2015

A framework for estimating preconstruction service costs at the functional level for highway construction projects

Emily K. Craigie
Iowa State University

A framework for estimating preconstruction service costs at the functional level for highway construction projects

by

Emily K. Craigie

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Civil Engineering (Construction Engineering and Management)

Program of Study Committee:
Douglas D. Gransberg, Major Professor
Hyung Seok "David" Jeong
Caroline C. Krejci

Iowa State University

Ames, Iowa

2015

TABLE OF CONTENTS

Page

LIST OF FIGURES v

LIST OF TABLES vi

ACKNOWLEDGEMENTS vii

ABSTRACT viii

CHAPTER 1 - INTRODUCTION 1
Content Organization 1

CHAPTER 2 - BACKGROUND AND MOTIVATIONS 4
Background 4
Motivation 5
Problem Statement 7

CHAPTER 3 - OVERALL APPROACH TO RESEARCH METHODOLOGY AND VALIDATION 8

CHAPTER 4 - CONSTRUCTION COST CERTAINTY VERSUS CONSTRUCTION SAVINGS: WHICH IS THE CORRECT APPROACH? 10
Abstract 10
Introduction 10
Background 11
Budgeting for preconstruction services 12
Construction cost growth 13
Methodology 14
Results 15
Conclusions 16

CHAPTER 5 - COST AND SCOPE BREAKDOWN STRUCTURE FOR FUNCTIONAL LEVEL ESTIMATING OF CONSULTANT FEES 18
Abstract 18
Introduction 19
Background 19
Methodology 22
Survey 22
Case studies 23
Current Functional Level Estimating Practices 24
Discussion 29
Conclusions and Recommendations 31

CHAPTER 6 - 3-POINT ESTIMATING: AN ALTERNATIVE METHOD FOR ESTIMATING PRECONSTRUCTION SERVICE HOURS 32
Abstract 32
Introduction 32
Background 33
Methodology 36
Interview findings 37
Developing a 3-Point estimating process 38
Case studies 40
Results 43
Discussion 48
Conclusions 50

CHAPTER 7 - A FRAMEWORK FOR ESTIMATING PRECONSTRUCTION SERVICE COSTS AT THE FUNCTIONAL LEVEL 52

CHAPTER 8 - A FRAMEWORK FOR VERIFYING THE EFFICACY OF HIGHWAY RESEARCH GUIDEBOOKS 55
Abstract 55
Introduction 56
Background 58
Research validation 58
Current dissemination practices 59
A review of highway agency guidebooks 60
Why evaluate dissemination? 61
Program evaluation 62
Logic models 63
Methodology 65
Guidebook vetting framework 65
Case-Study – NCHRP 15-51 guidebook 67
Discussion 74
Conclusions 75

CHAPTER 9 - CONSOLIDATED CONCLUSIONS AND LIMITATIONS 77
Conclusions 77
Limitations 78

CHAPTER 10 - CONTRIBUTIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH 80
Contributions 80
Recommendations for Future Research 81

REFERENCES 82

APPENDIX A - ESTIMATING CONSULTANT/DESIGN EFFORT HOURS FOR PCS CONTRACTS SURVEY 90

APPENDIX B - FEEDBACK SURVEY FOR NCHRP 15-51 GUIDEBOOK VETTING ... 93

APPENDIX C – INSTITUTIONAL REVIEW BOARD EXEMPTION DOCUMENT 95

LIST OF FIGURES

Page

Figure 1. Preconstruction Services Timeline (adapted from Anderson et al. 2008)................. 4
Figure 2. Functional estimate sequence 21
Figure 3. Geographic distribution of survey respondents 23
Figure 4. Example of a CSBS 27
Figure 5. Bottom-up estimating process 36
Figure 6. Cumulative Work Effort Hour Estimates for Project 2 47
Figure 7. Cumulative Work Effort Hour Estimates for Project 1 48
Figure 8. Functional level PCS cost estimating framework 53
Figure 9. Complete research process 57
Figure 10. Steps in Program Evaluation (adapted from UWex 2006).................... 63
Figure 11. Elements of a Logic Model (adapted from UWex 2002)...................... 64
Figure 12. Logic Model for NCHRP 15-51 Project... 68
Figure 13. PCS Guidebook Evaluation Observation Form..................................... 70
Figure 14. Examples of Vetting Survey Questions... 71

LIST OF TABLES

Page

Table 1. Design Fee and CGEE Comparison All Agencies.. 16
Table 2. Percentage of PCS Work Outsourced to Consultants by State 20
Table 3. Population, Land Area and Highway Information (U.S. Census Bureau 2014)....... 24
Table 4. Functional Level Estimating Methods 26
Table 5. Case Study Results... 28
Table 6. Collection of 3-Point Estimating Data 43
Table 7. 3-Point Estimates for Specific Work Tasks 44
Table 8. Work Effort Estimates derived from various approaches.. 44
Table 9. Typical validation and dissemination practices for different highway research 59

ACKNOWLEDGEMENTS

I have been very fortunate to have a large and enthusiastic support crew during my studies here at Iowa State. In particular I would like to acknowledge all the wonderful advice and guidance Dr. Gransberg has provided. He has been an endless source of knowledge and a great mentor to learn from. I must also acknowledge and thank Dr. Gransberg's lovely wife Gwen, who has been incredibly welcoming and generous to me during my time here.

I would also like to thank Dr. Jeong for his assistance developing the functional level estimating concepts within this thesis. I have learnt a great deal from Dr. Jeong and appreciate his eye for detail.

My fellow Construction Engineering graduate students, in particular Dr. Gransberg's team, have been a wonderful additional resource to me. Not only providing academic support, they have been so much fun to get to know and explore Iowa with, I thank them for their friendship. In particular a special thank you must go to Brendon for his unwavering support. He has been an invaluable ally in my graduate experience and a pillar of strength whenever I have needed him. I have thoroughly enjoyed our U.S. adventure together.

Finally, I would like to thank my parents for their continued support. Despite being on the other side of the world, they have always kept up to date on my progress and offered boundless encouragement.

ABSTRACT

Failing to budget an appropriate amount of funding for services rendered during the preconstruction phase of highway projects has been found to degrade the final quality of project construction documents, generating design errors, omissions, and ambiguities that must be remedied at additional cost during construction. The overall impact is to reduce cost certainty during the project development process. In other words, investment in the preconstruction process by developing an accurate estimate of preconstruction service (PCS) costs reaps a return measured in reduced cost growth during construction.

To deliver a high quality constructed product, the necessary resources must be allocated to the preconstruction process to permit planners and designers the time and funding to be able to solve technical, environmental, and constructability problems *before* the construction contract is advertised.

To ensure that the appropriate resources are made available during the preconstruction phase, an accurate estimation of PCS costs must first be developed. The preconstruction phase includes the delivery of many intermediate products and services such as environmental investigations, geotechnical studies, public involvement and permitting. The effort required to complete these tasks is project specific and influenced by location, resources impacted and regulations governing the project. Consequently, this research found the best way to quantify these services was to develop a scope of work for the effort required to complete each task. This is a 'bottom-up' estimating approach at the functional level.

This research develops a cost and scope breakdown structure (CSBS) to organize PCS work tasks. It then proposes a methodology that utilizes the CSBS with historical data to create estimates that are consistent and less reliant on the experience of senior staff. A framework is developed to better estimate PCS costs, improving the quality of final design documents and enhancing an agency's ability to control cost and schedule growth during project delivery.

Finally, this research identified a need to assess the quality of the products used to disseminate highway research project findings. A vetting framework is proposed to ensure that new PCS estimating concepts and other highway research dissemination is rigorously evaluated to ensure its communicability with industry practitioners.

CHAPTER 1 - INTRODUCTION

Preconstruction services (PCS) for a highway project are all the planning, programming, design, and procurement activities completed prior to the construction contract award. Highway agencies use many different techniques to estimate the cost of PCS prior to undertaking these services. Estimation can be undertaken in two ways, using either a high level 'top-down' approach, typically a percentage of estimated construction costs, or a 'bottom-up' approach which investigates the preconstruction tasks at the functional level. This research first investigates the difference between these techniques for PCS cost estimation. The findings from this initial research step suggested that estimating at the functional level is a more consistent approach for highway agencies to estimate PCS costs. Estimating at the functional level was the focus of the research from that point on. Specifically, the research aimed to contribute a formalized framework to estimate PCS costs at the functional level. This thesis has four primary areas of focus in order to contribute to this method:

- Proposing an industry mentality shift from striving for cost savings to striving for cost certainty,
- Developing a Cost and Scope Breakdown Structure (CSBS) framework to structure functional level estimation of consultant fees,
- Establishing a methodology for estimating preconstruction service hours, *and*
- Proposing a vetting process to evaluate the quality of highway research guidebook dissemination.

The research not only investigates the specifics of developing a PCS cost estimate at the functional-level, but also spans the broader topic of how to evaluate the quality of highway research dissemination techniques. This final step is included to help ensure that the practical concepts developed within this thesis and other highway research projects are transferred as efficiently as possible to the wider highway industry.

Content Organization

This thesis consists of four journal articles that are presented in Chapters 4, 5, 6 and 8. Despite each of these chapters originally being authored as stand-alone documents, they all focus on preconstruction service cost estimating and estimating research dissemination within the highway industry. The journal articles have been sequenced to logically build upon contributions to PCS estimating and answer the overall objectives of this thesis.

First, Chapter 2 furnishes the reader background information to understand the key components of PCS, including how and why an estimation of costs are required. Chapter 3 then details the overall methodology used to complete the research. Chapter 4 provides a broad overview of the attitudes of the highway industry towards the importance of PCS cost estimates, then the focus of the research narrows to propose a cost and scope structure for PCS cost estimating (Chapter 5). Chapter 6 narrows the focus further proposing an estimating method that utilizes the previously proposed cost and scope structure with historical data. Chapter 7 is not a journal article, but pulls together the concepts from the two preceding chapters to develop a framework for estimating PCS costs at the functional level. Finally the research broadens once more to discuss a framework to ensure new PCS estimating concepts and other highway research dissemination products can be evaluated to ensure communicability with practitioners in the field (Chapter 8).

Chapter 4 was submitted to the Transportation Research Board (TRB) and was accepted for presentation at the 2016 annual meeting. This chapter concludes that as the level of resources invested in the preconstruction service activities increases, a highway agency's ability to control the final cost of the constructed product increases. It recommends that transportation agencies review internal policies and potentially adopt maximizing cost certainty as the ultimate goal of the preconstruction period rather than minimizing project cost.

Chapter 5 was also submitted to the TRB and was accepted for presentation at the 2016 annual meeting. This article assesses current estimating practices and proposes a Cost and Scope Breakdown Structure (CSBS) framework to structure functional level estimation of consultant fees. Such a framework is promoted to reduce the chance that under-funded preconstruction services may degrade post-award construction contract cost certainty.

Chapter 6 will be submitted to the American Society of Civil Engineers *Journal of Construction Engineering and Management* and provides an agency with a methodology for estimating PCS costs using recorded work effort hours for specific work tasks. This technique does not rely solely on the experience of senior staff, a challenge commonly faced in current practice. It also provides a platform to incorporate historical data as it becomes available in the future.

Chapter 8 will be submitted for publication in the American Society of Civil Engineers *Journal of Construction Engineering and Management*. This final article analyzes how the dissemination of highway research products can be evaluated to ensure that it is meeting desired research objectives. The chapter provides a vetting framework to qualitatively evaluate whether guidebooks developed as research products effectively communicate their content to the intended users and fulfil their required research objectives.

The conclusions of the research are detailed in Chapter 9, along with their associated limitations. Chapter 10 discusses the important contributions the research has made to the PCS cost estimating body of knowledge and gives recommendations for future research.

CHAPTER 2 - BACKGROUND AND MOTIVATIONS

Background

To understand the important role of PCS cost estimating within a highway projects life-cycle it is imperative to first understand the conditions under which cost estimates are made during the early phases of a highway project.

Defining preconstruction services

Preconstruction services (PCS) covers a broad spectrum of project services and includes all work completed on the project from project conception through to the contract award. For the purposes of this research, PCS are defined as all of the work completed on a project commencing at the allocation of a project identification number (PIN), and ceasing at the award of the construction contract. Figure 1 displays the activities included within the preconstruction phase of a project timeline. It should be noted that with this definition all activities that occur prior to the PCS phase; initial startup, scoping and budget, corridor planning and conceptual design, are considered sunk costs and are encompassed in the departmental overhead rate assigned to all projects.

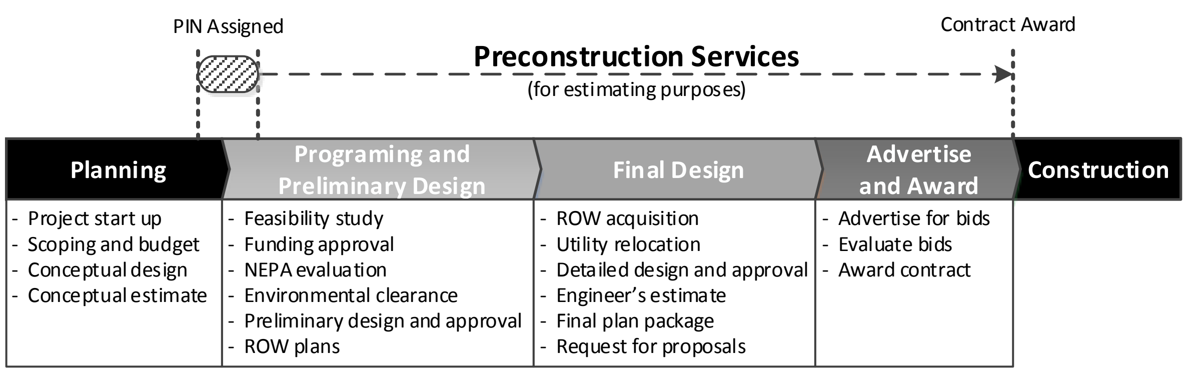


Figure 1. Preconstruction Services Timeline (adapted from Anderson et al. 2008)

Current PCS cost estimating practices

PCS costs are a small portion of the total project delivery cost, and therefore little effort is typically expended in estimating them. A common practice for establishing a preconstruction services (PCS) budget is to first estimate a predicted construction cost of a project and then multiply it by a percentage (Hunter and Gransberg, 2014; AASHTO 2013). Estimating PCS cost as a percentage of construction is a 'top-down' approach. It is a high-level approach used to form an order of magnitude when there is limited knowledge and information about the project (Larson and Gray 2011). The percentage used is typically based on either agency policy or the estimator's judgment from past experience with little or no attempt to quantify the actual input of work effort to complete the required services.

Estimating the construction cost at this early stage is made at the project development phase where the agency has the least knowledge of project information, this is because the design has not yet been completed (Bode 2000, AASHTO 2013). It is known that public highway agencies face frequent cost variance from this initial construction cost estimate (Flyvbjerg et al. 2002), Hence, the method of assigning PCS budget based on the construction cost is at best a gross approximation and at worst, merely multiplying the "best guess" of the construction cost by another guess (of a percentage) to arrive at the PCS budget. To add to the problem further, Flyvbjerg et al. (2002) proved that 86% of the time the initial construction estimate and subsequent estimates are too low, causing the PCS budget to also be too low. A total of 258 transportation projects with a collective value of $90 billion were investigated to reach this conclusion.

