT projects and which has not been larger than 13 in any single project awarded by MnDOT during the last seven years.

Following Iglewicz and Hoaglin's (1993) recommendations, the modified Z-score method would be a more appropriate method for this study since it works better for small data-sets. Instead of the mean and sample standard deviation, this method uses the median ($\tilde{x}$) and the absolute deviation of the median (MAD) to calculate the modified Z-score (M_i) for each number in the sample as shown below (Seo 2006).

$$MAD = median\{|x_i - \tilde{x}|\} \quad \text{eq.1}$$

$$M_i = \frac{0.6745(x_i - \tilde{x})}{MAD} \quad \text{eq.2}$$

Where: MAD = Absolute deviation of the median;

x_i = Each number in the data-set;

$\tilde{x}$ = Sample median; and

M_i = Modified Z-score for each number in the data-set.

Following Iglewicz and Hoaglin's suggestions (1993), all unit prices whose absolute modified Z-score was less than 3.5 ($|M_i| < 3.5$) were removed from the data-set.

ROUT Method

Proposed by Motulsky and Brown (2006), ROUT combines robust regression techniques with outlier removal to optimize non-linear regression methods by discarding extreme values that significantly differ from the other values in the sample. It allows finding curves that better fit the data. In this study, ROUT was used to identify unreasonable low or high unit prices not detected by the modified Z-score method. Extreme values not found by the first outlier filter may appear as a result of unusual contract requirements, forcing all contractors to bid outside the typical unit price ranges, or in contracts that involve only two price proposals. With two-data-point samples, the modified Z-score method always finds both values as valid. Both outlier detection methods assume that values are normally distributed around the mean value.

Unlike the traditional least-squares regression, robust regression techniques assign weights to the observations, decreasing the weights as observations deviate from the region where values are more concentrated. It reduces the impact that potential outliers may have on the regression analysis.

Commonly used outlier detection methods use the typical 95% confidence interval to discard values located on the tails of a Gaussian distribution; however, these methods are also often associated to a larger number of false positives mainly when dealing with large data-sets (Motulsky and Brown 2006). It should be noted that unlike the modified Z-score method, this second outlier filter is to be applied on all bid unit prices recorded for each pay item and included in MnDOT available bid data. In some cases, there are more than 1,500 observations for a single pay item. To overcome this issue, Motulsky and Brown (2006) proposed a modified version of the False Discovery Rate (FDR) controlling procedure developed by Benjamani and Hochberg (1995) to find and eliminate outliers. The Benjamani and Hochberg's method requires the establishment of a maximum desired FDR (Q) which works as a parameter to control the efficiency of the procedure. "If Q is set to 1%, you can expect fewer than 1% of the 'statistically significant' findings (discoveries) to be false positives, while the rest (more than 99%) are real" (Motulsky and Brown 2006).

The proposed adaptation of the FDR method first divides the residual of each observation by the Robust Standard Deviation of the Residuals (RSDR). This ratio is intended to approximate a t-distribution, which is then used to determine a two-tailed p-value. Subsequently, it uses FDR techniques to identify significant p-values that correspond to outliers. Motulsky and Brown (2006) summarize the ROUT method in three steps:

1. Find the best fitting curve using robust non-linear regression.
2. Identify outliers using the residuals of the robust fit and FDR techniques.
3. Discard identified outliers and perform least squares regression.

NCHRP Synthesis 473 – IDIQ Contracting Practices: Research Methodology

Information used for the development of the NCHRP Synthesis 473 was gathered using the following research instruments:

- Literature review
  - Comprehensive literature review of previous studies on IDIQ contracting.
  - Formal content analysis following the protocol proposed by Neuendorf (2002) of IDIQ related documents from 32 state DOTs, 2 local transportation agencies, and 20 federal agencies from different sectors.
- Surveys (surveys were developed using the protocol prescribed by Oppenheim [2000])
  - Survey responses from 43 state DOTs (84% response rate).
  - Survey responses from 18 members of the Association of General Contractors (AGC) and American Road and Transportation Builders Association (ARTBA).
  - Survey responses collected during a previous research project for the development of the MnDOT IDIQ Implementation Guide (this responses were also used in the

NCHRP Synthesis 473). These responses came from 56 contractors and subcontractors, 54 MnDOT staff members involved in the planning, execution, and closing of IDIQ contracts, and 39 surety companies doing business in Minnesota

- Structured interviews (the study used the structured interviewing techniques proposed by the US Government Accountability Office [GAO 1991])
  - Four face-to-face interviews with members of the AGC and ARTBA.
  - Face-to-face structure interviews with project engineers from Florida, Minnesota, Missouri, and New York State DOTs and the Central Federal Lands Highway Division (CFLHD). These structured interviews were part of case study analyses of IDIQ contracts executed by these agencies - the cases were collected using Yin's methodology for case study research data collection (1994).

Validation

As illustrated in Figure 6, the historical bid data from all projects awarded by MnDOT between January 2008 and April 2015 is divided into two data-sets; 1) a training data-set used to develop the construction cost estimating models for IDIQ and DBB contracts and 2) a validation data-set use to evaluate the performance of the cost estimating models. Projects awarded between January 2008 and August 2013 constitutes the training data-set, while the remaining projects were used for validation (September 2013 – April 2015). Both data-sets were intentionally grouped placing older projects in the training data-set since the purpose of this validation process is not only to determine the accuracy of the construction cost estimating models, but also the ability of bid data from previous projects to estimate current construction costs. More details and the results of the validation of the IDIQ project selection framework is presented in Chapter 7.

CHAPTER 4
US MAJOR TASK ORDER CONTRACTING AND NZ COLLABORATIVE ALLIANCES COMPARISON

Rueda-Benavides, J.A., E. Scheepbouwer, and D.D. Gransberg, “US Major Task Order Contracting and NZ Collaborative Alliances Comparison,” CDR-1878, *Proceedings*, 2015 AACE International Annual Meeting, June 28-July 1, 2015, Las Vegas, NV.

Abstract

Relational contracts which strive to create a project deliver environment that is fully integrated are becoming more prevalent in the US and are touted to be the “magic bullet” to eliminate disputes and maximize collaboration. Similar contracts have been in use in New Zealand for over two decades and are becoming ubiquitous in Australasia for the delivery of complex infrastructure construction projects. Alliancing’s key characteristic is a “no sue” clause that has led US agencies to shy away from it as impossible to implement under US law. This paper argues that the US Department of Defense’s major task order contract is very similar to the collaborative alliance contract currently in use to deliver the massive reconstruction program estimated at approximately NZ$2.5 billion in Canterbury, New Zealand. The paper compares case studies of a US and a New Zealand projects and finds that US public owners can accrue most of the advantages provided through an alliance contract without the need to include a “no sue” clause.

Introduction

Despite the US construction industry efforts to catch up with the global trend for the implementation of more integrated project delivery methods, the adversarial culture and legal regulations framing the business activity of this industry have prevented US public owners from attaining the high level of partnering seen in some infrastructure projects overseas (Weston and Gibson 1993). It implies than US agencies are unable to take advantage of the benefits frequently attributed to fully integrated procurement environments in relation to the achievement of more efficient procedures and superior performance during the construction of capital infrastructure projects (Barlow 2000; Van den Berg and Kamminga 2006; Duffield et al. 2014; SCIRT 2014).

The inability of public owners to create a “no blame” and “no disputes” procurement environment through “no sue” clauses is one of the principal aspects that prevent US public owners from establishing highly collaborative relationships (Gransberg et al. 2015b). However, as a result of the comparison of case studies of a US and a New Zealand projects, this paper proves that the US has procurement tools that allow federal agencies to accrue most of the advantages provided through collaborative alliancing with the need to include “no sue” clauses. The following are the two case studies compared in this study:

1. Air Force Contract Augmentation Program IV (AFCAP IV): This is an Indefinite Delivery/Indefinite Quantity (IDIQ) MATOC awarded by the US Department of Defense (DoD) as “a rapid response contingency contract tool for use by US Government entities needing urgent assistance” (USAF 2014a). It include the delivery of engineering and construction services.
2. Stronger Christchurch Infrastructure Rebuild Team (SCIRT): This is a collaborative alliance agreement among public owners and non-owner participants formed for the reconstruction of “publicly owned horizontal infrastructure […] damaged by the Canterbury earthquakes of 2010 and 2011” (SCIRT 2014).

The paper compares these two contracting mechanism on five aspects: (1) general procurement and administration procedures, (2) dispute resolution policies, (3) early contractor involvement (ECI), (4) incentive and disincentive provisions, and (5) documented advantages. Additionally, the paper identifies some key aspects that should be addressed by regulatory policy makers to allow greater collaboration in MATOCs at the level seen in alliance agreements.

Background

Increasing construction costs, aging infrastructures, stricter construction standards and specifications, greater public demands, and limited resources have brought new challenges for public owners worldwide (Thomas et al. 2014; Pakkala 2002); challenges that cannot be efficiently addressed by traditional Design-Bid-Build (DBB) practices (Walewski et al. 2001; Shrestha et al. 2013; Gransberg et al. 2015a). This situation has moved federal and local agencies to develop and implement alternative project delivery methods and contracting approaches such as Design-Build (DB), Construction Manager/General Contractor (CMGC) (also called Construction Manager-at-Risk or CMR), and Public Private Partnership (PPP or P3) (West et al. 2012). Rather than finding a single one-size-fits-all procurement method to replace DBB contracts, these alternative project delivery methods are intended to meet those agencies' needs that DBB cannot efficiently fulfil. In other words, "public owners have been expanding their procurement toolboxes and increasing their contracting capabilities with flexible sets of alternatives to adjust acquisition procedures to the unique needs of each project" (Gransberg et al. 2015a). Thus, the selection of the contracting method by the agency or client (in New Zealand contracting terms) is aimed to attain the best value-for-money (SCIRT 2014). In the particular case of the two contracting models analyzed in this paper, multiple award task order contracts (MATOC) and collaborative alliancing, they are specifically intended to procure construction services for large and complex projects (Scheepbouwer and Gransberg 2014), which usually represent higher risks for all stakeholders, demanding advanced procurement strategies and management practices.

Although both the MATOC and collaborative alliance agreement are mechanisms that involve a pool of contractors competing for multiple projects during the contract period, they can be considered philosophically different in terms the nature of the relationships among stakeholders. While collaborative alliancing promotes a high degree of integration among all contracting parties (Scheepbouwer and Gransberg 2014), the level of interaction between the owner, contractors, and consultants in a MATOC does not differ from that found in other delivery method, depending on the delivery method used at the project level (i.e. DBB, DB, CMGC) (Gransberg et al. 2015a).

In addition to those authors already cited in this paper, other researchers have published their findings highlighting the benefits of alliancing, and similar techniques that promote collaboration and integration among stakeholders, in terms of cost and time savings while improving or maintaining project quality (Scott 1995; Hauck et al. 2004; Fortune and Setiawan 2005; Spang and Riemann 2014). In a more specific study, Rowlinson et al. (2006) highlighted an important aspect that should be taken into consideration when using alliancing techniques. This research team evaluated the implications of "no sue" clauses in an alliancing agreement executed in Queensland, Australia. This study suggests that substantial efforts are required from the alliance board and clients to guaranteed the alliance climate required to maintain all parties committed to the “no blame/no disputes” philosophy. About 5% of the labor costs for this project were set aside for relationship management expenses, which include the salary of an alliance psychology required to maintain positive relationships among stakeholders (Rowlinson et al. 2006).

The following two sections present an overall description of the contracting systems analyzed in this paper.

Indefinite Delivery/Indefinite Quantity Contracting

The Federal Acquisition Regulation (FAR), which comprises the procedures and rules that govern the purchase of supplies and/or services by US federal agencies, defines IDIQ contracting as a mechanism that “provides for an indefinite quantity, within stated limits, of supplies or services during a fixed period” (FAR 2005). It is important to mention that this definition is only applicable to federal agencies since it has been found that the establishment of “stated limits” is not a requirement for many agencies state level (Gransberg et al. 2015a). The acquisition of supplies or services is controlled by the owner through the issuance of multiple task orders (also called work, delivery, or job orders) to one or multiple contractors. There are several different terms used by different agencies to refer to this type of contracts and the task orders. However, the discussion of the IDIQ terminology is beyond the scope of this paper. This issue has been covered in detail in a previous study conducted by the authors (Rueda and Gransberg 2014a; Gransberg et al. 2015a).

Figure 3 illustrates three different IDIQ contracting models defined based on the number of task orders issued under the contract and the number of awardees. Likewise, Table 2 illustrates the configuration of each model and describes the most suitable conditions for their implementation. Figure 3 and Table 2 also present the terminology used in this paper to refer to the different elements of IDIQ contracting.

Alliancing Contracting

The Australian Department of Infrastructure and Transport (ADIT) (2010) defines alliancing contracting as a “delivery model where the owner(s), contractor(s) and consultant(s) work collaboratively as an integrated team and their commercial interests are aligned with actual project outcomes." In spite of its increasing popularity, the US construction industry still considers "alliancing" as a foreign concept, which must not be equaled to the North American partnering concept (Gransberg et al. 2015b). Unlike alliancing agreements, US partnering contracts are based on non-binding agreements among contracting parties to adopt a non-adversarial philosophy (Murdough et al. 2007). In other words, in a US partnering agreement "two parties agree to cooperate at a very high level to achieve separate but complementary objectives" (Ernzen et al. 2000).

The alliancing literature presents three different types of alliance agreements; pure, competitive, and collaborative alliances. This contracting mechanism was initially used in Australia in the form of a pure alliance (Gransberg et al. 2015b). In a pure alliance, the owner or client uses Qualifications-Based Selection (QBS) techniques to select the design consultant and construction team(s) that will enter into the agreement for the construction of a single project. The construction team is usually conformed by two or more firms that team up to bid as a single entity. Figure 7 illustrates the generic configuration of a pure alliance.

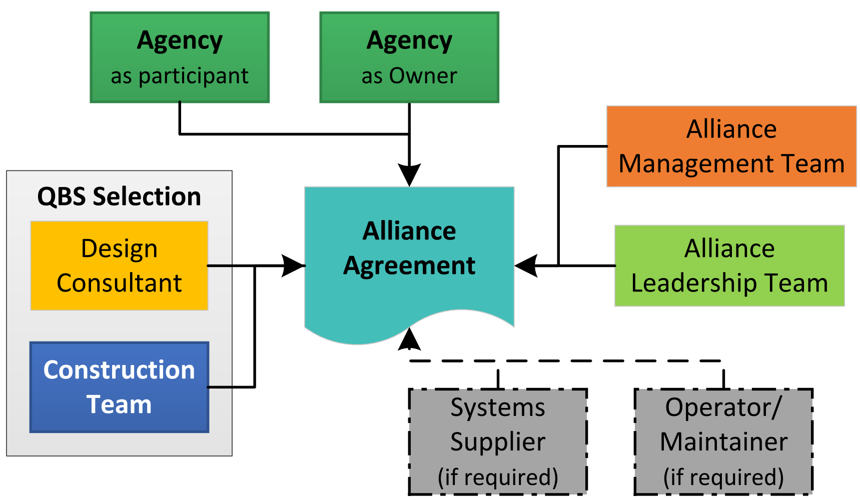


FIGURE 7 Pure alliance agreement (Adapted from Gransberg et al. 2015b).

The Alliance Leadership Team's (ALT) "primary responsibility is to operate at the high-level and ensure that the alliance members and the project management team think of the collective interests of the project, and not act in their own self-interest" (Gransberg et al. 2015b). This team is in charge of making strategic decisions and providing direction to the Alliance Management Team (AMT). In a pure alliance agreement, the ALT is formed by representatives of each participant involved in the alliance agreement and led by a member of the owner organization.

The AMT "ensures that the project gets designed and built and is normally composed of a members selected for their special expertise and experience" (Gransberg et al. 2015b). This team is responsible of providing day-to-day management on delivery operations. The AMT in a pure alliance agreement is led by a member of one alliance participants; the Alliance Manager (AM). The AM is selected by mutual agreement of all participant organizations.

Figure 8 correspond to a competitive alliance agreement. The principal difference with a pure alliancing agreement is that in a competitive alliancing the design consultant and the construction team are selected through best-value practices. The use for the first time of a competitive alliance agreement by the New Zealand Transport Agency (NZTA) was motivated by political pressure to demonstrate that this agency was obtaining the best value for its infrastructure projects (Gransberg et al. 2015b). Another difference between these two models is that under a competitive approach the AM is selected from outside of the alliance members' organizations.

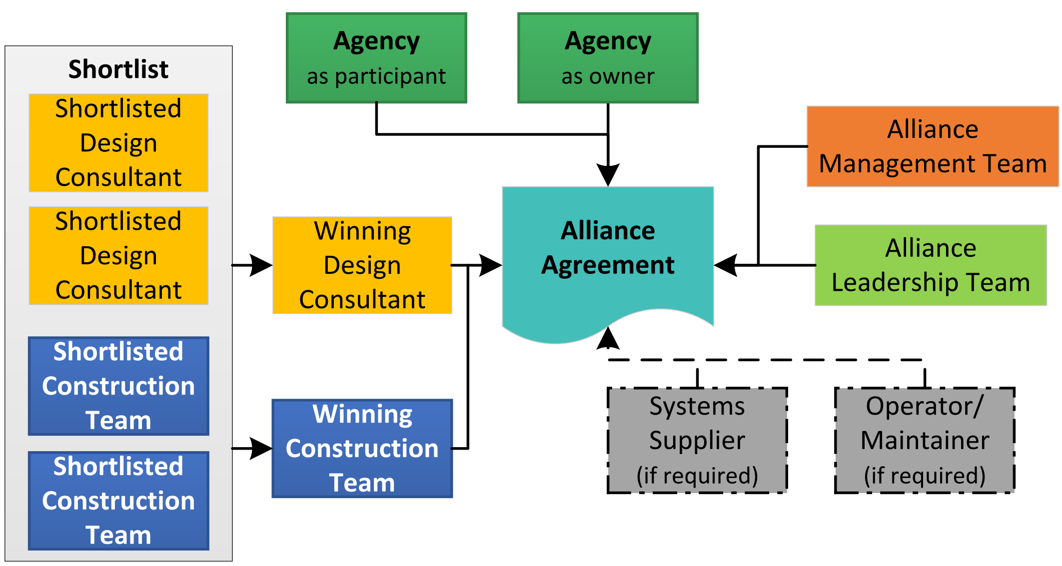


FIGURE 8 Competitive alliance agreement (Adapted from Gransberg et al. 2015b).

Unlike the pure and competitive alliancing, a collaborative alliance agreement involves multiple construction teams competing for multiple projects (see Figure 9). As with IDIQ contracts, the total amount of work to be performed by all construction teams cannot be reliably estimated when establishing the alliance agreement. Following the best-for-project principle commonly adopted in alliancing contracting (expect for competitive alliances which are focus on a best-value approach), the assignation of projects among construction teams is based on past performance indicators, which modify the portion of the total quantity of work to be assigned to each team. This alliancing model is discussed in more detail in the following sections.

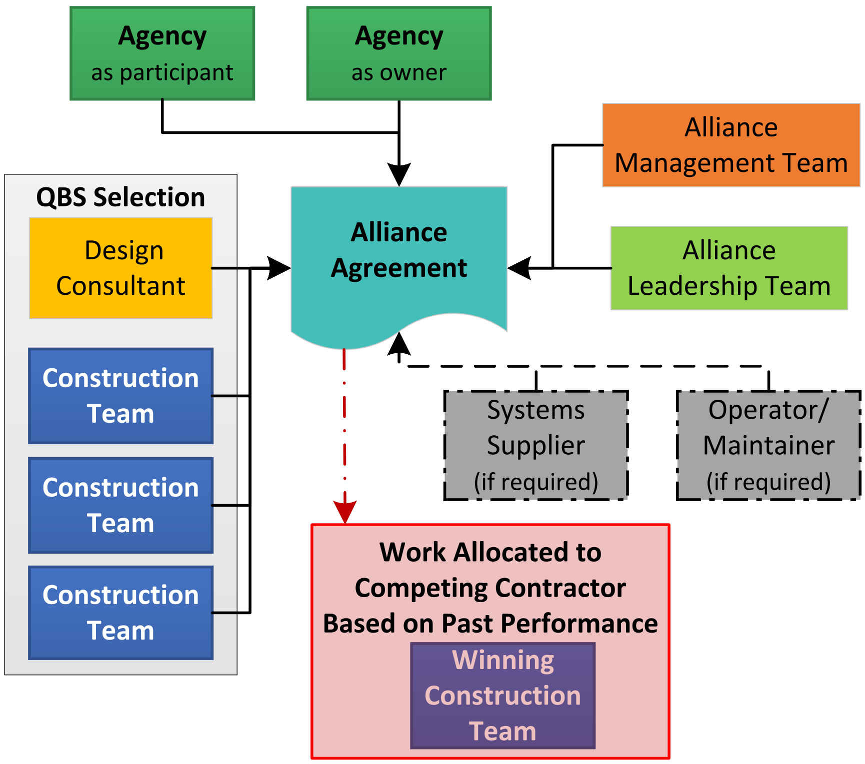


FIGURE 9 Collaborative alliance agreement (Adapted from Gransberg et al. 2015b).

Regardless of the alliancing contracting model used, the following key elements are usually found in all alliance agreements:

- Gainshare/Painshare Scheme
- Task Out-Turn Cost (TOC)
- "No Disputes" Provisions

Comparison of Case Studies

While the AFCAP IV is a highly developed version of a contracting mechanism initially intended for simple-scoped contracts to facilitate the acquisition of an indefinite quantity of supplies or services, the SCIRT was an innovative solution for an unusual, pressing, and challenging situation. The extensive and severe damage caused by the Canterbury earthquakes of 2010 and 2011, added to the small number of construction firms with the required capabilities to participate in the reconstruction of the damaged infrastructure, turned the local construction industry on its head with owners competing for the services of the construction companies (Le Masurier 2014). This situation led the NZTA and the Christchurch City Council to recommend the creation of the SCIRT to concentrate all rebuilding efforts and the administration of the limited resources on a single multi-stakeholder organization.

In spite of the philosophical difference between these two contracting schemes, both are intended to deal with broad/complex scopes and indefinite quantities of work. Likewise, both mechanisms involve the execution of multiple projects during the contract period and a pool of pre-selected construction teams competing for them. A closer look at Table 5 suggest an important aspect that differentiate these two approaches. While in the AFCAP IV decisions are made on a best-value basis, the collaborative environment of the SCIRT allows the acceptance of a best-for-project philosophy by all parties.

TABLE 5 Case Study Summary

Features/Provisions	AFCAP IV	SCIRT
Project Title	Air Force Contract Augmentation Program IV	Stronger Christchurch Infrastructure Rebuild Team
Contract Type	Indefinite Delivery/Indefinite Quantity Multiple Award Task Order Contract	Collaborative Alliance Agreement
Scope	"AFCAP is a rapid response contingency contract tool for use by U.S. Government entities needing urgent assistance" (USAF 2014a)	SCIRT "is a purpose-built organization rebuilding publicly owned horizontal infrastructure, namely roads, walls and bridges, fresh water, wastewater and stormwater networks damaged by the Canterbury earthquakes of 2010 and 2011" (SCIRT 2014)
Location	Worldwide	Christchurch, New Zealand
Duration	Base duration of 1 year, with 9 one-year options	5-year program
Contract Amount	The minimum guaranteed amount per contractor is US$2,000, with a maximum total contract amount US$5 billion (work performed by all contractors)	Initial program estimate of NZ$2.5 billion including NZ$1.6 to be paid to the construction teams
Contractor Selection	Best-Value	Qualifications-Based Selection
Project Placement Procedure	Best-Value	Based on past performance in previous alliance work
Payment Provisions	Firm Fixed Price (FFP); Fixed Price Incentive Firm (FPIF); Cost Plus Fixed Fee (CPFF); or Cost Plus Incentive Fee (CPIF)	Cost Reimbursable with Performance-Incentivized Fee

The following sections compare the AFCAP IV and the SCIRT on five different key aspects: (1) general procurement and administration procedures, (2) dispute resolution policies, (3) early contractor involvement (ECI), (4) incentive and disincentive provisions, and (5) documented advantages.

General Procurement and Administration Procedures

This section discusses two aspects that form part of the core characteristics of these contracting methodologies; selection of construction teams and work assignation procedures.

Selection of Construction Teams

When comparing the methods used for the selection of the contractors, it is important to bear in mind the critical situation of the Christchurch's construction industry when the SCIRT was formed. As mentioned above, it was an unusual situation in which the demand for construction services exceeded the capacity of the industry. Thus, making the best attempt to meet the demand, the government invited those contractors already engaged in earthquake recovery activities to join the alliance (SCIRT 2014). By inviting those contractors who have been showing a satisfactory performance, the owners created an expedite QBS mechanism to select the non-owner alliance participants.

Even though the AFCAP IV is also intended to provide quick response to situations that require urgent assistance, the selection of the contractors is conducted under less pressing conditions. Rather than being used to respond to ongoing emergency situations, the AFCAP IV is aimed to address potential future events. It gives the owner more time to conduct a more exhausting best-value selection procedure, commonly used by US public owners to award complex projects in an effort to guarantee the selection of a contractor with the sufficient capabilities to successfully deliver the project for a reasonable cost for the government. In this case, the DoD uses the Lowest Price Technical Acceptable (LPTA) source selection procedure described in the FAR (USAF 2014b). A LPTA selection process consist of rating non-price selection factors "acceptable" or "unacceptable" based on specific parameters described in the solicitation documents. Subsequently, the contract is awarded on a low-bid basis, but only considering price proposals submitted by technically "acceptable" offerors (FAR 2005). The

AFCAP IV is expected to be awarded in May 2015 to up to six contractors (Neyland 2014). Figure 10 illustrates the AFCAP IV contractor selection procedure.

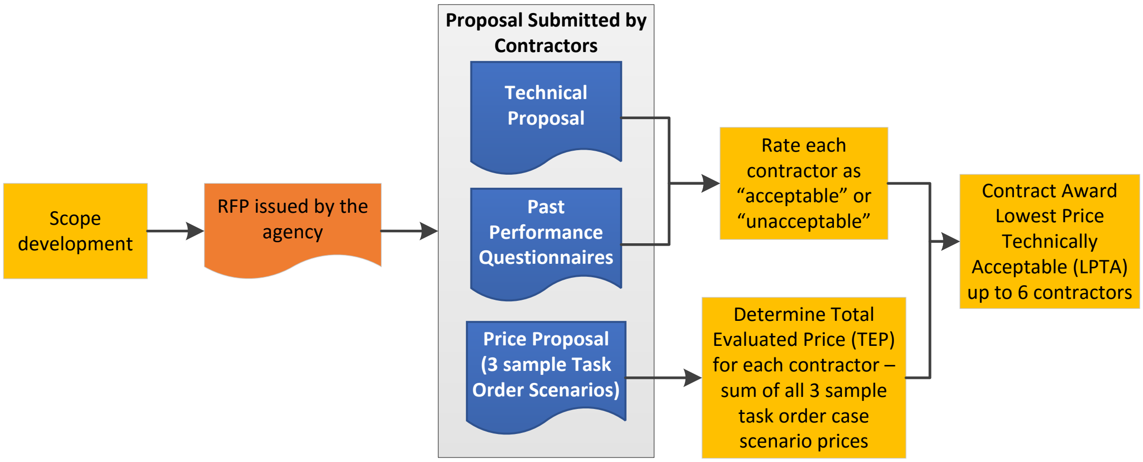


FIGURE 10 AFCAP IV contractors.

Given that the contractors that they are able provide quick response under emergency situation worldwide, it is easy to imagine that there are just a few firms with the sufficient capabilities to provide these services. In fact, the AFCAP I and II, executed in 1997 and 2002 (respectively) under a single award task order approach, were awarded through competitive procedures to the same firm; Readiness Management Support LC (Grasso 2010). Likewise, this company was one of awardees in the third version of the AFCAP, along with other five firms (the AFCAP III was the first developed using a MATOC approach). The few number of companies with the required capabilities to participate in these contracts places the AFCAP IV in a similar situation as the one described by the SCIRT in regard to the size of the market. It can be seen as an opportunity for the DoD to promote a collaborative environment and stronger relationships among all parties. Le Masurier (2014) argues that one of the aspects that facilitated the high level of integration achieve by the SCIRT was the small size of the construction market.

Work Assignation Procedures

This section discusses the procedures followed in each case study to distribute the work among the pre-selected construction teams. As mentioned above, both case studies assign upcoming projects on a competitive basis. In the AFCAP IV, the contracting office is granted great flexibility to select the most appropriate task order award approach based on the particular scope and requirements of each project. The decision is mainly driven by the type of task order used. The AFCAP IV allows the use of four different types of task orders; Firm Fixed Price (FFP); Fixed Price Incentive Firm (FPIF); Cost Plus Fixed Fee (CPFF); or Cost Plus Incentive Fee (CPIF). Thus, the bid package submitted by contractors to compete for a given task order would vary in accordance with its compensation method. The AFCAP IV contract language suggests some selection factors that may be used by the contracting officer and allows the use of others, at the discretion of the contracting officer. However, the FAR states that the owner must “consider price or cost under each order as one of the factors in the selection decision” (FAR 2005). The following is the list of selection factors suggested to the contracting officer (USAF 2014b)

- Past performance in previous task orders;
- Specific technical/management capabilities;
- Availability of resources;
- Proximity to the jobsite;
- Ability to meet requested deadlines; and
- Price/Cost.

The SCIRT mechanism for the assignation of projects among construction team is based on a best-for-project scheme. This procedure is based on a Delivery Performance Score (DPS) which is computed using 14 non-cost Key Performance Indicators (KPIs) designed to evaluate the work delivery by each construction team on five Key Result Areas (KRAs) (Gransberg et al. 2015b). Table 6 shows the non-cost KPIs with the weighting assigned to each of them. The calculation of the DPS also involves a cost performance factor termed “earn value per delivery team/cost to date.” The DPS is calculated on a monthly basis using the KPIs of the contractors for the last three months. The values obtained each month for all contractors are used to determine the distribution of future work among the construction teams. Construction teams with higher DPS are entitled to deliver a greater amount of work (in terms of money). Thus, it works as an incentive for contractors to provide and outstanding performance under each project.

TABLE 6 Non-cost KRAs and Accompanying KPIs (Gransberg et al. 2015b)

Key Result Area (% weighting)	**Key Performance Indicator (% weighting)**
Safety (25%)	• Measure of safety Engagement /Awareness (12.5%) • Safety Initiatives/Action (7.5%) • Protect of Utility Services (5%)
Value (30%)	• Productivity (12%) • Construction Quality (9%) • Innovations (9%)
Our Team (15%)	• Alignment & Involvement of Team (7.5%) • Wellbeing Initiatives (3.75%) • Developing a Skilled Workforce (3.75%)
Customer Satisfaction (20%)	• Community & Stakeholder satisfaction with Product (8%) • Community & Stakeholder satisfaction with communication (8%) • Planning & Execution of Communication Strategies (4%)
Environment (10%)	• Construction Culture & Incident/hazard reports (6%) • Waste Minimization (4%)

Dispute Resolution Policies

The use of “no blame/no disputes” clauses has been recognized as an important factor to promote a collaborative environment with open and honest communication among alliance participants (Gransberg et al. 2015b; Rowlinson 2006). These provisions usually state that “there will be no arbitration or litigation between the Participants on any Alliance Disagreement [and] Each of the Participants waives its rights of action against each of the other Participants arising out of any act or omission in connection with this PAA (Project Alliance Agreement)” (Rowlinson 2006).

Although the use of binding “no sue” provisions is not authorized by the FAR (Gransberg et al. 2015b), and despite the fact that some people in the US construction industry may disagree with the use of these clauses, multiple award IDIQ contracts seem to be one step closer to this philosophy. Even though MATOC participants do not waive their rights to sue, the FAR imposes some post-award limitations on these rights. No protests are allowed in regard to the issuance or proposed issuance of a task order (FAR 2005). Protests are mainly limited to deviations on the scope of work or increments in the duration or maximum value of the contract. In addition to these restrictions, an analysis of 76 legal cases associated to federal IDIQ contracts has shown that this mechanism "has produced a defensible contract form and associated procurement and administration processes as evidenced by the finding that the majority of IDIQ protests and claims are settled in favor of the government" (Gransberg et al. 2015a). Thus, the low risk of protest related to this contracting method suggests that this could be a good place to start any potential future initiative towards a "no blame/no disputes" philosophy.

Early Contractor Involvement

The ability to obtain early constructability reviews during planning and design activities has been identified as an important contribution of collaborative alliancing techniques. Having a pool of construction teams established before the development of the scope of work of all alliance projects allows the earliest possible contractor involvement. The construction industry worldwide seems to agree that "the ECI approach increases the opportunity for better relationships among the parties, which assist the design process from contractor's input and eventually lead to successful delivery of the project" (Rahman and Alhassan 2012). The construction industry in the US seems to be engaged with the development of contracting practices that allow ECI. It can be seen ECI, at different levels, in the use of DB and CMGC and in some alternative contracting approaches such as alternative technical concepts (ATCs). However, in these cases, the earliest possible moment during the preconstruction period to bring in the contractors' input is tied to the award of the contract, which usually occurs after some planning, programming, and design efforts by the owner. Rather than detracting from the value of the ECI provided by alternative delivery methods currently in use in the US, the latter statement is intended to argue that ECI benefits are enhanced in collaborative alliance agreements.

Some may argue that MATOCs provide an opportunity for ECI at the similar level as collaborative alliance agreements since construction firms are selected before the development of the task orders. However, the typical adversarial relationships between contracting parties in this contracts makes it difficult for public owners to handle input from multiple contractors while maintaining the sense of transparency and equity among awardees (Gransberg et al. 2015a). A single award IDIQ contract may be more suitable for the application of alliance-like ECI practices, but it would require the creation of an integrating environment that promotes collaboration, mutual trust, and open communication among all contracting parties; a scenario that is not commonly seen in the US construction industry.

Although ECI benefits in multiple award IDIQ contracts may be enhanced through the use of alternative contracting methods, such as DB, CMGC, and ATCs, the value added at the project level would not substantially differ from the benefits obtained by applying these alternative contracting methods in non-IDIQ projects (Gransberg et al. 2015a).

Incentive and Disincentive Provisions

There is a great similarity in the way how the AFCAP IV and SCIRT incentivize contractors to provide an outstanding performance on each project. This study identified in both case studies two methods to compensate or penalize contractors for exceeding of failing to meet expectations stated in terms of costs and technical execution.

The first method consists in the use of gainshare/painshare schemes where "the profit of the parties would be reduced in the case that the Project Target Cost is exceeded and increased in the case where the actual costs are less than Project Target Cost, in accordance with agreed formulae" (ACA 1999). While in the AFCAP IV the use of this scheme is limited to the issuance of FPIF and CPIF task orders, in the SCIRT it is applicable to all work performed under the alliance agreement.

The second incentive/disincentive mechanism refers to the ability of these contracting methods to incorporate past performance measurements into the assignation for future work under the contract. As mentioned above, the assignation of future projects to a construction team may be heavily affected by its poor performance in previous projects. In the AFCAP IV, this mechanism is introduced as one of the selection factors, whose relevance in project placement procedures would depend on the weighting assigned by the contracting officer to each selection factor. On the other hand, KPIs (cost and non-cost) indicators correspond to the only criterion for the distribution of work under the collaborative alliance.

Documented Advantages

Table 7 presents some documented advantages associated to each of the two contracting systems discussed in this paper. It evident from Table 7 that the SCIRT offers more advantages than the AFCAP VI. It is important to mention that Table 7 is not intended to state that MATOCs do not offer value-for-money. This box was not checked because this is an aspect that has not been appropriately addressed in the literature. Information in Table 7 was mainly obtained from an interim report published by the SCIRT (2014), a National Cooperative Highway Research Program (NCHRP) Synthesis about alliance contracting practice (Gransberg et al. 2015b) and an NCHRP Synthesis about IDIQ practices (Gransberg et al. 2015a).

TABLE 7 Documented Advantages in the AFCAP and SCIRT

Advantage	AFCAP IV	SCIRT
Useful to manage complex projects with broad scopes of work	☒	☒
Allow quick under emergency situations	☒	☒
Offer Value-for-Money	☐	☒
Reduce project delivery period	☒	☒
Flexibility in quantity and delivery scheduling	☒	☒
Optimize use of public resources	☒	☒
Simplicity of decision making framework	☐	☒
Use of "no disputes" provisions	☐	☒

The last two advantages listed in Table 7 are directly related to the highly integrated environment created by a collaborative alliance. Therefore, and despite the flexibility of the AFCAP IV, it is unlikely that these two benefits can be offered by a MATOC without a substantial change in the UD federal contracting regulations allowing the adoption a "we all win or we all lose" philosophy.

Discussion

Despite the absence of "no sue" provisions in the AFCAP IV and the clear adversarial relationship among contracting parties, the previous sections have highlighted several similarities among the AFCAP IV and the SCIRT. These similarities correspond to their ability to manage complex scopes of work, their operational configuration using multiple contractors for the execution of multiple projects, and their incentive and disincentive provisions. Although not as extensively applied as in SCIRT, ECI practices have also be used to add value to multiple award IDIQ contracts. Additionally, the paper has shown that the AFCAP IV shares most of the principal benefits provided by a collaborative alliance agreement. It means that US federal agencies have procurement tools flexible enough to emulate the logistical capabilities of the provided by a collaborative alliance. However, this conclusion must not discourage US policy makers from seeking options to increase the level of integration among contracting parties. The value of alliance-like contracting approaches has been widely proven in the literature. It should be noted that this study compares the benefits provided by both case studies in a general manner without comparing the magnitude of their impacts. The superiority of the SCIRT over the AFCAP in some point of comparisons (i.e. ECI practices, “no disputes” approach, and efficiency of decision making procedures), added to the positive attitude of most researchers towards the use of alliancing contracting, allows the authors to reasonably conclude that an eventual implementation of collaborative alliancing in the US may enhance the already remarkable capabilities of the AFCAP and other similar contracts.

Conclusions

The main objective of this paper was to determine if despite the banning imposed by the FAR on the use of some alliancing-related contracting elements, US federal agencies agency have procurement tools to obtain most of the benefits frequently attributed to alliance agreement. Thus, the authors compared the AFCAP, and MATOC awarded by DoD, and the SCIFT, a collaborative alliance agreement formed for the reconstruction of public infrastructure assets after the Canterbury earthquakes of 2010 and 2011. These case studies were compare on five different aspects: (1) general procurement and administration procedures, (2) dispute resolution policies, (3) early contractor involvement (ECI), (4) incentive and disincentive provisions, and (5) documented advantages. The authors found several similarities in all these aspects. The main difference found between these two contracting approaches is related to the absence of “no blame/no disputes” clauses in the AFCAP. However, it may be argued that the limitations stated by the FAR to the ability to file protests in multiple award IDIQ contracts reduce de need “no sue” provisions in these type of contracts. Ultimately, the authors concluded that regardless of the absence of “no sue” provisions in major infrastructure projects executed by US federal public owners, and despite the typical adversarial relationships among contracting participants, these agencies have the procurements mechanisms to accrue most of the benefits provided by a collaborative alliance

CHAPTER 5

SUITABILITY ANALYSIS OF EXISTING CONSTRUCTION COST INDEXES FOR MINNESOTA DEPARTMENT OF TRANSPORTATION CONSTRUCTION PROJECTS

Rueda-Benavides, J.A., and D.D. Gransberg, "Suitability Analysis of Existing Construction Cost Indexes for Minnesota Department of Transportation Construction Projects," *2015 Transportation Research Board Annual Meeting Compendium of Papers*, Paper 15-2293, National Academies, January 2015, Session 237, 16 pp.

Abstract

The suitability analysis presented in this paper was conducted during the development of an Indefinite Delivery/Indefinite Quantity (IDIQ) implementation guide for the Minnesota Department of Transportation (MnDOT) in an effort to find a fair and equitable approach to adjust unit prices in multi-year, single award, IDIQ contracts. However, this analysis is not restricted to contracts executed using IDIQ alone. This study compares the ability of several composite Construction Cost Indexes (CCIs) to reasonably estimate actual overall cost changes in MnDOT highway construction projects. The paper presents a qualitative analysis of general principles and assumptions associated with the development, maintenance, and use of CCIs. This analysis highlights the mismatch and lack of proportionality between CCI components and actual project activities as factors that hinder the efficient use of CCIs. The paper also presents a statistical analysis of twelve different composite indexes, including one published and maintained by MnDOT. All indexes were applied to four different types of projects over a five-year period. The paper concludes that MnDOT should develop an alternative price escalation method since all CCIs yielded values significantly different to those observed in MnDOT historical bid data.

Introduction

Multi-year construction contracts require the contractor to include contingencies for construction cost escalation in the out-years (West et al. 2012). To mitigate that risk, public agencies will often include escalation clauses that are tied to a particular cost index as a means of sharing the risk for escalation of material, equipment, and labor costs over the life of the contract

(Gransberg and Riemer 2009). This issue is particularly important to address in contracts such as Indefinite Delivery/Indefinite Quantity (IDIQ) contracts where options to extend the contract beyond its initial term are routinely included (Rueda and Gransberg 2014a). Without such a contractual mechanism, the pricing proposed by competing contractors could be so high that these contracts may not be able to be awarded. Therefore, the objective of this study is to evaluate the suite of available construction cost indexes (CCI) and determine their suitability for use in multi-year construction contracts. Specifically, the analysis reported herein will be conducted using the Minnesota Department of Transportation (MnDOT) as the case study agency.

Initially, index numbers were only used in an economic context to measure changes in the value of the money (purchasing power) (Fisher 1922; Allen 1975), starting with a simple (non-weighted) arithmetic index proposed by Carli in 1766 (Fisher 1922; Walsh 1901). Specifically, the first indexes were mainly intended to measure changes in the stock market, wholesale/retail prices, and wages (Fisher 1922). It was not until the early ‘20s that this practice started to be used by the construction industry (Fisher 1922). An example of this is the Aberthaw Index, which measured changes in the construction costs on a standard seven-story reinforced concrete factory building, and whose initial index number dates from 1914 (Hubbard 1921; Gill 1933). Nowadays it is possible to find several construction-related indexes intended to measure changes in factors other than money, such as quality (Lee 2013), safety (Du 2013), and sustainability indexes (Olson 2013). However, the original purpose of this mathematical instrument seems to be preserved with a wide use of CCIs to either forecast future construction costs or to adjust unit prices in long-term contracts.

Originally, this study was conducted to determine the suitability of twelve different composite CCIs for the adjustment of unit prices in multi-year single award IDIQ contracts executed by the MnDOT. However, the approach used to carry out the suitability analysis is designed to determine how well each CCI represents actual overall cost changes in MnDOT highway construction projects regardless of the procurement approach used. Initially, this paper presents a general assessment of some common assumptions made by public owners when using CCIs to adjust contract unit prices over time. The discussion at this point is mainly centered on two key aspects defined in this paper as the matching and proportionality principles, which seem to be severely violated when attempting to use a one-size-fits-all index to adjust all unit prices in contracts for any type of work. Although it was found that in traditionally procured contracts state Departments of Transportation (DOTs) tend to adjust only some selected items using specific indexes for them (Skolnik 2011), the appearance of alternative procurement approaches, such as IDIQ techniques, demands for the development of mechanisms that allow the integral price adjustment of the contract in order to reduce the greater uncertainty inherent to these techniques (Rueda 2013). The use of a single CCI to adjust all unit prices in a construction contract has been observed in IDIQs awarded by some state transportation agencies such as Florida and New York State DOTs (Gransberg and Riemer 2009).

A second part of the paper presents a statistical analysis conducted to measure the accuracy of twelve different CCIs, including one published and maintained by MnDOT, to adjust prices in different types of construction projects executed by this agency. Likewise, this analysis is used to challenge some of the assumptions and validate some findings presented in the paper. All indexes were applied to four different sample projects during a five-year period and their accuracy was determined by comparing adjusted prices with actual bid prices observed during the same period of time. Each of these sample projects is intended to resemble a different type of work commonly procured by MnDOT: asphalt pavement, concrete pavement, traffic barriers, and drainage. Actual unit prices for these sample projects at various stages during the five-year period represent average values for each pay item calculated by using MnDOT historical bid data. Historical data used to build the sample projects consists of price proposals from 1,361 contracts awarded by MnDOT, which corresponds to all contracts awarded by this agency during this period of time.

Most authors agree that by definition the accuracy of index numbers is an abstract concept (Fisher 1922; Allen 1975; Edgeworth 1925; Afrait and Milana 1984; Hansen 1984; Samuelson 1974), unless they are used as a variation indicator of a magnitude that can be exactly measured. In the case of CCIs, there is not a true number to indicate cost changes in the construction industry for a particular region or a given commodity over time. This is evident when considering that a variety of widely accepted index formulas yield different values using the same input data (Fisher 1922) and the fact that different contractors bid different price proposals for the same contract in accordance with their pricing systems. However, it does not mean that a public owner cannot evaluate the economic impact that the use of a given CCIs would have on the agency or its contractors. In this study, the impact was determined by comparing CCI-adjusted contract costs with the average costs for the same contract obtained by using observed bid unit prices. Thus, a CCI-adjusted cost above the average cost means that the agency could obtain a more advantageous project cost if awarded or the remaining portion of the contract to a new low bidder.

This paper uses the ‘one-sample t-test’ to draw conclusions regarding the suitability of the twelve evaluated CCIs, yielding values significantly different from the average values obtained from MnDOT historical bid data.

Background

Price indexing literature in the transportation industry is mainly focused on the use of CCIs for risk management purposes and to forecast project costs in an attempt to develop more accurate estimates. Situations under which CCIs are commonly used as rough indicators. Much has been written about the development, implementation, and use of different CCI forecasting approaches using different types of techniques such as time series, multiple regression, and neural network models (Hanna and Blair 1993; Touran and Lopez 2006; Williams 1994; Shandashti 2013). Conversely, little research has been done on effective practices for the use of CCIs in price adjustment clauses in highway construction projects and the economic impact of these clauses on transportation agencies and contractors. The lack of information on this matter was also an issue highlighted by Skolnik in 2011 on a final report for a research project conducted on price indexing practices adopted by state DOTs (Skolnik 2011).

This study found several criteria for the classification of price indexes. Some of these criteria are the mathematical model (e.g. arithmetic, geometric, aggregative), index composition and configuration (e.g. simple or unweighted, weighted, composite), frequency of publication (e.g. monthly, quarterly, annual), and scope or location(s) (e.g. national, local) (Fisher 1922; Allen 1975; Rueda 2013). CCIs may be also classified as input or output cost indexes. Input indexes measure the price change in one or more construction components or materials, while output indexes indicate observed changes in construction prices, including general costs, overhead, profit, risk, and other possible external factors (FHWA 2013; Caltrans 2013). Some of the index characteristics mentioned in this chapter are used later in this paper to describe each of the twelve evaluated CCIs.

Figure 11 presents a classification of CCIs in accordance with their usage. This classification was proposed by the authors to provide readers a better understanding of the indexes analyzed and mentioned in the paper. While indexes in Tier 1, which are aimed to adjust prices of specific commodities (e.g. fuel, asphalt, cement, steel), are mainly used for price adjustment purposes (Skolnik 2011), those in Tiers 2 and 3 are commonly intended to forecast total construction costs (Touran 2006; Williams 1994; Shahandashti 2013). Nonetheless, the incorporation of single award IDIQ techniques into the alternative contracting method toolbox of state DOTs represents a drastic change in this conception. Basically, the principal objective of this paper is to find an index in Tier 2 that allows fair and equitable price adjustments in MnDOT construction projects.

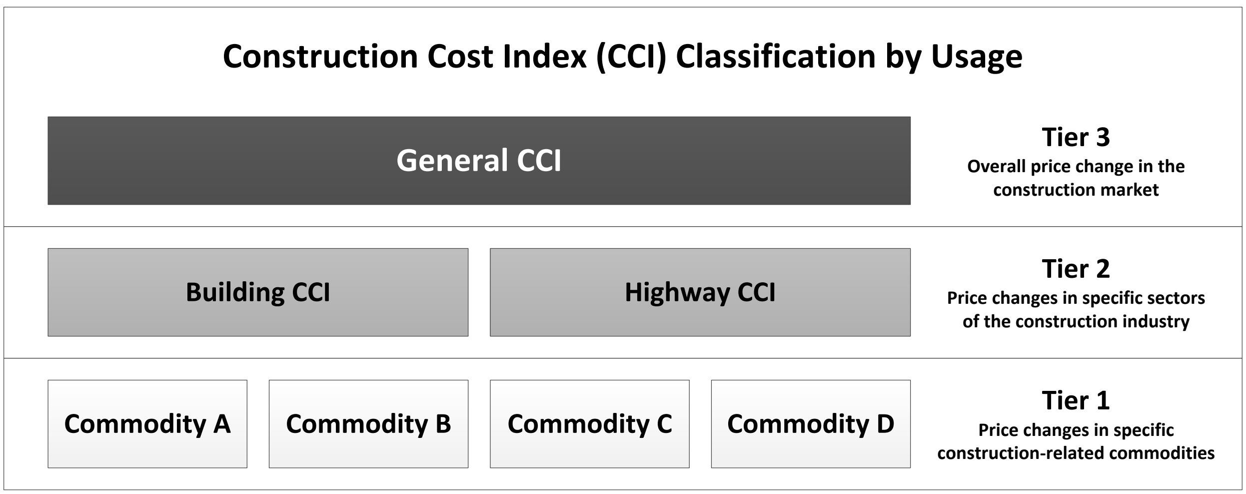


FIGURE 11 Construction cost index classification by usage.

Skolnik found that at least 47 state Departments of Transportation (DOTs) (94%) utilize price adjustment clauses using CCIs for one or more construction-related commodities (Skolnik 2011). On the other hand, the use of general, building, and highway CCIs (see Figure 11) to forecast construction costs seems to be a common practice for owners and contractors (Touran 2006; Williams 1994; Shahandashti 2013). The wide usage of CCIs and the lack of research on their effectiveness to measure changes in construction prices over time suggest that a satisfactory accuracy of these indexes has been taken for granted, which may be reconsidered in the light of the results obtained in this study.

Construction Cost Index Definition

By definition, "[a]n index number of prices […] shows the average percentage change of prices from point of time to another" (Fisher 1922). Thus, for the purposes of this paper, a CCI is defined as an indicator of the average cost movement over time of the construction market, specific sectors of the construction industry, or specific construction-related commodities. Additionally, it is important to note that all CCIs evaluated in this study are composite weighted indexes. It means that these indexes are built up by combining observed cost changes in a few significant commodities in accordance with fixed or variable weights associated to each of them.

Methodology

As mentioned before, this study is part of a larger research project conducted for MnDOT aimed to develop an IDIQ implementation guide. Information used for the development of this guide was gathered using a number of different research instruments including a comprehensive literature review complemented with a detailed content analysis of contract documents, structure interviews for the analysis of four case studies, and survey responses from different contract participants.

Data Collection, Processing, and Analysis

In order to determine the suitability of price adjustment procedures by using CCIs, twelve selected indexes, including one published and maintained by MnDOT (not used on IDIQ contracts), were applied to four different types of projects over a five-year period, from July 1, 2008 to July 1, 2013. Unit prices on these four sample projects were adjusted on an annual basis, and the results of these adjustments were compared with actual observed prices of the same construction activities during the same period of time. Historical bid data used to build up all sample projects was shaped into a three-dimensional arrangement based on the pay item identification number, letting date, and bid quantity.

The types of projects selected for this study are asphalt pavement, concrete pavement, traffic barriers and drainage projects. The selection, scoping, and pricing of sample projects for these four types of contracts, was conducted following the steps below:

- Identify types of projects commonly awarded by MnDOT.

- From MnDOT historical bid data, select a sample project for each type of contract identified in the previous step, in which the most representative items must be characteristic of its category.
- Discard those items whose units are not precisely defined (e.g. each, lump-sum), and keep those with consistent and specific characteristics that allow a price comparison over time.
- Determine the participation (%) of each pay item on the total cost of each sample project and discard irrelevant pay items that do not have a high impact on the final cost of the projects.
- After checking frequency of occurrence of each pay item in the historical bid data, replace those pay items with low frequency by more repetitive similar items whose price change over time would be easier to track.
- Assign the same final total cost to all four sample projects, $1.5 million, which will represent the total cost for all projects if performed during the first year. Then, adjust the extended price of each pay item (quantity times unit price) in order to keep the same proportions of the original contract. Thus, if two different types of asphalt were replaced by a type of asphalt that is more commonly used by MnDOT, its participation in the project (%) must be equal to the sum of the participation of both discarded pay items.

There is no specific reason for the selection of $1.5 million as the base total cost (from July 1, 2008 to July 1, 2009) for all projects. It is irrelevant to the goals of the study. Regardless of its value, it is important to have the same base total cost for all sample projects since it makes it easier to compare the impact of the same index on different types of contracts. Quantities and unit prices are also irrelevant for the sample projects, since price changes of each pay item will be applied to its extended price rather than to its unit price.

Since a deeper analysis on each pay item on the sample projects indicates that units prices in all pay items are inversely proportional to the bid quantity, except in one case (2501603/00124 Lining Culvert Pipe 24”) in which no relation was found between unit prices and quantity, and given that average bid quantities on a single pay item may vary from period to period, it was necessary to arrange all recorded bid prices in groups of similar work quantities. Bid quantity ranges for each pay item were determined based on the distribution of the bids on a scatter plot and the average largest variation between the lowest and largest bids received for the same item for the same contract at the same moment. In other words, this average variation may be understood as the average maximum difference between two bids for the same pay item and quantity. Figure 12 and Table 8 illustrate the process followed to define the bid quantity ranges for a given pay item and the estimation of average unit prices for that item in six-month intervals, respectively.

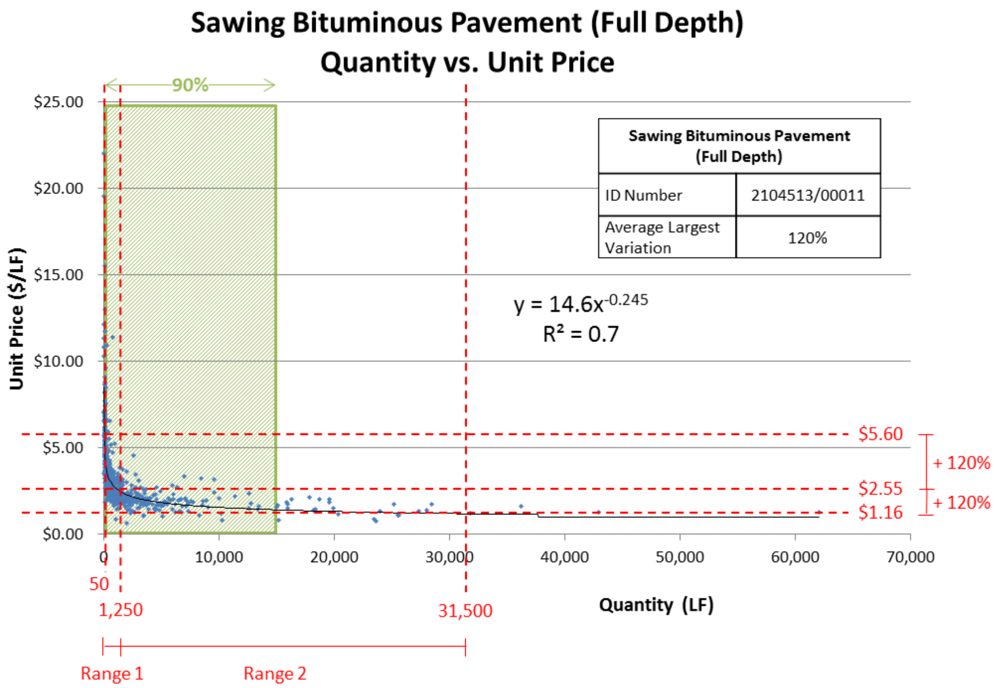


FIGURE 12 Sawing Bituminous Pavement – bid range determination.

TABLE 8 Sawing Bituminous Pavement – Average Unit Price

Sawing Bituminous Pavement (Full Depth) – Average Unit Price ($/LF)											
Time / Quantity (LF)	2008		2009		2010		2011		2012		2013
	Jul. 1st Apr-Sep	Jan. 1st Oct-Mar	Jul. 1st Apr-Sep	Jan. 1st Oct-Mar	Jul. 1st Apr-Sep	Jan. 1st Oct-Mar	Jul. 1st Apr-Sep	Jan. 1st Oct-Mar	Jul. 1st Apr-Sep	Jan. 1st Oct-Mar	Jul. 1st Apr-Sep
Range 1 (50 -1,250)	$3.24	$3.68	$3.51	$3.71	$3.34	$4.28	$3.83	$3.67	$3.84	$4.54	$4.05
Range 2 (1,250-31,500)	$1.96	$1.98	$1.76	$2.04	$2.00	$1.91	$2.21	$2.11	$2.05	$2.06	$2.10

As will be presented later in this paper, sample projects were adjusted on an annual basis since this is a common timeframe used to adjust construction prices. Adjustments in the actual total costs of all pay items were performed in six-month intervals. It was made with the intention of observing the behavior of the prices between adjustment dates. Actual prices in sample projects were estimated each year on January 1st and July 1st, from July 2008 to July 2013. Thus, bid unit prices recorded by MnDOT between October and March were used to estimate average unit prices on January 1st and those between April and September were used to estimate average unit prices on July 1st (see Table 8).

The variation in the unit price of each pay item was calculated by computing the arithmetic average of the variations of each quantity range between two periods of time, as shown in the Equation 3. In order to calculate the unit price variation between two periods in a single quantity range, both periods must contain an average price; otherwise, this quantity range is not considered to estimate the final price variation. This happens when a pay item is not used during a given period. Equation 3 shows the calculation of the variation between July 1st 2008 and January 1st 2009 for the pay item presented in Table 8.

$$\frac{Average\ Range\ 1 + Average\ Range\ 2}{Number\ of\ Average\ Rates} = \frac{\frac{\$3.24+\$3.68}{2} + \frac{\$1.96+\$1.98}{2}}{2} = \$2.71 \qquad \text{eq.3}$$

In an effort to discard unbalance bids, those bids with unit prices equal to $0.00 (zero) were excluded from the study. Likewise, outliers were removed from the data by applying the modified Z-score method on each quantity range on an annual basis. This outlier identification method was selected given that it is more suitable for small samples (Iglewicz and Hoaglin 1993), which was the case of some quantity ranges in this study. To use only commonly procured work quantities in the study, the five percent lowest quantities were discarded and quantity ranges were determined until at least 90% of the observations were covered (see Figure 12).

Analysis and Discussion

Cost Indexing Practices - Qualitative Analysis

Table 9 presents a description of the twelve indexes used in this study, whose use has been widely recognized in the building and highway construction industry. This table indicates the components used by each cost index, scope of each index based on the area covered by their periodical publications, frequency of publication, and type of index (input or output index). Four building CCIs were used in this study. The remaining eight correspond to CCIs commonly used on highway construction contracts, and others developed by three different state DOT agencies.

TABLE 9 Building and Highway Construction Cost Indexes

INDEX	COMPONENTS	SCOPE	FREQUENCY	TYPE
Building Construction				
RsMeans: Construction Cost Index (CCI) (National & Local)	• 9 types of buildings - 66 construction materials - Wage rates for 21 different trades - 6 types of construction equipment	• National: 30-city average • Local: 318 cities	• Quarterly	Input
Engineering News Record: Building Cost Index (BCI) (National & Local)	• Cement • Structural Steel • Lumber • Labor	• National: 20-city average • Local: 20 cities	• Monthly	Input
Highway Construction				
Engineering News Record: Construction Cost Index (CCI) (National & Local)	• Cement • Structural Steel • Lumber • Labor	• National: 20-city average • Local: 20 cities	• Monthly	Input
Bureau of Labor Statistics: Producer Price Index (PPI) – Highway and Street Construction (BHWY) & Other Non-Residential Construction (BONS)	• BHWY: Material and supply inputs for highway and street construction • BONS: Material and supply inputs for construction related to: - Water and sewer lines - Oil and gas pipelines - Power and communication lines - Highway, street and bridge construction - Flood control	• National	• Monthly	Input
U.S. Federal Highway Administration: National Highway Construction Cost Index (NHCCI)	• Pay items with constant price-determining characteristics from 45 U.S. states	• National	• Quarterly	Output
California Department of Transportation: Price Index for Selected Highway Construction Items (Quarterly & Annual)	• Roadway excavation • Aggregate base • Asphalt concrete pavement • Portland cement concrete (Pavement) • Portland cement concrete (Structure) • Bar reinforcing steel • Structural steel	• California	• Quarterly • Last 12 months	Output
South Dakota Department of Transportation: Construction Cost Index (CCI)	• Unclassified excavation • Liquid asphalt • Asphalt concrete • Gravel cushion (sub-base and base) • Portland cement concrete pavement • Class A concrete (structures) • Reinforcing steel • Structural Steel	• South Dakota	• Annual	Output
Minnesota Department of Transportation: Construction Composite Cost Index	• Excavation Index - Excavation • Structures Index - Reinforcing steel - Structural steel - Structural concrete • Surfacing Index - Bituminous pavement - Concrete Pavement	• Minnesota	• Quarterly • Annual	Output

Cost Indexing Principles and Assumptions

Economics and statistics literature mention several parameters that should be met in order to validate the applicability of an index. For instance; although his work has been strongly questioned by other authors (Eichhorn 1976; Swamy 1965), Fisher proposed seven different statistical tests (not discussed in this paper) to measure different properties of price indexes to determine their appropriateness (Fisher 1922; Allen 1975; Hansen 1984). Although most authors discuss issues that may result in inaccurate index numbers, they are mainly associated with the construction and maintenance process of the indexes. For example; Allen highlights three different causes for these issues; wrong choice of the index formula, errors of measurement, and sampling errors (Allen 1975). These issues may be addressed by an appropriate selection and application of an index formula and the implementation of effective data collection techniques. Therefore, this study is mainly focused on conceptual issues related to an incorrect interpretation of the price index theory by state DOTs. The principal misconception issues identified by the authors are related to the mismatch and lack of proportionality between CCI components and actual project activities, which are referred to in this paper as the matching and proportionality principles.

The matching principle refers to the degree of similarity between the commodities used for the calculation of index numbers and the actual project activities in CCI-adjusted contracts. The probability principle appears once the matching principle has been fairly met. It refers to the degree of consistency between the weights of index components and the actual contribution of these components to the total cost of CCI-adjusted contracts. Thus, a perfect application of a CCI (unlikely situation) implies that each pay item in a given CCI-adjusted contract is represented by one commodity in the CCI and the weights used in the calculation of the index numbers are exactly proportional to the contribution of their respective pay items to the total project cost. In this case, all discrepancies between adjusted and actual costs could be attributed to the three types of issues mentioned by Allen. It should be noted that a violation of the first principle implies a violation of the second one.

The principles mentioned above have been somehow referred to by other authors, who agree that perfectly consistent indexes are an unrealistic goal (Fisher 1922; Allen 1975; Hansen 1984). Below are listed some common assumptions identified in this study related to the use of CCIs to integrally adjust contract prices. The first two assumptions present the strongest violation to these principles. Basically, an agency decides to use a single CCI as the representation of an overall cost variation in the construction industry and apply this single index to adjust prices in different types of projects (assumption 1), making it impossible to match commodities and pay items in all potential CCI-adjusted contracts. Then, the agency selects a few significant materials, and using fixed or variable weights, calculates this single index (assumption 2). The latest statement entails a violation of both principles since not all contracts share the same pay items, and even if they do, they would not be equally included (contributing same % of total project costs) in all contracts.

1. Changes in the construction market from period to period have equal or similar impact on all kind of construction projects.
2. Weighted price changes between construction periods in a few significant materials or construction components represent an overall construction cost change during the same period of time.
3. Steady quality and production rates over time in construction materials and activities.
4. Construction prices for the oncoming period follow a trend marked between the base period (at letting date) and the last period with known index.

As mentioned before, the authors do not expect agencies to develop and/or implement CCIs that perfectly comply with the matching and probability principles. Therefore, the problem now is to determine how much a price adjustment method, using a CCI, can deviate from these principles, and how to measure this deviation. The statistical analysis presented in the remaining part of this paper is intended to solve these two problems. The evaluation of different CCIs, including some published by organizations with several decades of experience in this matter (e.g. BLS, ENR, RsMeans), mitigates the risk of errors due to the three types of issues mentioned by Allen. Thus, this study assumes that all variations obtained in the next section between CCI-adjusted prices and actual observed prices are the result of inconsistencies between the index commodities and contract pay items. On the other hand, the one-sample t-test was used as an instrument to determine the significance of these variations, providing a better interpretation of the results. It can be considered that those indexes that showed significant different price changes, than those actually observed in MnDOT historical bid data, deviated too much from the matching and probability principles and their use should be carefully considered by this agency.

Assumption 3 is not discussed in this paper. However, variations in labor productivity and quality rates are common issues in the construction industry. Several authors have studied different causes and consequences of these variations and have proposed techniques to mitigate owners' risk in relation to this matter (Halligan et al. 1994; Abdel-Razek et al. 2007; Rosen 1983). Thus, any agency efforts to reduce uncertainty in labor productivity and quality rates would help to mitigate the negative impact of this assumption.

Assumption 4 is related to the fact that unit prices are adjusted using indexes that correspond to two previous periods. In other words, next year prices are expected to follow the trend set by two previous indexes, preventing the agency from considering multiple potential factors that may impact the continuity of this trend.

Cost Indexing Practices - Statistical Analysis

Before comparing the impact of different CCIs on the four sample projects, the actual costs of these projects were calculated on six-month intervals and compared with each other. Figure 13 illustrates these costs for the five-year period comprised in this study. A five-year period was selected based on the fact that this is the largest possible contract period (base contract period + contract extensions) in IDIQ contracts already awarded by MnDOT.

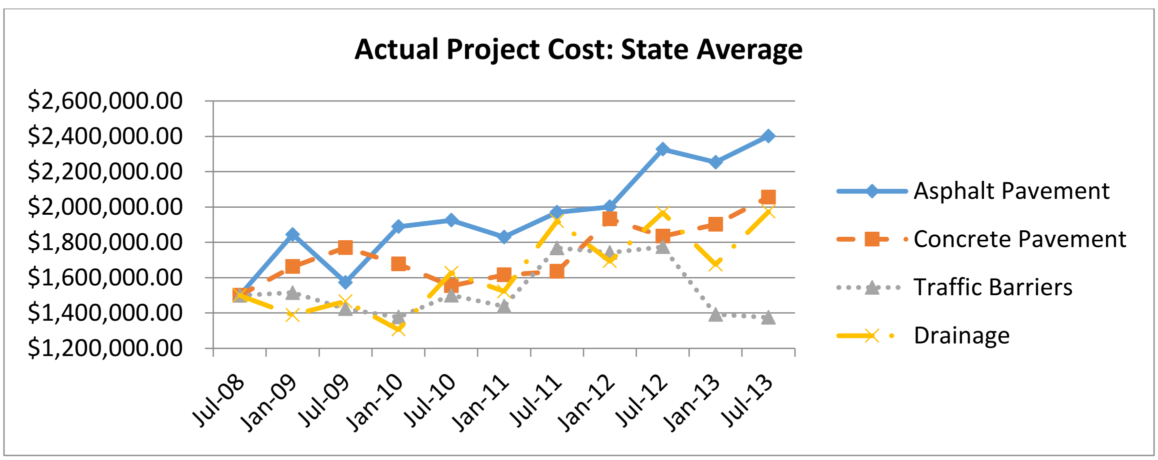


FIGURE 13 Actual project costs of sample projects – state average.

Figure 13 challenges assumptions 1 and 2 stated before regarding the use of CCIs to adjust contract prices. This figure shows how distinct types of projects are differently impacted by changes in the construction market during the same period of time. For instance, asphalt pavement projects present a higher volatility, while drainage projects show a seasonal behavior due to their cyclical variations. Only once during the ten six-month periods all the variations followed the same direction (project costs in all sample projects increased between January and July 2011).

Table 10 shows absolute average variations between CCI-adjusted costs and actual observed costs (|1-(adjusted cost/actual cost)|). This table allows a comparison between different CCIs performances, providing a general idea of the accuracy of each index.

TABLE 10 Average Variation pre Index and Type of Project

Cost Indexes	Average Variation (+/-)				
	Asphalt Pavement	Concrete Pavement	Traffic Barriers	Drainage	Average per Index
Building Construction Indexes (National)					
RSMeans - CCI (National)	18.82%	7.93%	6.44%	10.83%	**11.00%**
ENR - BCI (National)	18.76%	8.07%	10.25%	10.28%	**11.84%**
Average per Type of Project	**18.79%**	**8.00%**	**8.34%**	**10.56%**	-
Highway Construction Indexes					
ENR - CCI (National)	17.20%	7.72%	11.07%	9.30%	**11.32%**
BLS – PPI	26.98%	16.54%	10.62%	17.52%	**17.91%**
NHCCI	33.83%	25.16%	20.94%	26.41%	**26.58%**
Caltrans (Quarterly)	30.12%	19.96%	26.47%	21.90%	**24.61%**
Caltrans (12-M)	27.06%	17.59%	20.56%	18.94%	**21.04%**
SDDOT	16.96%	6.48%	12.38%	8.15%	**10.99%**
Average per Type of Project	**25.36%**	**15.58%**	**17.01%**	**17.04%**	-
Minnesota & Minneapolis Indexes					
RSMeans - CCI (Minneapolis)	18.33%	7.63%	11.02%	10.61%	**11.90%**
ENR - BCI (Minneapolis)	19.96%	9.40%	9.96%	10.76%	**12.52%**
ENR - CCI (Minneapolis)	20.34%	9.46%	10.26%	11.21%	**12.82%**
MnDOT - CCI	18.09%	5.50%	12.92%	10.19%	**11.68%**
Average per Type of Project	**19.18%**	**8.00%**	**11.04%**	**10.69%**	-

The following observations and conclusions were drawn from a deeper analysis of Table 10. It is important to note that these observations only apply to MnDOT and the five-year period comprised in this study:

- Unexpectedly, those national construction indexes commonly used to adjust contract prices in building construction projects (RSMeans and BCI) presented an overall closer relation to actual price changes in MnDOT construction projects.

- Regardless of the kind of CCI (building or highway) and the national or local coverage of the indexes, these CCIs seem to work best in concrete pavement contracts. Nine out of the twelve indexes showed a lower average variation in concrete pavement projects.
- The South Dakota DOT (SDDOT) CCI showed the lowest overall variation closely followed by national RSMeans CCI. However, the low average in the RSMeans index seems to be consequence of its considerably low variation in traffic barrier projects. If removing the traffic barrier sample project from the study, SDDOT CCI average variation would decrease even more (10.53%) followed by the MnDOT CCI (11.26%) and the national ENR CCI (11.41%), and sends the RSMeans CCI to the sixth place with an average variation of 12.53%.
- All CCIs presented the largest average variation in asphalt pavement projects, which is an important observation given that, as determined in this research, those pay items related to these types of projects represent the largest portion of MnDOT average annual construction budget (25%) for the period comprised in this study.
- When considering the actual sign (positive or negative) of each variation, it was found that the use of CCIs, as part of escalation clauses, seems to represent a higher benefit for MnDOT while allocating more risk to the contractors.
- In spite of the fact that MnDOT CCI did not show the lowest overall variation, this index presented the lowest variation for a single type of project; concrete pavement. Additionally, this was the only index that in the case of the concrete pavement project, increased when observed prices increased and decreased when they decreased.

One-Sample T-Test

The one-sample t-test was conducted following the methodology described by Boddy and Smith (Boddy and Smith 2009). Table 11 summarizes this statistical test, which is used to make objective conclusions about the accuracy of these indexes to predict changes in construction prices in MnDOT projects. A rejection of the null hypothesis indicates the value estimated using that CCI is significantly different to the actual value obtained from MnDOT historical bid data. Therefore, it was statistically proven that none of the twelve indexes considered in this study is suitable for cost escalation at the project level.

TABLE 11 One-Sample T-Test Summary

Null Hypothesis: Average Variation = 0.00% (μ = 0.00%) Alternative Hypothesis: Average Variation ≠ 0.00% ($\mu \neq$ 0.00%) Significance Level = 5% Table Value = 3.18		
Construction Cost Indexes	**Test Value**	**Conclusion**
Building Construction Indexes (National)		
RSMeans - CCI (National)	3.26	Reject Null Hypothesis
ENR - BCI (National)	4.19	Reject Null Hypothesis
Highway Construction Indexes		
ENR - CCI (National)	4.71	Reject Null Hypothesis
BLS – PPI	4.33	Reject Null Hypothesis
NHCCI	8.09	Reject Null Hypothesis
Caltrans (Quarterly)	9.57	Reject Null Hypothesis
Caltrans (12-M)	8.69	Reject Null Hypothesis
SDDOT	4.18	Reject Null Hypothesis
Minnesota & Minneapolis Indexes		
RSMeans - CCI (Minneapolis)	4.35	Reject Null Hypothesis
ENR - BCI (Minneapolis)	4.22	Reject Null Hypothesis
ENR - CCI (Minneapolis)	4.23	Reject Null Hypothesis
MnDOT - CCI	3.69	Reject Null Hypothesis

Significance Level: Probability of wrongly rejecting the null hypothesis.
Table Value: Taken from t-distribution table.
Test Value: (|mean – null hypothesis| x (sample size)^0.5)/sample standard deviation.
Conclusion: Test Value > Table Value → Reject null hypothesis;
Test Value < Table Value → Cannot reject null hypothesis.

Conclusions and Recommendations

Assuming that MnDOT contracting practices do not differ significantly from those adopted by other state DOTs, findings obtained by the qualitative and quantitative analyzes conducted in this paper may be seen as an indication that the great diversity in types of highway construction activities makes these kinds of projects bad candidates for the use of price adjustment clauses based on composite CCIs. It means that even if a given CCI can truly measure overall construction costs changes in the transportation industry, it would not be applicable for price adjustments at the project level. CCIs used in this study could probably be used as a decision-making criterion in situations that involve the transportation industry as a whole (or their respective construction sectors), but taking into consideration that the use of different indexes may lead to different decisions. The different results obtained when measuring changes in construction costs with different highway CCIs confirm what has been stated by several authors in regard to the high uncertainty inherent in price indexing techniques. Therefore, MnDOT and other public owners should bear that in mind if they decide to implement these techniques.