Motivation

The accurate estimation of PCS costs is linked to the efficient use of available public capital (Janacek 2006). Estimates developed in the early stages of a project often become legislative authorizations, evolving into project budgets before the final scope of project work is properly quantified (Anderson et al. 2007). This budget then limits the amount of effort that can be invested in quantifying the scope of work for the project, causing an inaccurate PCS cost estimate to become a design quality issue as DOT engineers and external consultants are forced to make the time spent on refining the design fit with the available budget (Carr and Beyor 2005).

The relationship between construction document quality, produced during preconstruction, and project cost growth has long been recognized. Early work by Morgen (1986) and Kirby (1988) identified that 56% of construction contract modifications were the result of design deficiencies, the need to correct design errors and omissions. A study by Burati et al. (1992) quantified the impact of design deficiencies uncovered during construction, finding that on average poor design quality was responsible for adding on average 9.5% to the final contract amount. The detrimental impact of poor quality construction documents on an owner's ability to control cost and time growth has been documented by a number of authors (McSkimming 2005, Molenaar 2005, FHWA 2006). A study of the Oklahoma Turnpike Authority reinforced this concept. Analysis of $90 million worth of projects found a direct relationship between amount spent on design and the construction cost growth of both bridge and roadway projects (Gransberg et al. 2007).

Research has proven that correcting the errors, omissions and ambiguities in construction documents is more expensive during construction than addressing them in the office before the contract is awarded (Anderson et al. 2007). This issue becomes more critical if the preconstruction process is outsourced to a consultant whose fee limits the number of billable hours it can spend before releasing final construction documents. Without sufficient funding, preconstruction staff are often forced to complete tasks within a tight hour budget, which may lead to "a set of poorly prepared construction documents detailing a product that may be functionally over-designed" (Hunter and Gransberg 2014). The consequences of this action are realized during construction. An example provided by Hunter and Gransberg (2014) is a geotechnical engineer, whose subsurface investigation budget has been exhausted, is then forced to increase the design factor of safety instead of undertaking additional borings to better classify a difficult soil condition. This over-design adds costs to the construction phase of the project by requiring more materials to build the over-specified foundations.

Initiatives such as FHWA's Every Day Counts (EDC) program encourages owners to compress project delivery periods, this also contributes to construction cost growth. A 2003 survey by the Construction Management Association of America (CMAA) found that the "demand for increasing speed of project delivery is the top reason for decline in construction document quality."

The underlying theme of existing PCS research is summarized in Figure 2. If sufficient resources are not assigned during the preconstruction phase then the quality of construction documents produced is compromised, this in turn creates additional (cost incurring) work during construction.

Figure 2. Relationship between PCS investment and construction cost growth

Building long-lasting highway infrastructure involves planning and designing highways in a manner that results in a high quality constructed product. In light of Figure 2, to achieve this, the necessary resources must be allocated to the preconstruction process to permit planners and designers the time and funding to be able to solve technical, environmental, and constructability problems *before* the construction contract is advertised. Developing a rational framework to better estimate PCS costs will not only improve a projects final design quality but also enhance an agency's ability to control cost and schedule growth during project delivery.

Problem Statement

Poor estimation of PCS costs across a number of projects can cause misallocation of available capital funding in the preconstruction phase. As a result, a need to redistribute funding late in an agency's fiscal year may arise to cover overages and to expend underruns before the authorization of fiscal year funding expires (Hollar 2011).

The objective of this research is to investigate current preconstruction service (PCS) cost estimating practices employed within the highway industry and furnish a framework for developing a PCS cost estimate using a 'bottom-up' approach. To fulfill this aim, the following questions will be answered:

- *How does cost certainty rather than cost savings improve the delivery of a highway project?*
- *Can historical project cost data, from the PCS stage, be integrated with estimating PCS costs at the functional level and improve estimate accuracy?*
- *How can researchers evaluate their ability to disseminate and communicate best practices of PCS estimating to highway agency personnel and who will benefit from these tools?*

CHAPTER 3 - OVERALL APPROACH TO RESEARCH METHODOLOGY AND VALIDATION

The authority of a researcher's findings are dependent on the rigor used by the researcher to collect data. This research employs a variety of quantitative and qualitative research methods. The main research instruments used within this research were:

- Literature review
- Case study research
- Survey

Because such a variety of research instruments have been applied within the research, this chapter will only provide a general overview of the key instruments. A detailed description of each instrument is provided within the chapter containing the topic it was applied to.

A literature review was first performed to establish the current state-of-practice for PCS cost estimating for highway projects. The seminal work related to PCS cost estimating within the context of the broader project life-cycle can be found in Chapter 2. In addition to the background literature review provided, additional literature reviews were performed for each of the four journal articles within this thesis. These offer more specific information related to the various topics of each particular article and can be found towards the beginning of Chapters 4, 5, 6, and 8.

Though research technique and protocol preferences vary for given scenarios, case study research has been shown to be an effective research tool for evaluating and analyzing emerging business practices such as PCS estimating approaches (Eisenhardt et al. 1991). Case studies can be useful in answering questions about the details of how things are done, particularly when investigating a number of different cases (Yin 2008). A perceived weakness of using case studies is lack of statistical rigor. To overcome this, a defensible and repeatable method to form the case study process was established using widely accepted case study protocol authored by Yin (2008).

Within Chapter 5 a case study approach is used to garner more information about PCS cost estimating practices at 9 different DOTs around the nation. In Chapters 6 and 7, instead of being used as a method to collect initial data, case studies have been employed as a validation tool. In this application the case studies are used to assess whether the new frameworks and methodologies proposed by the journal articles can be successfully applied to real industry scenarios.

The surveys conducted in this research involved self-performed questionnaires. The questionnaires were developed in accordance with survey methods suggested by Oppenheim (2000). The research team was careful to design concise surveys with focused questions that would garner useful information.

CHAPTER 4 - CONSTRUCTION COST CERTAINTY VERSUS CONSTRUCTION SAVINGS: WHICH IS THE CORRECT APPROACH?

Lopez del Puerto, C., E.K. Craigie, and D.D. Gransberg. "Construction Cost Certainty versus Construction Savings: Which is the Correct Approach?" *Compendium, Transportation Research Board: 2016* Paper #16-2754, National Academies. (Accepted for presentation and publication in the Compendium in January 2016).

Abstract

Most public agency engineers would place saving projects costs as a prime objective during the project development and delivery process. This paper argues that maximizing cost certainty rather than minimizing project cost is the more appropriate objective. The paper bases this assertion on the analysis of 1,267 projects from four states with a total construction value of $3.14 billion. The study compared the relationship between the design fee expressed as a percentage of estimated construction cost and cost growth from an early estimated construction cost used to establish the design fee itself. The paper finds that as the amount of resources invested in the preconstruction preliminary design and final design activities increases that the agency's ability to control the final cost of the constructed product also increases. It recommends that transportation agencies review internal policies and potentially adopt maximizing cost certainty as the ultimate goal of the preconstruction planning and design period.

Introduction

The question of whether the cliché "better, faster, cheaper" applied to a public transportation agency's construction projects has rarely, if ever, been asked. A strong argument can be made that the traveling public deserves something better than "cheap" roads and bridges. It can also be argued that an agency which must operate and maintain the completed project would want to build the very best, most resilient facility that its appropriated budget would allow to minimize life cycle and road user costs during its actual service life. In 2010, the Federal Highway Administration (FHWA) introduced the Every Day Counts (EDC) program whose aim is to proliferate proven methods to "get in, get out, and stay out." To accomplish that aim, the FHWA Administrator stated that "it's imperative we pursue better, faster, and smarter ways of doing business." (Mendez 2010). One must note that the FHWA substantially changed the cliché by substituting "smarter" for "cheaper." As the condition of the nation's transportation infrastructure continues to deteriorate, the apparent policy shift from cheap to smart seems to advocate the delivery of transportation facilities that ultimately last longer with less maintenance than the ones previously built. Therefore, this paper's objective is to test the idea that answers the following research question:

> *Should the long-term objective of the current project development and delivery process be minimizing project cost or maximizing project cost certainty?*

In doing so, the paper seeks to determine whether or not the emphasis on minimizing project costs actually reduces an agency's ability to control cost after the award of the construction contract. Crosset and Hines (2007) hinted at this possibility when their study found:

> "Not surprisingly, many DOTs' CEOs and chief engineers watch project cost and schedule performance closely. *Cost overruns or delays are often a sign of failure to take into account site specific factors* on a contract—the problems may be due to construction practices or they may have their *roots earlier in the project's design phase*" (Emphasis added).

Background

The constructed project's ultimate quality is defined during the preconstruction planning and design process (Gransberg et al. 2007). Thus, it would seem prudent to ensure that the preconstruction processes be allocated sufficient time and budget to produce a high quality set of construction documents upon which construction contractors will bid and build (Brown 2002). Research has shown that moving from the traditional design-bid-build (DBB) with a low bid award to project delivery methods like design-build (DB) and construction manager/general contractor (CMGC) have provided a means to increase the owner's control of cost and time growth (FHWA 2006, West et al. 2012). However, research has also found that the majority of the nation's transportation projects will continue to be delivered using DBB (Gransberg and Molenaar 2008). Given those facts, the research team decided to investigate the relationship between the amount of resources that are allocated to the preconstruction planning, design, and procurement phases and cost growth during construction.

Budgeting for preconstruction services

A dominant method for establishing the PCS budget was to first estimate the probable construction cost and then multiply it by a percentage. As stated within the Background section of this report there are a number of problems with this approach. The cliché "you get what you pay for" is applicable when an inaccurate PCS cost estimate becomes a design quality issue, forcing DOT preliminary engineering consultants to match the level of design refinement with the available budget in their contract. Crosset and Hines (2007) found that construction cost overruns indicate "a failure to take into account site specific factors" and may be rooted in the "project's design phase." The preconstruction phase is where the project's scope is developed and quantified taking into account not only the technical scope but also the site-specific factors that impact the technical design solution.

The issue of using a programming-level construction estimate to set the PCS budget is also one of the quality of the construction cost estimate itself. By definition, early estimates are made during project scope definition and as such cannot be considered as accurate. As project definition becomes more complete, these estimates tend to grow as the amount of design detail increases. They are also subject the phenomenon called "scope creep" (Crosset and Hines 2007). For the purposes of this article, scope creep is defined as the gradual, unrecognized addition of minor improvements to a project's scope of work, whose cumulative effect is to cause project cost growth during design. This definition assumes that the initial estimate is reasonably accurate. Failing to recognize scope requirements in early construction cost estimates is not scope creep. It is an estimating error. The impact of an error of this nature is compounded by using the number to generate the PCS cost budget using a fixed percentage. In other words, the error causes the unintentional under-funding of the planning and design activities necessary to fully define the final scope of work. According to a study of one DOT's program, "final construction costs were 46% higher than anticipated at the time of programming" (Alavi and Tavares 2009).

A recent study explored the issue of the need to accurately estimate DOT PCS costs (Gransberg et al. 2014). It found that in most cases PCS estimating accuracy was not considered important. It summed up the issue in the words of one DOT respondent.

"If 4% of the estimated construction cost is the preconstruction budget, then overrunning it by 10% is 0.4% which is a tiny number. So why waste time collecting, processing, and maintaining a preconstruction database when the overall impact of improved estimates and budgets results in a trivial savings." (Gransberg et al. 2014).

In other words, why care if the PCS budget is off because the outcome is a small amount. While that is a very pragmatic analysis, it ignores a several facts that effectively counter that argument. First, while preconstruction budgets are in dollars, the actual unit of effort is the billable hour. So if the hypothetical budget established by a fixed percentage translates into 20,000 hours of preconstruction planning, design, and administration effort, overrunning it by 10% equals 2,000 hours. Since there are 2080 working hours in the typical year, the overrun equates to nearly one person-year of additional effort. Given the typical cost for consulting engineer time with associated labor burden and benefits, the overrun will equate to something over $100,000. Worse yet, the consultant that performs the preconstruction activities would be lacking 2000 hours of billable work effort. Thus, failing to provide a sufficient budget for developing those documents is going to result in the entities involved in document development and production having to rush their work to completion or reduce the overall amount of time spent on the final construction documents. While it may be argued that this is not completely true for documents developed by in-house planning and design assets, the impact shifts appreciably when the DOT decides to outsource a majority of the preconstruction effort (Hunter and Gransberg 2014).

Construction cost growth

As previously mentioned within Chapter 2, design deficiencies are often responsible for cost growth. More recently, a 2007 study of 9 DOTs found that only 18% of projects over $5.0 million in the 5-year sample were completed within their original award amounts (Crosset and Hines 2007). The researchers summarized their findings in the following manner:

"In a world of uncertainty when the first shovel of dirt is moved, some surprises are inevitable. The clear ability of some DOTs to outperform others suggests that success factors for limiting surprises—or at least limiting their impact on cost and schedule—may include fostering accountability for cost and schedule, monitoring causes of problems to identify common culprits, creating incentives for staff and contractors to do better, and *strengthening connections between pre-construction and construction work phases*. Keeping construction on-schedule and on-budget enables DOTs to deliver more projects faster…*Avoiding cost overruns in construction* *means doing good work in preconstruction*. Each of the strong performers emphasizes the value of good coordination between the construction and pre-construction phases of project delivery." (Corsset and Hines 2007, *emphasis added*).

The findings of the above cited literature lead one to infer that cost certainty is not only low when the project development process starts, but also at the time it ends with the award of the construction contract. The comment from the typical DOT engineer regarding the value of accurate PCS estimates indicated that only "trivial savings" would be accrued may provide a previously unrecognized bias in the project development process: an inherent focus on cost savings. If true, the apparent impact is an institutional bias to minimize project cost, i.e. deliver it as cheap as possible. Combining the Crosset study (2007) finding that 82% of projects over $5.0 million overrun their budgets and the collective findings cited above that design deficiencies generated the majority of post-award contract modifications leads to the conclusion that a focus on cost savings during the preconstruction process has not been successful and may even exacerbate the problems by unintentionally capping the resources available to produce construction documents that are free of defects. Therefore, the remainder of this paper will explore the idea of changing the overarching preconstruction decision criterion from "minimize cost" to "maximize cost certainty." It will propose that PCS costs be viewed as an investment in the preconstruction planning, design, and procurement process and if the preconstruction process is adequately funded, cost certainty will be enhanced through the production of high quality construction and bidding documents.

Methodology

The analysis relies on a trend between the preconstruction cost and the final cost of completed projects using descriptive statistics. The following hypothesis is tested:

Construction cost growth will be inversely related to the percentage of project funding allocated to the PCS budget.

Data was collected from four agencies in four states. Because of the differences between agency internal policies and other environmental differences such as length of the construction season, the depth of the pool of qualified construction contractors, the statutory constraints, and so on, each agency is evaluated as a stand-alone case, and no attempt is made to aggregate the total pool of projects to avoid the potential for missing unrecognized factors between agencies and to relieve the need to test for skewing of the results due to unequal sample populations. The researchers also felt that in doing so it would allow a loose comparison between this study and the one by Crosset and Hines (2007) which found that DOTs that recognize “the value of good coordination between the construction and pre-construction phases of project delivery” were found to outperform the others.