In spite of the fact that the use of more specific indexes (e.g. liquid asphalt index, fuel index) to adjust one or a few specific pay items was not considered in this study, their narrower scope suggests a better compliance with the matching and proportionality. Although further research is needed to determine the effectiveness of these price indexes in escalation clauses, specifically focused on the economic impact of non-adjusted items, a previous study found a generalized acceptance of this practice by state DOTs in traditionally procured contracts. Nonetheless, for reasons not discussed in detail in this study, this approach would not fulfill the specific price escalation requirements of multi-year single award IDIQ contracts. Previous research found that IDIQ techniques require the implementation of escalation clauses that allow an integral adjustment of contract prices over time. In view of the results obtained by the qualitative and quantitative analysis presented in this paper, the authors recommend MnDOT to conduct further research intended to develop of more flexible price escalation approaches to adapt to the nature of each contract and with the ability to consider imminent future changes in the construction industry.

Acknowledgments

The authors acknowledge the members of Minnesota, Florida, New York State, and Missouri DOTs, as well as the Central Federal Lands Highway Division for their contribution to this study.

CHAPTER 6

EFFECTIVE RISK MANAGEMENT STRATEGIES IN CONSTRUCTION AND MAINTENANCE INDEFINITE DELIVERY/INDEFINITE QUANTITY CONTRACTS

Rueda-Benavides, J.A., and D.D. Gransberg, "Effective Risk Management Strategies in Construction and Maintenance Indefinite Delivery/Indefinite Quantity Contracts", *2016 Transportation Research Board Annual Meeting Compendium of Papers*, Paper 16-6287, National Academies, January 2016, Session 555, 18 pp.

Abstract

Indefinite Delivery/Indefinite Quantity (IDIQ) contracting has been used by state departments of transportation for decades under a wide variety of names: job order contracts, push-button contracts, on-call contracts, master contracts, stand-by contracts, and the list goes on. The common factor that makes each of these procurement methods to be generically classified as IDIQ agreements is their use of a single procurement transaction to advertise, evaluate, and award a contract that provides the capacity to execute multiple projects for a quantity of services or products that is not known at the time the contract is signed. The higher level of uncertainty resulting from the "indefinite" nature of this contracting methodology brings the need for a set of risk management practices that are somewhat different than those used in traditional procurement approaches because of the multiple, repetitive nature of IDIQ. This paper presents a two-part framework for IDIQ contract risk analysis. The framework suggests the use of several risk management strategies during the planning phase (first part) and monitoring/control phase (second part) of the risk analysis process. This study is the result of a formal content analysis of IDIQ procurement documents, policy and procedure manuals from public agencies and the careful examination of survey responses from different types of contract participants.

Introduction

"Risk is pervasive in transportation. Transportation agencies must develop explicit enterprise risk management strategies, methods, and tools." (Curtis et al. 2012). In the past several years, state departments of transportation (DOT) and other public transportation agencies have recognized the importance of formally addressing risk in the project development and delivery process (Gransberg and Gad 2014). However, as evidenced by the above quotation, most risk analysis is conducted at the project level. The advent of enterprise risk management seeks to elevate the process to the program level. The one gap in the literature is recognizing risk management as applied to Indefinite Delivery/Indefinite Quantity (IDIQ) contracts. IDIQ is a single contract with multiple projects as opposed to enterprise risk management which is composed of multiple projects with each having a single contract. One reason the gap exists is due to the size of the average DOT IDIQ work order (WO) (Rueda and Gransberg 2014b). As commonly applied by state public owners, IDIQ contracts are composed of a series of projects whose scopes are nearly identical and whose costs are comparatively low when compared to new construction. Nevertheless, IDIQ requires the agency to have specific risk management tools that are not present in a single-project/single-contract situation. A major difference is the ability for the agency to stop issuing new WOs due to the occurrence (or imminent occurrence) of an unfortunate event, such as a contractor whose quality and performance is unsatisfactory.

In order to attain the ability to effectively terminate a problematic contract without the risk of protest or claim by merely not issuing any further WOs, state DOTs must deal with risk factors not commonly found in traditionally procured single-project contracts. Thus, this paper's prime purpose is to propose a two-part framework for IDIQ contract risk assessment. The first part corresponds to the risk planning phase, where agency's planners must identify potential risk factors and develop a Risk Management Plan (RMP). In order to assist DOTs with these two tasks, the authors have developed an IDIQ Risk Planning Reference Sheet containing a series of risk management strategies to mitigate, avoid, or transfer the risk related to eight unfavorable situations associated with the use of IDIQ contracting practices. It includes some strategies proposed by the authors as well as others currently used by different types of government agencies and applicable to the transportation construction industry.

The second part of the framework refers to the risk monitoring and control phase. This formalizes the possible anticipated termination of IDIQ contracts through the cessation of issuing WOs to eliminate the risk of an imminent or ongoing negative event. The eight risk events in the reference sheet are listed below:

1. Higher than needed project administration costs and efforts.
2. Disproportion between the number of awardees and quantity of work

3. Final product below minimum performance standards.
4. Work order(s) substantially deviated from contract scope of work.
5. Erroneous identification of the low-bid.
6. Estimating, scheduling, and constructability errors found during construction.
7. Unreasonable compensation of mobilization expenses.
8. Large contingencies in price proposals due to potential cost escalation.

Background

IDIQ contracting practices were first used by the newly organized General Services Administration (GSA) by the Federal Property and Administrative Service Act of 1949. The implementation of these innovative contracting techniques was motivated by the need to accelerate the acquisition of supplies and services recurrently procured by federal agencies (GAO 1979; Matchette and Danis 1995; US Congress 1951). This method has been used for several decades by state and municipal agencies for the acquisition of architect-engineer and information technology services. However, it began to be applied to construction and maintenance activities only during the last ten years by state and municipal agencies in Florida, New York, and Missouri (Rueda and Gransberg 2014a). Repetitive protests claiming that contracting agencies were using it to circumvent competitive bidding regulations resulted in multiple congress studies on different IDIQ contracts (Sandner and Snyder 2001).

The lack of public confidence in IDIQ and other streamlined contracting approaches led Congress to enact the Federal Acquisition Streamlining Act (FASA) in 1994, which regulates the use of federal funds with these contracting techniques, making them more transparent, efficient, and competitive (Sandner and Snyder 2001; US Congress 1994). However, many state Departments of Transportation (DOTs) have found these statutes are not applicable to their IDIQ contracting programs due to the marked difference between contracting practices and policies applied at the federal and state level (Rueda and Gransberg 2014a). As a result, many DOTs have been individually dealing with the new challenges emerging from the execution of IDIQ highway construction/management contracts. This has led to the implementation of different sets of procedures and risk management practices by each agency.

This paper is an extension of a larger study conducted at the federal level intended to identify and analyze effective practices related to use of IDIQ contracting by state transportation agencies. A complete report of that study is presented in the NCHRP Synthesis 473: Indefinite Delivery/Indefinite Quantity Contracting Practices (Gransberg et al. 2015a). In NCHRP Synthesis 473 the authors concluded that IDIQ techniques can be used "on virtually all types of work as their scope comprises frequently required tasks" (Gransberg et al. 2015a). For this to be effective, DOTs need to implement flexible policies that allow for the adjustment of contracting procedures to incorporate different sets of risk management strategies based on the scope and size of the contract as well as the IDIQ model to be used (Gransberg et al. 2015a).

Motivation

The high uncertainty inherent in IDIQ contracting has forced contractors to adopt a risk profile that is fundamentally different from the one assumed when preparing a proposal for a traditionally procured contract (Farris 2002). Contractors participating in this study stated that they perceived IDIQ contracting as a high risk procurement mechanism in comparison with traditional approaches. Nonetheless, they were also clear at stating that this negative perception was not enough to prevent them from bidding IDIQ contracts since this higher risk is mitigated by including larger contingencies in the price proposals. This has resulted in DOTs requiring to develop and implement effective practices to reduce the uncertainty and risk contained in IDIQ contracts (Gransberg et al. 2015a).

Transportation agencies seem to be fully aware of the negative perception of IDIQ techniques (in terms of risk) among contractors and the effect that it may be having on price proposals. However, the increasing use of IDIQ contracts by DOTs suggest that the benefits outweigh the negative perception from contractors. These benefits include the reduction of project delivery periods, the flexibility in quantity and delivery scheduling, the ability to provide quick response under emergency situations, and the potential reduction in contract administration costs and efforts (Rueda and Gransberg 2014a; Gransberg et al. 2015a).

In spite of having proven its capacity to handle large contracts with broad scopes at the federal level (Rueda and Gransberg 2014a; USAF 2014b), most state transportation agencies have relegated the use of IDIQ contracting to minor construction and simple maintenance/repair activities. The NCHRP Synthesis 473 (Gransberg et al. 2015a) found that, in addition to local regulatory restrictions, the limited use given to these contracts by DOTs is due to the lack of suitable tools to handle the non-traditional risk factors present in IDIQ contracts. Larger and more complex contracts require the implementation of superior risk management procedures given the higher risk perceived by the different contract participants (Morris 2006; Touran and Lopez 2006). The ability of federal agencies to use IDIQ for broad and complex scopes of work may be explained by the mature set of procedures and policies available as a result of decades of experience of all US federal organizations (Rueda and Gransberg 2014b). Additionally, the diversified procurement practices found among state transportation agencies have hindered the standardization of IDIQ contracting procedures nationwide.

A critical factor that has prevented the exchange of experiences and lessons learned among DOTs is the use of different contract terminology. This is unique at almost every agency. Using different names to refer to IDIQ contracts and WOs not only has prevented the comparison of policies and procedures among agencies, but also within each of these organizations. There are some DOTs in the process of developing IDIQ programs for construction and maintenance projects unware of the existence of similar programs used by other offices within the same agency. For example; concurrently with this study, the California DOT (Caltrans) was planning for the development of a Job Order Contracting (another name for IDIQ) program for highway construction/maintenance projects. In doing so, this agency was interested in analyzing similar initiatives implemented by other DOTs. Nonetheless, this study found that Caltrans had already been successfully executing three-year multiple award IDIQ contracts for the removal of underground hazardous materials under the name of multi-provider agreements. These agreements are intended to provide services at an "on-call and as-needed basis" (Caltrans 2014) within different geographic regions established in the contract documents.

By definition, an IDIQ is "the type of contract that provides for an indefinite quantity of supplies and/or services whose performance and delivery scheduling is determined by placing work orders with one or multiple contractors during a fixed period of time" (Gransberg et al. 2015a). The list below corresponds to different terms used by various federal and state agencies to refer to contracting approaches that meet this definition. The recognition of the similarities among these types of contracts and the thorough analysis of these approaches have given the authors a unique perspective of the state of the practice of IDIQ contracting by public transportation agencies. It has allowed for an unprecedented nationwide compilation of effective risk management practices and the identification of opportunities for improvement applicable to all contracting mechanisms listed below:

- Task Order Contract
- Job Order Contract
- Delivery Order Contract
- On-Call Contract
- Push-Button Contract
- Term Agreement
- Master Contract
- Framework Contract

Fundamentals of IDIQ Contracting

As defined above, IDIQ contracting refers to a procurement approach that allows for the acquisition of an indefinite quantity of supplies and/or services during a fixed period of time and whose delivery schedule is determined by placing WOs with one or multiple contractors (Gransberg et al. 2015a*;* Rueda 2013). The following are the definitions of three IDIQ generic models currently identified in previous studies. These IDIQ contracting models will be repeatedly mentioned throughout this paper.

- *Single Work Order IDIQ:* "A single contract is awarded to single contractor. Once the need to issue the WO arises, the contractor then performs the desired services or furnishes the requisite supplies" (Rueda and Gransberg 2014a).
- *Single Award IDIQ:* "A single contract is advertised and awarded to a single contractor who then is awarded WOs based on the pricing furnished in the initial bid package" (Rueda and Gransberg 2014a).
- *Multiple Award IDIQ:* "A single contract is advertised and a pool of qualified contractors is selected. Only those selected are subsequently allowed to bid on WOs. In most cases the WOs are awarded to the lowest bidder among the contractors in the pool" (Rueda and Gransberg 2014a).

The Federal Acquisition Regulation (FAR), which regulates procurement procedures conducted by federal government organizations, establishes a clear preference for multiple award IDIQ contracts stating "the contracting officer must, to the maximum extent practical, give preference to making multiple awards of indefinite-quantity contracts" (FAR 2005). This preference however does not apply to architect-engineer services. It has been found that the highly competitive environment provided by multiple award approaches offer greater benefits to public owners (GAO 1979; OFPP 1997). However, some authors and practitioners agree that this may not always be the most suitable approach (Gransberg et al. 2015a; DoD 1999). Figure 14 presents a framework to guide DOT planners in the selection of IDIQ contracting models based on the scope of work, the expected number of WOs, and the availability of contractors with the required capabilities to perform all projects to be executed under the contract. As will be explained later in this paper, RMPs should be adjusted based on the IDIQ contracting model. Not all risk management strategies presented herein are applicable to all models.

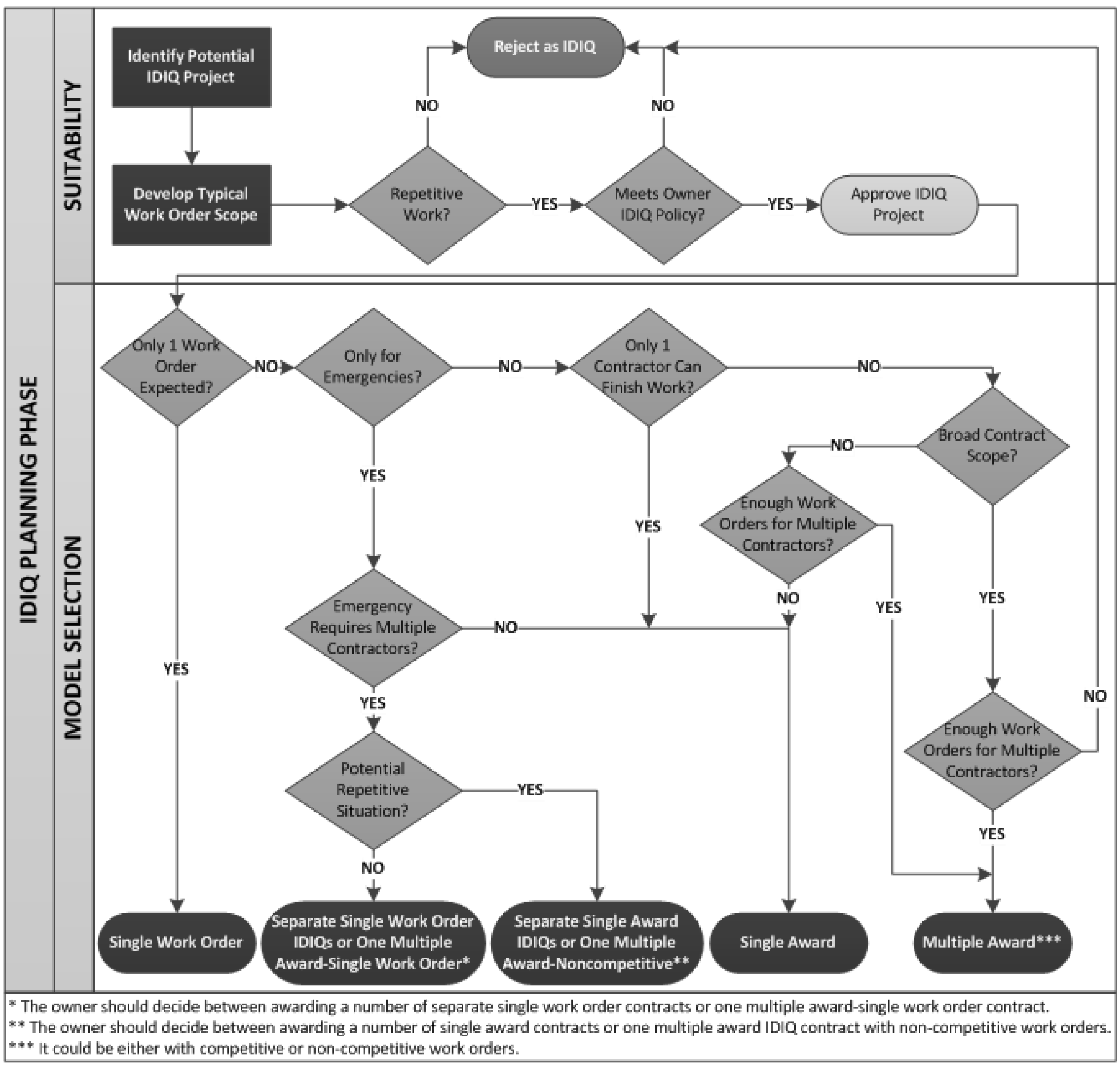


FIGURE 14 IDIQ model selection (Gransberg et al. 2015a).

As occurs with traditionally procured single-project contracts, in IDIQ contracts procurement and administration procedures are strategically selected to handle different types of risk factors. For example; a design-build WO could be used to transfer to the contractor the risk associated with potential cost overruns resulted from design inconsistencies or omissions discovered during construction; a two-step best-value selection approach could be used in a technically complex WO to ensure the selection of a contractor with the required capabilities to complete the project for a reasonable price; or cost reimbursable provisions may help to deal with projects whose prices and quantities of work are difficult to estimate. Some of the risk management strategies discussed in this paper are directly related to the proper selection of these project delivery methods and contracting approaches. However, the applicability of these strategies would depend on the contract language. Ideally, IDIQ contract provisions should allow for the use of all procurement/administrative procedures commonly used by the agency (in IDIQ and single-project contracts) in order to give contract officers the ability to customize WOs in accordance with their scope and in the best interest of the agency.

Research Methodology

Firstly this study conducted an extensive literature review and a detailed content analysis of IDIQ procurement documents, policy and procedure manuals collected from 64 public agencies. Literature studied was from different sectors of the construction industry and related to procurement practices used by different types of agencies, including non-transportation organizations. Content analysis techniques were conducted following the protocols outlined by Neuendorf (2002).

This study also included the careful examination of survey responses from 43 state DOTs and 18 industry representatives from the Associated General Contractors (AGC) and The American Road and Transportation Builders Association (ARTBA) members. Four face-to-face structured interviews with selected contractors were conducted in order to allow for an in-depth discussion on some key aspects associated with IDIQ contracting. These interviews were designed and conducted in accordance with the procedures used by the US Government Accountability Office (GAO 1991).

Information gathered through each research instrument was individually analyzed and then cross-examined. Intersections of trends found in two or more of these tools were used as the major factor to develop conclusions. Trends observed in more than one data-set helped identify effective IDIQ risk management practices and opportunities for improvement.

IDIQ Risk Management Framework

Figure 15 illustrates the two-part IDIQ risk management framework developed in this research. The risk planning phase (the first part) occurs before contract advertise/award activities and concurrently with other planning and preconstruction tasks. During this phase, DOTs could also use the IDIQ Risk Planning Reference Sheet, shown in Table 12, to aid the identification of potential risk factors and the development of the RMP. The RMP should include all relevant information related to risk management tools and strategies, the frequency of periodic risk reviews, and any guidelines and formats to be used for the preparation of the risk reports (Kendrick 2015).

The IDIQ Risk Planning Reference Sheet (Table 12) is not intended to work as a sole reference during the risk planning process; instead, it is just aimed to facilitate the identification of IDIQ-specific risk factors/strategies and their incorporation into regular risk planning activities. This sheet must be seen as a preventive tool. It can be used to help reduce the probability of occurrence for unfortunate events and minimize the impact on the project and stakeholders if they happen by supporting decision-making during planning activities at the contract and WO level.

The Risk Planning Reference Sheet provides strategies to handle eight different IDIQ contract risk events and suggest the type of response for this risk (i.e. mitigate, avoid, or transfer). Additionally, Table 12 describes the causes and effects related to each of these eight potential situations and shows the extension of the effects (at the contract [C] and/or the WO level). Finally, the last column in this table indicates the IDIQ models (single work order and single award IDIQ [SA]; and multiple award IDIQ [MA]) that are more susceptible to that type of risk. The eight risk events and their respective management strategies are described in the next sections.

A generic response plan to put into action upon occurrence (or imminent occurrence) of unfavorable situations is illustrated in the second part of the flow chart, during the risk monitoring and control phase (see Figure 15). Essentially, the agency should reserve the termination of the IDIQ contract, by stopping issuing any further WOs, only if the risk cannot be addressed without modifying contract provisions or specifications. The interruption of the contract allows the agency to make any required changes before re-procuring the contract, if it is still required.

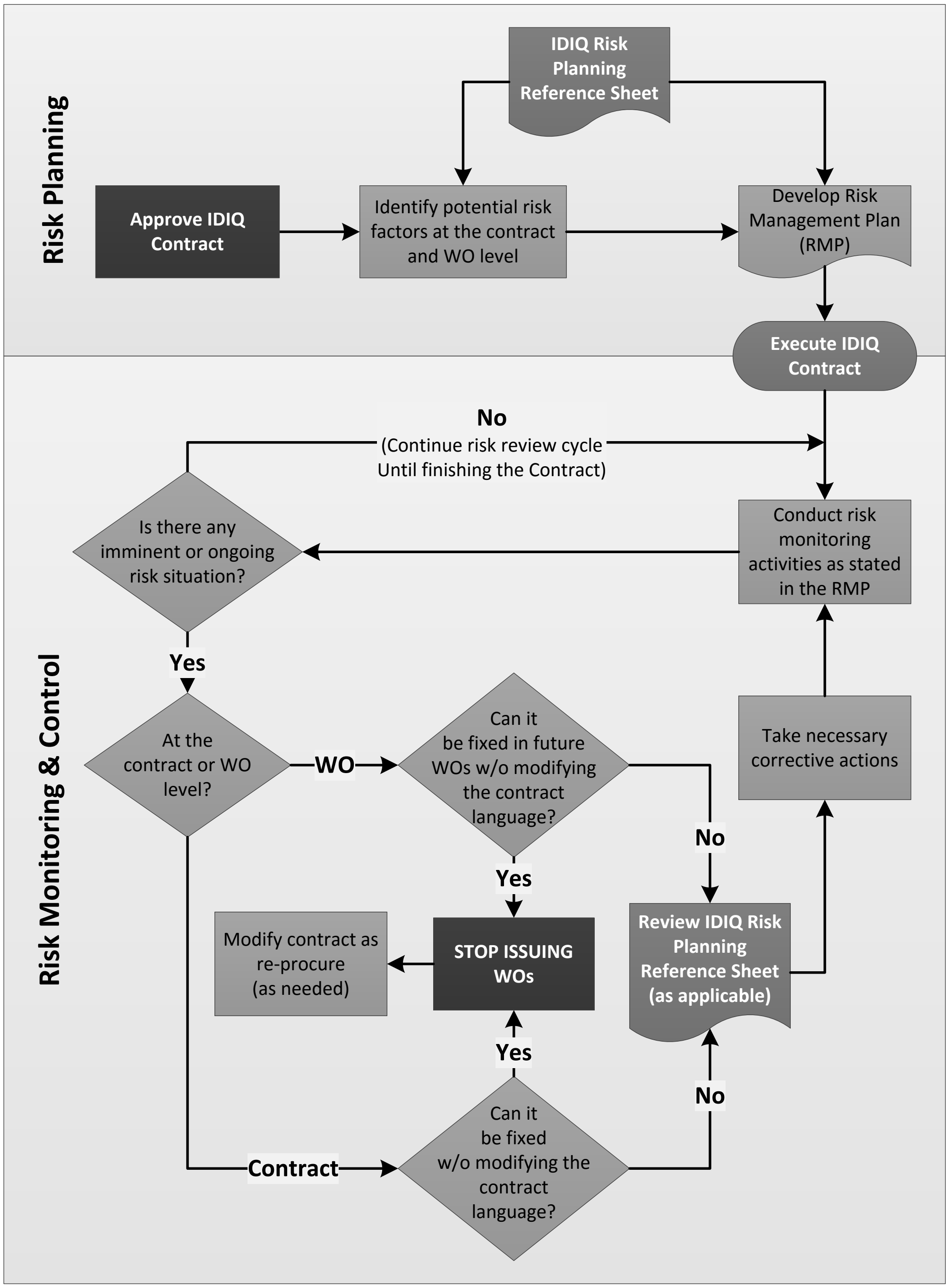


FIGURE 15 Two-part IDIQ risk management framework.

TABLE 12 IDIQ Risk Planning Reference Sheet

No.	Risk Event	Causes	Effects	Res	Risk Management Strategy	Extent	IDIQ Model
1	Higher than needed project administration costs and efforts	• Little experience with IDIQ • Attachment to traditional procurement practices • Strict and inflexible agency's policies and applicable regulations	• Decrease in agency's production capacity	Mitigate	• Streamlined/simplified procurement procedure (e.g. oral proposals, minimum submittal requirements) • Training sessions with in-house staff and pre-bid meetings with bidders	C & WO Level	All IDIQ models
2	Disproportion between the number of awardees and quantity of work	• Poor planning skills • Too small/large WOs • Inadequate selection of IDIQ model	• Too many contractors: Poor performance • Few contractors: Negative impact on agency's reputation; & high change for disputes.	Mitigate	• Determine the number of contractors correlating historical data with scope, complexity, expected number and size of WO, and required resources	C Level	All IDIQ models
3	Final product below minimum performance standards	• Inadequate project delivery method and/or contractor(s) selection procedures • Inadequate selection of IDIQ model	• Reduced serviceability and useful life of assets • Negative impact on agency's reputation	Mitigate	• Strategically select advertise/award approach (e.g. best-value selection for large and complex projects) • Advertise contract along with first WO • Include key performance indicators as a factor to award WO	C Level C & WO Level	SA IDIQ MA IDIQ
4	WO(s) substantially deviated from contract scope of work	• Poor planning skills • Unplanned use of contract to use year-end funds or to emergencies	• Higher construction prices • High chance for disputes	Mitigate	• Training sessions with in-house staff • Use historical data to define scope and to forecast future needs • Include contingency pay items (SA IDIQ)	WO Level	All IDIQ models
5	Erroneous identification of the low-bid	• The introduction of work items with negotiated unit prices not originally included in the contract and not used in the selection of the low bid. • Significant disproportion between bid quantities and total actual quantities of work	• Higher total contract cost	Mitigat Avoi	• Use historical data to define contract scope of work and determine pay items and bid quantities • Consider using MA or not using IDIQ	C Level	SA IDIQ
6	Estimating, scheduling, and constructability errors found during construction	• Design errors and omissions • Complex scope of work with quantities and prices difficult to estimate	• Delay of the project and cost overruns	Mitigate	• Take advantage of the preselected contractors to create opportunities for early contractor involvement • Use cost reimbursable WO for WOs that are difficult to estimate	WO Level	All IDIQ models
7	Unreasonable compensation of mobilization expenses	• Typical high uncertainty in IDIQ contracts due to the location and quantity of work	• Higher project costs	Mitiga	• Include multiple mobilization pay items in the contracts considering all possible project locations	C Level	SA IDIQ
8	Large contingencies in price proposals due to potential cost escalation	• Use of inappropriate or no price adjustment provisions	• Higher project costs	Mitigate Transfer	• Develop or select an existing construction cost index suitable for the scope of the project • Use AxE bidding	Contract Level	SA IDIQ

1. Higher than Needed Project Administration Costs and Efforts

Federal and state public owners seem to agree that the implementation of this contracting method represents savings in administration costs and efforts for the agency (Rueda and Gransberg 2014b; Sandner and Snyder 2001; OFPP 1997). It is almost intuitive when considering that IDIQ allows for the execution of multiple similar projects under a single solicitation, eliminating the need for re-procuring every new project. However, this benefit may be hindered by strict and inflexible contracting regulations by requiring large amounts of contract documents and complex procurement procedures (Thornton 2002).

Proposal submittal requirements should be adjusted according to the complexity and a level risk associated with the scope of contract or WO (the latter in the case of multiple award IDIQ contracts). Given that most DOTs are utilizing IDIQ for simple and small projects, it is highly recommended that these agencies consider the use of streamlined and simplified contracting techniques such as limiting proposal submittal requirements to a minimum (in terms of pieces of information to be submitted by contractors and number of pages) and oral proposals and WOs. Such procurement techniques have already been proposed for IDIQ contracts by other authors and government organizations (Sandner and Snyder 2001; OFPP 1997; AFMC 1999; Dunston and Reed 2000).

Since IDIQ techniques are relatively new for the acquisition of construction and maintenance services by DOTs, and as usually occurs with the implementation of any new procedure, the lack of experience and familiarity of DOT staff members and contractors has been hindering the utilization of this procurement method resulting in an inefficient use of agency resource (e.g. money and staff hours) (Rueda and Gransberg 2014a). Thus, it is recommended for DOTs to conduct training sessions with in-house staff and pre-bid meetings with potential bidders to educate all involved about this alternative contracting approach.

2. Disproportion between the Number of Awardees and Quantity of Work

According to Thomsen (Thomsen 2006), “by far the most important incentive [to do a high quality work] that an owner has is the promise of repeat work.” The use of this type of incentives in traditional procurement systems would require making a connection between past performance and the contractor ability to compete for future contracts, which usually implies that the agency must surmount statutory barriers (Thomsen 2006; Gransberg and Shane 2010). The multi-project nature of IDIQ contracting and the high similarity among projects provides a suitable environment for the establishment of this connection. However, the use of key performance indicators as a factor to assign WOs in multiple award IDIQ contracts may not be enough to encourage a good performance. This is the case when the contractor perceives a low probability of performing more WOs due to the large number of contractors competing. Additionally, if too many firms are awarded, contractors may be tempted to bid higher than normal prices given the lower expectations for future profits (Rueda 2013).

On the other hand, too many WOs assigned to a few contractors may increase the risk of complaints from unsuccessful bidders and regulatory entities claiming an inappropriate use of public funds (Rueda 2013). Thus, DOTs should, to the maximum extent possible, find a balance between the number contractors in a multiple award IDIQ and the expected number of WOs to be issued under the contract. It will give contractors a good opportunity to win WOs beyond a stated minimum guaranteed amount, if any. “The appropriate number of awardees is a function of project scope and complexity; expected number, frequency, and duration of work orders; and required resources for a contractor to perform all the types of work described in the contract documents” (Gransberg et al. 2015a). The correlation between these factors and the number of awardees should be established by a careful review of historical data from previous projects.

3. Final Product below Minimum Performance Standards

As mentioned above, poor contractor performance may be caused by an inappropriate determination in the number of contractors selected to enter into a multiple award IDIQ contract. Nonetheless, it was included as a separate factor in the IDIQ Risk Planning Reference Sheet in order to address other possible causes. These are: the use of an inadequate project delivery method or contractor selection procedure; and the erroneous selection of the IDIQ contracting model.

As in traditional procuring methods, the selection of the advertise/award approach and project delivery methods is dictated by the scope and complexity of the project and the risk profile of the agency. The selection of these procurement procedures (in IDIQ contracts) among those commonly used in highway construction projects follows the same principles applied by DOTs on non-IDIQ contracts. The benefits and risk management capabilities typically attributed to these project delivery methods and contracting approaches remain unchanged when they are used in IDIQ contracts.

Other risk management strategies mentioned in Table 12 refer to the use of key performance indicators for the assignment of WOs and the advertisement of the contract along with the first WO. The latter is mainly related to the use of best-value selection procedures in contracts with complex scopes of work, where the first project may help to determine the qualifications and technical capabilities of the bidders. It means that in addition to all other proposal submittal requirements, bidders must submit price and technical proposals for the first WO. It would ensure that all selected contractors would have the required capabilities to complete subsequent WOs.

4. WO(s) Substantially Deviated from Contract Scope of Work

This study found two main reasons that may lead DOTs to the issuance of WOs substantially deviated from the scope of work: poor planning skills; and the unplanned use of IDIQ contracts to quickly obligate year-end funds or to provide a quick response under emergency situations. The first of these causes might be addressed, to some extent, by the training sessions mentioned above in this paper. Rather than intentional deviations from the original contract scope of work, this situation may be the result of a failure of the planners to identify two key elements: the scope(s) of future needs to be fulfilled through the contract; and/or the work items required to address these needs. Thus, in this training sessions, DOT staff members should be instructed in the use of historical data from similar previous projects to gain a better understanding of the contract scope and a better idea of the work items usually required to complete these types of projects.

The risk related to the appearance of new pay items not originally included in the contract is higher in single award IDIQ contracts. Price proposals submitted by contractors in a single award IDIQ usually consist of a series of unit prices for a list of pay items included by the agency in the solicitation documents. Upon the award of the contract, these pay items and the unit prices submitted by the successful contractor are incorporated into the contract and used to define and price all WOs. Therefore, once awarded the contract, the agency must enter into negotiations with the contractor to determine a price for work items not included in the original price proposal. “The post-award negotiation of prices in a non-competitive environment, what would happen in a single award contract, would leave the agency in a vulnerable situation by increasing the contractor's bargaining power" (Gransberg et al. 2015a), allowing for the negotiation of disadvantageous prices for the agency.

A "voluntary" deviation from the original contract scope of work may be related to the decision of using an active non-emergency IDIQ contract during an emergency situation or motivated by the ability of IDIQ contracts to rapidly obligate available year-end funding. IDIQ contracting offer the possibility of performing work without engaging in a complete procurement process, making it a valuable response tool under these pressing situations. However, it may be a problem for the agency if work items used in this unplanned WOs were not originally included in the contract. Thus, DOTs are encouraged to plan for these situations and include in their contract documents a series of contingency pay items (only applies to single award IDIQ contracts). Contingency pay items are services or supplies that the contractor may be requested to furnish under special circumstances (Gransberg et al. 2015a). These items are not expected to be used in regular WOs.

5. Erroneous Identification of the Low-Bid

This risk event refers to the award of a single award IDIQ contract to the bidder that submitted the lowest price proposal, but which will potentially not result in the lowest cost for the agency at the end of the contract. It may happen when new work items, with post-award negotiated unit prices, are included into the contract. Under this circumstances, the agency may find it difficult to sustain or demonstrate the validity of its decision since these items were not used in the selection of the contractor. However, the closure or termination of the contract without adding any new work items does not guarantee an appropriate selection of the contractor. It would also depend on the degree of proportionality between bid quantities and actual quantities of work for all WOs at the end of the contract. Bid quantities in solicitation documents are used primarily for selection purposes and do not necessarily have to correspond to the expected total quantities of work. In fact, four DOT survey participants indicated that in the selection of the low-bid they use estimated quantities for a single typical WO. Other four agencies reported the use of standard quantities of work for all WOs. Regardless of the approach used to determine these quantities, the award decision may be sustained as long as "the bid quantities will be in the same proportion as the quantities of anticipated work required throughout the life of the contract" (Gransberg et al. 2015a).

The high sensitivity of low-bid contractor selection methods in single award IDIQ contracts, which is the usual approach in this type of contracts, implies that DOTs should try to keep the scope of the contract as uniform as possible. It would help to maintain a consistent use of the same work items and a fair proportionality between bid and actual quantities of work, regardless of the number of WOs to be issued. Thus, the selection of the low-bid would be guaranteed even after a premature termination of the contract. This conclusion supports the IDIQ model selection framework illustrated in Figure 14, which opposes to the use of single award IDIQ contracts for broad and not clearly defined scopes of works. In those cases, the framework recommends the use of multiple award IDIQ or not using IDIQ.

6. Estimating, Scheduling, and Constructability Errors Found During Construction

This risk event is considered by planners in almost all construction-related RMPs, regardless of the delivery method and contracting approaches to be used. Likewise, the causes and effects of estimating, scheduling, and constructability errors in IDIQ contracts are fundamentally the same as those in non-IDIQ agreements. The whole purpose of including this factor in the IDIQ Risk Planning Reference Sheet is to alert DOT planners of the remarkable ability of IDIQ contracts to facilitate contractor's involvement in the design and other preconstruction phases. Researchers and practitioners worldwide seem to agree with the positive impact of early contractor involvement practices in different types of contracting approaches (Rueda et al. 2015).

Having the contractor(s) selected before development of the scope of WOs allows for the earliest possible contractor involvement. Given the implications of handling inputs from multiple contractors during the design of WOs, the formal participation of contractors in preconstruction activities is more suitable for single award IDIQ contracts (Gransberg et al. 2015a). Nevertheless, certain degree of integration of design and construction phases may be achieved in multiple award IDIQ contracts by combining this methodology with other alternative contracting methods such as design-build, construction manager/general contractor, and alternative technical concepts (Gransberg and Shane 2010). The advantages and disadvantages usually attributed to these contracting techniques are realized in IDIQ contracts at the WO level. Although in these methods contractors' input cannot be brought on as early as in IDIQ contracts, this input is still considered very valuable for agencies and contractors (Gransberg and Shane 2010).