It was not possible to collect the data for the entire preconstruction period from each of the agencies in the sample. Therefore, the analysis is limited to the available information, which was the consultant design fee for each project, which covered both the preliminary engineering and final design phases. The study by Hunter showed that this represented the largest PCS expense for a typical project, excluding the costs of purchasing right of way. As such, the following analysis assuming that the consultant design fee is a representative analog for the PCS budget. Therefore, the above hypothesis is modified as following:

Up to some particular break-even point, construction cost growth is inversely related to the percentage of project funding allocated to the design fee.

By definition, the design fee is established before the design is complete. When a public agency negotiates a design fee, the only number they have available regarding the construction cost is the programming level estimate before design and hereafter referred to as the “Early Estimate.” The Cost Growth from the Early Estimate or CGEE is the change in construction costs from the early estimate at the start of the preconstruction period to the final construction contract value as shown in Equation 1.

$$CGEE = \frac{\text{Final Construction Cost} - \text{Early Estimate}}{\text{Early Estimate}} \qquad \text{Eq. 1}$$

Results

The research team analyzed a total of 1267 projects from four states with a total construction value of $3.14 billion dollars. The data analyzed was provided by the following agencies: Oklahoma Turnpike Authority (OTA), Texas Turnpike Authority (TTA), Massachusetts Turnpike Authority (MTA) and the Washington State Department of Transportation (WSDOT). As shown in Table 1, OTA had significantly lower design fee percentages that the other agencies analyzed. The average OTA design fee was 5.21%. The remaining agencies had average design fees that exceeded 10% of construction costs. OTA had the largest CGEE of all agencies at 9.65% followed by TTA at 0.29%. Both MTA and WSDOT had negative CGEE which means that these two agencies were able to reduce the average project's final cost during the project design and delivery process.

Table 1. Design Fee and CGEE Comparison All Agencies

Agency	Number of projects	Design Fee All Projects	CGEE All Projects
OTA	72	5.21%	9.65%
TTA	147	11.85%	0.29%
MTA	15	12.55%	-1.26%
WSDOT	1033	18.07%	-5.70%

Table 1 illustrates there is a clear trend between the design fee percentage and the CGEE: as the design fee increases the CGEE decreases. Previous research finds that there is a breakeven point where increasing the design fee will not provide no longer results in increased cost certainty (Gransberg et al. 2007, Bubshait 1998). The meaning of the trend must not be overstated. A decrease in cost growth does not translate to an increase in cost savings. Decreased cost growth is *cost avoidance, not cost savings*. What it shows is that allocating more resources to the preconstruction period to refine design assumptions and investigate actual site conditions gives the agency more control over the final cost of the constructed project. In other words, *investing in preconstruction activities increases cost certainty*.

Conclusions

There are some limitations of this study that affect the authority of the conclusions. First, the data comes from four agencies, and as such, only applies to those agencies. The results cannot be generalized to other agencies. Secondly, as found by Hunter and Gransberg (2014), each agency has its own definition as to what PCS costs are accounted for in the consultant design fee. Lastly, the focus of this paper is a test of the pervading philosophy that emphasizes maximizing cost savings as the agency's primary fiduciary responsibility. The trend found above does not necessarily debunk that notion, and to be clear, there is nothing wrong with trying to save money during project development. However, when the results of this research are mapped with previous studies (Gransberg et al. 2007, Bubshait 1998), the message is clear. Spending the resources necessary to solve project-specific problems during preconstruction enhances an agency's ability to control costs across the entire project development and delivery process, which tracks well with the 2007 study by Crosset and Hines.

Based on the introductory discussion and the results of the comparison of the design fee percentage and the CGEE the following conclusions were reached.

- The findings suggest that there is a trend between the design fee percentage and the CGEE.
- It seems that to some point as the design fee increases, the CGEE decreases.
- Saving money in design fees is counterproductive to achieving the goal of producing a high quality set of documents and increasing cost certainty in the construction phase.
- Public transportation agencies should allocate the necessary manpower and resources in preconstruction phases to achieve the best solution while increasing the certainty that their projects will not go over budget in the construction phase.
- The design fee can be viewed as an investment by owners to better manage their costs throughout the project lifecycle.

Ultimately, the agency's first goal in controlling overall costs during project development and delivery is to avoid reaching a point where it has to return to the funding source and ask for more money. That objective is literally achieved by increasing cost certainty from concept to ribbon-cutting. Therefore, the results of the above analysis provide a clear argument for reviewing agency policy and changing the emphasis from striving to complete the project as cheaply as possible to investing in preconstruction activities that reduce risk and result in increased cost certainty.

CHAPTER 5 - COST AND SCOPE BREAKDOWN STRUCTURE FOR FUNCTIONAL LEVEL ESTIMATING OF CONSULTANT FEES

Craigie, E.K., D.D. Gransberg and H.D. Jeong. "Cost and Scope Breakdown Structure for Functional Level Estimating of Consultant Fees." *Transportation Research Record: 2016* Paper #16-1146 National Academies. (Accepted for presentation and publication in the TRR in January 2016).

Abstract

Estimating the cost of preconstruction services (PCS) during the early phases of highway project development is an important task requiring an increased level of attention. Research has found a link between early investment in preconstruction planning and design services and final project costs. The purpose of this paper is to assess current estimating practices and propose a Cost and Scope Breakdown Structure (CSBS) framework to structure functional level estimation of consultant fees. Such a framework is promoted to reduce the chance that under-funded preconstruction services may degrade post-award construction contract cost certainty. This study found that preconstruction services are generally viewed as a minor component of a project's budget and as such are sometimes estimated without subsequent preconstruction cost control or accountability. Current practices for consultant fee estimating by state Departments of Transportation (DOT) documented in this study show little standardization in estimating practices across and within transportation agencies. As a consequence many individuals are creating their own tools to develop preconstruction service cost estimates. The result is that national and regional consultants that work in more than a single state are forced to expend additional effort to maintain agency-specific databases; the cost of which no doubt is passed back to the agency in increased overhead costs. This study found that application of a CSBS to classify specific work tasks and utilizing a database of previous project cost information are effective practices.

Introduction

A change in attitude towards preconstruction service (PCS) cost estimating is needed as increasing evidence in the literature shows that estimation of PCS costs have significant impacts on the total financial success of a project and the efficient use of an agency's fiscal year construction budget.

Consistency is an important quality of successful cost estimating. As such, providing a framework or process to facilitate a uniform approach to estimating is highly beneficial. Larson and Gray (2011) state "when people are guided by a core set of principles, they are naturally more predictable because their actions are consistent with these principles". The North American vertical construction industry have acknowledged the importance of core principles, implementing an information classification system called OmniClass to organize information about a project from its conception to demolition (OminClass, 2015). OmniClass consists of 15 tables, each representing a different facet of construction information (Cheng et al. 2009). These tables classify engineering tasks along with structural components of a project. A universal classification system for highway preconstruction services does not currently exist, making estimating practices between DOTs highly variable.

Background

There are a number of approaches to estimating PCS costs, this paper focuses on functional level estimating which is a 'bottom-up' approach used to assign resources within the preconstruction phase. Functional level estimating is a particularly important part of PCS estimating as this approach is used to form estimates that are used to negotiate PCS contracts with external consultants – commonly referred to as outsourcing.

The amount of PCS work that is outsourced varies from state to state. Some DOTs have sufficient staff capacity and expertise to complete the majority of work internally, while other agencies, such as Florida Department of Transportation (FDOT) employ consultants more frequently. Table 2 indicates the levels of PCS work outsourced from the responses of 17 DOTs surveyed at the 2013 AASHTO Subcommittee on Design conference. It is clear from this survey that outsourcing work to consultants is a task that affects the majority of states in some capacity; a total of 16 out of the 17 states surveyed seek external resources for PCS. The use of consultants to assist state DOTs with preconstruction services (PCS) has increased over the past 20 years (Wilmot at al. 1999). Interviews with various DOTs suggest that this trend will continue to grow.

Table 2. Percentage of PCS Work Outsourced to Consultants by State

Percentage Outsourced	State DOT
0%	WY
1-30%	CA, GA, KS, NC, WI
31-60%	AK, AL, AZ, ME, MD, MN, MS, NE, WV
61-90%	SD, WA

External consultants are typically employed in the following scenarios (CDOT 2013, MDOT 2010, Iowa DOT 2007):

1. *when an agency cannot complete the work within the desired time with its available resources, or*
2. *the work entails specialized professional or technical skills not readily available within the DOT.*

This chapter documents current practices used by DOTs for estimating PCS costs to benchmark approaches for determining the level of investment required for PCS services. Data has been collected from a national survey and nine case studies.

Functional level estimating

The preconstruction phase includes the delivery of many intermediate products and services such as environmental investigations, geotechnical studies, public involvement and permitting. The level of effort required to complete these tasks is project specific and influenced by location, resources impacted and regulations governing the project, rather than one specific project characteristic such as lane-miles or bridge length (AASHTO 2008). As a result, the best way to quantify these services is to develop a scope of work for the effort required to complete each task.

Functional level cost estimation is a form of 'bottom-up' estimating. The scope of work can be divided into smaller work tasks, which can be estimated individually. These smaller estimates are then combined to form a total estimate for a specific service. A bottom up estimate is typically estimated by a person who is involved in monitoring all preconstruction stages of the project, such as a senior designer who will manage their team to complete the work (Larson and Gray 2011).

Use of functional level PCS cost estimating

A functional level estimate can be used to quantify the number of work hours that will be required by a design team to complete a given work package. This can aid management's decision on whether to perform the work with in-house resources or outsource particular tasks. Figure 2 indicates the processes involved in the functional estimate and point at which the in-house or outsource decision should be made.

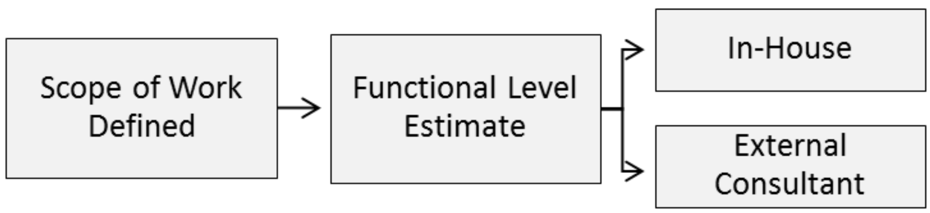


Figure 2. Functional estimate sequence

In-house design

If the estimated work effort does not require specialized services and can be accommodated into the departments schedule then a decision to do the work in-house can be made. The estimate can assist the resource management of the PCS team through distribution and monitoring of forward work load to available team members.

External consultant design

If the work package cannot be completed in-house, the functional level estimate is still useful. It can be used during negotiation with a consultant who will complete the work for the DOT. With an ever increasing number of external consultants being contracted for PCS services, there has been an implementation of various state policies and consultant services manuals across the nation. Within these documents DOT engineers are often required to perform detailed in-house cost estimates or independent cost estimates (UDOT 2013) for the work to be contracted out. The Federal Transit Administration (FTA 2014) has highlighted the importance of a well prepared in-house cost estimate (work estimate) "in order to meaningfully evaluate and negotiate [a consulting] firm's cost proposal".

The Brooks Act, introduced in 1972, requires that all applicable architectural and engineering service contracts be awarded in accordance to an open negotiation process on the basis of demonstrated competence and qualifications (Brooks Act, 1972). Federal regulation stipulates a "detailed cost estimate, except for contracts awarded under small purchase procedures, with an appropriate breakdown of specific types of labor required, work hours, and an estimate of the consultant's fixed fee…for use during negotiations" (General Services Administration, 2015).

The purpose of an independent in-house cost estimate is to provide a DOT with a comprehensive understanding of the scope of work and the effort required to complete the preconstruction services for a given project. This estimate can then be used as a guide to determine fair and reasonable compensation for services rendered. The independent cost estimate is "an important baseline for negotiations with the Consultant" (UDOT 2013). With such a strong emphasis on forming a high quality estimate, this paper investigates how DOTs are developing their preconstruction service estimates across the nation.

Methodology

To gain insight into how DOTs deal with PCS cost estimates on a daily basis, two data gathering techniques were employed. A digital survey was distributed to the AASHTO Subcommittee on Design and case studies were conducted. These studies provided a wealth of knowledge regarding the differing agency views related to PCS costs and the details of their PCS approach.

Survey

A survey was distributed to the AASHTO Subcommittee on Design (SCOD) titled "Estimating Consultant/Design Effort Hours for Preconstruction Service Contracts". A total of 47 responses were received yielding a response rate of 44% from the full committee. They came from the 29 different state DOTs shown in Figure 3. A copy of the survey is contained in Appendix A.

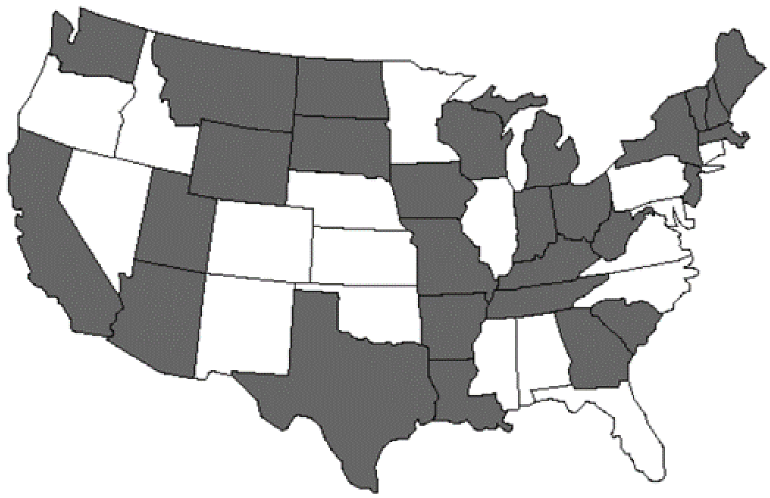


Figure 3. Geographic distribution of survey respondents

Case studies

Case study protocol

The case study research was initiated by issuing a separate screening survey to participants at the AASHTO SCOD conference in Bozeman, Montana June 2 – 6, 2013. Of the 35 states represented at the conference the researchers received 18 responses, a 51% response rate. The survey was designed to understand the preconstruction services facilitated by an agency and to identify what methods were currently being used to estimate preconstruction services costs. The survey also aimed to recognize what PCS data an agency had available and whether the agency would be willing to share the data for research purposes. From the results, several project-level case studies were identified.

Case study process

A pilot case study was conducted to assess effectiveness of the protocol and allow modifications to be made to the process before conducting multiple case studies. The case study protocol specified interactions and communication with project participants in a sequential order. Interviews were conducted on site at agency headquarters to ensure availability of appropriate staff to answer the questions provided. Questions were provided two weeks in advance of the interview.