7. Unreasonable Compensation of Mobilization Expenses

The literature review and a case study analysis conducted on a previous study (Rueda and Gransberg 2014b) led the authors to conclude that the compensation of mobilization expenses is a key issue that must be fully addressed in order to succeed in the use of single award IDIQ contracts. The use of a multiple award approach eliminates this need since contractors are requested to bid a lump sum mobilization price on a WO basis. This issue is the result of the high uncertainty inherent in IDIQ contracting in regard to the actual locations of future WOs and the contractors' equipment and personnel that will be required to complete all projects throughout the contract. Responses from DOT and industry survey/interview participants and effective practices found in the literature review have allowed the authors to conclude that a suitable mobilization compensation approach would be one in which contractors are required to bid fixed prices on multiple mobilization pay items. These items should correspond to different potential locations and scopes of work, as applicable.

8. Large Contingencies in Price Proposals due to Potential Cost Escalation

Price escalation in multi-year single award IDIQ contracts was another major issued identified in this study. As a result of the absence of competition in the assignation of WOs, the contractor is either required to maintain unit price for more than one year (no price escalation clauses) or rely on fair adjustments in contract prices made on a regular basis in accordance with observed price changes in the construction market. The first option was discarded given the high risk that it represents for both owners and contractors. The volatility of some construction material prices and the uncertainty regarding actual quantities of work make it difficult for contractors to estimate unit prices for multi-year IDIQ contracts. "Contractors are willing to bid on multi-year IDIQ contracts even without escalation clauses, although it would represent higher construction costs for the agency" (Gransberg et al. 2015a). Therefore, the next step to address this issue was to identify suitable price escalation clauses to adjust contract prices on a regular basis. Annual adjustments were found to be an effective practice.

Following a similar process as the one described above to find a suitable mobilization compensation method, DOT and industry representatives were asked their opinions about different types of price escalation clauses. This study found that the adjustment of contract prices using existing national or local construction cost indexes was an accepted practice for owners and contractors. However, if using construction cost indexes, DOTs should bear in mind that price indexing techniques also involve high levels of uncertainty (Rueda and Gransberg 2015). The complexity of the construction market and the great diversity in types of highway transportation activities make it difficult to find a construction cost index applicable at the project level (Rueda and Gransberg 2015).

During a previous study conducted for the Minnesota DOT (MnDOT) (Gransberg and Rueda 2014), it was found that even though contractors doing business with this agency seem to accept the use of external construction cost indexes for price adjustment purposes, it was not their preferred option. The contractors that participated in this study showed a clear preference for the use of a fixed annual adjustment rate bid by them (%). This fixed percentage would be intended to adjust contract prices over time and would be factored into the selection of the low-bid. Since such a method did not exist at that moment, the authors decided to create it. Using information provided by MnDOT, the authors developed a method call A *times* E (AxE) bidding. More information about this innovative bidding approach may be found in the NCHRP Synthesis 473 (Gransberg et al. 2015a); however, the following quotation provides a good overview of this method:

> “Similar to A+B contracting, in an IDIQ AxE contract contractors are required to bid in two different parts; A and E. In part A, contractors must submit unit prices for those pay items and bid quantities advertised by the agency; items that are expected to be repeatedly used in different work orders throughout the contract and bid quantities that are intended to be in proportion with typical work orders. In part E, bidders are required to submit a fixed annual adjustment rate to be used to modify bid unit prices on the anniversary date of the letting of the contract. This adjustment rate is then transformed into an escalation multiplier (E), which along with the

price proposal (A), compose the selection formula (AxE) used to determine the low bid" (Gransberg et al. 2015a).

Conclusions

The identification of several types of IDIQ contracting mechanisms in use by state transportation agencies allowed to overcome the terminology barriers that had prevented the sharing of experiences and effective practices among DOTs. It allowed for the development of this unique and comprehensive study on the identification of effective risk management practices in IDIQ contracts. Several risk management strategies currently used by DOTs and others proposed by the study have been brought together into a single IDIQ Risk Planning Reference Sheet to assist DOTs in the identification of risk factors and the development of RMPs. The paper explained how the strategies in this sheet help transportation agencies to mitigate, avoid, or transfer the risk associated with eight potential unfortunate situations identified in the use of this alternative procurement method. The paper also presented a framework to guide DOTs during the risk monitoring and control phase in IDIQ contracts, explaining decision makers how to take advantage of some exceptional risk management tools provided by this type of contracts.

By the implementation of the IDIQ risk management framework and the planning reference sheet presented in this paper, DOTs will be able to optimize and increase the capabilities of their IDIQ contracting programs. However, this is still an area where further research is highly needed. Future research could help DOTs to exploit the great versatility of IDIQ techniques. Giving its ability to be used for virtually any type of project and to be combined with almost all contracting approaches commonly used by DOTs, IDIQ could be used by these agencies as a valuable customizable tool, filling gaps traditional procurement cannot address.

CHAPTER 7

STOCHASTIC COST-BASED DECISION MAKING FRAMEWORK FOR THE SELECTION OF SUITABLE PROJECTS FOR IDIQ CONTRACTING

Rueda-Benavides, J. A., D.D. Gransberg, and B. Gardner. Stochastic Cost-Based Decision Making Framework for the Selection of Suitable Projects for IDIQ Contracting (to be submitted for publication in the *Journal for Construction Engineering and Management*, ASCE, in 2016).

Abstract

The search for shorter project delivery periods and greater flexibility in delivery scheduling has triggered a rapid growth in the use of Indefinite Delivery/Indefinite Quantity (IDIQ) techniques by state departments of transportation (DOTs) during the last few years. Even though these agencies are satisfied with the benefits obtained from IDIQ contracts, it is clear for them that IDIQ is not always the most suitable option. Thus, a major issue faced by these DOTs, and the one addressed in this paper, is how to decide whether to use IDIQ or a traditional Design-Bid-Build (DBB) contracting approach for a given project or group of projects. Current methods used to make this decision are mainly scobe-based, ignoring the cost implications of using IDIQ contracting. This study proposes a decision making framework that includes expected construction costs as an IDIQ project selection criterion. This framework combines the use of historical bid data, a multi-level construction cost index, non-linear regression techniques, and Monte Carlo simulation to develop both IDIQ and DBB stochastic construction cost estimates. The selection of the contracting approach is then based on the comparison of these stochastic values and the cost, if any, that the agency considers reasonable to pay for the benefits offered by IDIQ contracting. The use of this framework is illustrated using the Minnesota DOT IDIQ contracting program as a case study and historical bid data from all IDIQ and DBB projects awarded by this agency between January 2008 and April 2015 (1,746 projects). The study confirmed that the framework produced a statistically significant improvement in cost estimate accuracy over current practices.

Introduction

For many years, traditional Design-Bid-Build (DBB) contracting techniques were considered as a one-size-fits-all procurement tool for the acquisition of construction services. However, public owners and contractors in different construction sectors have realized that DBB procurement systems do not always offer the required means to cope with the tight deadlines and even tighter budgets of today's construction environment (Gransberg et al. 2015a). This situation has forced federal and state agencies to improve their contracting capabilities by expanding their procurement toolboxes with alternative project delivery methods and contracting approaches (Molenaar and Yakowenko 2007; Walewski et al. 2001; Sanvido and Konchar 1998). The implementation of non-traditional contracting methods by these agencies is usually a challenging process, which frequently leads to an inefficient use of public resources due to a "trial and error" approach (Gransberg and Shane 2010). One of the major challenges is how to choose between an alternative contracting method and a traditional approach for a specific project (Molenaar et al. 2014; Anderson and Damnjanovic 2008; Ghavamifar and Touran 2008). "Selecting the wrong project delivery method is often a significant driver of project failure" (Touran et al. 2009). This paper is focused on mitigating this risk from a financial perspective when the decision is limited to two alternatives: Indefinite Delivery/Indefinite Quantity (IDIQ) contracting or traditional DBB techniques.

Table 13 presents the main benefits attributed to IDIQ contracting, responsible for the increasing use of this alternative contracting method by DOTs, and the disadvantages associated with its implementation. It should be noted from Table 13 that the literature does not cite potential construction cost savings as a potential benefit of IDIQ contracting, but unreasonably high construction costs are not mentioned as a disadvantage either.

TABLE 13 Advantages and Disadvantages in IDIQ Contracting

Advantages	Disadvantages
• Shorter project delivery periods (Dunston and Reed 2000; Sandner and Snyder 2001; Farris 2002). • Greater flexibility in quantity and delivery scheduling (Dunston and Reed 2000; Fleeger 2011; Ferris 2002). • Useful contracting option during emergencies (Jeffrey and Menches 2008; Gransberg and Rueda 2015; Thornton 2002).	• Lack of experience of agencies and contractor (Farris 2002; Rueda and Gransberg 2014a). • Limited ability to conduct complete planning, programming, and budgeting procedures at the contract level (Gransberg et al. 2015a).

As a co-author of the National Cooperative Highway Research Program (NCHRP) Synthesis 473: *IDIQ Contracting Practices* (Gransberg et al. 2015a), a report that compiles and analyzes current IDIQ contracting practices used by states DOTs across the country, the author of this paper had the opportunity to interview project engineers from DOTs and contractors in the transportation construction industry. Based on the opinions expressed by the interviewees, the author could identify three different lines of thought in regard to public owners cost implications of using IDIQ contracting:

1. Those who think that the possibility of performing work in more than one project should work as an incentive for contractor to submit lower bid unit prices;
2. Those who consider that this incentive may be lost by a low level of pricing certainty due to the multi-year (as long as 5 or more years) nature of IDIQ contracts, resulting in higher price proposals; and
3. Those who think that this alternative contracting approach has the potential to reduce project costs, but it is actually increasing construction prices as a result of a poor implementation by public owners.

A review of the existing literature revealed no formal research supporting or opposing any of these three opinions. The lack of a formal method to evaluate construction costs of IDIQ contracting in comparison with a more traditional approach has prevented state DOTs from validating any of the three statements listed above. Likewise, the absence of these mechanisms does not permit the use of expected construction costs as an IDIQ project selection criterion. Current methods used to make this decision are mainly based on the scope of work, ignoring the cost implications of using IDIQ contracting. To fill this gap in the body of knowledge, this paper presents a cost-based decision making framework for the selection of projects appropriate for IDIQ contracting.

The framework uses historical bid data, an alternative cost indexing system called Multilevel Construction Cost Index (MCCI), non-linear regression, and Monte Carlo simulation techniques to develop both IDIQ and DBB stochastic construction cost estimates for each project or group of projects. The selection of the contracting approach is then based on the comparison of these two stochastic construction cost estimates, the risk profile of the agency, and the cost, if any, that the agency considers reasonable to pay for the benefits offered by IDIQ contracting.

The framework can be used either to make the initial decision to utilize IDIQ contract for a group of foreseen projects or to decide whether or not to execute a given project as a work order of an active IDIQ contract. The use of this framework is illustrated using single award IDIQ contracts awarded by the Minnesota DOT (MnDOT) and historical bid data from all IDIQ and DBB projects awarded by this agency between January 2008 and April 2015 (1,746 projects).

Background

The lack of mechanisms to factor construction cost estimates into the selection of the contracting approach is not just a problem in IDIQ contracting. This issue has been cataloged by some authors as a widespread problem in the realm of alternative contracting methods (Walewski et al. 2001; Anderson and Damnjanovic 2008; Miller 1997). “[B]ecause no adequate and systematic method exists to evaluate how project delivery methods and contracting approaches have impacted costs, it is difficult to validate the financial impacts of their use” (Walewski et al. 2001). However, the benefits perceived by the users of these methods (e.g. better budget control, increased quality, shorter project duration) seem to be sufficient to disregard the cost implications of their use (Sanvido and Konchar 1998; FHWA 1998).

Existing literature includes research efforts directed to compare construction costs associated with different alternative contracting methods. Nevertheless, it is difficult to draw general conclusions out of these studies since it is easy to find different authors obtaining opposite results from the study of the same contracting methods. For example, a study conducted by Roth (1995) for the comparison of construction costs between 6 DBB and 6 Design-Build (DB) projects found that unit costs are statistically significantly lower when DB contracting methods are used. On the other hand, a similar study done by Konchar and Sanvido (1998) and a research project sponsored by the state of Florida (FHWA 1996) found no significant difference between DB and DBB construction costs. The 351 building projects studied by Konchar and Sanvido showed unit costs for DB projects 6% lower than those for DBB projects, but this difference did not prove to be significantly different. In the same study, Konchar and Sanvido also found that even though the unit cost for construction management at risk (CMR) projects showed to be less than that in DBB, this difference was not statistically significant either.

Most studies intended to compare cost performance among alternative contracting methods focus on cost growth, which is defined “as the difference between the cost at the completion of the project and the original budget” (Ibbs et al. 2003). Based on this cost-related metric, some authors like Hale et al. (2009), Warne (2005), and Shrestha et al. (2007) have concluded that DB outperforms DBB from a cost perspective. In contrast to these findings, Ibbs et al. (2003) have found from the analysis of 67 construction projects (most of them between $25 and $75 million) that “while timesaving is a probable benefit for using DB as a project delivery strategy, the benefits in cost savings [measured in terms of cost growth] are debatable” (Ibbs et al. 2003). This statement was supported three years later by the Design-Build Effectives Study conducted by the Federal Highway Administration (FHWA 2006). From the comparison of 9 and 11 Db and DBB projects, respectively, the FHWA found a lower cost growth in DBB projects (4.3%) than that in DB contracts (8.1%).

A federal research project conducted by Anderson and Damnjanovic (2008) for the development of the NCHRP Synthesis 379: *Selection and Evaluation of Alternative Contracting Methods to Accelerate Project Completion* evaluated de performance of 17 different contracting strategies aimed to reduce project duration, including DB, CMR, and Public Private Partnership. Even though the results of this study were not conclusive regarding the cost-related impacts of using alternative contracting methods, Anderson and Damnjanovic found evidence indicating the use of these methods often increase cost. Thus, these authors concluded that further study is necessary on this matter and “more implementation experience is needed within the transportation industry to determine if they are truly cost-effective in meeting cost performance targets” (Anderson and Damnjanovic 2008).

Since the cost-based decision making framework proposed in this study uses only historical bid data, it is neither possible nor necessary to incorporate cost growth as an IDIQ project selection criterion. Cost growth is a post-construction performance metric and not highly germane to the selection of a project delivery method (Hinze 2012). Thus, since the typical IDIQ contract is for construction services only as is DBB, it can be reasonably inferred that expected cost growth would be similar in both cases. The single award IDIQ contracting approach (defined in the next section) adopted by MnDOT can be described as a contract for multiple DBB projects awarded to the same contractor under a single solicitation during a given period of time (Gransberg et al. 2015a). Therefore, the relationship, roles, and responsibilities among the all parties involved in the contract remain fundamentally unchanged if IDIQ is used instead of DBB. Likewise, the same benefits usually attributed to DBB contracts are expected to be found at the work order level in an IDIQ contract (Gransberg et al. 2015a). After reviewing the most common factors responsible for cost overruns in the construction industry (i.e. fluctuations in prices of materials, financial difficulties faced by contractors, poor site management and supervision, mistakes and errors in design, etc.) (Rahman et al. 2013), the authors found no reasons to believe that the impact of these factors would be substantially different between IDIQ and DBB projects.

The NCHRP Synthesis 379 (Anderson and Damnjanovic 2008) also analyzes existing formal processes used by DOTs for the selection of contracting methods. Although most state transportation agencies that participated in this study indicated the use of no systematic processes for the selection of contracting methods, Anderson and Damnjanovic found five DOTs that have developed formal procedures to select suitable project delivery methods and contracting approaches for their construction project. All these DOTs have business units strictly dedicated to develop and implement innovative contracting practices (Anderson and Damnjanovic 2008). These agencies are:

- Minnesota Department of Transportation (MnDOT)
- California Department of Transportation (Caltrans)
- Pennsylvania Department of Transportation (PennDOT)
- Ohio Department of Transportation (ODOT)
- Utah Department of Transportation (UDOT)

A review of these contracting methods selection procedures by the authors of this paper revealed that the decision making systems used by these five agencies are based on a qualitative analysis of scopes of work, project objective, and benefits/drawbacks usually associated with the different contracting alternatives under consideration. None of these systematic processes quantifies the cost implications of the available contracting options. The problem with this methods, as stated by Touran et al. (2009), is that they rely on benefits identified across a population of projects rather than on an individual analysis of each project. “[T]he reporting of benefits found in the literature should not be misconstrued as advocating on project delivery method over another. All project delivery methods have yielded both successes and failures”

(Touran et al. 2009), which explains the opposite findings from the studies mentioned above. The cost-based decision making framework presented in this paper was designed having in mind that contracting methods "should be selected on the basis of each project's unique characteristics" (Touran et al. 2009). Thus, stochastic construction cost estimates in this framework are calculated based on the specific construction activities constituting the project under consideration.

The Transit Cooperative Research Program (TCRP) Report 131: *A Guidebook for the Evaluation of Project Delivery Methods* (Touran et al. 2009) proposes a three-tiered project delivery selection framework that bases the decision on the analysis of the benefits offered by the available options at the project level. This analysis is performed according to the specific characteristics of each project. Table 14 describes and presents the primary objectives at each tier.

TABLE 14 Three-tiered Project Delivery Selection System (Adapted from Touran et al. 2009)

Tier 1 – Analytical Delivery Decision Approach
Tier 1 provides a framework for agencies to use in defining project goals and examining the advantages/disadvantages of each delivery method within the context of these goals. It helps agencies understand project delivery method attributes and helps them determine whether their specific project goals align with the attributes of a particular delivery method.
Tier 2 – Weighted-Matrix Delivery Decision Approach
Tier 2 provides a framework for agencies to use in prioritizing their project goals and selecting the project delivery method that best aligns with these goals. Priorities for project goals and critical selection issues are unique to each project.
Tier 3 – Optimal Risk Based Approach
Tier 3 consists of two phases. The first phase involves a qualitative analysis: developing a risk-allocation matrix that clearly portrays an owner's risk under competing delivery methods. Through review of these risks, the owner will have an opportunity to decide whether a specific delivery method is more appropriate than others. If the qualitative analysis does not provide a definitive answer to the delivery selection question, the second phase—a quantitative analysis—should be considered.

When using the three-tiered decision making system described in Table 14, transit agencies start with the framework provided at Tier 1. If there is not a clear and logical choice after using this framework, decision makers then move to Tier 2. If after following the procedures from Tier 2, the agency still has not identified a best choice, decision makers proceed with Tier 3, which is divided into both a qualitative and a quantitative assessment. The Tier 3 quantitative analysis compares stochastic construction cost estimates for competing contracting approaches, which is quite similar to the one presented in this paper for highway projects. However, in the decision making system proposed by Touran et al. (2009), the qualitative/quantitative assessment is the last step for the transit agency delivery method selection process. The stochastic analysis is only used if no decision can be made at Tier 1 or 2, or during the qualitative analysis at Tier 3. The quantitative is left to last because this is described as the most complex and time consuming part of the system. This analysis is "a major undertaking that requires hundreds of person-hours over the course of several weeks" (Touran et al. 2009).

The difficulty of the quantitative analysis proposed by Touran et al. (2009) lies in the fact that it consists of the comparison of stochastic early construction cost estimates, when there this still little information about the project. Ideally, this analysis is to be conducted during the project scoping process. The reason for conducting this analysis early during the project planning phase is that this decision making system is intended to deal with project delivery methods that have substantially different project life cycles (DBB, DB, CMR, and Design-Build-Operate-Maintain). Thus, a later selection of the contracting approach may prove to hold little value. The similarity of the project life cycle configurations of single award IDIQ contracts and DBB projects avoids this problem.

As mentioned before, single award IDIQ contracts used by MnDOT are fundamentally a group of DBB projects executed under a single solicitation. IDIQ and DBB projects have a similar sequence of project phases and configuration of preconstruction activities. Therefore, the decision of whether or not to use IDIQ or DBB can be made upon completion of the solicitation documents and after determining the bid quantities. The detailed designs for all anticipated IDIQ work order projects do not need to be known.

The following sections present a brief description of the DBB and the IDIQ contracting models used by MnDOT. The sections provide the reader with the necessary background to understand the proposed decision making framework.

IDIQ Contracting

An IDIQ contract "provides for an indefinite quantity of supplies and/or services whose performance an delivery scheduling is determined by placing work orders with one or multiple contractors during a fixed period of time" (Gransberg et al. 2015a). Previous studies of IDIQ practices identified three different IDIQ contracting models classified in accordance with the number of contractors selected to participate in the contract and the expected number of work orders to be issued (Rueda and Gransberg 2014a). Figure 3 (see Chapter 2) illustrates this classification and highlights the different IDIQ contracting models. The description of each of these models is presented below. Table 2 (see Chapter 2) shows the configuration of these models and describes the most appropriate conditions for the successful use of each of them.

- *Single Work Order Contract*: A single contract is awarded to a single contractor. Once the need to issue the work arises, the contractor then performs the desired services or furnishes the requisite supplies (a single work order issued during the contract period) (Rueda and Gransberg 2014a).
- *Single Award IDIQ*: A single contract is advertised and awarded to a single contractor who then is awarded work orders based on the pricing furnished in the initial bid package (Rueda and Gransberg 2014a).
- *Multiple Award IDIQ*: A single contract is advertised and a pool of qualified contractors is selected. Only those selected are subsequently allowed to bid on work orders. In most cases the work orders are awarded to the lowest bidder among the contractors in the pool (Rueda and Gransberg 2014a).

In an attempt to maximize competition (GAO 1979; OFPP 1997), the Federal Acquisition Regulation (FAR 2005) establishes a clear preference for multiple award IDIQ construction contracts for federally-funded IDIQ contracts. However, a multiple award approach is not always the most suitable option (DoD 1999), which appears to be the case for transportation agencies (Gransberg et al. 2015a). For DOTs, the single award IDIQ contracts seem to “better fit their procurement methods and limited resources, and even with less apparent benefits, DOTs have perceived an opportunity to improve their contracting practices” by executing single award IDIQ contracts (Rueda 2013). The MnDOT IDIQ contracting program is limited to a single award approach and that is the contracting model used for the development of the framework presented in this paper.

Design-Bid-Build

In this method, design must be fully accomplished by either in-house or consultant designers before proceeding with the advertisement and award of a separate construction contract (Gransberg and Shane 2010). In other words, design and construction activities are contracted separately, so that, there is no contractual relationship between the designer and the contractor as shown in Figure 16.

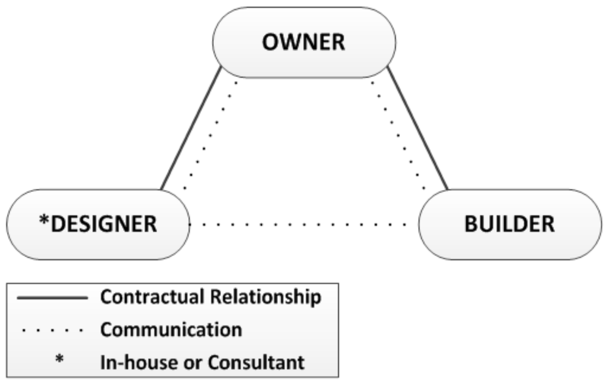


FIGURE 16 Design-Bid-Build (Gransberg et al. 2015a).

Even though DBB contracts are usually awarded to the low bid responsive contractor, they can also be awarded on a best-value or negotiated basis in order to mitigate risks related to the selection of a contractor who has submitted a low price proposal inconsistent with the construction documents (Gransberg and Shane 2010; Scott et al. 2006).

Methodology

Figure 17 illustrates the research methodology followed for this study. The point of departure for this study was the NCHRP Synthesis 473: *IDIQ Contracting Practices*. This is a report developed by the authors of this paper aimed to compile and evaluate effective IDIQ practices implemented by state DOTs across the country. The study began with a supplementary literature review aimed to collect either new knowledge or any additional information missed or not available when developing the synthesis. The study is then divided into a qualitative and a quantitative process.

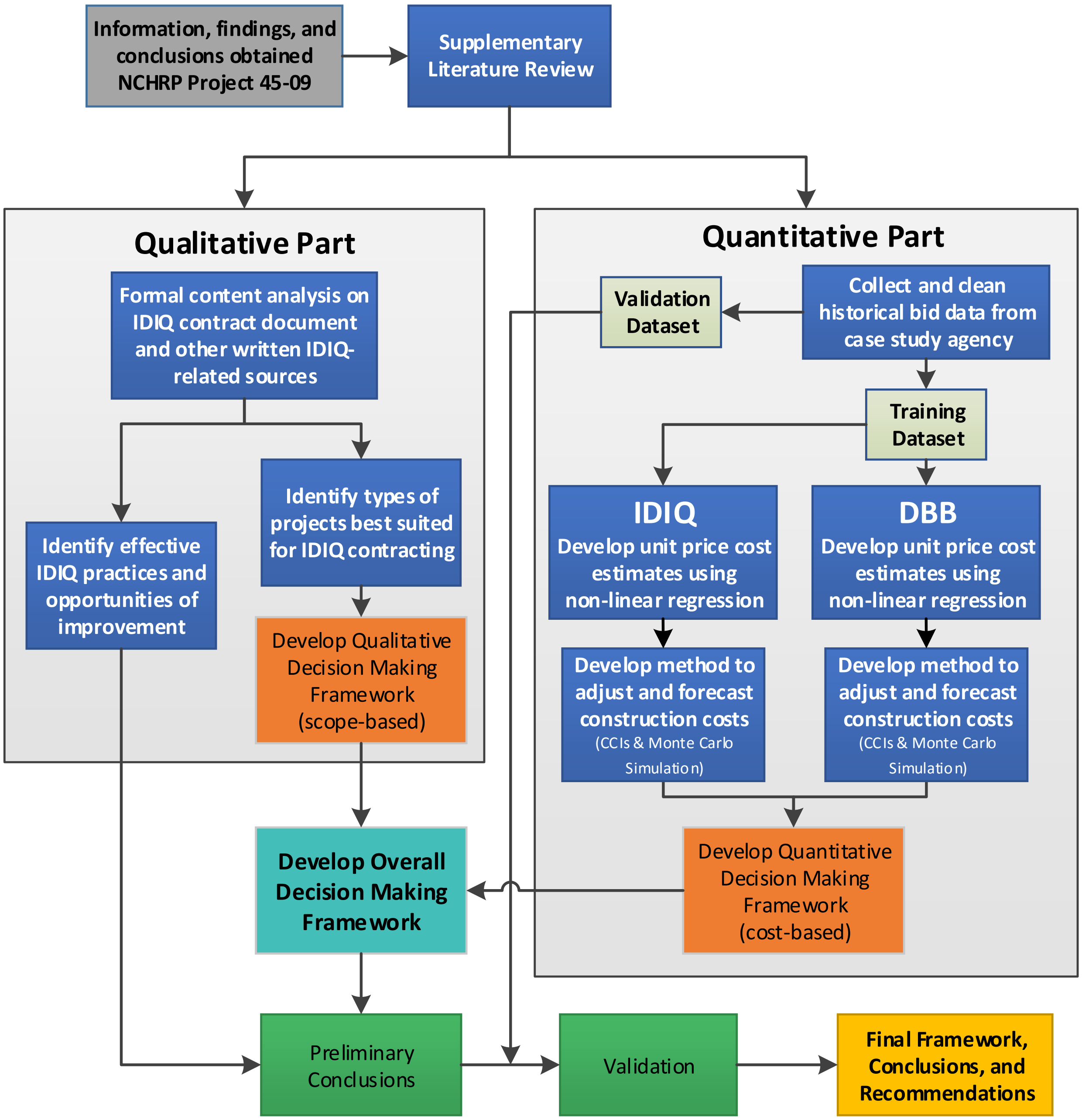


FIGURE 17 Research methodology.

Rather than replacing the current scope-based IDIQ project selection method used by DOTs, the decision making framework presented in this paper is intended to supplement existing practices to reduce the risk associated with an inappropriate selection of contracting methods. Thus, during the qualitative part of the study, the authors conducted a formal content analysis on contract documents, journal articles, research reports, and other written sources of information related to IDIQ contracting collected from the literature review. The study helped to identify effective IDIQ contracting practices and opportunities for improvement that were used to improve and formalize current scope-based project selection procedures. Content analysis techniques were applied following the methods proposed by Neuendorf (2002).

On the other hand, the quantitative part of Figure 16 refers to the development of construction cost prediction models for IDIQ and DBB projects. The prediction models are developed and their outputs are compared with each other using historical bid data, an alternative indexing system developed by the authors, non-linear regression techniques, and Monte Carlo simulation. The MnDOT IDIQ contracting program was used to develop the prediction models and to validate the overall decision making framework. The first step in the quantitative part of this study was to collect and clean bid data from all projects awarded by MnDOT between January 2008 and April 2015. Table 15 describes this data and shows how it was divided into training and validation data-sets.

TABLE 15 MnDOT Historical Bid Data

Type of Contract	**MnDOT Historical Bid Data – Number of Contracts January 2008 – April 2015**		
	Training Data-set January 2008 – August 2013	**Validation Data-set September 2013 – April 2015**	**Total Number of Contracts**
IDIQ	22	11	33
DBB	1,361	352	1,713

The training data-set was used to develop the construction cost prediction models and projects in the validation data-set were used to evaluate the performance of these models. MnDOT historical bid data was intentionally divided placing older projects in the training data-set since the purpose of this validation process is not only to determine the accuracy of the construction cost estimating models, but also the ability of bid data from previous projects to estimate current construction costs.

Subsequently, the results and observations from both the qualitative and quantitative parts of this study were combined and analyzed together to create and overall decision making framework. The framework initiates with a qualitative assessment (scope-based) for the pre-selection of IDIQ candidates, which are then moved forward for a quantitative analysis (cost-based). Finally, the overall decision making framework and preliminary conclusions are subjected to validation before disclosing the results of the study.

Decision Making Framework – IDIQ vs. DBB

Although the analytical development of the decision making framework described in this paper uses a fixed training data-set and fixed construction cost prediction models, the objective of this study is to provide DOTs with a standard set of procedures that can be repeated as often as needed to evaluate candidate projects using the most recent bid data. This framework uses data currently being collected and stored in a digital form by DOTs. Therefore, the process can be fully automated to facilitate the decision making process. Figure 18 illustrates the decision making framework. Each of the elements in this framework in described in detail in the following sections.

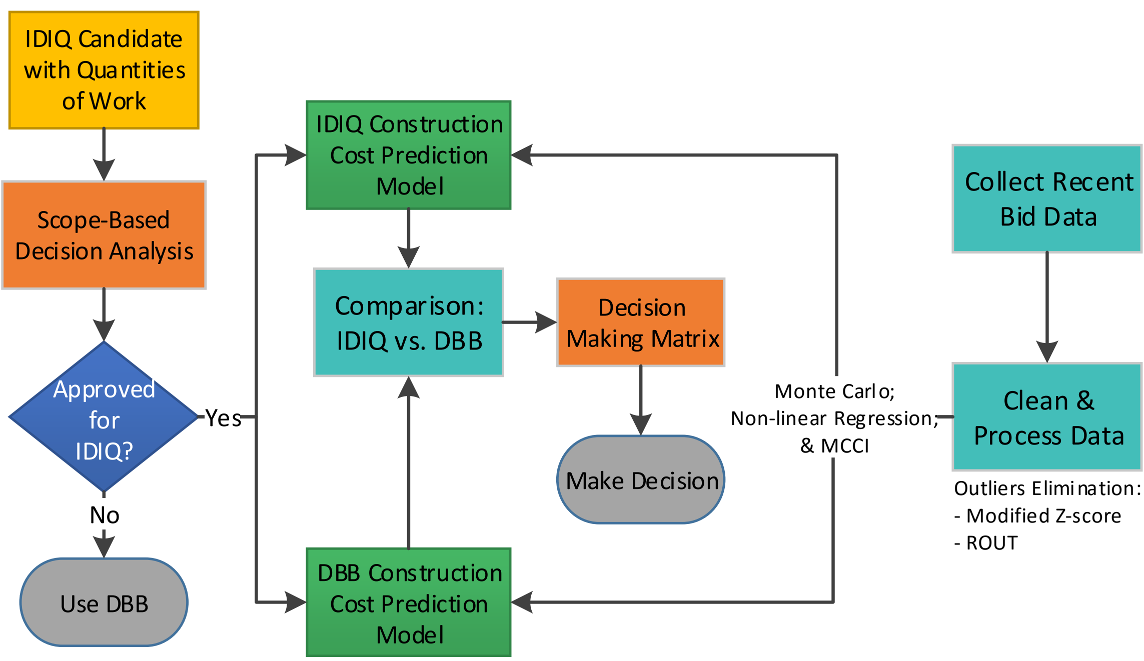


FIGURE 18 Decision making framework – IDIQ vs. DBB

Scope-Based Decision Analysis

Figure 14 (see Chapter 6) corresponds to the improved scope-based project selection framework proposed by the author. Besides being used to determine the suitability of a given project (or group of projects) for IDIQ contracting, the project scope (along with main project objectives) is analyzed to suggest the most suitable IDIQ contracting model for the specific project (i.e. single work order, single award, or multiple award). This scope-based decision analysis proposes three different scenarios to reject the use of an IDIQ contract:

1. When the scope of the contract does not constitute repetitive, technically similar work;
2. When the scope does not meet the owners' IDIQ policies or other applicable regulations; or
3. When the scope is broad and the size of the project is not great enough to justify awarding to multiple contractors.

As suggested in the NCHRP Synthesis 473 (Gransberg et al. 2015a), single award IDIQ contracts should be only used for narrow scopes of work when all work orders executed under the contract are expected to be fairly similar. It increases budget control and reduces the risk of an erroneous selection of the apparent low bidder. Broader scopes of work involving different types of work orders are better handled by multiple award IDIQ contracts. Therefore, MnDOT's IDIQ contracts are restricted to narrow scopes of work since this agency use a multiple award approach in its IDIQ contracting program.

Data Collection, Cleaning, and Processing

Although MnDOT estimators are already estimating construction costs for IDIQ and DBB contracts, the heavy reliance of the proposed decision making tool proposed in this paper on the accuracy of these estimates led the authors to invest efforts in the improvement of these estimates. The concept of "accuracy," as used in this study, refers to the degree to which the estimated unit prices conform to the actual values in the lowest bid. To improve the performance of these estimates, the author used the available historical bid data to develop non-linear regression equations (power series regression) for MnDOT's most frequently used pay items. For each regressed pay item, the agency has an equation to calculate the unit price for this pay item in terms of its bid quantity.

Figure 19 illustrates the process to develop the non-linear regression equations. This process was separately used to develop equations for both IDIQ and DBB contracts. The only difference in the process lies on the input data, which must come only from their respective types of contracts (IDIQ model will use only data form IDIQ contracts and DBB model will use only data from DBB contracts). Figure 20 shows how the available historical bid data was used to develop non-linear regression equations for IDIQ and DBB contracts and how these equations, together with MnDOT current estimating practices for non-regressed pay items, make up the construction cost estimating models. It should be noted that the process shown in Figure 19 was only applied to the training data-set.

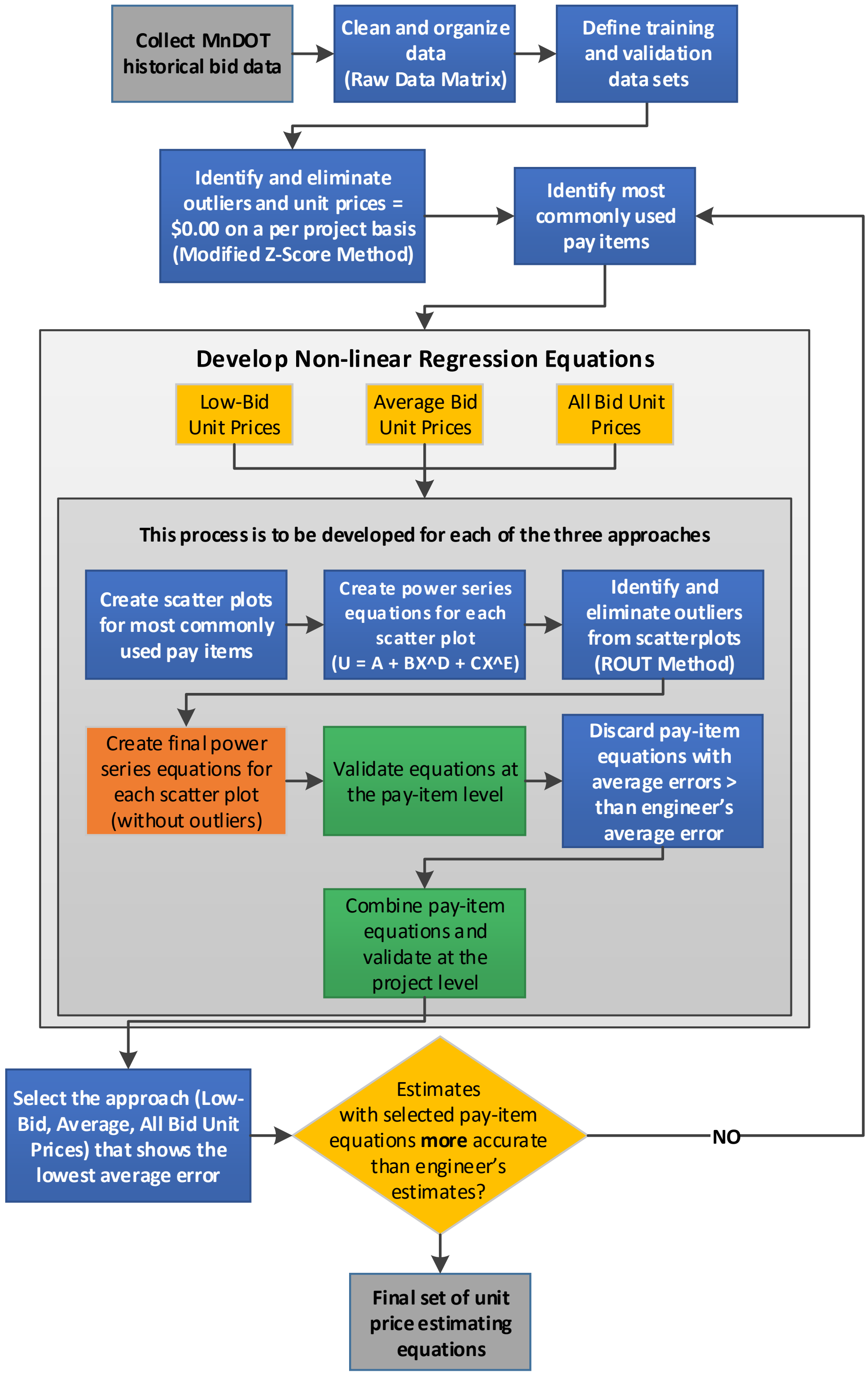


FIGURE 19 Quantitative data processing.