Case study selection

Various case study options were considered based upon factors such as land area and budget. From an original shortlist of 16 proposed states, nine DOTs were selected. Data was collected on the agencies PCS cost estimating procedures and some project case study projects were obtained. The list of the nine participating agencies is displayed in Table 3 along with the state's population, land area, yearly construction budget and lane miles. The table demonstrates that difference in funding per lane mile for each state. A state with a large land area and relatively small population, for example Montana, has a significantly low dollar ($) per lane mile budget. This differs greatly from smaller states with denser populations, for instance Maryland, that have far higher dollar per lane mile budgets.

Table 3. Population, Land Area and Highway Information (U.S. Census Bureau 2014)

Agency	Population (million)	Land area (square miles)	Budget ($ Million)	Lane-Miles	$/Lane-Mile
California	38.3	155,779	$13,000 - $15,000	171,874	$81,455
Colorado	5.27	103,642	$500 – $700	88,278	$6,797
Iowa	3.09	55,857	$400	114,347	$3,498
Maryland	5.93	9,707	$600 – $800	31,461	$22,250
Montana	1.02	145,546	$385	73,627	$5,229
New York	19.7	47,126	$1000	114,546	$8,730
Oklahoma	3.85	68,595	$632 – $790	115,851	$6,137
Rhode Island	1.05	1,034	$300	6,400	$46,875
Utah	2.90	82,170	$1,100	44,877	$24,511

Current Functional Level Estimating Practices

Analysis interviews with case study DOTs and survey responses indicate that not all DOTs create an independent estimate to negotiate with. In the cases where an independent estimate is not created a department may review a submitted consultant proposal using professional judgment and anecdotal experience on how long their in-house team would typically take to complete the same task.

Reasons for not completing an independent cost estimate included having limited time and resources. Another challenge that can hinder estimate development is definition of the project scope – this may be a task that the consultant is expected to render as part of their services, or a task may be so unique it is difficult to define. It is important for an engineering department to develop a scope of work that is sufficiently detailed so that cost estimates based on the specific tasks can be performed. AASHTO (1996) specifies that "an effective scope of services is written in clear, unambiguous, and precise language. It contains provisions for determining the quality of services or products rendered".

Estimating tools

There is significant variation in the current practices for functional level PCS estimating across the nation for those DOTs who do create an independent estimate. Results from the survey of AASHTO SCOD show that only 35% of respondents that perform a functional level estimate for consultant negotiation have a formalized tool provided by their agency to assist them. An estimating tool is defined as any procedure that assists forming an estimate, the most basic example being an excel spreadsheet. The survey found that individuals have created their own tools to help with preparing estimates in 53% of cases reported due to the lack of a standardized tool. The remaining 13% of those surveyed commented that no estimating tool was used at all.

This result reflects a lack of estimating standardization within agencies. While it is excellent to acknowledge that individuals are furnishing their own techniques for developing estimates to better perform their duties, utilizing independent approaches does not provide a consistent product across an agency. For those agencies without any means or methods, estimating tasks will be limited to those with extensive personal experience in PCS cost estimating. It is very difficult for in-experienced engineers to develop estimates without guidance. Survey respondents were asked what type of tools they used for developing functional level estimates. The tools from the survey responses have been categorized into five different methods as detailed in Table 4.

Table 4. Functional Level Estimating Methods

Method	Description
First Principles	Utilize metrics such as man-days per mile, or other ‘rules of thumb’.
Work Breakdown Structure (WBS)	Use a specific list of PCS tasks to assign work hours and calculate costs.
Historical Database	Utilize cost/hour data collected from previous projects.
Software	Sophisticated software that incorporates historical data with a WBS, for example ePM.
Experience	Base estimates on professional judgment acquired from experience.

Table 4 summarizes a broad spectrum of estimating methods, however from this list, only three of the methods can be deemed scientific; able to be repeated consistently by a variety of people and more easily transferrable to less-experienced engineers. Both utilizing a historical database and a work breakdown structure provide guidance within the estimating procedure to make it serviceable to a range of staff. Within the vertical construction industry, “Table 34 – Services” of the OmniClass classification system defines specific activities and processes provided by project participants in the design phase (OmniClass 2015). As the highway preconstruction phase does not currently have a similar system, using a database and WBS are identified as the first steps in moving towards a standardized classification. Using a software package such as ePM (electronic project management), encompasses both these approaches. Experience and First Principle driven approaches require a level of professional experience and this can vary greatly between staff members.

Cost and scope breakdown structure

Accurately understanding and defining the scope of a project is a fundamental step within a project. This research found that 78% of survey respondents that create functional level estimates for negotiation utilize a work breakdown structure (WBS) to organize the scope of work for estimating. For purposes of this report and to eliminate potential confusion with the classic WBS used during construction phases, the term Cost and Scope Breakdown Structure

(CSBS) is coined to represent the practice when applied to the preconstruction portion of project delivery.

To create a CSBS the activities that occur during preconstruction can be organized into a hierarchy, as displayed in Figure 4. It provides an orderly classification of work tasks and indicates when they should occur during the preconstruction phase. A CSBS is typically set up as a spreadsheet, listing preconstruction tasks specific to different departments and then assigning effort hours to them. Breaking each functional level into specific tasks allows work to be clearly identified, managed and controlled (AACE 2012).

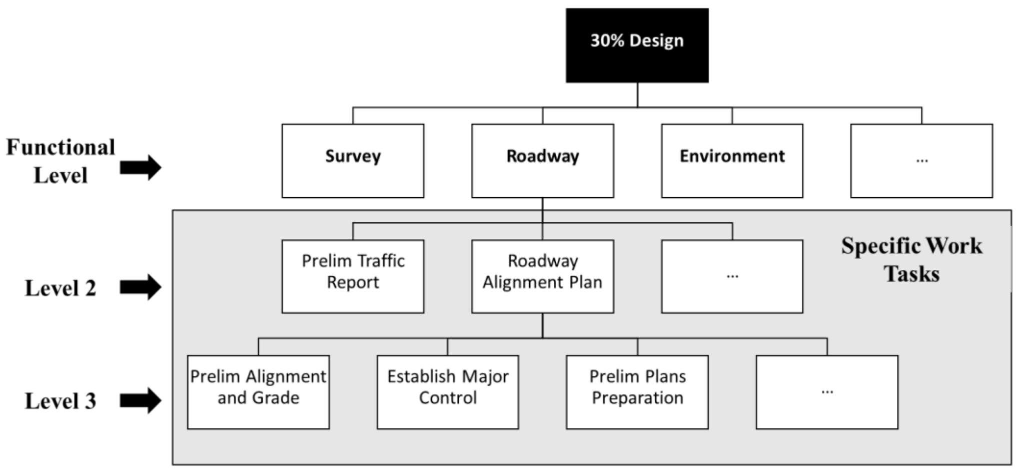


Figure 4. Example of a CSBS

Across state DOTs the level of detail and sequence of tasks varies greatly, however the benefits to using a CSBS for the PCS phase are universally recognized. Formal classification of specific work tasks:

- Provides a template that can be reused to quickly identify tasks required for future projects.
- Allows the collection of work effort hours and costs to aid future estimates.
- Ensures that all appropriate tasks are included within an estimate – no portions are omitted.

Another application of a CSBS is to provide it as the template for consultants submitting a cost proposal. In Florida the estimates developed by both the DOT and the consultant are made in the same format, for “ease of reconciliation” (FDOT 2015). Standard Staff Hour Estimation forms are provided in Excel format for project development and environmental tasks, highway and bridge/structural design projects on the Department's Project Management/Production Support Office website.

Utilizing historic data

From the interviews within the case studies, it was possible to gain insight into how DOTs currently value PCS and whether they take any steps to estimate the cost of this phase within the project lifecycle. Some of the information gained from these interviews is summarized in Table 5. Six of the nine DOTs calculate PCS cost, and while they also keep a record of PCS cost, only three of those DOTs go on to use that recorded data for future estimates. Colorado, Iowa and Oklahoma do not estimate PCS costs at all.

Table 5. Case Study Results

Agency	Calculate PCS Costs	Collect PSC Costs	Use Historical PCS Costs for New Estimates
California	Yes	Yes	Yes
Colorado	No	No	No
Iowa	No	Yes	No
Maryland	Yes	Yes	No
Montana	Yes	Yes	No
New York	Yes	Yes	Yes
Oklahoma	No	No	No
Rhode Island	Yes	Yes	No
Utah	Yes	Yes	Yes

The separate survey from the Subcommittee on Design identified 74% of respondents do not use organized historical data to aid the development of estimates, however a large portion (68%) recognized they "may look" at previous projects to assist their decision making. While this practice is a good sense check, without an organized database of historical projects to reference, experience is required to recall similar projects and relate differences in the expected scope-of-works. Many opportunities are lost when useful data is not recognized and applied. Within the construction industry, it is commonly accepted that collecting and archiving data on past project estimates and actual costs is a successful way to improve future estimates. This same principle applies for functional level PCS cost estimating, despite it not currently being widely recognized by DOTs.

It is interesting to observe in Table 4 that of the nine case studies, seven currently collect PCS cost data, but only three utilize this information. While the survey did not specifically ask what the purpose of the data collection is for, it is likely that many of these DOTs that collect the data do not formally use it for anything other than record keeping. Information from previous projects can be collected in the form of accounting systems and timesheet records provided that there is a standardized WBS in-place at the DOT to classify tasks.

New York State DOT has developed a commercial spreadsheet / database program that aids design hour estimates for its highway projects. The model utilizes 12 “key” project characteristics to search for similar completed projects or generate an estimate of total design hours expected for a new project (Williams et al. 2013). The hours are calculated from a regression model. As more project data is made available the model is expected to become more accurate.

Utilizing information about specific tasks and corresponding work hours from previous consultant contracts and in-house projects creates a knowledge base that is valuable in developing more accurate future estimates. It also provides a formal resource to aid the professional judgment of less-experienced engineers when they are charged with developing PCS cost estimates of their own.

Discussion

This research has documented current practices for functional level estimating of PCS costs. The results of the case studies and survey identified that of the DOTs that currently create a functional level estimate for negotiation, many use informal tools or independent tools. Several barriers to forming functional level estimates were identified during this investigation:

1. Limited time and resources.
2. Project scope not yet defined – sometimes this will be included in the PCS contract with the consultant.
3. Some tasks within scope are very unique and complex making it hard to define tasks.
4. Little importance placed on accurate estimating, no tracking to check performance

5. No formal tools or processes in place to aid estimating PCS costs.

Of the formalized and independent estimating tools used by DOTs to aid functional level estimates the CSBS and historical database methods are the most effective. This is because these methods are highly structured and do not rely primarily on personal judgment. The tools go hand-in-hand with the structure of a CSBS allowing accurate collection of data, such as the work effort hours for specific work tasks.

Implementing a CSBS could greatly reduce the amount of time needing to be invested into each PCS cost estimate, for both DOTs and consultants. As Florida DOT has already recognized, there is value in using the 'same standard format' for agency estimates and consultant cost proposals. It allows for easy comparison between parties estimates, streamlining the negotiation process. In addition to improving the negotiation itself, a standardized CSBS could have an influence on reducing overhead costs passed on to a DOT from a consultant. For the purposes of this paper standardization is defined as "the extensive use of (a process), in which there is regularity, repetition and a record of successful practice" (Gibb and Isack 2001). National and regional consultants that work in more than a single state must currently maintain agency-specific databases in each states they offer services. If PCS cost proposals had a standardized CSBS, less effort would need to be expended on maintaining multiple cost proposal formats and historic project cost information would be more easily comparable for proposal development. A reduction in administration efforts should translate to smaller overhead costs passed onto DOTs.

There are a number of issues that can make implementing a CSBS difficult. For example, if the scope of the work has not yet been defined and its definition is an activity to be included within a consulting contract then it can be hard to identify specific tasks to estimate. Also, if tasks are very unique and complex it is unlikely there is any historic data that can be used as a reference for estimating. In both of these situations a wide estimate range should be used to reflect the high uncertainty. As more information comes to light, the estimate can be refined until an acceptable level of confidence is achieved.

The fact that many DOTs do not have an organized database of completed project information, yet still recognize the need to evaluate previous projects when forming a new estimate, highlights the value of utilizing historical data for estimating purposes. Keeping a record of each project, its work tasks and final effort hours provides useful information to base new estimates on. In order to successfully learn from previous projects a DOT needs to store this information in an accessible and easy to use system. A database of historical project information, whether just a simple spreadsheet or something more robust, is a valuable asset. The low percentage of surveyed staff that have organized databases to draw estimating information from infer that agencies do not yet understand the true value of this resource.

Conclusions and Recommendations

Current practices indicate that most DOTs form functional level estimates of PCS costs for either consultant negotiation or to allocate resources internally, however the approaches used to do so vary widely. Of the five different methodologies identified from survey respondents, only two were defined as effective practices. The use of a CSBS and a historical database complement one another well for developing functional level estimates. The CSBS provides a task classification system that data can be associated to. Both these methods create a standardized approach that are not dependent on personal judgment. An additional benefit of a CSBS is that, if standardized across the nation, it could simplify fee proposal efforts for consultants, reducing overhead fees, which are no doubt passed back to DOTs.

Ensuring the correct investment in PCS is very important to control construction cost growth. DOTs need to invest in tools that ensure PCS are consistently estimated across an agency. Providing a formalized estimation tool for all employees is a way to achieve this. Currently only a third of the DOTs surveyed have this resource. It is imperative DOTs recognize the importance of creating a standard classification for work tasks and the benefits of well-organized historical data for developing estimates.

Future research needs to address the barriers to utilizing organized historical data in an effort to aid PCS estimates. The construction industry has benefited from added estimate accuracy established with historical data. There is no reason the preconstruction phase could not also benefit from adopting some of these practices if a correct implementation framework was developed.

CHAPTER 6 - 3-POINT ESTIMATING: AN ALTERNATIVE METHOD FOR ESTIMATING PRECONSTRUCTION SERVICE HOURS

Craigie, E.K., D.D. Gransberg, and H.D. Jeong. "3-Point Estimating: An Alternative Method for Estimating Preconstruction Service Hours." (to be submitted for publication in the *Journal for Construction Engineering and Management*, ASCE, in 2015).

Abstract

Sufficient investment in preconstruction services (PCS) has been linked to reduced project cost growth from project development through construction. Because preconstruction services vary on a project-specific basis, it is not always appropriate to estimate their cost using parametric means or assigning hours based on expected construction costs. Estimating PCS with work effort hours is the most appropriate approach as it provides a foundation to allocate resources to the different preconstruction activities and is easily converted into a preconstruction budget using known pay rates. This is especially vital for in-house PCS work as it enables future work load to be appropriately managed. Public engineering agencies face challenges with losing experienced staff and having limited historical project data to aid effective PCS cost estimating. To address these issues, this paper proposes a functional-level methodology that utilizes 3-Point estimating of specific work tasks. This technique provides a structured approach that can be repeated by all staff and does not rely solely on the experience of senior staff as is often found in current practice. It also provides a platform to incorporate historical data as it becomes available in the future. A case study of two projects from the Iowa DOT compares the 3-Point approach to the performance of traditional estimating methods and actual work effort hours recorded. This paper concludes that 3-Point estimation better recognizes the number of work effort hours required for a project and provides consistent estimate development.

Introduction

State departments of transportation (DOTs) are working in an environment of tightening budgets and increased emphasis on accountability, creating a critical need to manage and control costs in capital development projects (Gransberg et al. 2014). As discussed in detail within

Chapter 2, the allocation of resources during the PCS phase has a significant influence of the final cost of a project. It is therefore important to estimate PCS costs as accurately as possible.

Background

The PCS cost estimator must understand that the functional unit of preconstruction planning and design effort is the engineer-hour, not the dollar. When the PCS budget is fixed, the decision functionally creates a cap on the amount of professional engineering hours that are available to complete the development of the project's construction documents (Gransberg et al. 2007). As a result, it is important to differentiate those projects that require a greater level of preconstruction design and analysis from those that are the typical routine projects. Hence, PCS estimating tools must reflect the diversity of an agency's project portfolio and allocate preconstruction funding according to project complexity.

The preconstruction phase includes the delivery of many intermediate products. The mainline tasks do not necessarily give an authoritative indication of the overall design effort required. A prime example is the additional design effort required for inclusions of American with Disabilities Act (ADA) intersections in a pavement preservation project. One DOT indicated that these upgrade requirements involve additional survey and right-of-way analysis and possible right-of way acquisition usually not present in this work type (Snyder, 2015). Furthermore the number of drawings that the designer needs to produce faces a significant increase to that of a typical roadway sections to which ADA isn't an active design constraint. Because of the inherent variability of transportation projects, it can be argued that basing the PCS budget as a fixed percent of estimated construction cost before design begins, may not the most effective way to estimate the preconstruction work effort required.

Instead of directly estimating the total cost of PCS, research has found that a reliable estimate of work effort is the foundation from which schedule and cost estimates can be developed (Adrangi and Harrisom, 1987). A number of attempts have been made to create models that can reliably estimate the work effort required for PCS. Jacome and Lapinshii (1997) proposed a model that accounted for the project factors of size, complexity and productivity. Bashir and Thompson (2001) derived a parametric model to create a quantitative estimation methodology for design effort, based on complexity and strictness of design requirements.

This paper proposes a functional level PCS estimating methodology to better identify necessary work effort and hence estimate associated costs during the preconstruction phase. The approach described attempts to address a number of issues faced by DOTs today, and be simple enough to be incorporated into an agencies operations with relative ease, consistency, and minimal set up costs.

PCS cost estimating methods and practices

There are several different methods that can be used to estimate total project PCS costs. In practice, DOT's are observed using percentage of construction or a work breakdown structure (WBS) based method. Parametric estimating by using historical costs and then scaling them appropriately to a new project is another method, however this has not been observed in use by any DOT (Gransberg et al. 2014).

Estimating PCS cost as a percentage of construction is a 'top-down' approach and is elaborated on in Chapter 2. Some of the agencies using this approach for initial budgeting include Colorado DOT, Montana DOT and Rhode Island DOT (Gransberg et al. 2014).

WBS based PCS cost estimating is a 'bottom-up' approach used to assign resources required for the preconstruction phase of a project. This approach is also called functional level estimating and discussed at length within the Background of Chapter 5. Florida DOT is an example of an agency employing this technique to estimate its PCS costs.

While a 'top-down' estimating approach may be significantly less time demanding, it relies greatly on the professional judgment of experienced staff and provides a very loose estimate of PCS costs that cannot be traced to any specific project features. It is well known that that 'many senior [agency] staff members are retiring and being replaced by younger professionals with much less experience' (Cochran et al. 2004). Although professional judgment will always be the cornerstone of all engineering decisions, creating an estimating methodology that can be effectively carried out by less experienced engineers is important to ensure the longevity of an agency. To achieve this goal for junior engineers, the methodology needs to be systematic; it also needs to be logical with simple fundamental principles that can be understood by all. Ideally the methodology would be supported by historical information, to assist junior engineers in their decision making.

The WBS based approach requires more intensive labor effort to complete but is more transparent and aids the allocation of resources for the PCS tasks. It also has the advantage fulfilling federal regulations, as previously discussed in the Background of Chapter 5. To enable this type of estimate detail to be achieved, the scope of work to be contracted must be defined to a point where all functions can be identified.

Utilization of historical data

Within the construction industry, it is commonly accepted that collecting and archiving data on past project estimates and actual costs is a successful way to improve future estimates. This same principle applies for PCS cost estimating. Utilizing specific project information and corresponding actual PCS costs and/or work hours from previous project creates a knowledge base that is valuable in creating more accurate future estimates.

Reliable historical data for PCS effort hours at the functional level is difficult to obtain because agencies often make no effort to collect, reduce, and archive it. For many the only records are financial time sheets and payroll documents, but typically not to the level of detail or format that renders it useful for estimating work effort of specific tasks. A change in DOT practices to actively record this information in a usable database format would be required. However in the interim, before sufficient data has been collected, subjective data generated by experienced estimators is the best alternative. Chau (1995a) justifies the use of subjective data as they ‘are not random guestimates but based on (the estimators) experience which includes historical hard facts’.

In addition to overcoming the challenges of losing experienced staff and poorly documented historical data, an efficient estimating methodology must acknowledge the many unknowns that can influence the amount of work effort required during the preconstruction stage. To incorporate the uncertainty present within an estimate, the methodology proposed by this paper will use range estimating.

Bottom-up estimating

This research proposes that each office has its own breakdown that can be used consistently for all projects. A WBS, as shown in Figure 4, provides a framework upon which a consistent estimation methodology can be built. Once work tasks have been defined within the WBS they can then be assigned a level of effort to complete and a rate of pay for that effort. The level of expertise needed to complete each task must be identified as this will influence the payment rate. Figure 5 summarizes the process of forming a PCS estimate for a department. Aggregating all departments' total estimates yields the Final PCS cost estimate for a project.

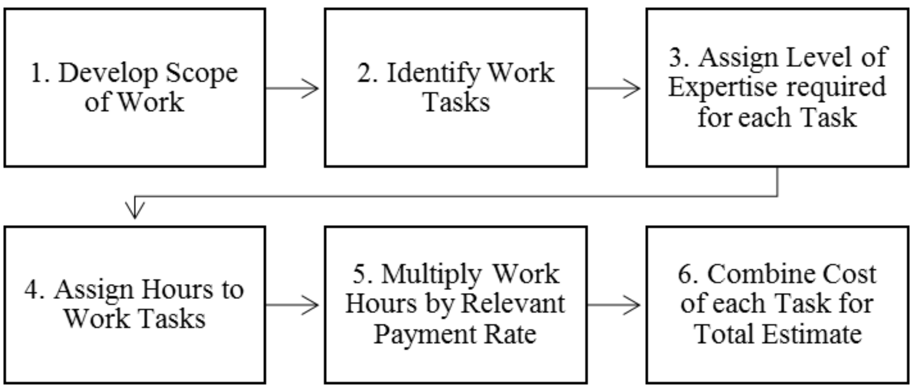


Figure 5. Bottom-up estimating process

Methodology

A combination of techniques were used to elicit information on how PCS cost estimating could be improved. An extensive literature review was first carried out. This found that with the exception of calculating a percentage of total construction costs, there are few established protocols for estimating PCS costs in their entirety. Instead approaches for estimating specific activities within the PCS phase (most typically design costs) are more common (Gransberg et al. 2014).

To develop and test a new estimating technique that could be extended to encompass the entire PCS phase case studies from a DOT were carried out. This approach required initial interviews with personnel from Iowa DOT to establish a baseline of current practice. After the interviews the 3-Point estimating process was developed and then applied to two bridge design projects.

Interview findings

The information gathered during interviews with staff formed the current state-of-practices on preconstruction cost estimating within the Office of Bridges and Structures at Iowa DOT. This was used as validation to evaluate the usefulness of the proposed methodology in this research. Key points of information gathered from personnel included:

- Work effort hours for final design stage is currently being estimated after the preliminary design has been completed. At this stage the type, size and location of the bridge have already been determined. This leaves the Office of Bridges and Design to perform the detailed bridge design and produce the final set of drawings that will be used for contractors to bid then construct.
- In-house estimating is focused solely on hours, as opposed to costs. The reason for this is that the engineering manager main concern and focus is to balance the forward work load of design staff.
- Current practices used to estimate in-house work hours are arbitrary and rely greatly on the experience of a senior engineer. Previous experience of the bridge consultant coordinator with consultant contracts is the primary basis for the hours selected.
- Monthly target review meetings are held at Iowa DOT to review current project status and to assign new projects work effort hours. Typically there are numerous projects to be covered over the course of 4 hours, and very little time is spent on each. At this meeting a brief discussion of key bridge features is held before an estimate is agreed on through group consensus.
- Budgeted hours are adjusted at future target meetings if the project is more complex to design than originally perceived, however often the insufficient budget is not identified until the team has already completed a substantial portion of the project, making the adjustment irrelevant for resource leveling and planning purposes.
- For outsourced design contracts, consultants are selected on demonstrated competence and qualifications (Brooks Act, 1972). Only during negotiations does the engineering manager have an opportunity to influence the work effort budget allocated to the project. The consultant coordinator maintains a personal catalog of previously completed design projects and uses these for comparison.

- Consultant over-head and fixed fee costs are used to calculate an hourly cost of doing business to make projects more directly comparable. In the case of Project 1, two historical projects had similar features and were used to guide the final original estimate.
- When there are no similar projects available for comparison, a factors approach is used. This methodology was developed by the consultant coordinator and involves multiplying a base number by various factors depending on the complexity of specific design components. This technique requires extensive professional experience to perform.

Developing a 3-Point estimating process

Range estimating

At the functional level, the estimate range is bounded by a best and a worst case estimate of work effort hours. The best (optimistic) case defined as being the minimum number of hours required, and the worst (pessimistic) being the maximum hours for a specific work task. For unfamiliar and complex tasks, where there is little historical data to aid a decision, this range will be relatively wide. The high and low estimates for a work task are influenced by its complexity. Range estimating allows a manager or department engineer an opportunity to assess the confidence associated with the work hours (Larson and Gray 2011).

Acknowledging uncertainty is important to ensure the validity of any estimate. Knowing the exact work effort hours required for a specific task would not require an estimate at all, however an estimator of PCS is rarely so fortunate. Assigning a range of possible hours for any given task recognizes uncertainty and allows a 3-Point estimate to be formed.

3-Point estimating

3-Point estimating for activity durations was established within the Program Evaluation and Review Technique (PERT). It was developed by the Special Projects Office of the U.S Navy in 1958 with assistance from management consulting firm Booz, Allen and Hamilton. The motivation for the development of PERT was to create a statistical decision-making tool to “save time in achieving end-objectives” (Malcom et. al 1959).

Realizing that the accuracy of single-point activity duration could be improved on by considering uncertainty and risk, the developers of PERT looked for a method to recognize this during estimation (Project Management Institute, 2013). PERT uses three estimates to define the approximate range for an activity's duration:

Minimum (t_{Min}): An activities duration based on the best case scenario. The shortest amount of time the activity could take.

Most Likely (t_{Likely}): The activities duration that would be reported most often if the activity was repeated over and over again.

Maximum (t_{Max}): An activities duration based on the worst case scenario. The longest amount of time the activity could take.

While it is valuable to visually inspect the level of confidence associated with a task, "most of the end uses of an estimate require a single point value within the probable values to be selected" (AACE 2012). The three estimates can be combined into a single value for expected time (t_E) using Equation 2.

$$t_E = \frac{t_{Min} + 4t_{Likely} + t_{Max}}{6} \qquad \text{Eq. (2)}$$

3-Point estimating is an elegant resolution to the challenges of lost experience and lack historical reliable data discussed previously. Extracting subjective estimates of the models parameters (minimum, most likely and maximum) is relatively easy (Chau 1995b). Likewise once a database is established, the three parameters can be automatically populated into the estimate spreadsheet. In terms of providing a methodology with simple fundamentals for less experienced staff, calculating the expected time of a specific work task can be easily completed with little opportunity for error. Equation 2 is based on the assumption that the work effort hours of a specific work task are represented by a beta distribution.

Beta distributions

Very little is known about the distribution of design effort hours as they are rarely collected consistently or assigned to specific tasks (Nelson, 2015). There are however a number of necessary features that we can identify to help discern the most appropriate distribution for this application.

A distribution used to model a tasks duration should (MacCrimmon and Rayvec, 1964; Swanson and Pazer, 1971):

1. Be continuous over the entire range,
2. Have a unique mode in the range, and
3. Be bound between two positive limits

A beta distribution complies with all three of these conditions.

In the absence of data, an expert must use subjective information to estimate the parameters of the probability density function (PDF) (Schexnayder et al. 2005). These parameters need to be easy for people to perceive and provide parameter inputs. Reasons for adopting a beta distribution are:

- The computational effort required is relatively simple and,
- Subjective estimates of the parameters of the distribution (i.e. minimum, most likely and maximum) are relatively easy to extract from estimators (Chau, 1995b).

There has been much debate over the accuracy of the beta distribution for representing activity durations (Heally 1961; Grubbs 1962; Pleguezelo et al. 2002). It is true that more accurate distributions are available, however these require additional investment of effort and further data manipulation. Given the uncertainty of the actual distribution of effort hours and for the purposes of providing a simple technique that can be grasped by an average DOT employee, the sacrifice in estimate accuracy is deemed small for the purposes of this investigation.

The beta distribution can model positive and negative skewness, making it highly flexible and hence a better reflection of the true probability distribution function given the minimum, maximum and most likely parameters 'known'. Because of the beta distribution adaptability it has been applied by AbouRizk et al. (1994) to model the duration of repetitive construction activities and endorsed by Flanagan and Stevens (1990) for modelling construction costs. Likewise, other agencies have decided to create their own construction cost.

Case studies

Two case studies were investigated to analyze the performance of a 3-Point preconstruction estimation methodology at state DOTs. The Office of Bridges and Structures at Iowa DOT provided information on two final bridge design projects that have now been constructed. Whilst design is only a portion of the total preconstruction services required for a project, it demonstrates how one major preconstruction function can be estimated. The detailed bridge design for Project 1 was completed externally by consultant designers and Project 2 was completed by in-house designers. The projects were selected to permit the evaluation of the effectiveness of the proposed estimation methods under both scenarios.

Both projects involved the design of pretensioned, prestressed concrete beam (PPCB) bridges with construction costs of $2.0 million - $2.4million. The authors recognize that the varying scopes of each project will affect the estimation of preconstruction work effort; however, instead of focusing on the physical differences involved, this paper investigates the PCS estimation methods and the 3-Point technique for one specific project type. Finally, the preconstruction estimating methods were compared based on the work effort hours and not converted into a final cost through the use of the designated hourly rates – a task easily completed but of no value to this research.

Each case study involved two stages:

- *Stage 1)* collection of project scope information, the original preconstruction estimating hours at the allocation of the project and the actual final preconstruction hours
- *Stage 2)* a return by the research team to Iowa DOT with a WBS to collect perceived work effort hours based on each individual work tasks.

The implementation of two stages enabled the research team to systematically break down the scope of both projects into a proposed WBS. Additionally, the time separation enabled the research team to return and collect the perceived work effort hours for individual tasks without allowing the Iowa DOT personnel involved to reflect on the total number of hours discussed at the previous meeting. This removed bias from the experiment, as it is anticipated the staff would naturally try to make the aggregated work effort hours come close to those actually recorded.