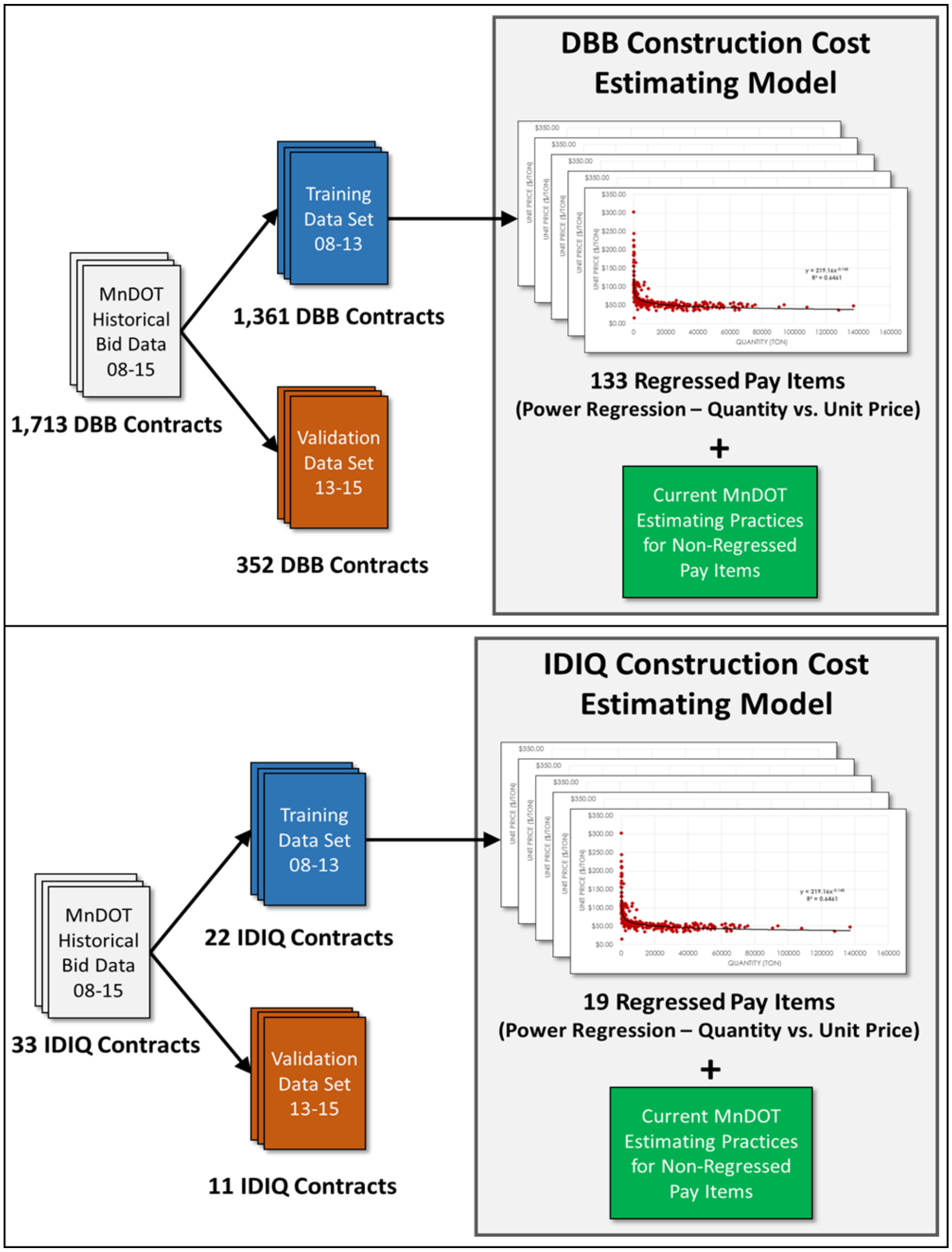


FIGURE 20 DBB and IDIQ construction cost estimating models.

The substantially lower amount of IDIQ contracts awarded by MnDOT in comparison with DBB is due to the fact that the tool is new to that agency. Therefore, the available amount of data from IDIQ contracts is less than for DBB. As such, only 19 non-linear regression equations were developed for IDIQ while 133 pay items were regressed for DBB. Not only must the regressed pay items be commonly used by MnDOT, but they must also show a strong relationship between historical bid unit prices and bid quantities to improve the accuracy observed when using MnDOT current estimating methods.

The use of power series models in the form $U = AX^B + CX^D$ (where U is the unit price, A, C, and D are constant values calculated as a result of a power regression, and X is the total quantity of work estimated for a given pay item) was selected from a group of non-linear regression alternatives since this is the one that best fits the historical data in most pay items. A shorter version of this equation ($U = AX^B$) was more suitable for some pay items.

Table 16 shows the results of the validation of IDIQ and DBB construction cost estimating models. For both models the results of the validation were positive and statistically significant (using two-sample t-test) at both the project and the agency level. The performance at the project refers to the reduction in the mean absolute percentage error (MAPE) when using the proposed models instead of current MnDOT estimating practices for all pay items. The MAPE is the absolute arithmetic average of the errors (%) of all projects. On the other hand, the performance at the agency level was quantified by comparing the total estimated cost for all projects against the aggregated price proposals submitted by successful bidders in all contracts ([Σsuccessful actual bid prices – Σestimated bid prices]/ Σsuccessful actual bid prices).

TABLE 16 Construction Cost Estimating Model – Validation Results

Estimating Model	**Validation of Construction Cost Estimating Models**	
	MAPE Reduction at the Project Level	**Absolute Error Reduction at the Agency Level**
IDIQ	54%	54%
DBB	10%	64%

<u>Outlier Detection Methods</u>

Figure 19 also shows two different outlier detection methods. The first method is the modified Z-Score method and is applied prior to regression as a mechanism to purge anomalies due to the ever-present unbalancing of bid tabulation unit prices in the initial data set. It finds outliers at the pay item level by comparing bid unit prices submitted for the same item in the same contract. The modified Z-Score method to eliminate materially unbalanced data points, along with the elimination of those where the bid unit prices equal to $0.00 (zero), are required to preserve the integrity of the construction cost estimating models. The modified Z-Score method is typically used for analyses involving small sample sizes (Seo 2006; Iglewicz and Hoaglin 1993), such as those that may result when one to three contractors are competing for a given contract.

The second method used to detect outliers is robust regression and outlier removal (ROUT) approach, which is applied to the scatter plots (Quantity vs Unit Price) developed for each of the selected pay items. The ROUT method allows for the identification of outliers in non-linear regression models such as the power series regressions used in this study (Motulsky and Brown 2006). The purpose of this second data filter is to discard significantly low or high unit prices that may result from unusual project conditions. For example; if all the competing unit prices submitted for a structural concrete pay item on the same contract are fairly similar, they will not be discarded by the modified Z-Score method; however, an unusual project requirement, which in this example is a requirement to place the concrete in the winter necessitating construction of a temporary enclosure, heater, and 24-hour watchman, forces all the competing contractors to greatly increase the bid price for this item in comparison with its normal price range, which in turn causes these particular values would be discarded by the ROUT method. The same would be true if the condition made the bid prices substantially lower than normal.

Use of Construction Cost Estimating Models

Figure 21 shows two ways to use the unit price estimating models under two different decision-making scenarios. The first scenario involves a decision about grouping similar potential projects into a single IDIQ contract or executing these projects under individual DBB contracts. On the other hand, the second case scenario refers to a single project and the decision of whether using an existing IDIQ, with known fixed unit prices, or awarding a new DBB. It should be noted that the first case scenario uses both construction cost estimating models (IDIQ and DBB) to compare the total expected cost of a single IDIQ against multiple DBB contracts. The second scenario only requires the estimation DBB construction cost for the given project, which is compared against the cost if the existing IDIQ with its already stated unit prices is used. Figure 21 illustrates both case scenarios using four hypothetical pay items. Bid quantities for pay items *A, B, C,* and *D* (case scenario 1) are assumed to represent total expected quantities of work to be ordered under an IDIQ contract. On the other hand, bid quantities for items *a, b, c*, and *d* (case scenario 2) refer to a single project.

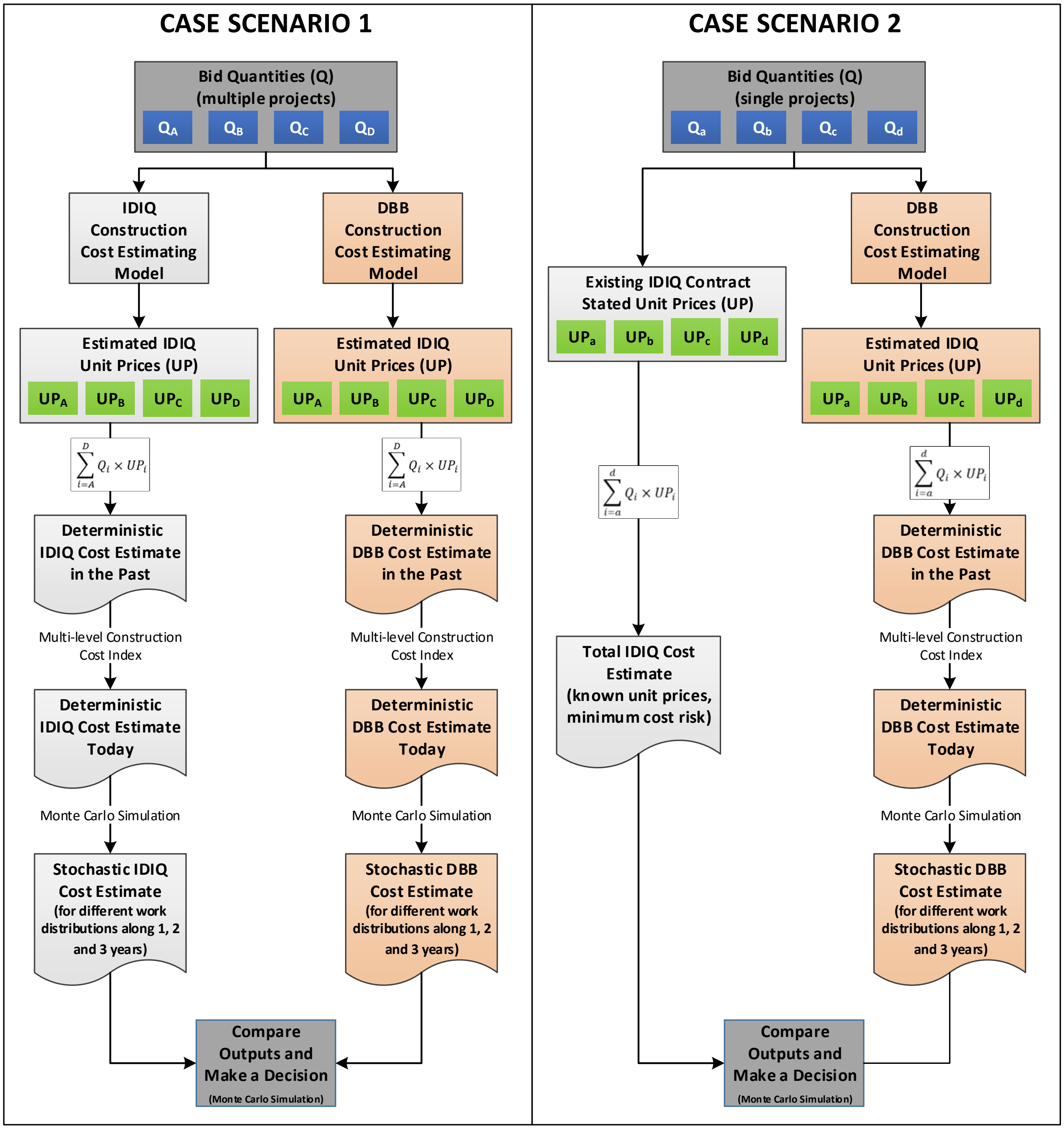


FIGURE 21 Use construction cost estimating models.

An initial deterministic total construction cost is calculated by adding the estimated extended prices of all pay items. However, since construction cost estimating models are developed using data from previous projects, their direct outputs are not in current dollars. Initially, the authors considered the use of an existing construction cost index (CCI) to address this problem. CCIs track changes in the construction market over time; thus, they can be used to compare construction prices between two points in time or to bring construction costs from past to present.

A previous study of CCIs conducted by the author uncovered a major issue in the use of these indexes at the project level. That study found that it was unreasonable to believe that a single index number can be used to adjust all types of projects due to the nearly unpredictable impact that dynamic changes in the construction material commodities market have on different types of projects; for example, concrete bridge projects versus asphalt paving projects (Rueda and Gransberg 2015). The study also found that the least accurate adjustments obtained when using CCIs on MnDOT projects were on asphalt paving projects, which is the most common type of work done by MnDOT (Rueda and Gransberg 2015). This situation led the authors to develop an alternative indexing system to overcome the limitations and lack of flexibility of the existing indexes: a Multi-level CCI (MCCI).

The MCCI is a group of indexes organized in a multi-level arrangement. Each pay item is individually adjusted using its corresponding index from the MCCI. Therefore, different projects are adjusted with different indexes according to the unique characteristics of each project. The development and characteristics of the MCCI are described in detail in a research report done for MnDOT by Gransberg and Rueda (2014).

Construction costs calculated with the models illustrated in Figure 20 are assumed to be estimates at the midpoint of the training data-set. These estimates are brought forward to the present letting date using the MCCI. For both contracting methods these estimates are expected to be effective only for one year. A review of the project durations of a randomly selected sample of 10% of all DBB in the available bid data found no contracts with an expected duration of more than one year. Therefore, construction cost estimates performed from this data should not be considered for periods longer than a year. Likewise, unit prices submitted by the successful contractor in an IDIQ are adjusted on an annual basis in accordance with the IDIQ price escalation clause used by MnDOT:

> "To compensate for the potential of this Contract to extend over several construction seasons the Department will adjust the Unit Prices of all items on the TOIL by 2% once per year on the anniversary date of the letting of this Contract. Items not listed on the TOIL will not be adjusted. Fuel escalation will not be paid for items where the Inflation Index for cost increase is utilized" (MnDOT 2013)

Most IDIQ contracts awarded by MnDOT are multi-year contracts with a maximum duration of three years. Thus, it was also necessary in this framework to forecast construction processes for a potential second or third year. While changes in IDIQ prices are subject to the contract price escalation provision, which in the case of MnDOT is a fixed annual adjustment of 2% in all pay items, DBB prices will be affected by actual fluctuations of construction prices. It should be noted that DBB contracts are advertised and awarded as the funding for the projects becomes available. Thus, DBB projects awarded in two or three years from today will be priced by bidders based on the current construction prices at their letting dates. To estimate construction prices for the next two or three years, the authors used Monte Carlo techniques to simulate values for the MCCI. From this point forward, the paper is focused on case scenario 1 in Figure 22, which refers to the most complex situation of the two decision-making scenarios.

Figure 22 shows the steps to move construction prices from past to future by first using the MCCI to bring them to present, and then simulate index values to project them into the future. This process is simpler for IDIQ contracts given the 2% fixed annual adjustment rate used by MnDOT (see Figure 23). It does not require the use of Monte Carlo simulation techniques. As shown in Figure 21, the decision-making scenario 1 depends on the distribution of work among the different contract periods. Thus, if the bid quantities in Figures 22 and 23 are assumed to be the total amount of work for all projects under the IDIQ contract; the total bid schedule is the stochastic value of the sum of all extended unit prices in the contract; and *a%, b%,* and *c%* are the estimated percentages of work to be performed during the first, second, and third year, respectively, the stochastic construction cost estimates used to compare IDIQ vs. DBB can be calculated as follows:

$$Stochastic\ Const.Cost_{IDIQ} = Total\ BS\ 1_{IDIQ} \times a\% + Total\ BS\ 2_{IDIQ} \times b\% + Total\ BS\ 3_{IDIQ} \times c\% \qquad \text{eq. 4}$$

$$Stochastic\ Const.Cost_{DBB} = Total\ BS\ 1_{DBB} \times a\% + Total\ BS\ 2_{DBB} \times b\% + Total\ BS\ 3_{DBB} \times c\% \qquad \text{eq. 5}$$

Where: $Stochastic\ Const.Cost_{IDIQ} = Stochastic\ Construction\ Cost\ Estimate\ for\ IDIQ$

$Stochastic\ Const.Cost_{DBB} = Stochastic\ Construction\ Cost\ Estimate\ for\ DBB$

$Total\ BS\ 1_{IDIQ} = Stochastic\ Total\ Bid\ Schedule\ for\ the\ 1st\ Year\ for\ IDIQ$

$Total\ BS\ 3_{DBB} = Stochastic\ Total\ Bid\ Schedule\ for\ the\ 3rd\ Year\ for\ DBB$

$a\% = Estimated\ Percentage\ of\ Work\ to\ be\ Performed\ During\ 1st\ Year$

$b\% = Estimated\ Percentage\ of\ Work\ to\ be\ Performed\ During\ 2nd\ Year$

$c\% = Estimated\ Percentage\ of\ Work\ to\ be\ Performed\ During\ 3st\ Year$

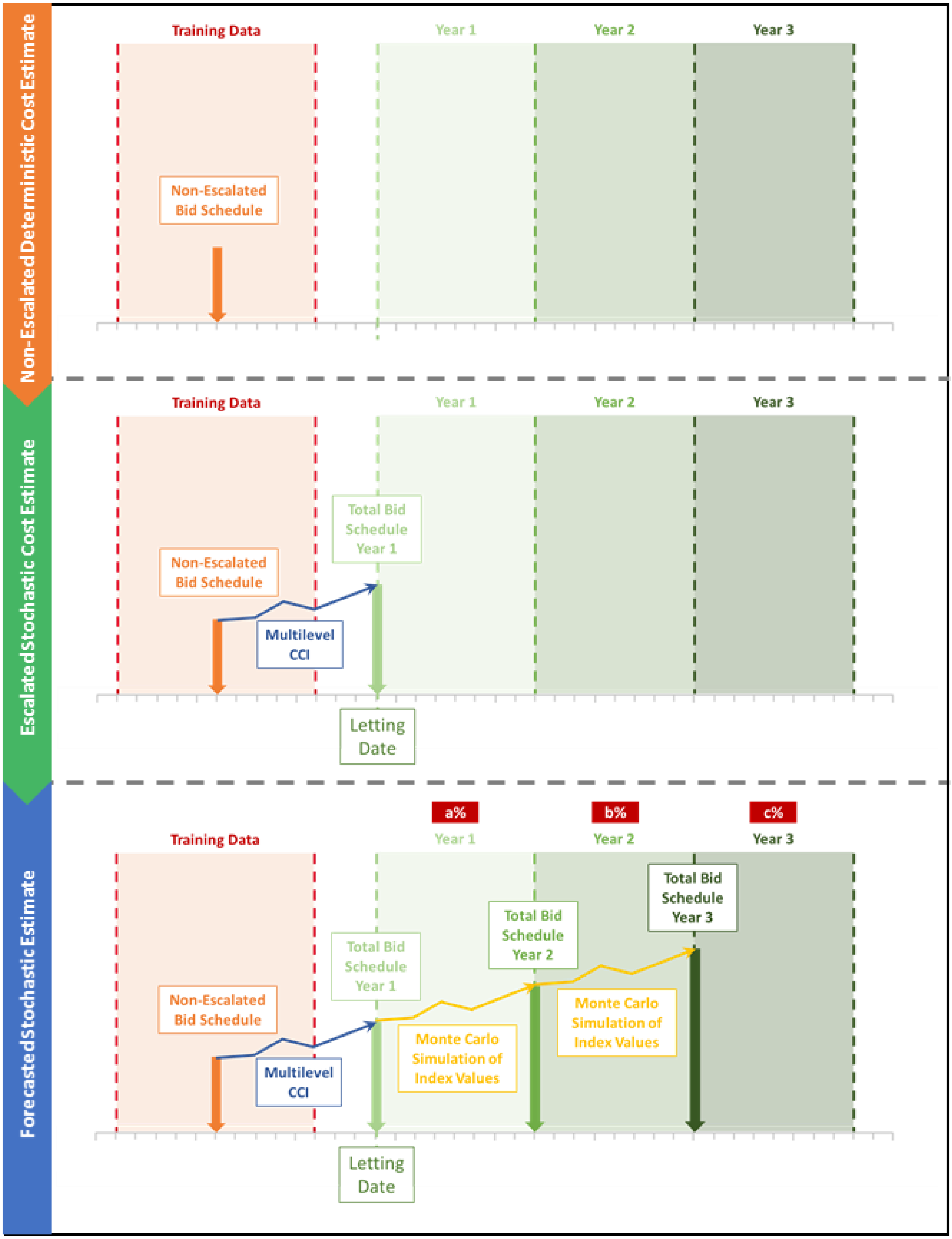


FIGURE 22 Development of construction cost estimate – DBB.

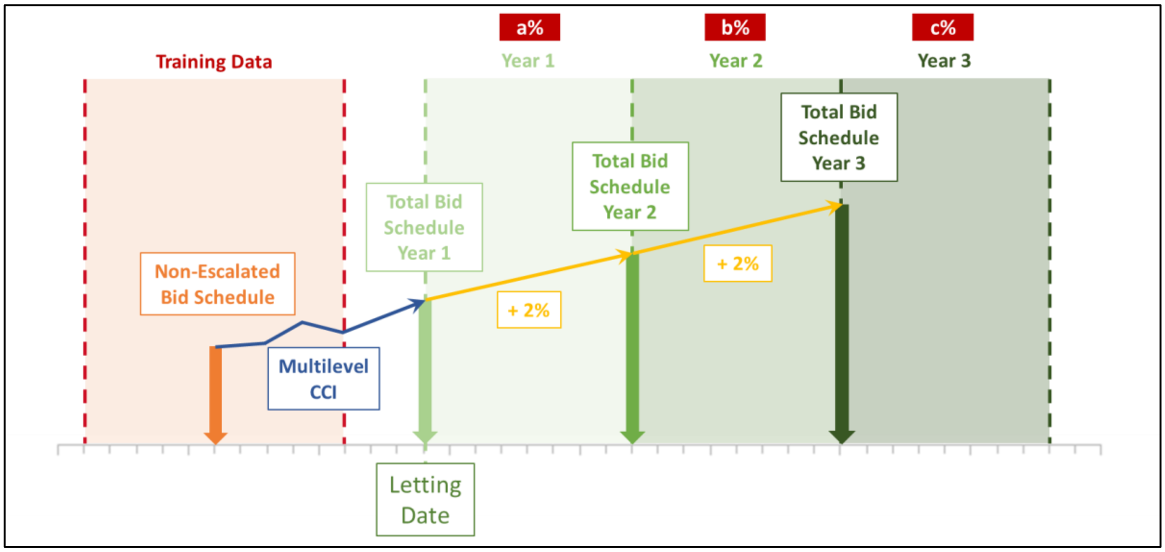


FIGURE 23 Development of construction cost estimate – IDIQ.

Once calculated the stochastic cost estimates for IDIQ and DBB, the next step is to compare these estimates using Monte Carlo simulation. For example; Figure 24 shows the IDIQ and DBB stochastic estimate for a three-year contract with an expected distribution of work of 50%, 40%, and 10% during the first, second, and third year of the contract. Thousands of iterations were run generating and comparing pairs of values under each iteration; one value for each distribution. The decision maker can see a distribution of the differences between the two random values under each iteration: *IDIQ Bid Price – DBB Bid Price* (probability density function top right corner of Figure 24). Likewise, at the end of this simulation, the decision maker can see that there is a 56% probability of having a lower cost if using IDIQ contracting for the projects under consideration and with the given distribution of work.

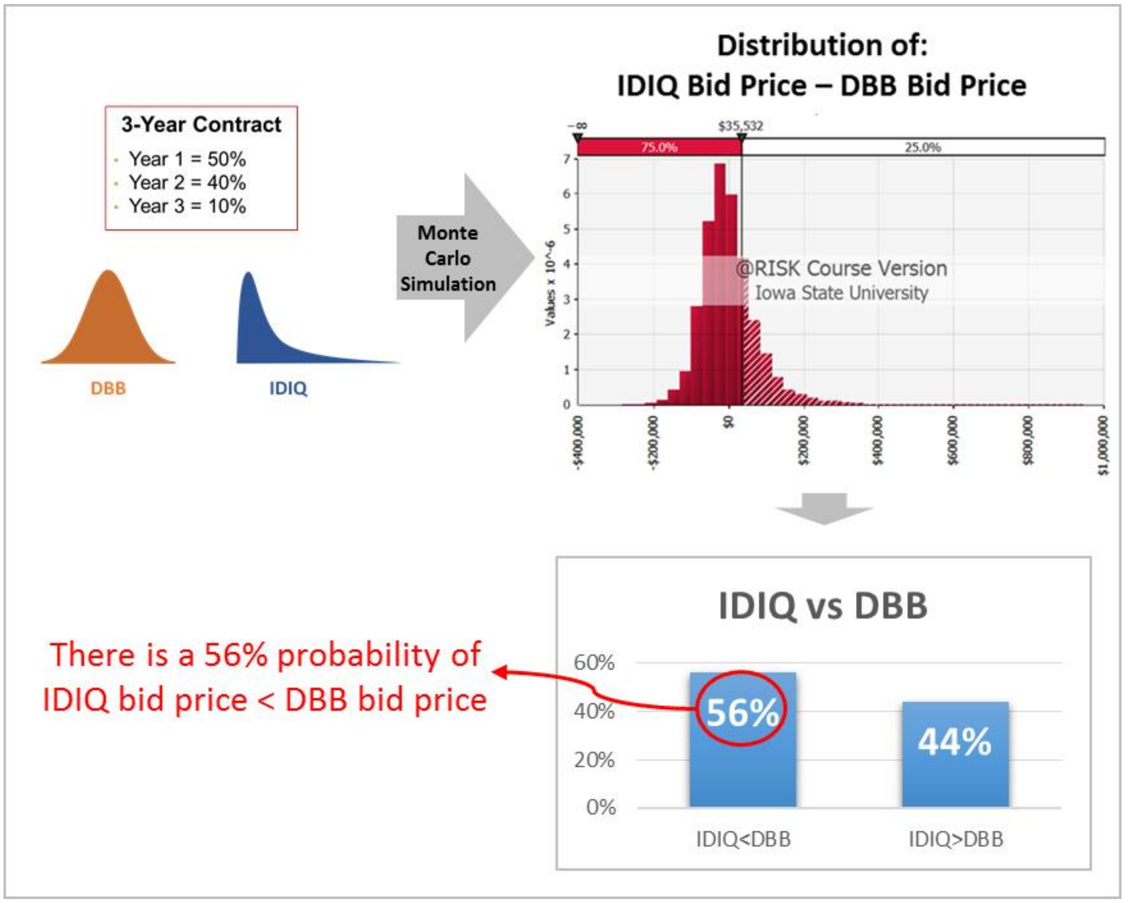


FIGURE 24 Comparison of stochastic values.

Due to the fact that a reliable distribution of work among different contract periods might be difficult to determine in an IDIQ contract, an effective decision making framework should conduct a sensitivity analysis considering multiple potential distributions of work. It must also clearly communicate the results of this analysis to the decision makers to facilitate de selection of the contracting method. Having this in mind, the authors designed the Decision Making Matrix shown in Figure 25, summarizing all possible distributions of work for up to three-year contracts.

Each cell in the Decision Making Matrix shows the probability of having a lower IDIQ bid price for a different distribution of work. Figure 25 highlights the cell for the same example shown in Figure 24. The horizontal and vertical axis of the matrix correspond to the percentage of work conducted during the first and second contract periods, respectively. The percentage of work for the third year is incidental to values of the vertical and horizontal axis (100% - %work year 1 - %work year2).

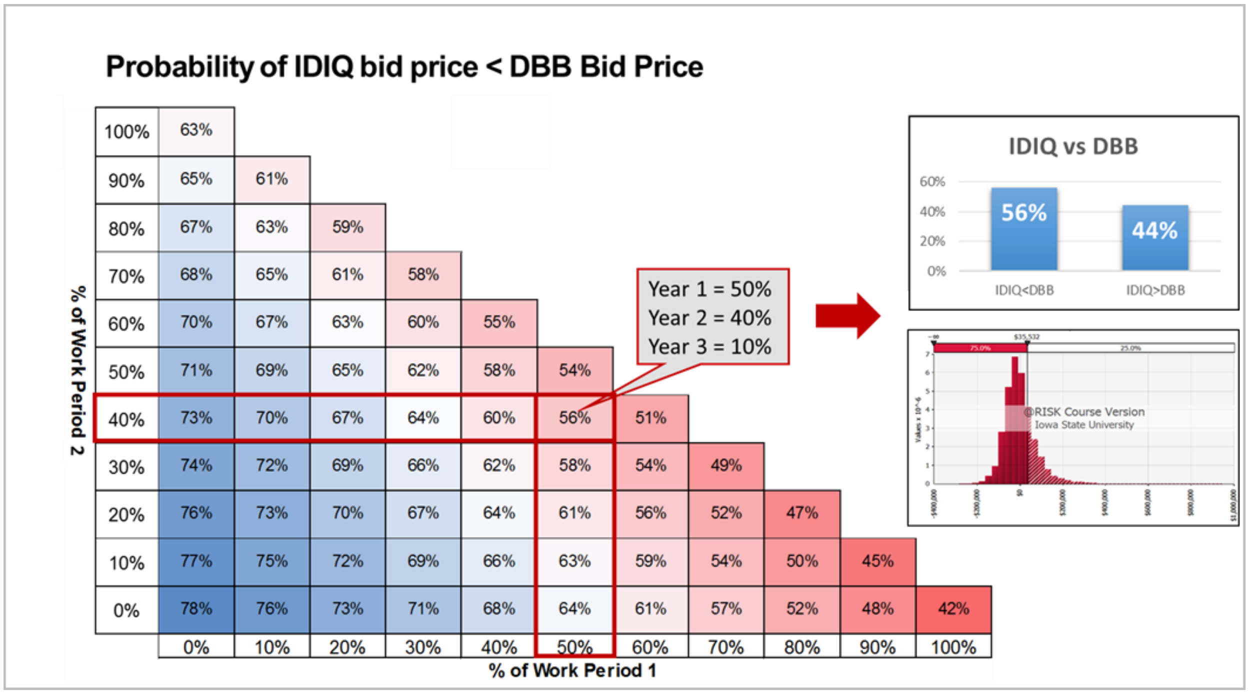


FIGURE 25 Decision Making Matrix – IDIQ vs. DBB.

The quantitative analysis in Figure 25 was conducted on a real micro-surfacing IDIQ contract awarded by MnDOT on June 2014. This was actually a two-year contract, which means that MnDOT would have increased its chances of achieving lower construction prices for IDIQ by performing at least 70% of the work during the first year. Regardless of the high uncertainty attributed to IDIQ in comparison with DBB contracting, which has led some to assume higher construction costs for IDIQ contracts due to higher contingencies considered by contractors, Figure 25 shows that for this specific project more than 90% of all possible distributions of work IDIQ outperforms DDB in terms of cost. Finding this in a single project does not make it conclusive argument, but it is something they might warrant further research.

Rather than pointing out the “best” alternative to the agency, the decision making framework and matrix proposed in this paper are aimed to provide DOTs with tools to make better informed decision when selecting projects for IDIQ contracting. These tools are also intended to provide a base for discussion on the cost implications of using IDIQ contracting and the reasonable price (if any) to be paid for its benefits.

Conclusion

During the last few decades, owners and contractors in the construction industry have invested considerable efforts in the development and implementation of alternative contracting as a measure to deal with the tighter schedules and budgets of today's construction industry. Research has shown that implementing alternative contracting methods in the transportation construction industry has improved the contracting capabilities of DOTs by expanding the flexibility with which individual project requirements can be better addressed during procurement (Oyetunji and Anderson 2006). However, alternative contracting has also brought new challenges that if not effectively addressed, could prevent these agencies from taking full advantage of the benefits accrued via these methods. The increased number alternative contracting methods has expanded the options available to DOTs when determining the most suitable approach to deliver a given project. This paper's objective is to add structure to that process by proposing a decision making framework to choose between IDIQ or a traditional DBB contracting.

The proposed framework combines qualitative (scope-based) and quantitative (cost-based) methods for the selection of suitable projects for IDIQ. The quantitative analysis was illustrated in this paper using the MnDOT IDIQ contracting program as a case study. This analysis combines bid data from previous projects, an alternative construction cost indexing system, non-linear regression, and Monte Carlo simulation techniques to stochastic develop cost models and compare IDIQ and DBB stochastic construction cost estimates for the same project. The analysis described in previous sections showed a statistically significant improvement in the accuracy of the stochastic estimates when compared with MnDOT's current deterministic construction cost estimating methods.

The results of a sensitivity analysis conducted on the comparison of the stochastic estimates for IDIQ and DBB are presented to decision makers in a matrix, considering different distributions of work among various contract periods. The purpose of this matrix is to facilitate the interpretation of the framework's output and provide DOTs with valuable information to make better decisions when selecting for IDIQ contracting.

Finally, the analysis demonstrated that there is no clear answer to the question of whether the use of IDIQ contracting costs the DOT more or less than DBB. However, it did clearly prove the longstanding conventional wisdom in construction estimating: it depends on the specifics of the given project, which also validates the construct articulated by Touran et al. (2009): “The project delivery method should be selected on the basis of each project’s unique characteristics.” Hence the primary contribution to the body of knowledge in this paper is a framework which structures IDIQ decision making process and furnishes improved quantitative output upon which a public agency can decide whether the costs of this alternative outweigh the benefits accrued by reducing the procurement process to a single transaction.

CHAPTER 8

CONSOLIDATED CONCLUSIONS AND LIMITATIONS

The literature review showed that current methods used to determine the suitability of projects for IDIQ contracting are mainly based on a qualitative assessment of the scope of the projects without regard to potential costs. Almost any group of projects that involves repetitive tasks is a good candidate for IDIQ contracting. The literature review also revealed that the lack formal tools to determine the cost consequences of the selection of procurement strategies for a given project is a common issue in the realm of alternative contracting methods. This dissertation presented an IDIQ project selection framework that incorporates a cost-related criterion through the stochastic comparison of estimated IDIQ construction costs for a project or a group of projects against the expected costs if a traditional DBB is used. This framework has been presented in Chapter 7 using data from both MnDOT's traditional DBB and its newly adopted IDIQ program.

The construction cost estimating process for both IDIQ and DBB was conducted using estimating models proposed by the author, which have statistically proven to be significantly more accurate than MnDOT current estimating practices. The development and comparison of stochastic construction cost estimates for both alternatives involves the use of historical bid data, a construction cost indexing system created by the author, non-linear regression techniques, and Monte Carlo simulation. In order to simplify the communication of the results of the stochastic comparison to the decision makers, and to increase the "user friendliness" of this framework, the framework's output has been organized into a Decision Making Matrix. Rather than work as a sole decision-making criterion, the framework and final matrix are intended to inform the decision making process of the potential cost implications of using IDIQ, which in turn can be assessed against the benefits provided by this alternative contracting method.

Before developing the framework, the author studied various aspects impacting budget control and IDIQ construction costs. The first aspect was the degree of early contractor involvement (ECI) in IDIQ contracts, which was evaluated through a comparison of a worldwide multiple-award IDIQ contract awarded by the US Department of Defense and the fully integrated collaborative alliance agreement use in New Zealand for the reconstruction work after the earthquakes of 2010 and 2011 (Chapter 4). This study found that regardless of the similarities between these two contracting approaches, the lower level of integration of all parties involved in a multiple award IDIQ contract is limiting the use of ECI practices. In fact, it was found that single award IDIQ contracts are more suitable for the application ECI practices.