Stage 1

The Iowa DOT engineers provided the original estimated number of work hours for each project and the actual recorded hours at the completion of the project. Total actual hours were sourced from time sheet records or invoicing documentation. The source of the original hour estimates varied for both Project 1 and Project 2 depending on whether the design was to be carried out in-house or contracted externally. These different formats employed further highlighted the issue of data collection and comparability for preconstruction stage and are motivation for this research.

The scopes of both projects were collected. This included gathering the Type, Size and Location (TS&L) sheet, the preliminary bridge design that is delivered to the Office of Bridges and Structures for final design to be based upon. The TS&L sheet is used for establishing the type of work that needs to be completed and is the current method used by Iowa DOT for estimating the work effort hours of the project. In addition to the TS&L, a copy of the final detailed bridge drawings was obtained to assess what design services were provided for each project.

Finally, interviews with the design staff helped the research team quickly grasp the main aspects of the preconstruction activities involved. The purpose of this information collection and interviews was to enable the team to create a WBS for bridges which could be used for both projects – providing a standardized approach, a major goal of the 3-Point estimation method. The interviews also provided information which could be useful for later diagnosis and comparison of the estimate techniques. The team discussed unusual aspects of the project that evolved during the preconstruction and construction phases of the contract which may have effected variation from the original estimate of the preconstruction hours.

Stage 2

This stage first required the research team to develop a WBS that could be used by both of the bridge design projects and prove that standardization could be achieved by one department despite different design approaches being employed. Results from the interviews and the collected documents from Stage 1 were used to create an appropriate WBS. Further collaboration with Iowa DOT staff was used to refine the specific work tasks to be included.

Once the WBS was finalized, the research team returned to Iowa DOT to collect the 3-Point estimate for each tasks duration. Senior design staff originally involved with the projects were selected to collect this information using their extensive design experience, holistic knowledge of all design activities and familiarity with the specific case study projects. One staff member completed work effort hour estimates for Project 1 and two staff members independently completed estimates for Project 2. The purpose of having two members complete Project 2 was to investigate if the WBS and 3-Point estimation method could provide consistency in estimate development when completed by different staff members. Only one engineer was sufficiently qualified to estimate hours for outsourced projects so no comparison could be made for Project 1.

The 3-Point estimates required the design staff to allocate a most likely number of hours they would expect each task to take for a typical project of similar scope to the case study project. They also assigned the minimum number of hours they would expect the tasks to take in perfect conditions and the maximum hours required if issues were confronted. Staff were reminded not to simply allocate a range to their most likely values, and were instead encouraged to think of a pessimistic and optimistic value of hours to complete each activity.

An excerpt of the information gathered is displayed in Table 6. The expected total hours for each task was calculated using Equation 2.

Table 6. Collection of 3-Point Estimating Data

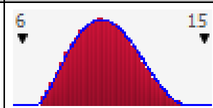
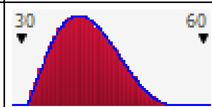
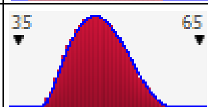
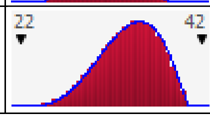
Task	Units	No. of Sheets	Min. Hours/Unit	Most Likely Hours/Unit	Max. Hours/Unit	Expected Total Hours
Beam Details	Sheet	6				
Haunch Data	Sheet	2				
Superstructure Details	Sheet	2				
Superstructure Cross Section	Sheet	2				

Results

Work effort hours results

Table 7 shows a selection of specific work tasks from Project 1 and their estimate profiles, as assigned by the 3-Point estimate values from the estimator. The shape of the profile is dictated by a beta distribution. Culminating the individual profiles of for the most likely hours, from Table 7, of each specific work task results in the total expected hour’s for each project.

Table 7. 3-Point Estimates for Specific Work Tasks

Task	Beta Distribution	Min. Hours	Most Likely Hours	Max. Hours
Pier Geometry		7	10	14
Pier Pile Design		32	40	55
Pier Structural Design		40	48	60
Pier Plan and Elevation		24	35	40

A summary of total work effort hours at different stages of each project is provided in Table 8. The original DOT estimate of hours is the unadjusted preconstruction work effort estimate assigned at the beginning of each project. In the case of Project 1 that was outsourced, this estimate is then negotiated with the consultant until a final number of hours are agreed upon. The actual hours indicate the total number of work effort hours expended for each project. The expected total hours using 3-Point estimating is the number of hours estimated from the WBS method proposed in this chapter.

Table 8. Work Effort Estimates derived from various approaches

	Project 1	**Project 2**	
	Outsourced	*In-House*	
Original DOT Estimate of Hours	881	800	
Negotiated Hours	1092	N/A	
Actual Hours	1179	2188	
Expected Total Hours (using 3-Point Estimation)	1068	1311 (Estimator 1)	1329 (Estimator 2)

It can be observed that for both projects the original estimate of hours was lower than that of the final actual hours expended. For the in-house project the initial estimate is almost three times lower. This difference highlights the importance of improvement in preconstruction hour estimation for adequate resource allocation.

The in-house design team currently has some flexibility to increase work hours and reshuffle other projects to accommodate for projects whose hours creep, consultants often do not, instead over-designing to speed up the process and deliver the project in the allocated hour budget. In this study the outsourced project consumed 87 more hours than agreed during negotiations, however it should be noted that the contract was fulfilled within the set budget. This was due to a reshuffle of expertise within the consultant's team to complete the project.

The significant increase in work effort hours since the initial estimate for Project 2 was held accountable for two factors:

1. Unexpected complexity resulting in scope creep
2. Tying of this project with neighboring contracts for award

Firstly, the overall complexity of the bridge was much larger than typical projects of comparable size and not fully realized in the original estimated hours, nor in the 3-point methodology. The final design required work effort hours for non-standard prestressed beams, severe down drag in the soils, a non-standard longitudinal expansion joint, unusual aesthetic enhancements, and additional details to accommodate construction staging and utilities for the whole corridor.

Secondly, it was determined during the preconstruction stage that this project would be tied with other projects during the letting stage for economies of scale during construction, a common practice by agencies. The bridge design was tied to a large grading and paving design project to form a single construction project to be awarded to one general contractor. Because of the broad scope of this bundled contract the project management hours required from the Office of Bridges and Structures were much greater than that of a typical project. The lead engineer estimated for this project that around 5 times more effort was spent coordinating with the other design offices and the corridor planning committee than on a usual spot replacement project. Due to the nature of large corridor projects not all pertinent issues are resolved up front and many issues crop-up, prolonging the design process.

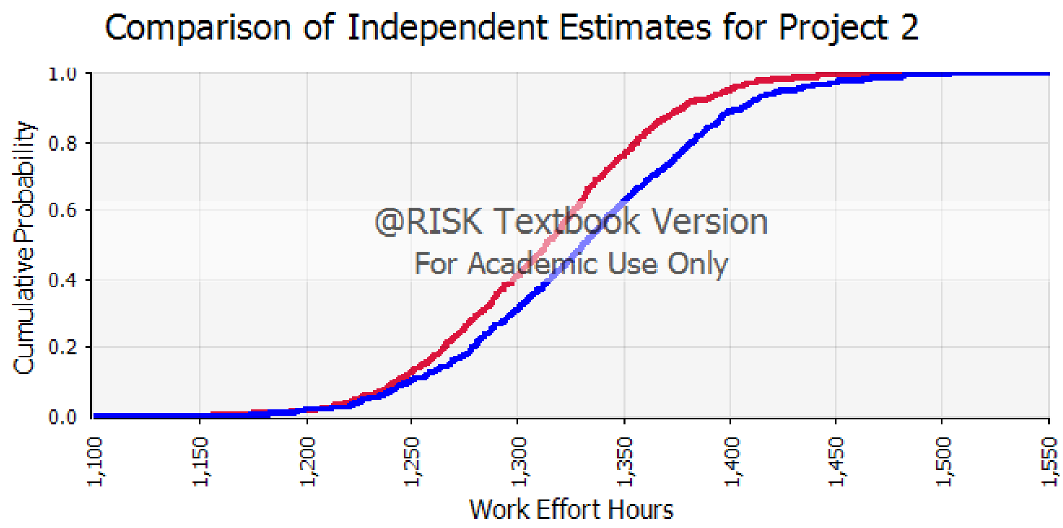
The discrepancy between the actual hours and original hours for both projects is considerable. On both occasions the 3-point estimates are significantly higher than the original estimates. For Project 1 the scope of the work to be completed was better realized using the 3-point approach than traditional means. This is shown by the 1068 hours estimated aligning well with the negotiated 1092 hours. Ultimately the consultant coordinator agreed that 1092 hours was an appropriate value, perhaps this outcome could have been decided more efficiently when negotiations are supported by a WBS of task hours.

Using the 3-Point method for Project 2 the estimation method accounted for more uncertainty and allowed more (necessary) PCS hours to be allocated. However, the 3-point estimate for Project 2 was not as accurate as Project 1. This is most probably due to project scope creep, unforeseeable at the time of estimation. Despite this scope-creep, unknown at the early stage, the 3-Point method did allow an additional 520 hours over the 800 hour estimate completed using the traditional method.

The 3-point estimate of Project 2 was completed by two independent engineering staff, both of the results are very similar, 1311 and 1329 hours, within 2% of one another. This finding is significant as it infers that if two people estimate many individual items separately with optimistic and pessimistic values the final result can still be in close agreement. As part of the results analysis our research undertook a simulation of the two estimators to discern variances.

Simulation/comparison of independent estimators

To observe the differences between the results from the two independent estimators (Project 2) the results for all individual work items were aggregated with Monte-Carlo simulation. Commercial software was used to combine the beta distributions for Estimator 1 and 2. The cumulative distribution function can be seen in Figure 6 below. It should be noted that the central limit theorem could also be used to find the mean number of hours, as the combined beta-distributions create a normal distribution.



	Minimum	Maximum	Mean	85% confidence	95% confidence
Estimator 1	1,145	1,477	1,311	1,365	1,400
Estimator 2	1,164	1,526	1,330	1,392	1,427

Figure 6. Cumulative Work Effort Hour Estimates for Project 2

From Figure 6 the blue line to the right indicates that Estimator 2 is slightly more conservative than Estimator 1, however in general the two estimates are visually very similar. Although the estimators had to individually assign hours to 35 different preconstruction activities, when these are combined the total estimated hours are comparable in scale. This illustrates the benefit of aggregating individual activity estimations. Figure 4 also shows that even if the agency assigned a conservative number of hours by 2 independent estimators to each activity, then conducted a Monte-Carlo simulation, and wanted to be 95% confident of not exceeding values from either estimator, the number of hours to complete the design would still be insufficient. This implies that the level of scope creep to design Project 2 was substantial.

Project 1 results

The cumulative distribution function of Project 1 is displayed in Figure 7. This Figure provides a visual display of the probability of expected work effort hours based on the 3-point estimates of each work task. For this project the actual recorded work effort hours are within the probable range of estimated expected hours. This CDF shows that the negotiated agreement of 1092 hours is in the 89th percentile, implying that, based on the data provided, there is 89% confidence that the hours will not be exceeded. If this estimate were based on historical data, the illustration in Figure 7 could be an excellent tool to analyze the appropriateness of negotiations. A DOT would be able to quantify whether an increase in hours proposed by the consultant provides a commensurate improvement in confidence.

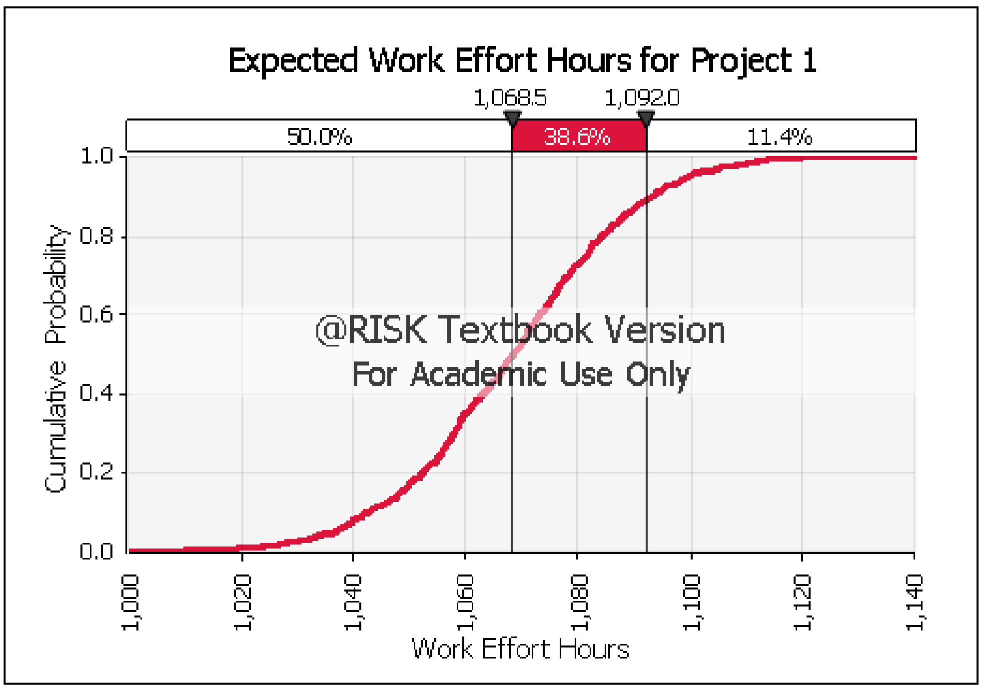


Figure 7. Cumulative Work Effort Hour Estimates for Project 1

Discussion

Comparison of the original estimated work effort hours to the final actual hours reinforced the motivation for this study. In both cases the original work effort hours completed for the project was significantly lower than the final hours spent with differences of 23% and 65% from the final hours spent for Project 1 and 2 respectively. This work effort hours over-run highlights the uncertainty associated with estimating the preconstruction services costs at the early stage.

One design engineer stated ‘I…think we’ve been conditioned as engineers to be conservative’, however comparison of the original estimate and the expected hours estimate indicates that there are many risks and uncertainties that were not acknowledged and incorporated into the original estimate. Both of the 3-point and original estimates were formed using the same early project information. The difference with the final actual hours reduced from 23% to 9% for Project 1 and 65% to on average 40% for Project 2. This improvement in estimating accuracy is noteworthy. The large 40% difference for Project 2, with the 3-point approach, was determined to be due to the unforeseen complexities at the early stage and additional work effort hours when multiple projects were tied to let.

For Project 1 it is difficult to draw firm conclusions on the performance of the 3-point estimate compared with the actual hours recorded as the consultant has an obligation to work within the budget agreed upon during negotiation. It was observed that the 3-point estimate (1068 hours) was very similar to the negotiated hours (1092 hours) compared to the original estimate (881 hours). This study shows that the 3-point approach may be able to aid negotiation processes by providing the DOT with a well-supported estimate to negotiate with. Florida DOT has recognized the value of estimating PCS contracts using a WBS. Both the DOT and the consultant are made in the same format, for “ease of reconciliation” (FDOT, 2015).