Because of the multi-year format of IDIQ, the research evaluated the applicability of twelve existing construction cost indexes (CCIs) in IDIQ contracts (Chapter 5). Eight years of MnDOT historical bid data were used to test the efficacy of the existing CCIs. The evaluation found that contrary to conventional engineering economic theory, using a single CII to model future escalation in construction prices at the project level fails to furnish a reliable outcome when using these indexes to adjust unit prices in IDIQ contracts. This is due to the fact that relative volatility in the different commodities used in a single project is high. Use of a single index to adjust unit prices for all types of projects incorrectly assumes that changes in the construction market have the same impact on prices for all types of work. The study proved that this assumption actually made estimates of asphalt paving projects the least accurate, which, unfortunately, is the most common type of work done by state transportation agencies. The contribution here is to demonstrate the need for alternative tools to adjust unit prices in IDIQ, as well as all multi-year contracts.

The higher level of uncertainty on IDIQ contracts due to their “indefinite” nature creates new risk management challenges for state transportation agencies. Recognizing the need for research in this area, an IDIQ risk management framework was developed to guide DOTs on risk planning and monitoring activities on this type of contracts (Chapter 6). This framework includes a Risk Planning Reference Sheet which describes eight common risk events in IDIQ contracts. The reference sheet explains the causes and effects of these potential risk situations as well as provides DOTs with different strategies to mitigate, avoid, or transfer this risk.

In addition to the research limitations stated in each of the papers contained in this doctoral dissertation, it should be noted that the stochastic IDIQ project selection framework and all other findings obtained from using the data provided by MnDOT are only applicable to construction/maintenance projects executed by this agency. The framework is intended to be flexible enough to be used by other transportation agencies; however, the outcome will be always constrained by the data source and the quantity, quality, and other characteristics of the data.

CHAPTER 9
CONTRIBUTIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter discusses the main findings drawn during the elaboration of this dissertation and the most relevant contributions from the four academic articles compiled in this document. Furthermore, this chapter presents some recommendations for future research aimed to improve the stochastic IDIQ project selection framework proposed in this dissertation as well as other aspects of IDIQ contracting. Further research should be also focused on looking for opportunities for the implementation of this framework with other agencies and alternative contracting methods.

Contributions

The main contribution of this dissertation is a stochastic decision making framework for the selection of suitable highway construction projects for IDIQ contracting. Additionally, the final dissertation document will include an assessment of current IDIQ contracting practices in the transportation industry, as well as some effective practices and improvement opportunities that may help to optimize IDIQ construction costs. Other important contributions are mentioned below.

- *Benefits of Implementing and Alliance-like Contracting Approach in the US:* The comparison made in Chapter 4 between a major IDIQ contract awarded by the US Department of Defense and the Collaborating Alliance Agreement use in NZ revealed substantial similarities between these two contracting approaches. However, the author found that in some aspects the collaborating alliancing agreement outperforms the major task order contracts used in the US. This study could be used to support the arguments made by those advocating for the implementation for enhanced integration in contracting practices in the US or by policy makers when evaluating the possibility and potential benefits of implementing alliancing-like contracts in the US.
- *Analysis of existing construction cost indexes*: The analysis of existing construction cost indexes presented in Chapter 5 to evaluate their performance tracking changes in the construction market at the project level offers a better understanding of the capabilities

and limitations of this tools. A full understanding the matching and proportionality principles introduced by the author in this paper can be used to develop construction cost indexing systems for specific agencies that furnish enhanced flexibility and accuracy.

- *IDIQ Risk Management Framework:* The IDIQ risk management framework proposed in Chapter 6 is intended to be used by DOTs as a reference to create their own risk management programs for IDIQ contracting. This framework explains how to take advantage of some unique characteristics of IDIQ contracting to improve risk monitoring and control activities in this type of contracts.
- *IDIQ Planning Reference Sheet*: As part of the IDIQ risk management framework, the planning reference sheet presented in Chapter 6 can be used by state transportation agencies to evaluate the causes and effects of eight potential risk events in IDIQ contracts. Likewise, this reference sheet suggests different risk mitigation strategies for each of the eight risk events.
- *Data-driven Construction Cost Estimating Models*: The non-linear regression equations developed in Chapter 7 to model the relationship between bid quantities and unit prices in transportation construction contracts are an example of the potential benefits DOTs could obtain from an appropriate use of the large amounts of bid data collected and stored by these agencies.

Recommendation for Future Research

The rapid growth in the use of IDIQ contracting techniques by state DOTs during the last few years and the little existing literature on this matter have increased the need for further research intended to gain a better understanding of the benefits, disadvantage, and implications of using IDIQ contracts. An effective implementation of IDIQ contracting techniques requires an adequate understanding of this contracting approach. The following list of future research topics suggested by the author are expected to fill gaps in the body of knowledge, optimizing and providing a better understanding of IDIQ contracting practices. This list also includes recommendations for future research not directly related to IDIQ that arose from the development of this dissertation as well as some ideas of how to apply the findings of this dissertation to other contracting methods and industries.

- Stochastic IDIQ project selection framework preliminary implementation: A case study.
- A comprehensive data-driven analysis of the cost implications of using IDIQ contracting.
- Analysis of the applicability of the stochastic IDIQ project selection framework in multiple award IDIQ contracts.
- Analysis of the applicability of the stochastic IDIQ project selection framework in other state DOTs, federal agencies, and other industries.
- A guidebook for multiple-award IDIQ contracting for state DOTs.
- “No blame/no disputes” in the US construction industry: a feasibility study.
- Combination of major task order contracts used by the US Department of Defense into a single collaborative alliancing agreement: a feasibility study

REFERENCES

Abdel-Razek, R., Abd Elshakour M, H., and M. Abdel-Hamid (2007). "Labor productivity: Benchmarking and variability in Egyptian projects." International Journal of Project Management, 25(2), 189-197.

Afrait, S. N., and C. Milana (2009). Economics and the Price Index, Routledge, UK.

Ahadzi, M., and G. Bowles (2004). Public–private partnerships and contract negotiations: an empirical study. *Construction Management and Economics*,*22*(9), 967-978.

Air Force Materiel Command (AFMC) (1999). *Guide for Use of Oral Presentations in Contracting by Negotiation*. AFMC, Wright-Paterson Air Force Base, OH.

Allen, R. (1975). *Index numbers in theory and practice*. Chicago: Aldine.

Anderson, S., and I.D. Damnjanovic (2008). *NCHRP Synthesis 379: Selection and Evaluation of Alternative Contracting Methods to Accelerate Project Completion*, Transportation Research Board of the National Academies, Washington, D.C., 77pp.

Australian Constructors Association (ACA) (1999). *Relationship Contracting*, Sydney, NSW, Australia, [Online]. Available: http://www.constructors.com.au/publications/ rc_general/Relationship%20Contracting%20Optimis ing%20Project%20Outcomes.pdf [accessed Apr. 21, 2014].

Australian Government, Department of Infrastructure and Transport (ADIT) (2010). *Infrastructure planning and delivery: best practice case studies,"* [Online]. Available: https://www.infrastructure.gov.au/infrastructure/publications/files/Best_Practice_Guide.pdf. [April 21, 2014].

Barlow, J. (2000). "Innovation and Learning in Complex Offshore Construction Projects," *Research Policy*, Vol. 29, pp. 973–989.

Benjamini Y, and Y. Hochberg (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. J R Statist Soc B, 57:290-300.

Boddy R., and G. Smith (2009). Statistical Methods in Practice for Scientists and technologists, John Wiley and Sons, UK.

California Department of Transportation (Caltrans) Division of Engineering Services (2013). Price Index for Selected Highway Construction Items: Third Quarter Ending September 30, 2013. Caltrans.

California Department of Transportation (Caltrans) (2014), *Invitation for Bid # 06A1964 Notice to Prospective Contractor*. Division of Procurement and Contracts, Caltrans, Sacramento, CA.

Chan, A. P., and C. M. Yeong (1995). A comparison of strategies for reducing variations. *Construction Management and Economics*, *13*(6), 467-473.

Curtis, J., D'Angelo, D., Hallowell, M., Henkel, T., and K. Molenaar (2012). Enterprise Risk Management for Transportation Agencies. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2271*, Transportation Research Board of the National Academies, Washington, D.C., pp. 57-65.

Department of Defense (DoD) (1999). *DOD Use of Multiple Award Task Order Contracts*. US Office of the Inspector General Department of Defense.

Dixon, T., Pottinger, G., and A. Jordan (2005). Lessons from the private finance initiative in the UK: Benefits, problems and critical success factors.*Journal of Property Investment & Finance*, *23*(5), 412-423.

Du, X. (2013). Traffic Safety Evaluation Model for Highway in Cold Region Based on Fuzzy Theory. *Research Journal of Applied Sciences, Engineering and Technology,* (6), 1048.

Duffield, C., Young, D., Hadgraft, R., and R. Foster (2014). Alliance contracting – evolving alternative project delivery, University of Melbourne, [Online] Available: http://www.commercial. unimelb.edu.au/alliancecontracting. [April 1, 2014]

Dunston, P., and A. Reed (2000). Benefits of Small Projects Team Initiative. *Journal of Construction Engineering and Management,* ASCE, Vol. 126, No. 1, pp. 22-28.

Edgeworth, F. (1925). The Plurality of Index-Numbers. *The Economic Journal,*(139), 379-388.

Eichhorn, W. (1976). Fisher's Tests Revisited. *Econometrica,* (2), 247-256.

Ernzen, J., Murdough, G, and D. Drecksel (2000). “Partnering on a Design-build Project: Making the Three-way Love Affair Work,” *Transportation Research Record No.1712,* Transportation Research Board, National Research Council, Washington, D.C., pp. 202–212.

Farris, D. Checking Your Indefinite Delivery/Indefinite Quantity (IDIQ) IQ (2002). *The Construction Lawyer*, Vol. 22, No. 4, p. 24.

Federal Acquisition Regulation (FAR) (2005), General Services Administration (GSA), U.S. Department of Defense (DoD), and National Aeronautics and Space Administration (NASA). *Federal Acquisition Regulation (FAR)*, Volume I, Subpart 16.5.

Federal Highway Administration (FHWA) (1988). “Bid Analysis and Unbalanced Bids,” Memorandum HHO-32, US Department of Transportation, May 16, 2988, http://www.fhwa.dot.gov/programadmin/contracts/051688.cfm [October 22, 2008].

Federal Highway Administration (FHWA) (1996). ‘‘Design-build: FHWA’s role in the design-build program under special experimental projects No. 14 (SEP-14).’’ (1996). Rep., U.S. Dept. of Transp., Federal Highway Administration, Washington, D.C.

Federal Highway Administration (FHWA) (1998). “Initiatives to Encourage Quality Through Innovative Contracting Practices Special Experimental Projects No. 14 (SEP-14),” US Department of Transportation, Federal Highway Administration.

Federal Highway Administration (FHWA) (2006). Design-build effectiveness study, Washington, DC.

Federal Highway Administration (FHWA) (2013). National Highway Construction Cost Index (NHCCI). U.S. Department of Transportation (USDOT). http://www.fhwa.dot.gov/policyinformation/nhcci.cfm. Accessed August 30, 2013.

Fisher, I. (1922). *The making of index numbers; a study of their varieties, tests, and reliability*, Boston, New York: Houghton Mifflin Company.

Fleeger, K. E. (2011). *Service Contracts: Is Red Tape Tying the Hands of Operational Commanders?*. Naval War Coll Newport Ri Joint Military Operations Department.

Florida Department of Transportation (FDOT) (2012). *Design-Build Guidelines.* FDOT.

Fortune, C., and S. Setiawan (2005). "Partnering practice and the delivery of construction projects for Housing Associations in the UK." *Engineering, Construction and Architectural Management*, 12, 181–193.

General Accounting Office (GAO) (1979). *Ineffective Management of GSA's Multiple Award Schedule Program – A Costly, Serious, and Longstanding Problem*. Controller General of the United States.

Ghavamifar, K., and A. Touran (2008). Alternative project delivery systems: Applications and legal limits in transportation projects. *Journal of Professional Issues in Engineering Education and Practice*, *134*(1), 106-111.

Gill, C. (1933). Construction Statistics. *Journal of the American Statistical Association,*(181), 31-54.

Government Accounting Office (GAO) (1991). *Using Structured Interviewing Techniques*, GAO/PEMD-10.1.5, Government Accounting Office, Washington, D.C., 191pp.

Gransberg, D.D. and C. Riemer (2009). "Impact of Inaccurate Engineer's Estimated Quantities on Unit Price Contracts," *Journal of Construction Engineering and Management,* ASCE, Vol. 135 (11), pp. 1138-1145.

Gransberg, D.D., and J.S. Shane (2010), *NCHRP Synthesis 402: Construction Manager-at-Risk Project Delivery for Highway Programs*, Transportation Research Board of the National Academies, Washington, D.C., 127pp.

Gransberg, D. D., and G. M. Gad (2014). Geotechnical Requirements in the Design-Build Selection Process. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2408*, Transportation Research Board of the National Academies, Washington, D.C., pp. 26-33.

Gransberg D.D., and J. A. Rueda (2014). *Indefinite Delivery/Indefinite Quantity Final Report, MnDOT Contract 99/004/Work Order*. MnDOT.

Gransberg, D.D., and J.A. Rueda Benavides (2015) *Expediting Emergency Construction Procurements: Case Studies in Success*, Proceedings, Canadian Society of Civil Engineers International Construction Specialty Conference, Vancouver, British Columbia, Canada.

Gransberg, D.D., J.A. Rueda, and M.C. Loulakis (2015a) *NCHRP Synthesis 473: Indefinite Delivery/Indefinite Quantity Contracting Practices*. Transportation Research Board, National Academies, Washington, D.C., 131 pp.

Gransberg, D.D., Scheepbouwer, E., and M. Loulakis (2015b). *NCHRP Synthesis466: Alliance Contracting – Evolving Alternative Projecy Delivery.* Transportation Research Board, National Academies, Washington D.C., 81 pp.

Grasso, V.B (2010). *Defense logistical support contracts in Iraq and Afghanistan: Issues for Congress*. Congress Research Services, 7-5700, 40 pp.

Hale, D. R., Shrestha, P. P., Gibson Jr, G. E., and G. C. Migliaccio (2009). Empirical comparison of design/build and design/bid/build project delivery methods. *Journal of Construction Engineering and Management, 135*(7), 579-587.

Halligan, D.W., Demsetz, L.A., Brown, J.D., and C.B. Pace (1994). "Action-Response Model and Loss of Productivity in Construction." J. Constr. Eng. Manage., 120(1), 47–64.

Hanna, A. S., and A. N. Blair (1993). "Computerized approach for forecasting the rate of cost escalation." *Computing in Civil and Building Engineering*. ASCE, 1993.

Hansen, B. (1984). On the Accuracy of Index Numbers. *Review of Income and Wealth,* (1), 25-38.

Hauck, A.J., Walker, D.H., Hampson, K.D., and R.J. (2004) "Peters Project Alliancing at National Museum of Australia-Collaborative Process." Journal of Construction Engineering and Management, 130(1), 143-152.

Hinze, J. W. (2011). *Construction planning and scheduling*. Pearson Education, Inc., Pblished as Prentice Hall, Upper Saddle River, NJ.

Hubbard, J. (1921). The Aberthaw Index of Building Costs. *The Review of Economics and Statistics,* (10), 342-344.

Ibbs, C., Y. Kwak, T. Ng, and A. Odabasi (2003). Project Delivery Systems and Project Change: Quantitative Analysis. *Journal of Construction Engineering and Management,* ASCE, Vol. 129, No. 4, pp. 382-387.

Iglewicz, B., and D. Hoaglin (1993). *How to detect and handle outliers*. ASQC Quality Press, Wisconsin, 1993.

Jeffrey, J., and C. Menches (2008). Emergency Contracting Strategies for Federal Projects. *Journal of Professional Issues in Engineering Education and Practice*. ASCE, Vol. 134, No.4, pp. 371-379.

Kendrick, Tom (2015). *Identifying and managing project risk: essential tools for failure-proofing your project*. AMACOM Division of American Management Association.

Konchar, M., and V. Sanvido (1998). Comparison of US project delivery systems. *Journal of construction engineering and management*, *124*(6), 435-444.

Le Masurier, Jason (2014). Briefing: *Affirming alliancing procurement for Christchurch rebuild, New Zealand*. Management, Procurement and Law, Proceeding of the Institution of Civil Engineers, pp. 1-3.

Lee, Y. (2013). Assessment of expressway construction using Quality Performance Index (QPI). *KSCE Journal of Civil Engineering*, (2), 377-385.

Maine Department of Transportation (MaineDOT) (2011). *On Call Paving Services (No Pin Project) Statewide*. Maintenance and Operations.

Manzo, F. A. (1997). “The impact of an unbalanced bid on the change order process,” *Constr. For. News* 7 (1), 8.

Matchette, R. B., and J. S. Danis (1995). Guide to Federal Records in the National Archives of the United States. *United States National Archives and Records Administration*, Washington, D.C.

Miller, J. B. (1997). Engineering systems integration for civil infrastructure projects. *Journal of Management in Engineering*, *13*(5), 61-69

Minnesota Department of Transportation (MnDOT) (2014). *Indefinite Delivery/Indefinite Quantity Implementation Guide*. Office of Construction and Innovative Contracting (OCIC).

Minnesota Department of Transportation (MnDOT) (2013). *Noise Walls (IDIQ)*. Office of Construction and Innovative Contracting (OCIC).

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

Molenaar, K. R., and D. D. Gransberg (2001). Design-builder selection for small highway projects. *Journal of Management in Engineering*, 17.4, 214-223.

Molenaar, K. R., and G. Yakowenko, eds (2007). *Alternative project delivery, procurement, and contracting methods for highways*. Reston: American Society of Civil Engineers.

Molenaar, K., Harper, C., and I. Yugar-Arias (2014). *Guidebook for Selecting Alternative Contracting Methods for Roadway Projects: Project Delivery Methods, Procurement Procedures, and Payment Provisions*. Next-Generation Transportation Construction Management, Transportation Pooled Fund Program Study TPF-5(260), University of Colorado, Boulder, CO.

Morris, P., and W. F. Willson (2006). Measuring and Managing Cost Escalation. *AACE International Transactions*, pp. 06.1–06.7.

Motulsky, H. J., and R. E. Brown (2006). Detecting outliers when fitting data with nonlinear regression–a new method based on robust nonlinear regression and the false discovery rate. *BMC bioinformatics*, *7*(1), 123.

Murdough, G., Drecksel, D., Sharp, G., and J. Ernzen (2007). "Performance in the Project Trailer: a Partnering Evaluation Tool." *Transportation Research Record No. 1994, Journal of the Transportation Research Board,* National Academies, pp. 26-34.

Neuendorf, K.A (2002). *The Content Analysis Guidebook*. Sage Publications, California.

Neyland, M. (2014). *How to win AFCAP IV*, Organizational Communication Inc. [Online]. Available: http://www.ociwins.com/Business-Development/how-to-win-afcap-iv.html. [November 4, 2014]

Office of Federal Procurement Policy (OFPP) (1997). *Best Practices for Multiple Award Task and Delivery Order Contracting*. Office of Management and Budget (OMB).

Olson, M. (2013). Quantification of sustainability index for underground utility infrastructure projects.(Author abstract). *Journal of Construction Engineering and Management*, (12).

Oppenheim, A. N. (2000). *Questionnaire Design, Interviewing and Attitude Measurement*. Continuum, London.

Oyetunji, A. A., and S. D. Anderson (2006). Relative effectiveness of project delivery and contract strategies. *Journal of Construction Engineering and Management*, *132*(1), 3-13.

Pakkala, P. (2002) *Innovative project delivery methods for infrastructure: An International Perspective*. Finnish Road Enterprise, Helsinki, Finland.

Rahman, M., and A. Alhassan (2012). "A contractor's perception on early contractor involvement", Built Environment Project and Asset Management, 2(2), pp. 217 – 233.

Rahman, I., Hameed Mem, A., and K. A. Abd. (2013). Significant Factors Causing Cost Overruns in Large Construction Projects in Malaysia. *Journal of Applied Sciences, 13*(2), 286-293.

Rosen, S. (1983). A Note on Aggregation of Skills and Labor Quality. The Journal of Human Resources, (3), 425-431.

Roth, M. (1995). "An empirical analysis of United States Navy design/build contracts." M.S. thesis, Univ. of Texas at Austin, Austin, TX.

Rowlinson, S., Cheung, F., Simons, R., and A. Rafferty (2006). "Alliancing in Australia—No-Litigation Contracts: A Tautology?," *J. Prof. Issues Eng. Educ. Pract.*, 132(1), 77–81.

Rueda, J. A. (2013). *Develop a Price Escalation Method for Minnesota Department of Transportation Indefinite Delivery/Indefinite Quantity: AxE Bidding* (Master's Thesis), Iowa State University, Ames, IA.

Rueda, J. A., D.D. Gransberg (2014a). Fundamentals of Indefinite Delivery/Indefinite Quantity Contracting: A Primer for Public Transportation Agencies. *Transportation Research Board 93rd Annual Meeting Compendium of Papers*, Paper # 14-0631, Washington, D.C., Jan. 12-16.

Rueda-Benavides, J.A., and D.D. Gransberg (2014b), "Indefinite Delivery/Indefinite Quantity Contracting: A Case Study Analysis," *Transportation Research Record No. 2408, Journal of the Transportation Research Board,* National Academies, pp. 17-25.

Rueda-Benavides, J. A., and D. D. Gransberg (2015). Suitability Analysis of Existing Construction Cost Indexes for the Minnesota Department of Transportation Construction Projects. *Transportation Research Board 94th Annual Meeting Compendium of Papers*, Paper 15-2293, Washington, D.C., 16 pp.

Rueda-Benavides, J. A., Scheepbouwer, E., and D. D. Gransberg (2015) US Major Task Order Contracting and NZ Collaborative Alliances Comparison, Paper CDR-1878, *AACE International Annual Meeting*, Las Vegas, NV, 2015.

SCIRT (2014). *The Value of SCIRT (Interim Report)*, January 2014, 83pp. [Online] Available: http://strongerchristchurch.govt.nz/sites/strongerchristchurch.govt.nz/files/2013-12-11%20The%20Value%20of%20SCIRT%20Abridged_0.pdf. [June 26, 2014]

Samuelson, P. (1974). Invariant Economic Index Numbers and Canonical Duality: Survey and Synthesis. *The American Economic Review,* (4), 566-593.

Sandner, C. L., and M. I. Snyder (2001). Multiple Award Task and Delivery Order Contracting: A Contracting Primer. *Public Contract Law Journal*, Vol. 30, p. 461.

Sanvido, Victor Ernest, and Mark D. Konchar (2014). *Project delivery systems: CM at risk, design-build, design-bid-build*. Construction Industry Institute, 1998.

Scheepbouwer, E. and D.D. Gransberg. "Comparative Analysis of New Zealand Alliance Contracting and U.S. Delivery Models," 93rd Annual Meeting of the Transportation Research Board Compendium of Papers, 10 pp.

Scott, B. (1995). "Competitive advantage through alliancing." *Engineering, Construction and Architectural Management*, 2, 83–92.

Scott, S., K. Molenaar, D. Gransberg, and N. Smith (2006). *NCHRP Report 561: Best-Value Procurement Methods for Highway Construction Projects*, Transportation Research Board of the National Academies, Washington, D.C., 167 pp.

Seo, S. (2006) *A review and comparison of methods for detecting outliers in univariate data sets*. Dissertation. University of Pittsburgh.

Shahandashti, S. M. (2013). Forecasting engineering news-record construction cost index using multivariate time series models.(Author abstract). *Journal of Construction Engineering and Management*, (9), 1237.

Shrestha, P., Migliaccio, G. C., O'Connor, J. T., and G. E. Gibson, Jr. (2007). "Benchmarking of large design-build highway projects: One-toone comparison and comparison with DBB projects." Transportation Research Record 1994, Transportation Research Board, Washington, DC, 17–25.

Shrestha, P., J. O'Connor, and G. Gibson, Jr. (2013). "Performance Comparison of Large Design-Build and Design-Bid-Build Highway Projects." *Journal of Construction Engineering and Management*, ASCE, Vol. 138, No.1, pp. 1-13.

Skolnik, J. (2011). *Price Indexing in Transportation Construction Contracts*. Jack Faucett Associates.

Spang, K., and S. Riemann (2014). "Partnering in Infrastructure Projects in Germany." *Procedia - Social and Behavioral Sciences*, 119, 219-228.

Swamy, S. (1965). "Consistency of Fisher's tests." *Econometrica: Journal of the Econometric Society*, 619-623.

Tennessee Department of Transportation (TDOT) (2010). *General Notes Regarding On-Call Emergency Flood Repairs.* Contracts CNJ210 thru CNJ221, Various Counties, TDOT.

Thomas, A,, Triolo, A., and R. Ortiz (2014). *Alternative Project Delivery Methods*, New Mexico Department of Transportation, Transportation Commission Meeting, Fort Sumner, NM, 2014.

Thomsen, C (2006). *Project Delivery Processes*. Parsons Corporation. http://isites.harvard.edu/fs/docs/icb.topic893720.files/6-2_Thomsen_Project%20Delivery%20Processes.pdf. Accessed July 28, 2015.

Thornton, K.D. (2002) "Fine-Tuning Acquisition Reform's Favorite Procurement Vehicle, The Indefinite Delivery Contract," Public Contract Law Journal, 383(31), p.2.

Touran, A., Gransberg, D., Molenaar K., Mason, D.J., and L. Fithian (2009) *TCRP Report 131: A Guidebook for the Evaluation of Project Delivery Methods*. Transportaiton Research Board, National Academies, Washington, D.C., 171 pp.

Touran, A., and R. Lopez (2006). Modeling cost escalation in large infrastructure projects. *Journal of Construction Engineering and Management*, *132*(8), 853–860.

US Air Force (USAF) (2014a). *Air Force Contract Augmentation Program (AFCAP)*, Air Force Civil Engineer Center, Department of Defense. [Online] Available: http://www.afcec.af.mil/shared/media/document/AFD-140227-020.pdf [January 20, 2015]

US Air Force (USAF) (2014b), *Air Force Contract Augmentation Program (AFCAP) – Performance Work Statement*, Solicitation No. FA8051-14-R-0001, Department of Defense.

U.S. Congress (1951). *The Budget of the United States Government for the Fiscal Year Ending June 30, 1952*. Unite States Government Printing Office, House Document No. 17, Washington, D.C.

U.S. Congress (1994). *Federal Acquisition Streamlining Act (FASA) of 1994*. Public Law 103-355.

Utah Department of Transportation (UDOT) (2010). *Multiple Project Contracting for On-Call Professional/Engineering Services Process*. UDOT.

Van Den Berg, M., and P. Kamminga (2006). "Optimising contracting for alliances in infrastructure projects" International Construction Law Review, 23, pp. 59–77.

Walewski, J., E. Gibson, and J. Jasper (2001). Project Delivery Methods and Contracting Approaches Available for Implementation by the Texas Department of Transportation. *Center for Transportation Research, The University of Texas at Austin*. FHWA/TX-0-2129-1.

Walsh, C. M. (1901). *The measurement of general exchange-value*. Vol. 25. The Macmillan Company.

Warne, T. R. (2005). Design build contracting for highway projects: A performance assessment, Tom Warne and Associates, South Jordan, UT.

West, N.J.N., D.D. Gransberg, and J. McMinimee (2012). "Effective Tools for Projects Delivered Using the Construction Manager/General Contractor", *Transportation Research Record No. 2268*, *Journal of the Transportation Research Board*, National Academies, *pp.33-42*.

Weston, D.C. and G.E. Gibson (1993). "Partnering-Project Performance in U.S. Army Corps of Engineers," *Journal of Management in Engineering*, Vol. 9, No. 4, pp. 410–425.

Williams, T. P. (1994). Predicting changes in construction cost indexes using neural networks. *Journal of Construction Engineering and Management,* (2), 306.

Yin, R. K. (1994), *Case Study Research: Design and Methods*, Sage Publications Beverly Hills, California.

APPENDIX A

MINNESOTA DEPARTMENT OF TRANSPORTATION HISTORICAL BID DATA

The historical bid data collected from MnDOT website and used in this dissertation corresponds to all contracts awarded between January 2008 and April 2015. There was a total of 1,746 contracts awarded throughout that period of time, and were distributed as presented below in Table A.1 and Table A.2.

TABLE A.1 Contract Distribution by Year

NUMBER OF CONTRACTS = 1361							
	Annual	**1st Half**	**2nd Half**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
2008	163	126	37	45	81	24	13
2009	287	208	79	88	120	45	34
2010	224	167	57	66	101	34	23
2011	219	167	52	71	96	29	23
2012	238	185	53	74	111	26	27
2013	294	242	52	75	167	16	36
2014	240	152	88	56	96	36	52
2015	81	81	-	67	14	-	-

TABLE A.2 Contract Distribution by District

District	No. of Contracts
1	171
2	127
3	204
4	142
6	576
7	244
8	150
Metro	132
Total	**1746**

APPENDIX B
INDEFINITE DELIVERY/INDEFINITE QUANTITY SAMPLE PROJECTS

This appendix presents the sample projects used in Chapter 5 and the original MnDOT contracts used to form these sample projects. A further explanation about how these sample projects were selected and form is presented in Chapter 5. This appendix also contains the actual unit price for each sample project calculated from MnDOT historical bid data. The four sample projects are presented as shown below:

B.1 Asphalt Pavement Project
B.2 Concrete Pavement Project
B.3 Traffic Barriers Project
B.4 Drainage Project

B.1 Asphalt Pavement Project

TABLE B.1.1 Asphalt Pavement - Original Contract

Original Contract	
Description	Bituminous Surfacing, Aggregate Shouldering, Guardrail
Contract ID	80117
S.P. Number	1213-10
Letting Date	06/06/2008
District	8

TABLE B.1.2 Asphalt Pavement - Original Contract Pay Items

Item Number	Item ID	Description	Units	% of Total Cost
1	2021501/00010	MOBILIZATION	LS	2.08%
2	2051501/00010	MAINT AND RESTORATION OF HAUL ROADS	LS	Removed
3	2104509/00055	REMOVE TWISTED END TREATMENT	EACH	0.09%
4	2104521/00220	SALVAGE GUARD RAIL-PLATE BEAM	L F	0.08%
5	2104601/01011	HAUL SALVAGED MATERIAL	LS	0.05%
6	2105501/00010	COMMON EXCAVATION	C Y	0.07%
7	2221501/00010	AGGREGATE SHOULDERING CLASS 1	TON	3.20%
8	2221604/00010	AGGREGATE SHOULDERING	S Y	0.17%
9	2232501/00040	MILL BITUMINOUS SURFACE (1.5")	S Y	0.38%
10	2232602/00010	MILLED RUMBLE STRIPS	EACH	0.44%
11	2357606/00010	BITUMINOUS MATERIAL FOR SHOULDER TACK	GAL	0.07%
12	2360501/22200	TYPE SP 12.5 WEARING COURSE MIXTURE (2,B)	TON	87.15%
13	2411507/00060	CONCRETE END POST	EACH	Removed
14	2540602/00150	MAIL BOX SUPPORT	EACH	Removed
15	2554501/00001	TRAFFIC BARRIER DESIGN SPECIAL	L F	0.69%
16	2554501/02007	TRAFFIC BARRIER DESIGN B8307	L F	0.33%
17	2554501/02038	TRAFFIC BARRIER DESIGN B8338	L F	0.58%
18	2554521/00020	ANCHORAGE ASSEMBLY-PLATE BEAM	EACH	0.12%
19	2554523/00028	END TREATMENT-TANGENT TERMINAL	EACH	0.25%
20	2563601/00010	TRAFFIC CONTROL	LS	1.01%
21	2580603/00010	INTERIM PAVEMENT MARKING	L F	0.39%
22	2582501/03008	PAVEMENT MESSAGE (STOP AHEAD) EPOXY	EACH	0.15%
23	2582502/41104	4" SOLID LINE WHITE-EPOXY	L F	2.17%
24	2582502/41524	24" STOP LINE WHITE-EPOXY	L F	0.03%
25	2582502/42104	4" SOLID LINE YELLOW-EPOXY	L F	0.25%
26	2582502/42204	4" BROKEN LINE YELLOW-EPOXY	L F	0.23%

TABLE B.1.3 Asphalt Pavement – Sample Project

Item ID	Description	Units	% of Total Cost	Items Represented
2021501/00010	MOBILIZATION	LS	2.08%	1
2104501/00042	REMOVE GUARD RAIL-PLATE BEAM	L F	0.09%	3
2104521/00220	SALVAGE GUARD RAIL-PLATE BEAM	L F	0.13%	4-5
2105501/00010	COMMON EXCAVATION	C Y	0.07%	6
2211503/00050	AGGREGATE BASE (CV) CLASS 5	C Y	3.37%	7-8
2232501/00040	MILL BITUMINOUS SURFACE (1.5")	S Y	0.38%	9
2232603/00025	MILLED RUMBLE STRIPS	L F	0.44%	10
2356505/00010	BITUMINOUS MATERIAL FOR SEAL COAT	GAL	0.00%	0
2360501/23200	TYPE SP 12.5 WEARING COURSE MIXTURE (3,B)	TON	87.23%	11-12
2554501/02038	TRAFFIC BARRIER DESIGN B8338	L F	1.97%	15-19
2563601/00010	TRAFFIC CONTROL	LS	1.01%	20
2582502/11104	4" SOLID LINE WHITE-PAINT	L F	0.39%	21
2582502/41104	4" SOLID LINE WHITE-EPOXY	L F	2.34%	22-24
2582502/42104	4" SOLID LINE YELLOW-EPOXY	L F	0.25%	25
2582502/42204	4" BROKEN LINE YELLOW-EPOXY	L F	0.23%	26

TABLE B.1.4 Asphalt Pavement – Actual Unit Prices

Item Number			2021501/00010	2104501/00042	2104521/00220	2105501/00010	2211503/00050	2232501/00040	2232603/00025	2360501/23200	2554501/02038	2563601/00010	2582502/11104	2582502/41104	2582502/42104	2582502/42204	TOTAL
Units			LS	L F	L F	C Y	C Y	S Y	L F	TON	L F	LS	L F	L F	L F	L F	
Year	Period	Quantity	1	385	364	63	2533	1518	74905	31410	1467	1	101038	177221	14059	16914	
2008	Q2-Q3	Unit price	$ 31,231.25	$ 3.65	$ 5.37	$ 17.47	$ 19.97	$ 3.76	$ 0.09	$ 41.66	$ 20.19	$ 15,104.01	$ 0.06	$ 0.20	$ 0.27	$ 0.21	
		Extension	$ 31,231.25	$ 1,402.90	$ 1,954.57	$ 1,102.91	$ 50,599.18	$ 5,704.64	$ 6,554.20	$1,308,392.26	$ 29,614.42	$ 15,104.01	$ 5,917.92	$ 35,127.76	$ 3,802.86	$ 3,491.12	**$1,500,000.00**
	Q4-Q1	Unit price	$ 38,408.07	$ 3.47	$ 5.77	$ 17.68	$ 18.34	$ 4.14	$ 0.09	$ 52.46	$ 18.20	$ 18,574.85	$ 0.09	$ 0.19	$ 0.19	$ 0.23	
		Extension	$ 38,408.07	$ 1,333.93	$ 2,101.36	$ 1,115.89	$ 46,469.39	$ 6,280.66	$ 6,939.09	$1,647,868.63	$ 26,695.56	$ 18,574.85	$ 9,001.51	$ 33,254.66	$ 2,688.38	$ 3,962.04	**$1,844,694.02**
2009	Q2-Q3	Unit price	$ 31,765.85	$ 3.50	$ 6.94	$ 16.90	$ 21.31	$ 3.49	$ 0.12	$ 43.59	$ 18.41	$ 15,362.55	$ 0.08	$ 0.23	$ 0.25	$ 0.23	
		Extension	$ 31,765.85	$ 1,347.62	$ 2,526.91	$ 1,066.73	$ 53,974.78	$ 5,295.46	$ 8,911.31	$1,369,002.33	$ 27,004.79	$ 15,362.55	$ 8,224.76	$ 40,924.84	$ 3,448.61	$ 3,947.80	**$1,525,675.93**
	Q4-Q1	Unit price	$ 38,149.35	$ 3.23	$ 6.44	$ 21.71	$ 20.84	$ 4.40	$ 0.10	$ 53.49	$ 17.50	$ 18,449.73	$ 0.07	$ 0.22	$ 0.26	$ 0.27	
		Extension	$ 38,149.35	$ 1,241.01	$ 2,343.75	$ 1,370.45	$ 52,805.59	$ 6,677.05	$ 7,441.59	$1,679,966.14	$ 25,672.84	$ 18,449.73	$ 7,033.92	$ 39,565.49	$ 3,590.38	$ 4,559.87	**$1,832,268.10**
2010	Q2-Q3	Unit price	$ 38,869.51	$ 3.25	$ 11.58	$ 20.93	$ 20.26	$ 4.83	$ 0.07	$ 54.56	$ 17.65	$ 18,798.01	$ 0.09	$ 0.22	$ 0.30	$ 0.24	
		Extension	$ 38,869.51	$ 1,250.36	$ 4,215.27	$ 1,321.28	$ 51,323.63	$ 7,323.10	$ 5,561.61	$1,713,804.36	$ 25,889.18	$ 18,798.01	$ 8,790.54	$ 39,181.53	$ 4,214.11	$ 3,981.63	**$1,866,856.58**
	Q4-Q1	Unit price	$ 36,959.62	$ 3.49	$ 10.28	$ 16.40	$ 21.83	$ 5.19	$ 0.09	$ 51.06	$ 18.24	$ 17,874.35	$ 0.10	$ 0.27	$ 0.31	$ 0.31	
		Extension	$ 36,959.62	$ 1,343.87	$ 3,742.66	$ 1,035.26	$ 55,299.24	$ 7,883.71	$ 7,069.07	$1,603,704.77	$ 26,748.44	$ 17,874.35	$ 10,486.81	$ 48,084.47	$ 4,428.34	$ 5,300.21	**$1,775,126.85**
2011	Q2-Q3	Unit price	$ 39,789.12	$ 3.78	$ 11.88	$ 23.04	$ 23.10	$ 5.78	$ 0.09	$ 55.16	$ 19.94	$ 19,242.75	$ 0.13	$ 0.26	$ 0.33	$ 0.28	
		Extension	$ 39,789.12	$ 1,452.92	$ 4,322.63	$ 1,454.45	$ 58,532.11	$ 8,775.40	$ 6,628.95	$1,732,710.35	$ 29,253.63	$ 19,242.75	$ 12,874.89	$ 45,604.86	$ 4,607.48	$ 4,806.66	**$1,911,024.34**
	Q4-Q1	Unit price	$ 40,418.65	$ 3.02	$ 12.41	$ 33.41	$ 22.27	$ 7.39	$ 0.09	$ 55.58	$ 18.05	$ 19,547.20	$ 0.17	$ 0.32	$ 0.48	$ 0.38	
		Extension	$ 40,418.65	$ 1,160.83	$ 4,518.24	$ 2,109.24	$ 56,423.92	$ 11,215.88	$ 6,948.50	$1,745,841.34	$ 26,471.68	$ 19,547.20	$ 17,480.08	$ 55,891.73	$ 6,792.08	$ 6,406.34	**$1,941,259.87**
2012	Q2-Q3	Unit price	$ 46,993.15	$ 3.82	$ 15.78	$ 28.15	$ 23.22	$ 6.67	$ 0.15	$ 64.72	$ 19.09	$ 22,726.75	$ 0.26	$ 0.38	$ 0.52	$ 0.35	
		Extension	$ 46,993.15	$ 1,470.58	$ 5,742.04	$ 1,776.95	$ 58,818.52	$ 10,127.43	$ 11,566.59	$2,032,823.84	$ 28,008.87	$ 22,726.75	$ 26,042.63	$ 67,446.91	$ 7,309.29	$ 5,891.78	**$2,257,025.43**
	Q4-Q1	Unit price	$ 45,508.79	$ 3.25	$ 12.37	$ 25.42	$ 25.84	$ 7.21	$ 0.18	$ 62.35	$ 18.18	$ 22,008.89	$ 0.23	$ 0.37	$ 0.45	$ 0.41	
		Extension	$ 45,508.79	$ 1,249.16	$ 4,501.98	$ 1,604.60	$ 65,472.99	$ 10,947.40	$ 13,527.24	$1,958,341.18	$ 26,668.63	$ 22,008.89	$ 23,724.74	$ 66,444.47	$ 6,374.59	$ 6,876.39	**$2,185,733.38**
2013	Q2-Q3	Unit price	$ 48,501.11	$ 3.11	$ 13.59	$ 26.18	$ 28.05	$ 7.63	$ 0.14	$ 65.66	$ 18.83	$ 23,456.03	$ 0.40	$ 0.43	$ 0.91	$ 0.57	
		Extension	$ 48,501.11	$ 1,198.09	$ 4,946.95	$ 1,652.93	$ 71,050.11	$ 11,578.05	$ 10,637.09	$2,062,343.74	$ 27,616.95	$ 23,456.03	$ 40,277.84	$ 75,607.61	$ 12,832.91	$ 9,708.27	**$2,329,450.54**