It is interesting to observe the similarity between the two in-house expected hour estimates developed independently by two different experienced design engineers, shown in Table 8 (1311 and 1329 hours). The structured approach of using a WBS to assign hours to each specific work task ensures that all estimators address every task required for the project, reducing omissions and over oversight in the work needing to be completed. Another advantage of such a methodology is that it is highly repeatable, allowing less experienced staff to complete estimates on their own.

While this study is limited to two projects from Iowa DOT it leads one to infer that traditional estimating methods do not fully realize the total work effort required during detailed design and therefore fail to appropriately allocate enough resources during the PCS phase. It can be observed from these case studies that using the 3-Point estimating method increased the amount of work effort hours for both projects. While the values estimated in this study were improvements on current practice, further development of this methodology could yield more accurate results. Two specific issues could be addressed to realize these improvements; better define the WBS and incorporate historical data.

An example of adjusting the WBS to better reflect the project at hand would be to include project management hours associated with tying multiple projects together, this was overseen during the original WBS creation for Project 2 as it was an atypical design task and not a required component from the TS&L. Scope creep will always limit the effectiveness of an initial estimate, however acknowledging risk and uncertainty through this 3-Point task based estimate will help better reflect likely maximum and minimum hours.

The three different hour values assigned to each task were completely subjective for this study. It has been recognized that while subjective data generated by experienced estimators is the next best alternative to objective data (Chau 1995a), objective data will always be superior. Ideally objective data of work task hours would be collected by an agency and utilized to create more precise risk profiles for each work task. With the increased abilities of data storage, and small changes to work hour recording practices of staff it would be possible to create a database to draw the 3-Point values from. Simple statistics can be used to assess the minimum and maximum hours required for a specific task along with the most frequent number of hours observed. These practices would be highly efficient once sufficient projects were included in the database, additionally over time data quality will improve (Larson and Gray 2011). It must be noted that projects would need to be separated into different databases depending on complexity and scale to ensure that only comparable data is used to generate estimates.

Conclusions

Correct investment in preconstruction services is vital to minimize cost growth during construction. Due to the variable nature of PCS it is not always appropriate to estimate their cost using parametric means. It is suggested that estimating PCS with work effort is the most appropriate method as it provides a foundation from which to estimate costs or schedules and also allows resources to be allocated during the preconstruction phase. This is especially vital for in-house PCS work as it enables future work load to be appropriately managed. This paper concludes that:

- Traditional estimating methods are heavily reliant on experienced staff
- 3-Point estimation better recognizes the number of work effort hours required for a project, allowing better allocation of resources to the PCS phase
- 3-Point estimation provides a consistent estimate development

It must be noted that these conclusions are limited to the Iowa DOT case-study and cannot be generalized across all transport agencies. Despite this, 3-Point estimating should be investigated for other DOT applications as the simple approach can overcome challenges of losing experienced staff and having limited historical project data (if any) to aid better PCS cost estimating and reduce project cost growth.

CHAPTER 7 - A FRAMEWORK FOR ESTIMATING PRECONSTRUCTION SERVICE COSTS AT THE FUNCTIONAL LEVEL

This chapter brings together the concepts developed within Chapters 5 and 6 to illustrate a complete framework for estimating PCS costs using a 'bottom-up' approach. The framework displayed in Figure 8 shows the proposed flow of decisions and tasks that should be followed in order to complete a PCS cost estimate. Most typically an estimator will first select which estimating approach they will use, this will depend on the amount of information known on that project and planned end-use for the estimate. If the estimate is for negotiating consultant services or planning internal resources a 'bottom-up' approach will be required and it is suggested to follow this proposed approach.

The first step of a functional level estimate is to identify the scope of the project and the necessary work tasks that need to be completed. To do this a Cost/Scope Breakdown Structure (CSBS), from Chapter 5, is used to organize the work tasks and distinguish which office (function) is responsible for each task. The required work tasks are then distributed to the appropriate function.

Each function is then responsible for estimating the required hours for each work task. To do this the estimator may either use historical project data if it is available, or professional judgment. This study encourages the use of historical data, however it is recognized that currently many agencies do not have the correct resources in place to effectively store and maintain this information. This section of the framework gives the estimator the ability to utilize professional judgment during the interim period until historical project databases are readily accessible.

Using either source of information, a 3-Point estimate of each work task can then be completed. This process is described in depth within Chapter 6 and involves the assignment of minimum, maximum and most likely hour values to estimate the expected hours required for a given work task. These expected hours are then multiplied by an appropriate payment rate to estimate a cost. Finally the expected costs for each work task can be aggregated to provide an estimated total PCS cost for a specific function. This process is paralleled by each function so that all the functional estimates can be combined to develop a total PCS cost estimate for the entire project. It should be noted that the entire 'bottom-up' estimating procedure should be

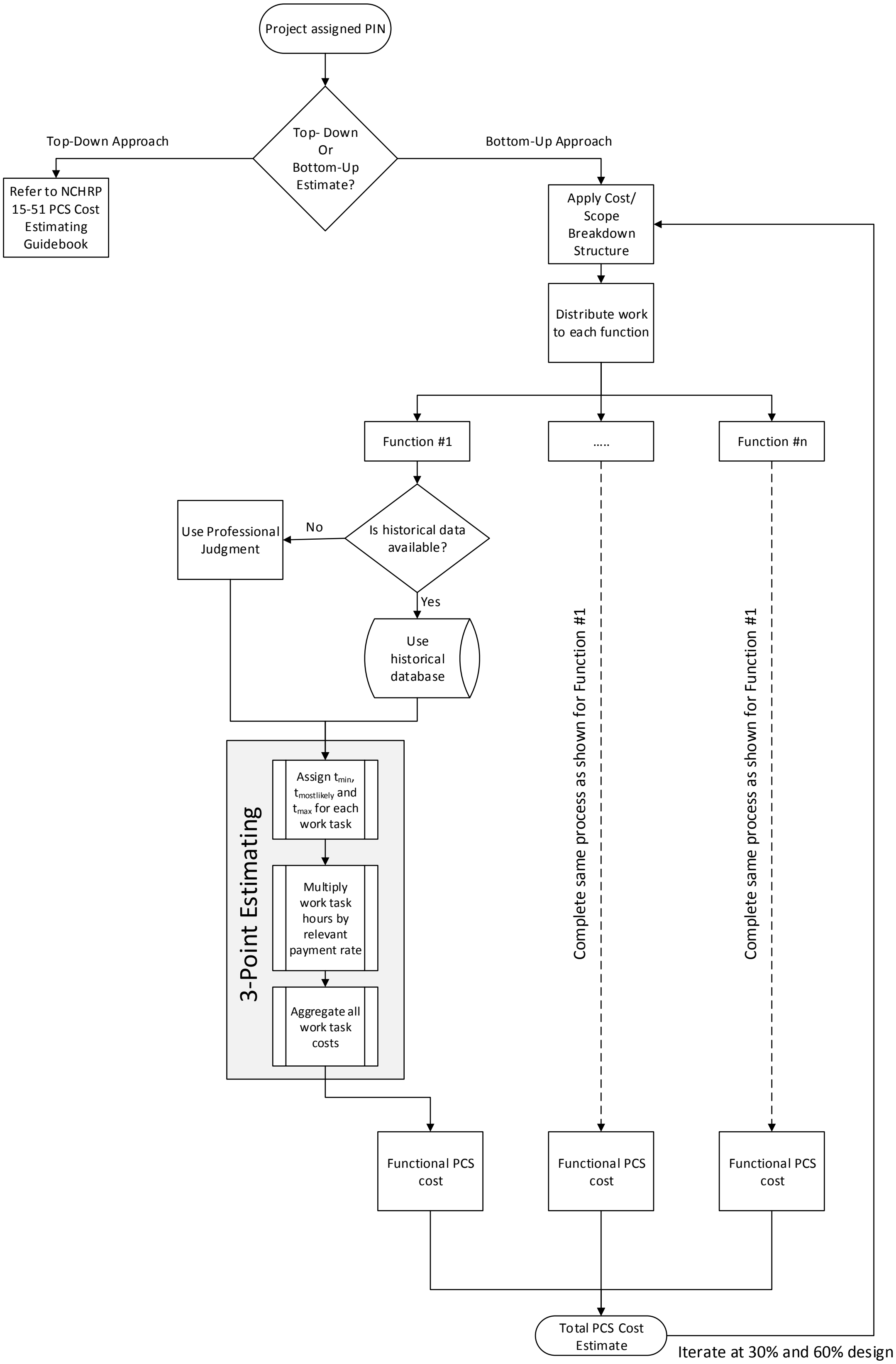


Figure 8. Functional level PCS cost estimating framework

completed iteratively during the preconstruction phase. As more information about the project becomes known, it is possible to repeat each functional level estimate to furnish a more accurate estimate of PCS costs. Typically an estimate will be completed at a highway agency for 30% design, and again at 60% design. There is no value in completing an estimate at 100% design as all PCS will have been rendered and their corresponding costs will be known.

As discussed in Chapter 5, very few agencies currently have a formalized process for estimating PCS costs for negotiation with external consultants. For the first time, this framework provides a complete process to aid DOT personnel as they develop a 'bottom-up' PCS cost estimate.

CHAPTER 8 - A FRAMEWORK FOR VERIFYING THE EFFICACY OF HIGHWAY RESEARCH GUIDEBOOKS

Craigie, E.K., and D.D. Gransberg. A Framework for Verifying the Efficacy of Highway Research Guidebooks. (to be submitted for publication in the *Journal for Construction Engineering and Management*, ASCE, in 2015).

Abstract

There has been recent call for better quantification of the societal impacts of scientific research. As a result, research sponsors require better assurances that the product of their sponsored research satisfies a specified research need and can actually be fully understood and expeditiously implemented by the practitioners for whom the research was intended. Academic transportation research quality is determined by the validation of research methodologies applied as part of the research work plan. However, to date, few have recognized that the effectiveness of the research's dissemination is also an important component. Currently there are no resources available to evaluate the quality of dissemination within the highway industry outside of academic measures like journal impact factors and numbers of citations for a given journal paper. These measures are neither understood nor valuable outside of the academic research community.

Dissemination of highway research classically takes the form of archival journal papers, research reports, conference presentations and a variety of the manuals, handbooks, and guidebooks. In the past five years there has been a discernable preference by members of the American Association of State Highway and Transportation Officials (AASHTO) to require that their sponsored research be disseminated by collecting and synopsizing the salient research project findings in the form of a guidebook that allows the practitioner to immediately implement the research product with minimal or no training. This paper uses the term "vetting" to describe the process of evaluating the quality of the dissemination instrument. This term is used as it recognizes the qualitative nature of the proposed framework, distinguishing this technique from traditional research "validation". Hence, this paper focuses on how to evaluate the quality of newly developed AASHTO guidebooks.

This paper proposes a vetting framework to qualitatively evaluate whether guidebooks developed as research products effectively communicate their content to the intended users and fulfil their desired research outcomes. The benefits of a vetted guidebook extend beyond those in the industry who directly use it. Research sponsors can be confident that vetted research delivered to them is meeting its required outcomes and highway research as an industry can be assured that society is advancing from these investments. A case study from a typical guidebook that was the primary deliverable from a highway research project is furnished to demonstrate how a research team can prove the guidebook meets its research objectives. The study also found that value was added to the guidebook by iteratively applying the vetting framework.

Introduction

Research is an "inquiry that aims to contribute to a body of knowledge or theory" (ESRC 2015). The information produced by each inquiry provides a stepping stone in the advancement of knowledge. The goal of research is to share results and implement state-of-the-art findings to daily practice, ultimately improving the welfare of society (Lucko and Rojas 2010). In the US highway context, $90million per annum is spent on research sponsored by the National Academies' Transportation Research Board alone (TRB 2015). The Federal Highway Agency (FHWA 2015a) also sponsors roughly $177 million each year and claims that highway research has "yielded many advances and innovations that have contributed to improvements in all aspects of the highway system, including longer lasting pavements, structurally sound bridges, and advanced traffic systems" (FHWA 2015b). FHWA goes on to state that this research helps saves lives, time and money. To accrue these desired benefits, sponsoring agencies must require that their research teams validate the research, the final and crucial step in the scientific research process.

Validation is the demonstration of truth or value (Oxford Dictionary 2015a). Many industries are validated through quantifiable measures. For instance oil manufacturers can determine their daily output in barrels and therefore profitability, and property investors calculate return on investment (ROI). Research as an industry must also validate its expenditures and benefits to society. This can be difficult because the output of research is less quantifiable than other industries; the value of research is measured in increased scientific knowledge and innovation. Additionally, it has specifically been recognized that research validation within the construction domain can be challenging (Liu et al. 2014; Lucko and Rojas 2010; Taylor and Jaselskis 2010; Davis and Songer 2003). Reasons for this include the fact that construction projects are rarely identical making study samples highly variable and difficult to compare. The construction industry also involves interdisciplinary teams and industry is often hesitant to trial new research in the field.

Once the research has been validated there is one more link in the chain prior to the work being implemented in practice. The findings or failure of a given research topic needs to be shared to relevant personnel. This step is called dissemination, shown as step three in Figure 9. Highway research is often disseminated as journal articles, industry publications and specification guides. Commonly the research process ends at this stage and researchers deeming their work complete, move on to their next project.

Figure 9. Complete research process

Traditionally, federally funded scientific research "has promoted scientific knowledge, innovation, economic growth, and social well-being" (Lane and Burtuzzi 2011). However, recently focus has been moving toward quantifying how much work is linked to innovation (Stokes 1997) by documenting the results of research investments in a scientific form (Macilwain 2010; Orszag and Holdren 2010). Sutherland et al. (2011) have also noted a recent call for better quantification of the societal impacts of scientific research. This paper proposes a fourth and final step required in the research process, an evaluation of the dissemination effort as shown in Figure 9. Such a step aims to measure the impact of a research project and whether its messages are effectively communicated to its intended audience.

In order to transfer research outcomes to industry there must be a willingness to learn. Davis and Songer (2003) found that there was a hesitation of the construction industry to adopt innovations. This further emphasizes the need to have effective communication tools to disseminate the research, and a method to evaluate their effectiveness.

Evaluating the quality of the dissemination effort is a challenge as it involves quantitatively assessing the effectiveness of the chosen tool for communicating newly discovered concepts. Therefore, this paper strives to fill the gap in the research methods body of knowledge by proposing a qualitative framework to evaluate the effectiveness of a research's dissemination. The authors attempt to differentiate the process from the more quantitative validation process by use of the term "vetting" to describe the process of evaluating the quality of the dissemination. To reinforce this subtle difference, the side-by-side definitions are:

"vetting" = evaluating the quality of research dissemination

"validation" = evaluating the truth of the research findings

In addition to proposing a vetting framework for highway industry guidebooks, this paper includes a case-study of how the framework can be used i.e. validating the vetting framework!

Background

Research validation

The purpose of *validation* is to ensure that each phase of the chosen research methodology rigorously adheres to the highest standards of quality. This level of quality in planning, executing, and evaluating research is measured as validity (Lucko and Rojas 2010). Table 9 illustrates some examples of typical validation practices that are employed in highways research.