B.2 Concrete Pavement Project

TABLE B.2.1 Concrete Pavement - Original Contract

Original Contract	
Description	Concrete Pavement
Contract ID	120038
S.P. Number	2770-01
Letting Date	03/23/2012
District	Metro

TABLE B.2.2 Concrete Pavement – Original Contract Unit Prices

Item Number	Item ID	Description	Units	% of Total Cost
1	2021501/00010	MOBILIZATION	LS	10.79%
2	2104501/00022	REMOVE CURB AND GUTTER	L F	6.23%
3	2104505/00120	REMOVE BITUMINOUS PAVEMENT	S Y	3.74%
4	2104513/00011	SAWING BITUMINOUS PAVEMENT (FULL DEPTH)	L F	1.91%
5	2104523/00004	SALVAGE CASTING	EACH	0.76%
6	2105501/00010	COMMON EXCAVATION	C Y	3.09%
7	2105525/00030	TOPSOIL BORROW (CV)	C Y	1.36%
8	2301511/00010	STRUCTURAL CONCRETE	C Y	30.83%
9	2301538/00010	DOWEL BAR	EACH	5.53%
10	2301541/00404	INTEGRANT CURB DESIGN D4	L F	5.66%
11	2301604/03080	PLACE CONCRETE PAVEMENT 8.0"	S Y	24.87%
12	2506503/00010	RECONSTRUCT DRAINAGE STRUCTURE	L F	Removed
13	2506516/00010	CASTING ASSEMBLY	EACH	Removed
14	2506521/00010	INSTALL CASTING	EACH	Removed
15	2531501/02000	CONCRETE CURB & GUTTER DESIGN SPECIAL	L F	Removed
16	2563601/00010	TRAFFIC CONTROL	LS	2.61%
17	2563602/00002	RAISED PAVEMENT MARKER TEMPORARY	EACH	0.05%
18	2573530/00010	STORM DRAIN INLET PROTECTION	EACH	Removed
19	2575555/00010	TURF ESTABLISHMENT	LS	Removed
20	2581501/00010	REMOVABLE PREFORMED PLASTIC MARKING	L F	1.15%
21	2581603/00020	REMOVABLE PREFORMED PLASTIC MASK (BLACK)	L F	0.54%
22	2582502/41104	4" SOLID LINE WHITE-EPOXY	L F	0.88%

TABLE B.2.3 Concrete Pavement – Sample Contract

Item ID	Description	Units	% of Total Cost	Items Represented
2021501/00010	MOBILIZATION	LS	10.79%	1
2104501/00022	REMOVE CURB AND GUTTER	L F	6.23%	2
2104505/00120	REMOVE BITUMINOUS PAVEMENT	S Y	3.74%	3
2104513/00011	SAWING BITUMINOUS PAVEMENT (FULL DEPTH)	L F	1.91%	4
2104521/00220	SALVAGE GUARD RAIL-PLATE BEAM	L F	0.76%	5
2105501/00010	COMMON EXCAVATION	C Y	3.09%	6
2105522/00030	SELECT GRANULAR BORROW (CV)	C Y	1.36%	7
2301511/00010	STRUCTURAL CONCRETE	C Y	61.36%	8,10-11
2401541/00011	REINFORCEMENT BARS (EPOXY COATED)	LB	5.53%	9
2563601/00010	TRAFFIC CONTROL	LS	2.66%	16-17
2582502/31104	4" SOLID LINE WHITE-POLY PREFORM (GROUND IN)	L F	1.69%	20-21
2582502/41104	4" SOLID LINE WHITE-EPOXY	L F	0.88%	22

TABLE B.2.4 Concrete Pavement – Actual Unit Prices

Item Number			2021501/00010	2104501/00022	2104505/00120	2104513/00011	2104521/00220	2105501/00010	2105522/00030	2301511/00010	2401541/00011	2563601/00010	2582502/31104	2582502/41104	TOTAL
Units			LS	L F	S Y	L F	L F	C Y	C Y	C Y	LB	LS	L F	L F	
Year	Period	Quantity	1	31543	23950	14634	1923	4399	1187	10582	44512	1	7401	46297	
2008	Q2-Q3	Unit price	$ 161,833.97	$ 2.96	$ 2.34	$ 1.96	$ 5.91	$ 10.54	$ 17.19	$ 86.98	$ 1.86	$ 39,895.16	$ 3.43	$ 0.28	
		Extension	$ 161,833.97	$ 93,510.90	$ 56,079.25	$ 28,677.90	$ 11,363.27	$ 46,359.63	$ 20,405.60	$ 920,470.54	$ 82,897.13	$ 39,895.16	$ 25,369.96	$ 13,136.69	**$ 1,500,000.00**
	Q4-Q1	Unit price	$ 179,400.08	$ 2.19	$ 2.18	$ 2.10	$ 6.35	$ 10.66	$ 16.98	$ 103.98	$ 1.57	$ 44,225.54	$ 3.41	$ 0.27	
		Extension	$ 179,400.08	$ 69,082.11	$ 52,239.87	$ 30,736.31	$ 12,216.66	$ 46,905.07	$ 20,157.78	$ 1,100,375.04	$ 69,827.79	$ 44,225.54	$ 25,213.57	$ 12,436.21	**$ 1,662,816.01**
2009	Q2-Q3	Unit price	$ 190,950.55	$ 2.41	$ 2.24	$ 1.94	$ 7.64	$ 10.19	$ 18.94	$ 111.60	$ 1.46	$ 47,072.95	$ 4.14	$ 0.33	
		Extension	$ 190,950.55	$ 75,932.58	$ 53,687.70	$ 28,340.57	$ 14,690.70	$ 44,838.74	$ 22,479.54	$ 1,180,945.22	$ 64,952.82	$ 47,072.95	$ 30,678.54	$ 15,304.62	**$ 1,769,874.54**
	Q4-Q1	Unit price	$ 180,934.32	$ 2.98	$ 2.65	$ 2.15	$ 7.09	$ 13.10	$ 19.00	$ 100.78	$ 1.35	$ 44,603.76	$ 3.71	$ 0.32	
		Extension	$ 180,934.32	$ 93,975.22	$ 63,420.11	$ 31,391.87	$ 13,625.86	$ 57,605.38	$ 22,550.55	$ 1,066,416.88	$ 60,222.20	$ 44,603.76	$ 27,494.10	$ 14,796.26	**$ 1,677,036.50**
2010	Q2-Q3	Unit price	$ 167,611.26	$ 2.78	$ 3.03	$ 2.02	$ 12.75	$ 12.63	$ 21.43	$ 88.84	$ 1.49	$ 41,319.37	$ 3.82	$ 0.32	
		Extension	$ 167,611.26	$ 87,584.36	$ 72,613.64	$ 29,562.29	$ 24,506.32	$ 55,538.42	$ 25,443.26	$ 940,162.14	$ 66,270.29	$ 41,319.37	$ 28,284.30	$ 14,652.68	**$ 1,553,548.33**
	Q4-Q1	Unit price	$ 174,275.12	$ 3.04	$ 2.89	$ 2.26	$ 11.32	$ 9.89	$ 19.76	$ 94.25	$ 1.53	$ 42,962.14	$ 3.76	$ 0.39	
		Extension	$ 174,275.12	$ 95,820.26	$ 69,100.44	$ 33,003.22	$ 21,758.72	$ 43,515.91	$ 23,458.41	$ 997,398.24	$ 68,231.14	$ 42,962.14	$ 27,808.27	$ 17,982.10	**$ 1,615,313.96**
2011	Q2-Q3	Unit price	$ 176,394.32	$ 3.79	$ 3.28	$ 2.32	$ 13.07	$ 13.90	$ 20.70	$ 90.48	$ 1.57	$ 43,484.56	$ 3.77	$ 0.37	
		Extension	$ 176,394.32	$ 119,413.72	$ 78,645.90	$ 33,879.91	$ 25,130.48	$ 61,136.26	$ 24,574.91	$ 957,499.18	$ 69,853.48	$ 43,484.56	$ 27,888.79	$ 17,054.80	**$ 1,634,956.31**
	Q4-Q1	Unit price	$ 208,408.73	$ 3.68	$ 4.07	$ 2.22	$ 13.66	$ 20.16	$ 18.24	$ 110.14	$ 1.75	$ 51,376.72	$ 3.39	$ 0.45	
		Extension	$ 208,408.73	$ 116,120.75	$ 97,570.59	$ 32,441.77	$ 26,267.71	$ 88,659.37	$ 21,651.70	$ 1,165,475.83	$ 77,741.77	$ 51,376.72	$ 25,073.51	$ 20,901.77	**$ 1,931,690.23**
2012	Q2-Q3	Unit price	$ 197,870.35	$ 3.51	$ 4.08	$ 2.23	$ 17.36	$ 16.98	$ 21.88	$ 102.65	$ 1.68	$ 48,778.81	$ 3.48	$ 0.54	
		Extension	$ 197,870.35	$ 110,835.69	$ 97,623.18	$ 32,699.78	$ 33,382.47	$ 74,692.10	$ 25,977.93	$ 1,086,218.30	$ 74,987.07	$ 48,778.81	$ 25,723.77	$ 25,223.05	**$ 1,834,012.49**
	Q4-Q1	Unit price	$ 205,170.61	$ 3.44	$ 4.14	$ 2.45	$ 13.61	$ 15.33	$ 20.11	$ 109.57	$ 1.69	$ 50,578.46	$ 3.43	$ 0.54	
		Extension	$ 205,170.61	$ 108,446.98	$ 99,196.53	$ 35,799.95	$ 26,173.17	$ 67,447.68	$ 23,873.47	$ 1,159,441.25	$ 75,297.80	$ 50,578.46	$ 25,402.77	$ 24,848.17	**$ 1,901,676.84**
2013	Q2-Q3	Unit price	$ 221,792.98	$ 3.93	$ 4.11	$ 2.34	$ 14.96	$ 15.80	$ 25.09	$ 120.06	$ 1.55	$ 54,676.19	$ 3.63	$ 0.61	
		Extension	$ 221,792.98	$ 124,039.43	$ 98,442.86	$ 34,233.47	$ 28,760.08	$ 69,479.19	$ 29,788.05	$ 1,270,482.92	$ 68,912.10	$ 54,676.19	$ 26,863.39	$ 28,274.90	**$ 2,055,745.57**

B.3 Traffic Barriers Project

TABLE B.3.1 Traffic Barriers - Original Contract

Original Contract	
Description	Tension Cable Guardrail
Contract ID	80115
S.P. Number	0282-28
Letting Date	06/06/2008
District	Metro

TABLE B.3.2 Traffic Barriers – Original Contract Unit Prices

Item Number	Item ID	Description	Units	% of Total Cost
1	2021501/00010	MOBILIZATION	LS	2.96%
2	2104501/00018	REMOVE PIPE SEWERS	L F	0.03%
3	2104501/00042	REMOVE GUARD RAIL-PLATE BEAM	L F	0.77%
4	2104509/00106	REMOVE CATCH BASIN GRATE CASTING	EACH	0.02%
5	2105523/00010	COMMON BORROW (LV)	C Y	0.08%
6	2105603/00010	MINOR GRADING	L F	0.29%
7	2211501/00050	AGGREGATE BASE CLASS 5	TON	0.13%
8	2501569/02912	12" RC SAFETY APRON	EACH	0.05%
9	2503541/90122	12" RC PIPE SEWER DESIGN 3006	L F	0.11%
10	2506522/00011	ADJUST FRAME & RING CASTING	EACH	0.03%
11	2506602/00024	CONNECT INTO EXISTING CATCH BASIN	EACH	0.03%
12	2506602/00034	GRATE CASTING NO 716	EACH	0.07%
13	2533507/00010	PORTABLE PRECAST CONCRETE BARRIER DESIGN 8337	L F	0.58%
14	2554501/00001	TRAFFIC BARRIER DESIGN SPECIAL	L F	0.54%
15	2554501/00040	TRAFFIC BARRIER DESIGN BULLNOSE	L F	3.52%
16	2554501/02038	TRAFFIC BARRIER DESIGN B8338	L F	13.72%
17	2554521/00020	ANCHORAGE ASSEMBLY-PLATE BEAM	EACH	0.37%
18	2554523/00028	END TREATMENT-TANGENT TERMINAL	EACH	2.92%
19	2554602/00005	IMPACT ATTENUATOR BARRELS	EACH	0.39%
20	2554602/00040	T-BARRIER BRIDGE CONN DES 8318	EACH	0.05%
21	2554603/00080	TENSION CABLE GUARDRAIL	L F	69.87%
22	2563601/00010	TRAFFIC CONTROL	LS	3.47%

TABLE B.3.3 Traffic Barriers – Sample Contract

Item ID	Description	Units	% of Total Cost	Items Represente d
2021501/00010	MOBILIZATION	LS	2.96%	1
2104501/00016	REMOVE SEWER PIPE (STORM)	L F	0.03%	2
2104501/00042	REMOVE GUARD RAIL-PLATE BEAM	L F	0.77%	3-4
2105522/00030	SELECT GRANULAR BORROW (CV)	C Y	0.08%	5-6
2211503/00050	AGGREGATE BASE (CV) CLASS 5	C Y	0.13%	7
2501511/20180	18" CS PIPE CULVERT	L F	0.05%	8
2503541/90122	12" RC PIPE SEWER DESIGN 3006	L F	0.11%	9-12
2554501/02038	TRAFFIC BARRIER DESIGN B8338	L F	22.09%	13-20
2554603/00080	TENSION CABLE GUARDRAIL	L F	69.87%	21
2563601/00010	TRAFFIC CONTROL	LS	3.47%	22

TABLE B.3.4 Traffic Barriers – Actual Unit Prices

Item Number			2021501/00010	2104501/00016	2104501/00042	2105522/00030	2211503/00050	2501511/20180	2503541/90122	2554501/02038	2554603/00080	2563601/00010	TOTAL
Units			LS	L F	L F	C Y	C Y	L F	L F	L F	L F	LS	
Year	**Period**	**Quantity**	1	42	3998	318	75	12	86	16410	49374	1	
2008	**Q2-Q3**	Unit price	$ 44,426.36	$ 10.69	$ 2.98	$ 17.19	$ 26.39	$ 63.43	$ 42.18	$ 20.19	$ 21.23	$ 52,055.02	
		Extension	$ 44,426.36	$ 444.91	$ 11,913.53	$ 5,471.15	$ 1,990.18	$ 773.17	$ 3,642.78	$ 331,300.44	$1,047,982.45	$ 52,055.02	**$ 1,500,000.00**
	Q4-Q1	Unit price	$ 44,863.43	$ 12.03	$ 2.83	$ 16.98	$ 24.23	$ 49.95	$ 36.96	$ 18.20	$ 22.19	$ 52,567.14	
		Extension	$ 44,863.43	$ 501.06	$ 11,327.88	$ 5,404.70	$ 1,827.75	$ 608.87	$ 3,191.90	$ 298,646.87	$1,095,817.39	$ 52,567.14	**$ 1,514,756.98**
2009	**Q2-Q3**	Unit price	$ 42,168.70	$ 10.98	$ 2.86	$ 18.94	$ 28.15	$ 65.58	$ 32.46	$ 18.41	$ 20.38	$ 49,409.68	
		Extension	$ 42,168.70	$ 456.97	$ 11,444.07	$ 6,027.21	$ 2,122.95	$ 799.43	$ 2,803.09	$ 302,106.18	$1,006,434.45	$ 49,409.68	**$ 1,423,772.73**
	Q4-Q1	Unit price	$ 40,776.77	$ 10.06	$ 2.64	$ 19.00	$ 27.54	$ 47.80	$ 42.17	$ 17.50	$ 19.80	$ 47,778.74	
		Extension	$ 40,776.77	$ 418.79	$ 10,538.78	$ 6,046.25	$ 2,076.96	$ 582.74	$ 3,641.97	$ 287,205.49	$ 977,709.57	$ 47,778.74	**$ 1,376,776.07**
2010	**Q2-Q3**	Unit price	$ 44,443.19	$ 10.77	$ 2.66	$ 21.43	$ 26.77	$ 55.08	$ 43.37	$ 17.65	$ 22.08	$ 52,074.74	
		Extension	$ 44,443.19	$ 448.31	$ 10,618.17	$ 6,821.85	$ 2,018.67	$ 671.44	$ 3,745.17	$ 289,625.68	$1,090,100.93	$ 52,074.74	**$ 1,500,568.15**
	Q4-Q1	Unit price	$ 42,582.64	$ 11.84	$ 2.85	$ 19.76	$ 28.84	$ 50.95	$ 43.01	$ 18.24	$ 20.69	$ 49,894.71	
		Extension	$ 42,582.64	$ 492.93	$ 11,412.22	$ 6,289.67	$ 2,175.04	$ 621.14	$ 3,714.51	$ 299,238.42	$1,021,327.74	$ 49,894.71	**$ 1,437,749.02**
2011	**Q2-Q3**	Unit price	$ 52,371.28	$ 10.88	$ 3.09	$ 20.70	$ 30.53	$ 49.80	$ 36.70	$ 19.94	$ 26.37	$ 61,364.20	
		Extension	$ 52,371.28	$ 453.21	$ 12,338.29	$ 6,589.02	$ 2,302.20	$ 607.13	$ 3,169.69	$ 327,264.26	$1,301,790.82	$ 61,364.20	**$ 1,768,250.10**
	Q4-Q1	Unit price	$ 51,587.47	$ 12.46	$ 2.47	$ 18.24	$ 29.43	$ 63.81	$ 45.56	$ 18.05	$ 26.54	$ 60,445.79	
		Extension	$ 51,587.47	$ 518.73	$ 9,857.90	$ 5,805.25	$ 2,219.28	$ 777.82	$ 3,934.22	$ 296,142.28	$1,310,496.85	$ 60,445.79	**$ 1,741,785.58**
2012	**Q2-Q3**	Unit price	$ 52,548.93	$ 13.44	$ 3.12	$ 21.88	$ 30.67	$ 67.31	$ 51.40	$ 19.09	$ 26.72	$ 61,572.36	
		Extension	$ 52,548.93	$ 559.40	$ 12,488.32	$ 6,965.20	$ 2,313.46	$ 820.50	$ 4,438.31	$ 313,338.94	$1,319,202.88	$ 61,572.36	**$ 1,774,248.32**
	Q4-Q1	Unit price	$ 41,228.35	$ 13.54	$ 2.65	$ 20.11	$ 34.15	$ 64.46	$ 39.33	$ 18.18	$ 19.84	$ 48,307.87	
		Extension	$ 41,228.35	$ 563.62	$ 10,607.97	$ 6,400.95	$ 2,575.20	$ 785.74	$ 3,395.98	$ 298,345.60	$ 979,811.89	$ 48,307.87	**$ 1,392,023.17**
2013	**Q2-Q3**	Unit price	$ 40,723.06	$ 15.54	$ 2.54	$ 25.09	$ 37.05	$ 85.02	$ 45.68	$ 18.83	$ 19.26	$ 47,715.81	
		Extension	$ 40,723.06	$ 647.08	$ 10,174.26	$ 7,986.77	$ 2,794.56	$ 1,036.46	$ 3,944.87	$ 308,954.55	$ 950,985.28	$ 47,715.81	**$ 1,374,962.70**

B.4 Drainage Project

TABLE B.4.1 Drainage - Original Contract

Original Contract	
Description	Drainage Structures and Pipe Culverts
Contract ID	100129
S.P. Number	0303-62
Letting Date	06/04/2010
District	4

TABLE B.4.2 Drainage – Original Contract Unit Prices

Item Number	Item ID	Description	Units	% of Total Cost
1	2021501/00010	MOBILIZATION	LS	5.65%
2	2051501/00010	MAINT AND RESTORATION OF HAUL ROADS	LS	Removed
3	2104501/00022	REMOVE CURB AND GUTTER	L F	0.05%
4	2104505/00120	REMOVE BITUMINOUS PAVEMENT	S Y	0.06%
5	2104509/00013	REMOVE PIPE APRON	EACH	0.86%
6	2104509/00102	REMOVE CATCH BASIN	EACH	0.10%
7	2104509/00105	REMOVE CASTING	EACH	0.04%
8	2104513/00011	SAWING BITUMINOUS PAVEMENT (FULL DEPTH)	L F	0.09%
9	2105522/00010	SELECT GRANULAR BORROW (LV)	C Y	0.14%
10	2105601/00010	DEWATERING	LS	12.01%
11	2360501/23200	TYPE SP 12.5 WEARING COURSE MIXTURE (3,B)	TON	0.41%
12	2501511/90249	24" RC PIPE CULVERT CLASS V-JACKED	L F	41.64%
13	2501511/90309	30" RC PIPE CULVERT CLASS V-JACKED	L F	22.43%
14	2501515/90240	24" RC PIPE APRON	EACH	0.88%
15	2501515/90300	30" RC PIPE APRON	EACH	0.58%
16	2501569/01024	24" CS SAFETY APRON	EACH	1.26%
17	2501569/02924	24" RC SAFETY APRON	EACH	0.44%
18	2501602/00011	PLUG & ABANDON PIPE CULVERT	EACH	3.76%
19	2501603/00124	LINING CULVERT PIPE (24")	L F	6.82%
20	2506501/00070	CONSTRUCT DRAINAGE STRUCTURE DESIGN G	L F	0.44%
21	2506516/00010	CASTING ASSEMBLY	EACH	0.19%
22	2519607/00010	CLSM LOW DENSITY	C Y	Removed
23	2531501/02320	CONCRETE CURB & GUTTER DESIGN B624	L F	Removed
24	2563601/00010	TRAFFIC CONTROL	LS	2.15%
25	2573502/00040	SILT FENCE, TYPE MACHINE SLICED	L F	Removed
26	2575555/00010	TURF ESTABLISHMENT	LS	Removed

TABLE B.4.3 Drainage – Sample Contract

Item ID	Description	Unit s	% of Total Cost	Items Represented
2021501/00010	MOBILIZATION	LS	5.65%	1
2104501/00022	REMOVE CURB AND GUTTER	L F	2.46%	3, (1/5 of 10)
2104505/00120	REMOVE BITUMINOUS PAVEMENT	S Y	2.47%	4, (1/5 of 10)
2104501/00042	REMOVE GUARD RAIL-PLATE BEAM	L F	3.40%	5-7, (1/5 of 10)
2104513/00011	SAWING BITUMINOUS PAVEMENT (FULL DEPTH)	L F	2.49%	8, (1/5 of 10)
2105522/00030	SELECT GRANULAR BORROW (CV)	C Y	2.54%	9, (1/5 of 10)
2360501/23200	TYPE SP 12.5 WEARING COURSE MIXTURE (3,B)	TON	0.41%	11
2501511/90242	24" RC PIPE CULVERT	L F	42.96%	12,14,17
2501511/90302	30" RC PIPE CULVERT	L F	23.01%	13,15
2501511/20180	18" CS PIPE CULVERT	L F	1.26%	16
2501603/00124	LINING CULVERT PIPE (24")	L F	11.21%	18-21
2563601/00010	TRAFFIC CONTROL	LS	2.15%	24

TABLE B.4.4 Drainage – Actual Unit Prices

Item Number			2021501/00010	2104501/00022	2104505/00120	2104501/00042	2104513/00011	2105522/00030	2360501/23200	2501511/90242	2501511/90302	2501511/20180	2501603/00124	2563601/00010	TOTAL
Units			LS	L F	S Y	L F	L F	C Y	TON	L F	L F	L F	L F	LS	
Year	Period	Quantity	1	12422	15793	20468	19049	2215	73	10496	3404	299	2479	1	
2008	Q2-Q3	Unit price	$ 84,778.44	$ 2.96	$ 2.34	$ 2.49	$ 1.96	$ 17.19	$ 84.00	$ 61.40	$ 101.38	$ 63.43	$ 67.85	$ 32,184.32	
		Extension	$ 84,778.44	$ 36,825.24	$ 36,980.46	$ 51,016.54	$ 37,329.18	$ 38,072.97	$ 6,158.13	$ 644,407.94	$ 345,114.47	$ 18,968.00	$ 168,164.32	$ 32,184.32	$ 1,500,000.00
	Q4-Q1	Unit price	$ 78,458.32	$ 2.19	$ 2.18	$ 2.37	$ 2.10	$ 16.98	$ 105.79	$ 60.32	$ 63.84	$ 49.95	$ 88.35	$ 29,785.02	
		Extension	$ 78,458.32	$ 27,205.01	$ 34,448.65	$ 48,508.65	$ 40,008.55	$ 37,610.57	$ 7,755.92	$ 633,132.06	$ 217,332.75	$ 14,937.23	$ 218,994.29	$ 29,785.02	$ 1,388,177.02
2009	Q2-Q3	Unit price	$ 82,868.23	$ 2.41	$ 2.24	$ 2.39	$ 1.94	$ 18.94	$ 87.89	$ 64.86	$ 58.20	$ 65.58	$ 102.40	$ 31,459.15	
		Extension	$ 82,868.23	$ 29,902.77	$ 35,403.39	$ 49,006.22	$ 36,890.08	$ 41,942.55	$ 6,443.40	$ 680,748.59	$ 198,128.49	$ 19,612.12	$ 253,797.29	$ 31,459.15	$ 1,466,202.28
	Q4-Q1	Unit price	$ 73,797.42	$ 2.98	$ 2.65	$ 2.20	$ 2.15	$ 19.00	$ 107.86	$ 54.23	$ 49.55	$ 47.80	$ 95.59	$ 28,015.61	
		Extension	$ 73,797.42	$ 37,008.09	$ 41,821.26	$ 45,129.56	$ 40,861.87	$ 42,075.03	$ 7,906.99	$ 569,205.58	$ 168,673.41	$ 14,296.22	$ 236,919.83	$ 28,015.61	$ 1,305,710.87
2010	Q2-Q3	Unit price	$ 91,939.85	$ 2.78	$ 3.03	$ 2.22	$ 2.02	$ 21.43	$ 110.03	$ 71.90	$ 73.15	$ 55.08	$ 104.02	$ 34,903.00	
		Extension	$ 91,939.85	$ 34,491.32	$ 47,883.77	$ 45,469.51	$ 38,480.37	$ 47,472.29	$ 8,066.26	$ 754,692.01	$ 249,023.61	$ 16,472.24	$ 257,813.86	$ 34,903.00	$ 1,626,708.07
	Q4-Q1	Unit price	$ 86,016.61	$ 3.04	$ 2.89	$ 2.39	$ 2.26	$ 19.76	$ 102.96	$ 59.21	$ 66.03	$ 50.95	$ 127.23	$ 32,654.37	
		Extension	$ 86,016.61	$ 37,734.68	$ 45,567.05	$ 48,869.82	$ 42,959.32	$ 43,768.93	$ 7,548.06	$ 621,412.85	$ 224,775.27	$ 15,238.07	$ 315,362.10	$ 32,654.37	$ 1,521,907.11
2011	Q2-Q3	Unit price	$ 108,542.86	$ 3.79	$ 3.28	$ 2.58	$ 2.32	$ 20.70	$ 111.24	$ 95.45	$ 57.70	$ 49.80	$ 124.16	$ 41,205.98	
		Extension	$ 108,542.86	$ 47,025.94	$ 51,861.64	$ 52,835.45	$ 44,100.49	$ 45,852.10	$ 8,155.24	$ 1,001,803.67	$ 196,441.90	$ 14,894.59	$ 307,748.30	$ 41,205.98	$ 1,920,468.15
	Q4-Q1	Unit price	$ 95,675.84	$ 3.68	$ 4.07	$ 2.06	$ 2.22	$ 18.24	$ 112.08	$ 68.75	$ 67.98	$ 63.81	$ 139.42	$ 36,321.29	
		Extension	$ 95,675.84	$ 45,729.15	$ 64,341.19	$ 42,213.84	$ 42,228.50	$ 40,397.95	$ 8,217.04	$ 721,599.23	$ 231,433.32	$ 19,081.85	$ 345,570.43	$ 36,321.29	$ 1,692,809.63
2012	Q2-Q3	Unit price	$ 111,218.25	$ 3.51	$ 4.08	$ 2.61	$ 2.23	$ 21.88	$ 130.51	$ 83.63	$ 76.54	$ 67.31	$ 158.89	$ 42,221.63	
		Extension	$ 111,218.25	$ 43,647.86	$ 64,375.86	$ 53,477.94	$ 42,564.34	$ 48,469.87	$ 9,567.77	$ 877,719.48	$ 260,577.77	$ 20,129.02	$ 393,834.38	$ 42,221.63	$ 1,967,804.16
	Q4-Q1	Unit price	$ 94,634.00	$ 3.44	$ 4.14	$ 2.22	$ 2.45	$ 20.11	$ 125.73	$ 68.36	$ 63.49	$ 64.46	$ 135.95	$ 35,925.77	
		Extension	$ 94,634.00	$ 42,707.16	$ 65,413.38	$ 45,425.84	$ 46,599.74	$ 44,543.35	$ 9,217.20	$ 717,523.23	$ 216,131.19	$ 19,276.36	$ 336,978.92	$ 35,925.77	$ 1,674,376.15
2013	Q2-Q3	Unit price	$ 111,574.23	$ 3.93	$ 4.11	$ 2.13	$ 2.34	$ 25.09	$ 132.40	$ 84.79	$ 72.91	$ 85.02	$ 157.12	$ 42,356.77	
		Extension	$ 111,574.23	$ 48,847.58	$ 64,916.38	$ 43,568.58	$ 44,560.71	$ 55,578.84	$ 9,706.70	$ 889,917.11	$ 248,215.31	$ 25,427.09	$ 389,433.38	$ 42,356.77	$ 1,974,102.70

APPENDIX C

COST INDEXES AND ADJUSTED PRICES FOR SAMPLE PROJECTS

This appendix contains the twelve cost indexes analyzed in Chapter 5. Indexes presented below correspond to the last known index on July 1st each year from 2008 to 2013. The Producer Price Indexes (PPIs) Highway and Street Construction (BHWY) and Other Non-residential Construction (BONS) are used as a single index in Chapter 5 since the BHWY was discontinued in 2010 and combined with other indexes into the BONS. The RSMeans 20-city average index and National Highway Construction Cost Index (NHCCI) were not published or available at the moment of this study. More information about these indexes may be found in Table 9, Chapter 5.

TABLE C.1 Cost Indexes

Adjustment Dates		Jul-08	Jul-09	Jul-10	Jul-11	Jul-12	Jul-13
RSMeans	20-City Average	180.4	180.1	183.5	191.2	194.6	-
	Minneapolis	190.6	203.1	203.8	208.1	214.7	216.3
PPI	BHWY	234.4	208.7	217.1	-	-	-
	BONS	-	-	100.0	110.4	110.1	111.3
NHCCI		1.2938	1.0901	1.0671	1.0691	1.1468	-
CCI	20-City Average	8185	8578	8805	9053	9291	9542
	Minneapolis	9662.41	9745.02	10081.54	10177	10561.49	10852.11
BCI	20-City Average	4640	4771	4888	5059	5170	5286
	Minneapolis	4850.69	4885.99	5113.2	5213.9	5296.68	5415.65
Caltrans Quarterly		95.4	74.5	79.3	85.2	84.6	129.8
Caltrans 12-month		90.7	92	79.1	78.9	81.3	110.3
SDDOT		268.045	276.101	286.363	289.484	307.761	332.369
MnDOT Annual		212.88	234.22	225.32	229.17	245.95	257.36

BCI = Building Cost Index – Engineering News-Record; BHWY = Highway and Street Construction Index – Bureau of Labor Statistics; BONS = Other Non-residential Construction Index – Bureau of Labor Statistics; Caltrans = California Department of Transportation; CCI = Construction Cost Index – Engineering News-Record; MnDOT = Minnesota Department of Transportation; NHCCI = National Highway Construction Cost Index – Federal Highway Administration; PPI = Producer Price Index – Bureau of Labor Statistics; SDDOT = South Dakota Department of Transportation

This appendix also contains the adjusted cost of the sample projects in July 1st each year, since 2008 until 2013. Given the base price for all sample project was the same ($1,500,000.00) and since these indexes are equally applied to all contracts, adjusted prices for each period are the same for all sample projects.

TABLE C.2 Adjusted Contract Prices

Cost Indexes	Adjustment Dates					
	Jul-08	Jul-09	Jul-10	Jul-11	Jul-12	Jul-13
RsMeans National	$1,500,000.00	$1,497,505.54	$1,525,776.05	$1,589,800.44	$1,618,070.95	-
RsMeans Minneapolis	$1,500,000.00	$1,598,373.56	$1,603,882.48	$1,637,722.98	$1,689,664.22	$1,702,256.03
PPI	$1,500,000.00	$1,335,537.54	$1,389,291.81	$1,533,778.16	$1,529,610.28	$1,546,281.78
NHCCI	$1,500,000.00	$1,263,835.21	$1,237,169.58	$1,239,488.33	$1,329,571.80	-
CC National	$1,500,000.00	$1,572,021.99	$1,613,622.48	$1,659,071.47	$1,702,687.84	$1,748,686.62
CCI Minneapolis	$1,500,000.00	$1,512,824.44	$1,565,066.07	$1,579,885.35	$1,639,573.87	$1,684,689.95
BCI National	$1,500,000.00	$1,542,349.14	$1,580,172.41	$1,635,452.59	$1,671,336.21	$1,708,836.21
BCI Minneapolis	$1,500,000.00	$1,510,915.97	$1,581,177.11	$1,612,317.01	$1,637,915.43	$1,674,705.04
Caltrans Quarterly	$1,500,000.00	$1,171,383.65	$1,246,855.35	$1,339,622.64	$1,330,188.68	$2,040,880.50
Caltrans Last 12 months	$1,500,000.00	$1,521,499.45	$1,308,158.77	$1,304,851.16	$1,344,542.45	$1,824,145.53
SDDOT	$1,500,000.00	$1,545,081.98	$1,602,508.91	$1,619,974.26	$1,722,253.73	$1,859,961.95
MnDOT Annual	$1,500,000.00	$1,650,366.40	$1,587,655.02	$1,614,782.98	$1,733,018.60	$1,813,416.01

APPENDIX D
QUANTITY RANGES PER PAY ITEM

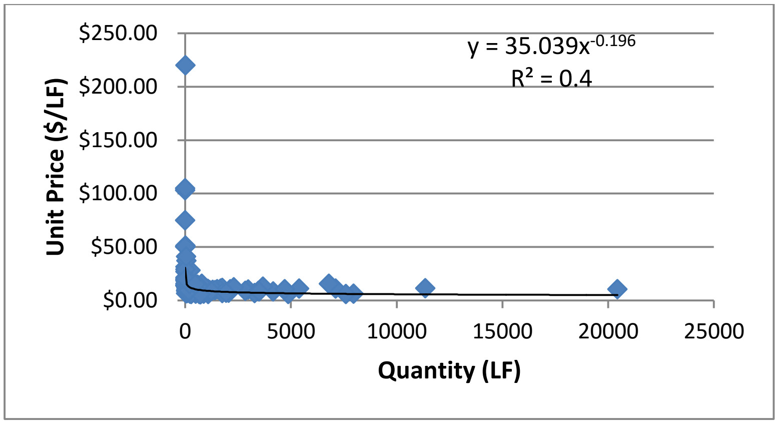
This appendix contains the quantity ranges used for each pay item in the sample projects to arrange and analyze MnDOT historical bid data. Besides the quantity ranges, this appendix presents the scatter plot with all bids received by MnDOT for each pay item (Quantity vs. Unit Price) and the regression used in the determination of the ranges. The pay item list shown in Table D.1 does include neither Mobilization nor Traffic Control since those items were handles in a different way. See Chapter 5 for more information about these quantity ranges. Pay items in this appendix are presented as shown below:

TABLE D.1 Sample Projects Pay Item List

PAY ITEMS		
No.	**Item ID**	**Description**
1	2104501/00016	REMOVE SEWER PIPE (STORM)
2	2104501/00022	REMOVE CURB AND GUTTER
3	2104501/00042	REMOVE GUARD RAIL-PLATE BEAM
4	2104505/00120	REMOVE BITUMINOUS PAVEMENT
5	2104513/00011	SAWING BITUMINOUS PAVEMENT (FULL DEPTH)
6	2104521/00220	SALVAGE GUARD RAIL-PLATE BEAM
7	2105501/00010	COMMON EXCAVATION
8	2105522/00030	SELECT GRANULAR BORROW (CV)
9	2211503/00050	AGGREGATE BASE (CV) CLASS 5
10	2232501/00040	MILL BITUMINOUS SURFACE (1.5")
11	2232603/00025	MILLED RUMBLE STRIPS
12	2301511/00010	STRUCTURAL CONCRETE
13	2356505/00010	BITUMINOUS MATERIAL FOR SEAL COAT
14	2360501/23200	TYPE SP 12.5 WEARING COURSE MIXTURE (3,B)
15	2401541/00011	REINFORCEMENT BARS (EPOXY COATED)
16	2501511/20180	18" CS PIPE CULVERT
17	2501511/90242	24" RC PIPE CULVERT
18	2501511/90302	30" RC PIPE CULVERT
19	2501603/00124	LINING CULVERT PIPE (24")
20	2503541/90122	12" RC PIPE SEWER DESIGN 3006
21	2554501/02038	TRAFFIC BARRIER DESIGN B8338
22	2554603/00080	TENSION CABLE GUARDRAIL
23	2582502/11104	4" SOLID LINE WHITE-PAINT
24	2582502/31104	4" SOLID LINE WHITE-POLY PREFORM (GROUND IN)
25	2582502/41104	4" SOLID LINE WHITE-EPOXY
26	2582502/42104	4" SOLID LINE YELLOW-EPOXY
27	2582502/42204	4" BROKEN LINE YELLOW-EPOXY

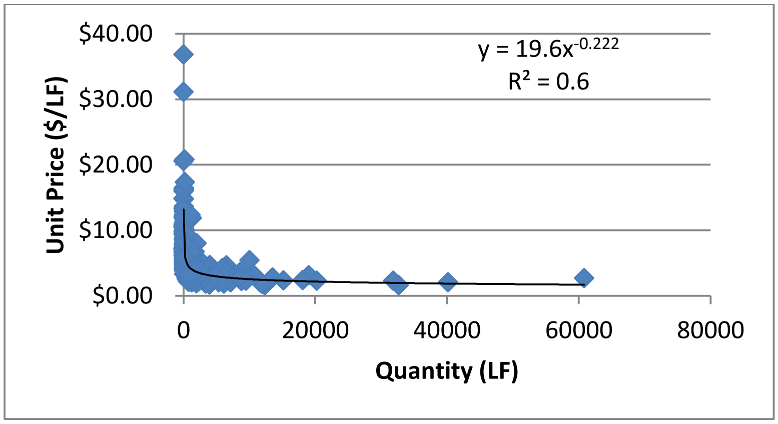
1. **2104501/00016 Remove Sewer Pipe (Storm)**

2104501/00016	
Average Variance	101%
Range 1 (LF)	10-350
Range 2 (LF)	350-12200



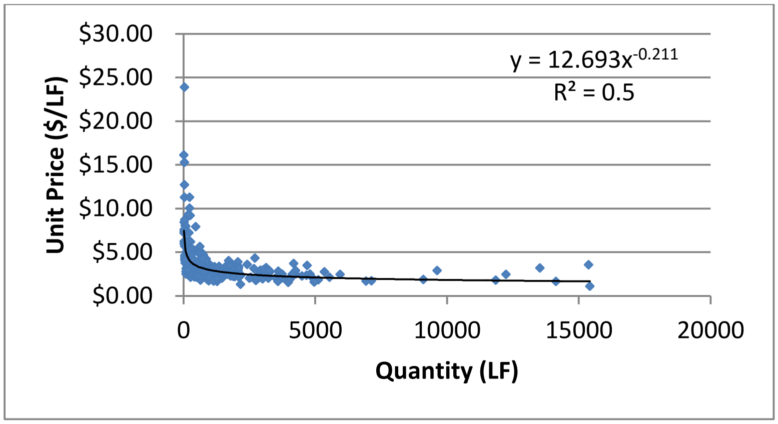
2. **2104501/00022 Remove Curb And Gutter**

2104501/00022	
Average Variance	115%
Range 1 (LF)	20-600
Range 2 (LF)	600-18000



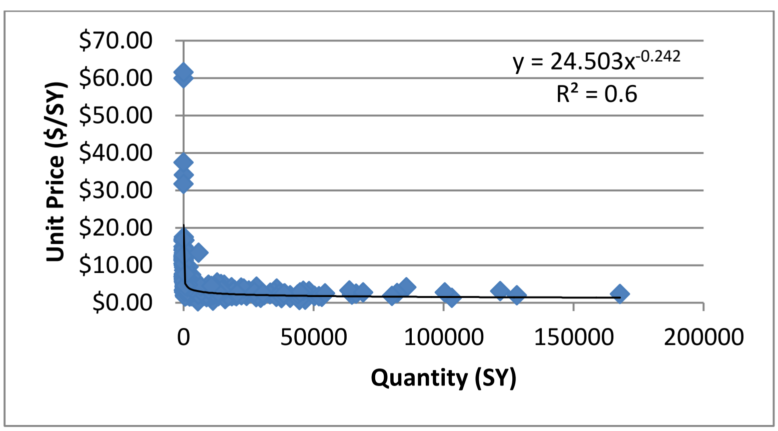
3. **2104501/00042 Remove Guard Rail-Plate Beam**

2104501/00042	
Average Variance	37%
Range 1 (LF)	50-220
Range 2 (LF)	220-990
Range 3 (LF)	990-4400
Range 4 (LF)	4400-19500



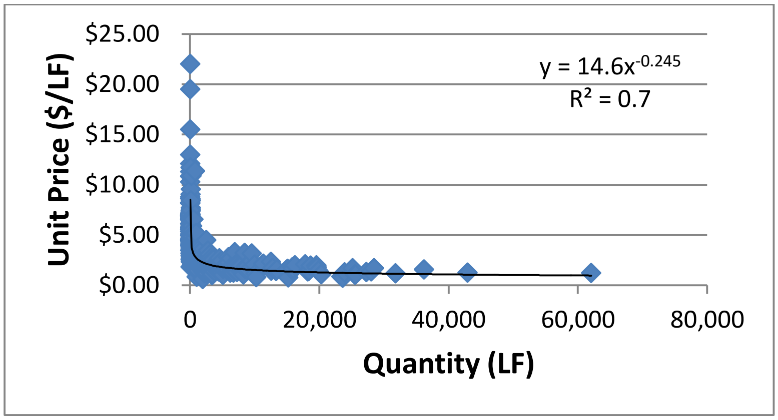
4. **2104505/00120 Remove Bituminous Pavement**

2104505/00120	
Average Variance	121%
Range 1 (SY)	60-1500
Range 2 (SY)	1500-37500
Range 3 (SY)	37500-937500



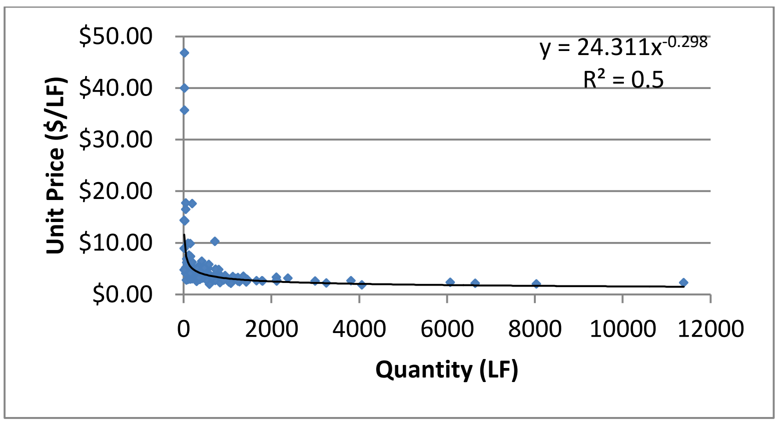
5. 2104513/00011 Sawing Bituminous Pavement (Full Depth)

2104513/00011	
Average Variance	120%
Range 1 (LF)	50-1250
Range 2 (LF)	1250-31500



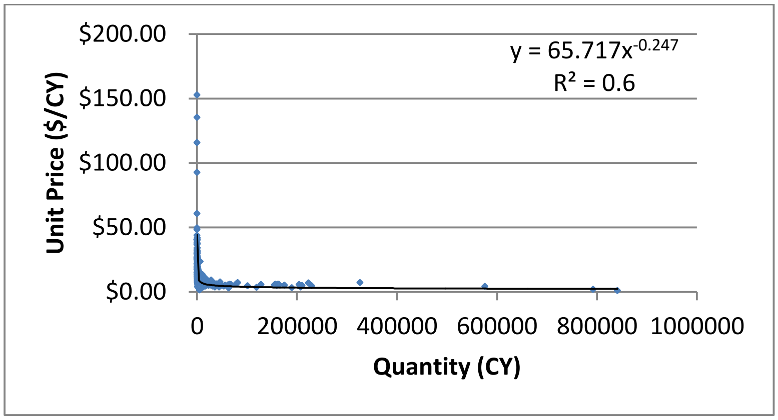
6. 2104521/00220 Salvage Guard Rail-Plate Beam

2104521/00220	
Average Variance	26%
Range 1 (LF)	25-55
Range 2 (LF)	55-120
Range 3 (LF)	120-260
Range 4 (LF)	260-570
Range 5 (LF)	570-1250
Range 6 (LF)	1250-2750
Range 7 (LF)	2750-6000



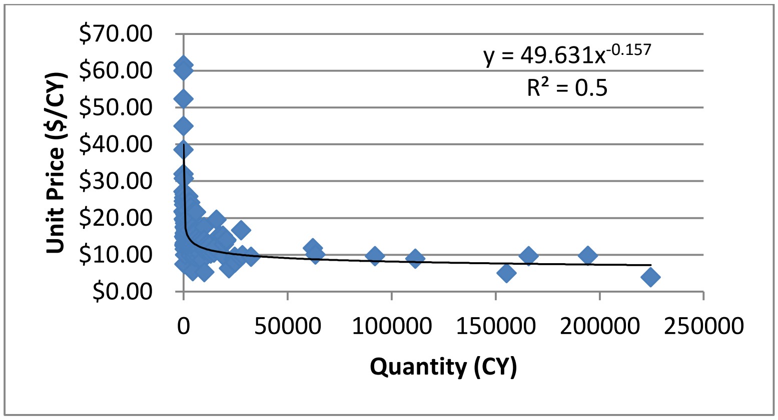
7. 2105501/00010 Common Excavation

2105501/00010	
Average Variance	93%
Range 1 (CY)	40-570
Range 2 (CY)	570-8200
Range 3 (CY)	8200-118000
Range 4 (CY)	118000-1700000



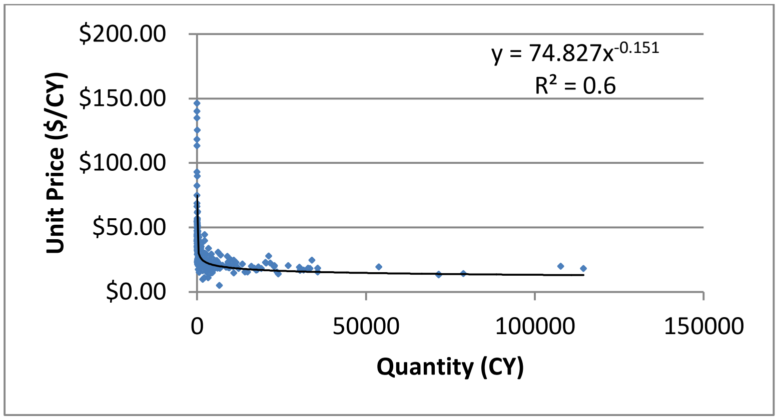
8. 2105522/00030 Select Granular Borrow (cv)

2105522/00030	
Average Variance	65%
Range 1 (CY)	70-1700
Range 2 (CY)	1700-41000
Range 3 (CY)	41000-1000000



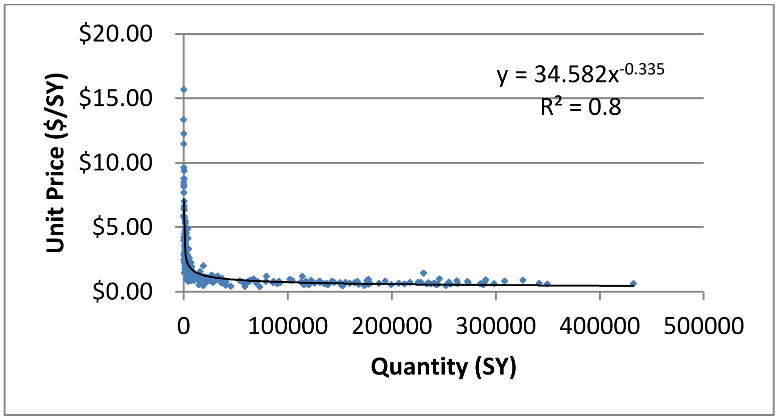
9. 2211503/00050 Aggregate Base (cv) Class 5

2211503/00050	
Average Variance	51%
Range 1 (CY)	75-1150
Range 2 (CY)	1150-18000
Range 3 (CY)	18000-280000



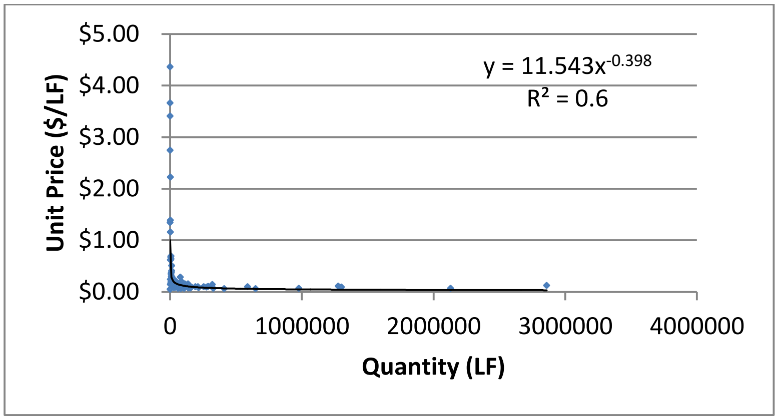
10. 2232501/00040 Mill Bituminous Surface (1.5")

2232501/00040	
Average Variance	113%
Range 1 (SY)	300-2850
Range 2 (SY)	2850-27200
Range 3 (SY)	27200-261000
Range 4 (SY)	261000-2500000



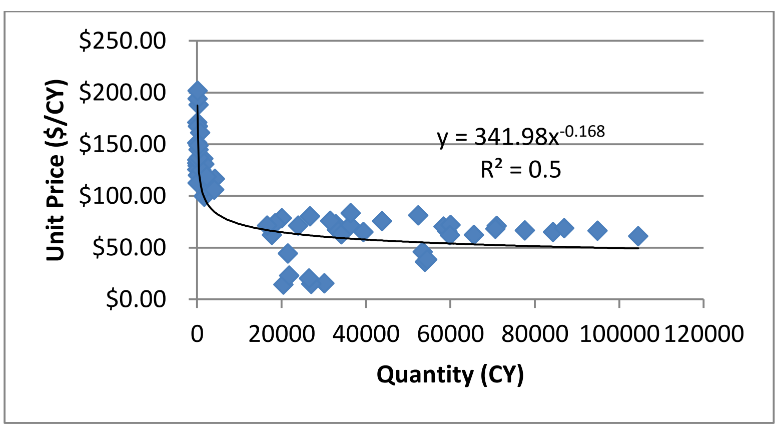
11. 2232603/00025 Milled Rumble Strips

2232603/00025	
Average Variance	99%
Range 1 (LF)	2600-14700
Range 2 (LF)	14700-83000
Range 3 (LF)	83000-470000
Range 4 (LF)	470000-2650000



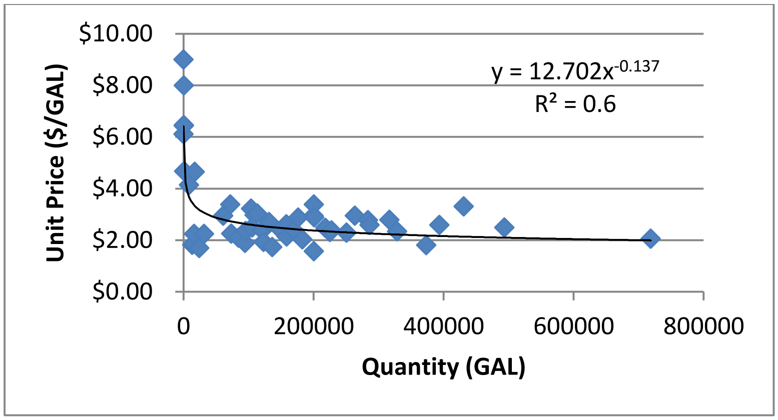
12. 2301511/00010 Structural Concrete

2301511/00010	
Average Variance	17%
Range 1 (CY)	75-190
Range 2 (CY)	190-490
Range 3 (CY)	490-1250
Range 4 (CY)	1250-3200
Range 5 (CY)	3200-8300
Range 6 (CY)	8300-21500
Range 7 (CY)	21500-55500
Range 8 (CY)	55500-144000



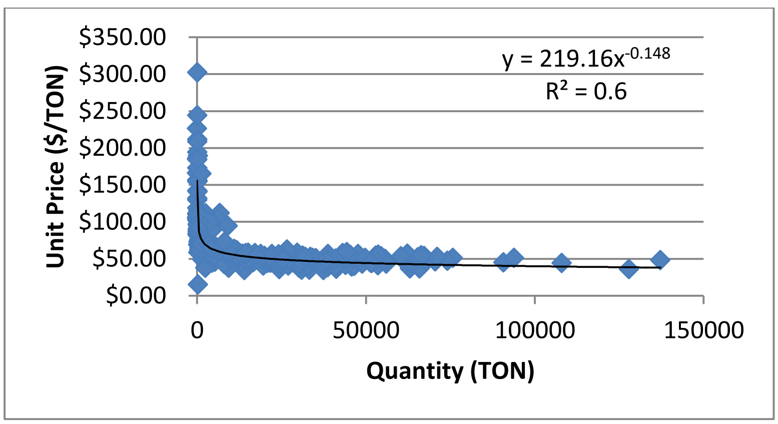
13. 2356505/00010 Bituminous Material For Seal Coat

2356505/00010	
Average Variance	48%
Range 1 (GAL)	500-8900
Range 2 (GAL)	8900-155000
Range 3 (GAL)	155000-2700000



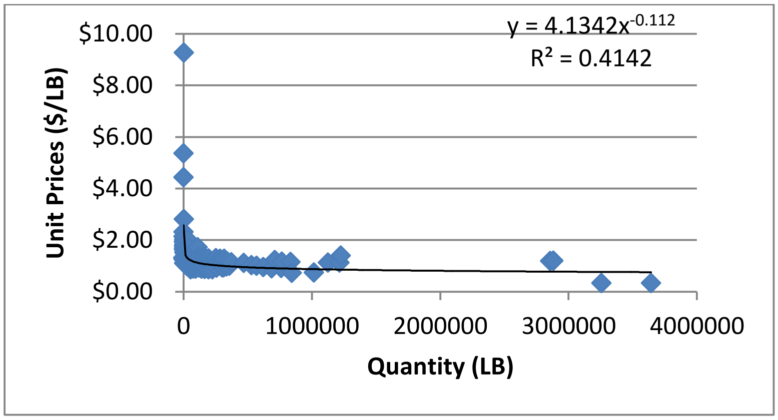
14. 2360501/23200 Type SP 12.5 Wearing Course Mixture (3,b)

2360501/23200	
Average Variance	18%
Range 1 (TON)	70-220
Range 2 (TON)	220-690
Range 3 (TON)	690-2100
Range 4 (TON)	2100-6600
Range 5 (TON)	6600-20700
Range 6 (TON)	20700-65000



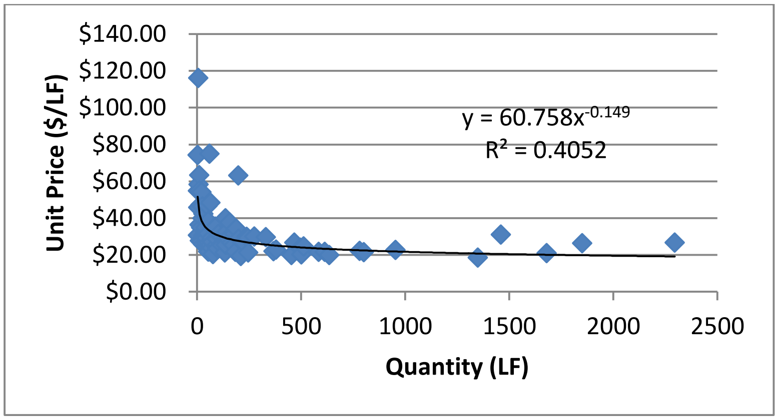
15. 2401541/00011 Reinforcement Bars (Epoxy Coated)

2401541/00011	
Average Variance	22%
Range 1 (LB)	3400-20800
Range 2 (LB)	20800-127000
Range 3 (LB)	127000-777000
Range 4 (LB)	777000-4662000



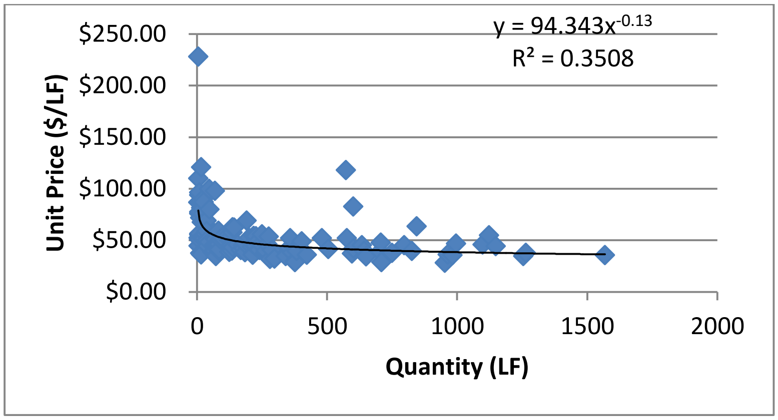
16. 2501511/20180 18" CS Pipe Culvert

2501511/20180	
Average Variance	52%
Range 1 (LF)	8-130
Range 2 (LF)	130-2200



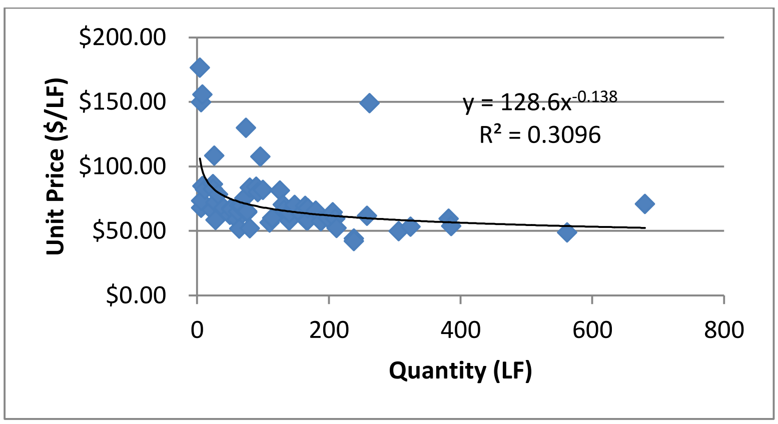
17. 2501511/90242 24" RC Pipe Culvert

2501511/90242	
Average Variance	54%
Range 1 (LF)	8-220
Range 2 (LF)	220-6200



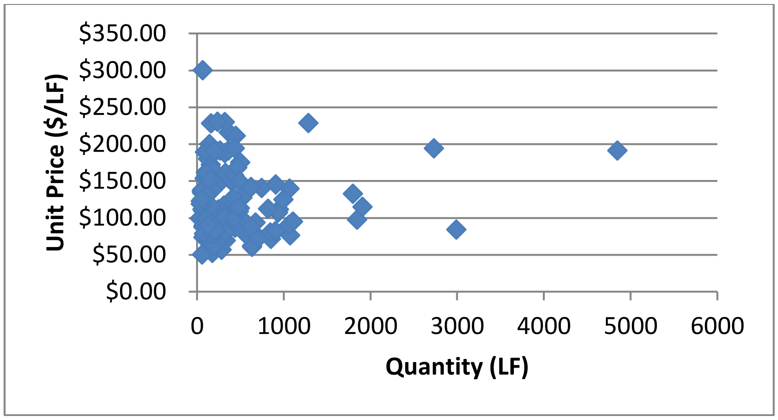
18. 2501511/90302 30" RC Pipe Culvert

2501511/90302	
Average Variance	46%
Range 1 (LF)	6-95
Range 2 (LF)	95-1500



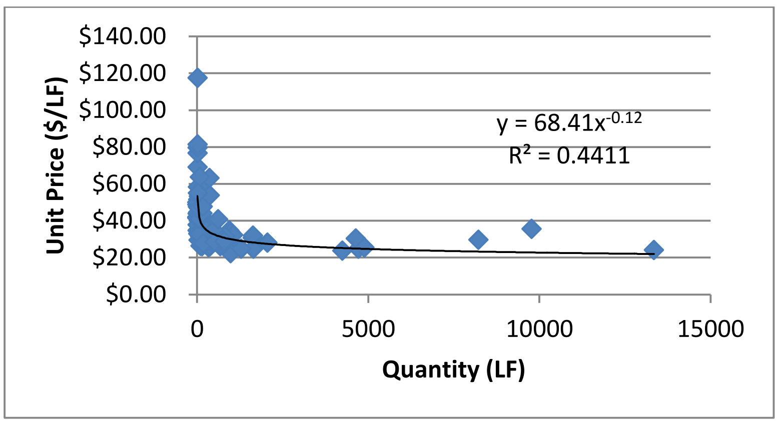
19. 2501603/00124 Lining Culvert Pipe (24")

No relation was found between unit price and quantity for this item. Therefore, all bids are considered in a single quantity range



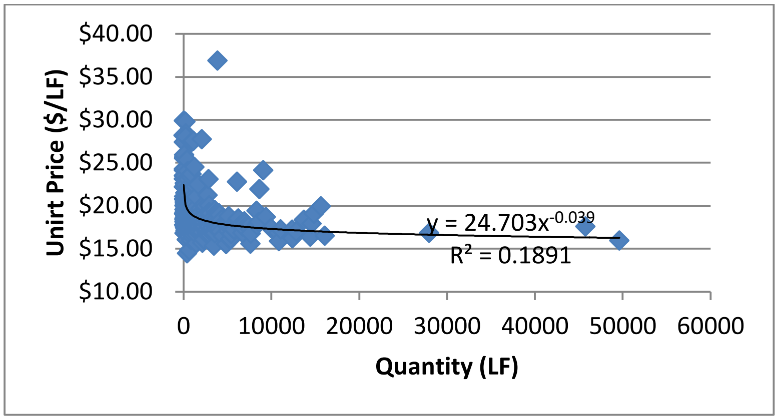
20. 2503541/90122 12" RC Pipe Sewer Design 3006

2503541/90122	
Average Variance	64%
Range 1 (LF)	12-750
Range 2 (LF)	750-47400



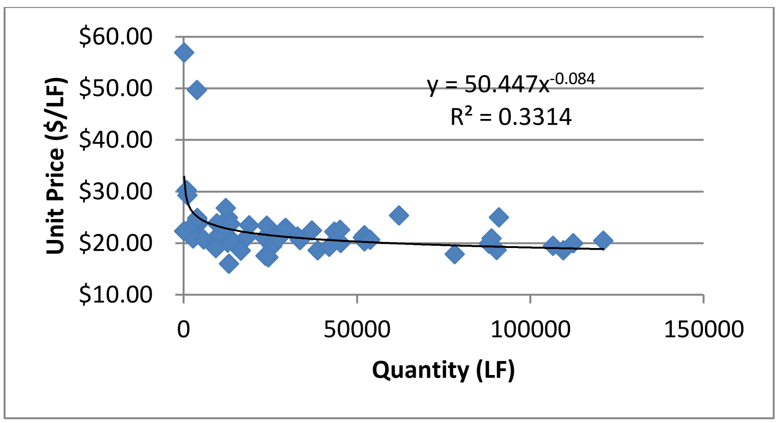
21. 2554501/02038 Traffic Barrier Design b8338

2554501/02038	
Average Variance	10%
Range 1 (LF)	100-1250
Range 2 (LF)	1250-15900



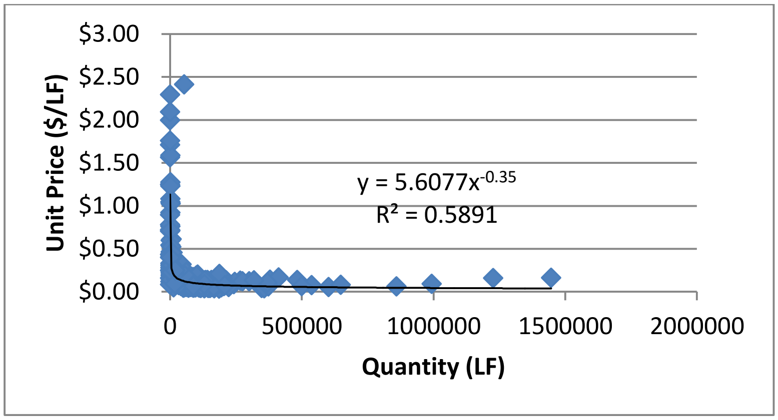
22. 2554603/00080 Tension Cable Guardrail

2554603/00080	
Average Variance	19%
Range 1 (LF)	1000-8300
Range 2 (LF)	8300-69000
Range 3 (LF)	69000-575000



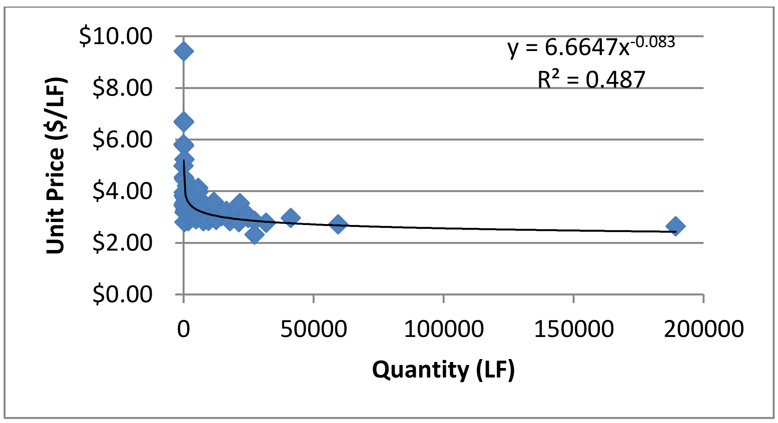
23. 2582502/11104 4" Solid Line White-Paint

2582502/11104	
Average Variance	35%
Range 1 (LF)	700-1650
Range 2 (LF)	1650-3930
Range 3 (LF)	3930-9300
Range 4 (LF)	9300-22100
Range 5 (LF)	22100-52600
Range 6 (LF)	52600-125300
Range 7 (LF)	125300-295000
Range 8 (LF)	295000-700000



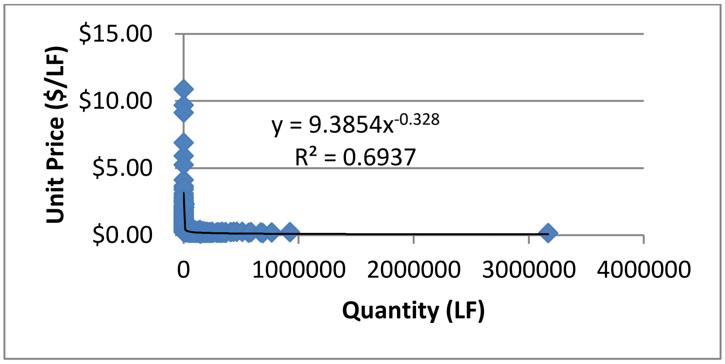
24. 2582502/31104 4" Solid Line White-Poly Preform (Ground In)

2582502/31104	
Average Variance	15%
Range 1 (LF)	110-620
Range 2 (LF)	620-3500
Range 3 (LF)	3500-19800
Range 4 (LF)	19800-110000



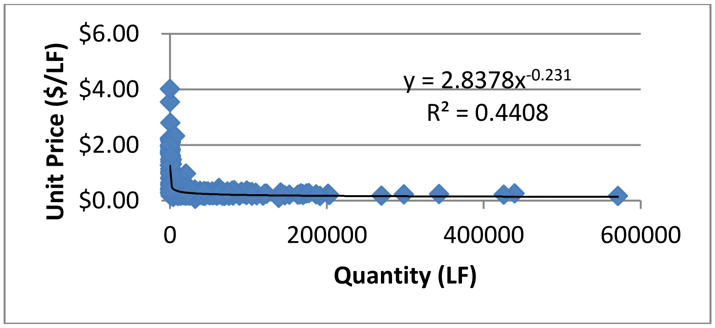
25. 2582502/41104 4" Solid Line White-Epoxy

2582502/41104	
Average Variance	17%
Range 1 (LF)	750-1200
Range 2 (LF)	1200-1900
Range 3 (LF)	1900-3100
Range 4 (LF)	3100-5000
Range 5 (LF)	5000-8000
Range 6 (LF)	8000-13000
Range 7 (LF)	13000-21000
Range 8 (LF)	21000-34000
Range 9 (LF)	34000-55000
Range 10 (LF)	55000-89000
Range 11 (LF)	89000-145000
Range 12 (LF)	145000-235000
Range 13 (LF)	235000-380000



26. 2582502/42104 4" Solid Line Yellow-Epoxy

2582502/42104	
Average Variance	15%
Range 1 (LF)	600-1100
Range 2 (LF)	1100-2000
Range 3 (LF)	2000-3700
Range 4 (LF)	3700-6900
Range 5 (LF)	6900-12000
Range 6 (LF)	12000-22000
Range 7 (LF)	22000-41000
Range 8 (LF)	41000-76000
Range 9 (LF)	76000-140000



27. 2582502/42204 4" Broken Line Yellow-Epoxy

2582502/42204	
Average Variance	14%
Range 1 (LF)	75-120
Range 2 (LF)	120-200
Range 3 (LF)	200-330
Range 4 (LF)	330-560
Range 5 (LF)	560-950
Range 6 (LF)	950-1600
Range 7 (LF)	1600-2700
Range 8 (LF)	2700-4500
Range 9 (LF)	4500-7600
Range 10 (LF)	7600-12800
Range 11 (LF)	12800-21700
Range 12 (LF)	21700-36800