Validation in the construction industry was placed in the spotlight with a special ASCE *Journal of Construction Engineering and Management* issue focused on research methods in 2010. The issue aimed to "initiate dialog on the [….] application of research methodologies in construction engineering and management (CEM) research" and improve methodological consistency in the research effort (Taylor and Jaselskis 2010). Papers included covered topics on simulation, experimental research, empirical modelling, observational video research and the Delphi method.

Table 9. Typical validation and dissemination practices for different highway research

<table>
<tr><th>Research</th><th>Validation</th><th>Dissemination</th></tr>
<tr><td>Materials technology</td><td>Physical testing
Surveys from consumers</td><td rowspan="3">Academic Journals
Industry Publications
Guidebooks
Manuals
Formal Trainings</td></tr>
<tr><td>Design Practices</td><td>Experimental testing
Statistical testing
Scale models
Computer modelling
Economic evaluations</td></tr>
<tr><td>Processes
- Agency Operations
such as: Estimating methods
- Management
such as: Contract Delivery
- Construction
such as: Pile replacement</td><td>Error of actual outcome versus the forecast outcome
Case Studies
Case Studies</td></tr>
</table>

Within the construction management literature, CEM validation is noted to be challenging. Selecting appropriate validation methodologies can be difficult due to the interdisciplinary nature of many CEM topics (Lui et al. 2003). However, there are an increasing number of solutions available to overcome them. Lucko and Rojas (2010) describe ongoing efforts to enhance access of validation tools to researchers and new tools emerging. This paper is contributing to the unique field of CEM research methods by formalizing a protocol that is encapsulated in a framework for evaluating highway research dissemination practices, referred to as vetting in this paper.

Current dissemination practices

Dissemination, in an academic sense, is the act of spreading information widely (Oxford Dictionary 2015b). In 2001 the Office of Management and Budget (OMB) issued government-wide guidelines that "provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies." The guidelines on information dissemination are shaped by three substantive terms; utility, objectivity and integrity. These terms focus on the usefulness of the information to its intended users and the presentation of the information in a reliable, unbiased and accurate manner. The OMB guidelines also seek to ensure the security of information, aiming to protect information from unauthorized revision or falsification.

Highway research in the US is not a centrally managed program. It is formed by many individual programs. These research programs include the FHWA Research and Technology (R&T) program, the National Cooperative Highway Research Program (NCHRP), various state R&T programs and many activities within the private-sector (TRB Special Report 261 2001). Table 1 illustrates a number of different types of dissemination that are employed by these programs.

The Department of Transportation has issued *Information Dissemination Quality Guidelines* (2002) in response to the OMBs requirements. However, in that guideline no tools were provided to researchers to evaluate whether their dissemination is effectively communicated with intended users. Additionally, a review of literature and policies from highway R&T programs found no standard for assessing the quality of dissemination products. This paper aims to fill this void in knowledge. Specifically the focus will be on Guidebooks as a dissemination instrument; however further research could extend the process to other dissemination media.

The development of a vetting framework for Guidebooks was based on the experiences of the research team as part of a larger research project creating the *National Cooperative Highway Research Program (NCHRP) Guidebook on Preconstruction Cost Estimating, Project 15-51*. Motivation for this paper was arose from the lack of literature available to help the research term validate the success of the 15-51 Guidebook as a dissemination tool. The research team wanted to prove conclusively that their guidebook was suitably tailored in a manner that effectively communicated the research findings with its intended audience.

A review of highway agency guidebooks

Guidebooks are created to assist industry practitioners working in a specific field. Typically a guidebook will identify current best practices, and explain the recommended tools and techniques to perform a specific task or function. The guidebook is usually a research deliverable intended to facilitate the implementation of the specific research product into a certain practice area. The guide may also provide resources to apply the fore mentioned tools and techniques to their practice as a 'tool-belt' for practitioners.

Due to the variable size, laws and resources of each agency, there is often not one single research solution that can be prescribed across all DOTs. Instead of providing a set methodology, a guidebook provides a step-by-step 'recipe' from which a DOT can tailor its own implementation of the research. This flexibility is important as each DOT is organized differently and there are many internal policies that must be navigated whenever new technology is introduced.

Because of the 'recipe' nature of a guidebook it can be difficult to effectively evaluate how successful the research has been in addressing the underlying problem that instigated the research in the first place. Currently technical panels that administer and monitor research progress determine the acceptability of final deliverables (TRB, 2015). While research statements are formed with well-defined project objectives, across the board there appears to be no evaluation methodology to assess the communicability of guidebooks.

Guidebooks are a tool to educate people on how to address problems presented in the highway field and facilitate a transfer of knowledge into practical solutions for an agency. The value of a guidebook is difficult to quantify as it cannot be judged with traditional metrics such as money or time saved. Instead it needs to be assessed by its ability to connect with readers and aid them in improving systems of operation. To measure this one must look beyond the realm of highways and construction and apply lessons on adult education theory and program evaluation most commonly utilized with social sciences.

Why evaluate dissemination?

As previously discussed, pressure is building from funding bodies to better assess the impact of research. In the United States, the United Kingdom, the Netherlands and Australia efforts have already been instigated in a number of research industries (Grant et. al 2009; Lane and Burtuzzi 2011). The focus of this initiative is provide accountability for the research. Mark et al. (2002) summarizes the four benefits for undertaking an evaluation:

1. Accountability: to judge the merit or worth of a program, to assess its effects, to assess costs and benefits.
2. Improvement: to improve the program, to enhance quality, to manage more effectively and efficiently.
3. Knowledge Development: to gain new insights.
4. Oversight and Compliance: to assess program compliance with formal expectations.

In addition to providing accountability and improving the quality of the output of the research, evaluation also can assess whether a program complies with the goals of its original Request for Proposal (RFP). The principles behind these four reasons align well with what will be applied to the vetting framework to ensure that the final guidebook is to the highest possible quality.

Program evaluation

Program evaluation can be carried out in a number of ways, however there are several key steps that need to be applied universally, as shown in Figure 10. There are five key steps. First and foremost an evaluation must engage its stakeholders throughout the process, this ensures that the information collected is "relevant and that there is a commitment to use it" (Taylor-Powell et al. 1996). Step 2 involves defining the purpose of the evaluation and determining who will use the evaluation. If the purpose of the evaluation is not clearly articulated it will lack direction, reducing the value of the resulting information. A logic model is a useful tool used to elicit program outcomes and how their success can be measured. These are discussed in depth in the following section. During Step 3 potential sources of information are identified and data collection methods are selected. Step 4 covers the processing and analysis of the collected data. The data can then be interpreted to establish what has been learnt during the evaluation. Finally, Step 5 comprises of sharing the findings and using these to make decisions to improve the evaluated program.

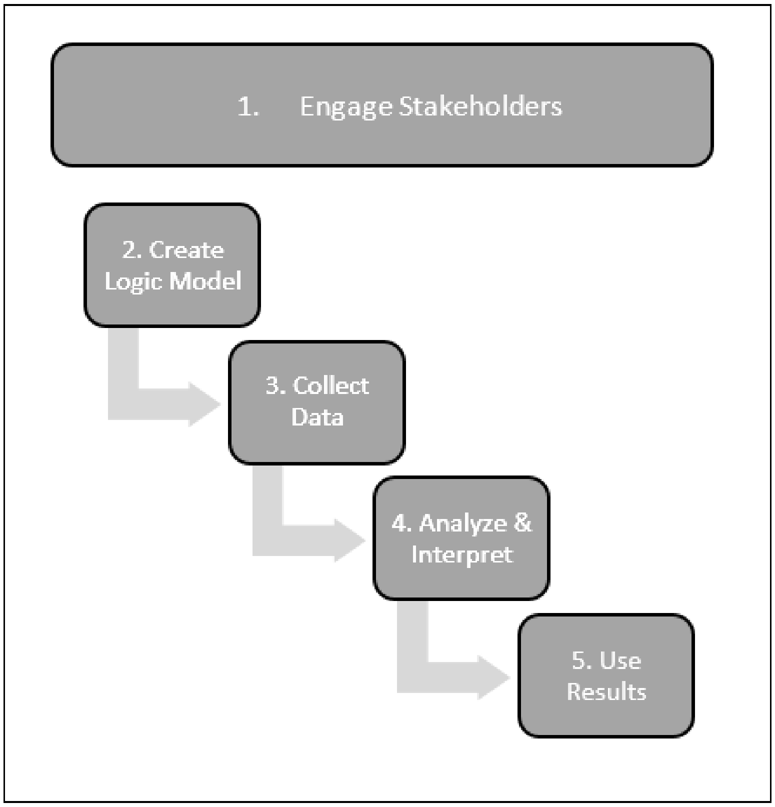


Figure 10. Steps in Program Evaluation (adapted from UWex 2006)

Logic models

Logic models are a visual representation of the relationships between the resources that are invested into a program, the activities the program undertakes and the changes or benefits that result (Taylor-Powell and Henert 2008). A logic model is useful for evaluating or explaining the connections between "what a program (research project) requests in terms of resources and the outcomes it seeks to accomplish" (Millar et al. 2001). Figure 11 illustrates how a logic model is configured. A situation statement communicates the relevance of the project. It identifies what the problem is, who is affected and whether there are other stakeholders interested in the problem. This establishes a baseline for comparison at the completion of the program (McCrawley no date). Inputs are resources invested to the program effort. Outputs are the products, services and activities that reach the target audience. In the context of a research project this is the dissemination. "These outputs are intended to lead to specific outcomes" (Taylor-Powell and Henert 2008). Outcomes are what happened as a result of the program. They can be short-, medium- or long-term. Long-term outcomes are sometimes also referred to as impacts (McCrawley no date). These are the ultimate consequence or effects of the program.

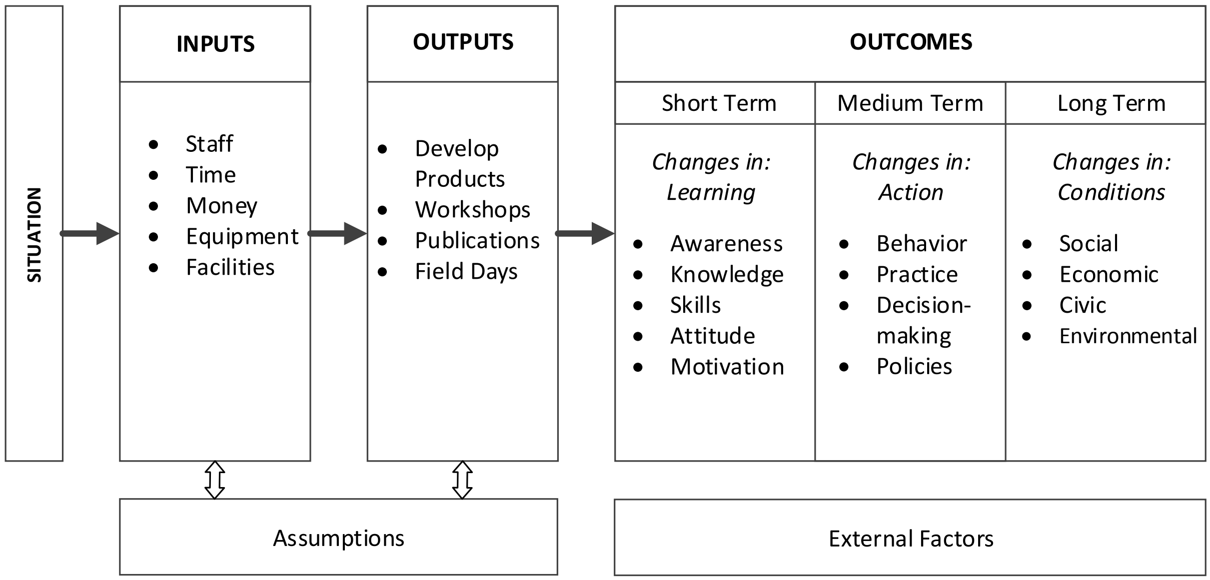


Figure 11. Elements of a Logic Model (adapted from UWex 2002)

In addition to displaying the underlying logic of a program, the model also identifies the key items that must be monitored for performance (Hatry et al. 1996). A logic model helps establish when and what to evaluate. Through evaluation, a researcher can test "the reality of the program theory – how we believe the program will work" (Taylor-Powell & Henert 2008). The pattern of relationships observed in the collected data is compared to the pattern of relationships defined by the program theory (Cooksy et al. 2010; Marquart, 1990;).

Cooksy et al. 2001 believe logic models improve evaluation as they present data in a different way:

1. Collection methods are organized by program element instead of by source or method. This allows the consistency of different data and methods to be examined using triangulation. (Greene et al. 1989; Mathison, 1988).
2. This organization allows element data to be interpreted in relation to its origins and consequences, "not in isolation". This provides a more holistic analysis.

Methodology

A literature review to identify any dissemination evaluation techniques within the highway industry was unsuccessful; there was silence on the topic. Efforts moved to reviewing material from the social sciences, where social programs are often qualitatively evaluated to measure their impact on communities. Suitable program evaluation techniques that were identified are discussed in the following sections. These techniques were then incorporated to form a guidebook vetting framework. To assess the framework in practice a case-study was carried out using the *NCHRP 15-51 Guidebook.*

Guidebook vetting framework

This framework is based on the five steps in program evaluation developed by UWex (2006) for extension programs. It has been adapted to apply to the evaluation of a highway agency guidebook. The purpose of each step has been described earlier. This section describes the specific tasks that should be completed by Guidebook authors.

Step 1: Engage stakeholders

The audience for a guidebook is typically DOT employees or independent practitioners. This audience should be involved throughout the evaluation process. This includes considering where and how to conduct the evaluation. Due to restricted funding within a DOT is it often logical to undertake the evaluation on site, rather than expect staff to travel. Generally there are multiple people within an organization who will impacted by the contents of a guidebook, therefore it is wise to include all of these people in the vetting.

Step 2: Create a logic model

Create a logic model that describes the research projects. This will help determine the purpose of the evaluation and what will indicate when this purpose has been fulfilled. Having a clear idea about what the evaluation results will be used for is important to ensure the entire process stays on track and produces useful information.

Step 3: Collect data

Identify specific DOT staff and practitioners as a key source of data and feedback. Create a workshop to present the key features of the guidebook to this audience. Ensure that participants are provided with a copy of the guidebook two weeks before the workshop to allow time for workshop attendees to read it prior.

To establish whether key concepts of the guidebook have been effectively communicated to participant's using three methods of data collection:

- End of sessions survey
- Observation of participants during the workshop
- Focus Group to discuss the practicality of the guidebook

Using three collection methods allows information gathered to be triangulated. Triangulation helps reduce or eliminate the disadvantages of each individual method, whilst benefiting from the advantages of each (Fellows and Liu 2008). Additionally reoccurring patterns within the feedback should be detectable by vetting evaluators (Abowitz and Toole 2010).

Step 4: Analyze and interpret

Process the collected data into a useful format and then analyze it to interpret the key messages from the workshop participants. Establish what can be learnt from this information and any limitations to the results collected.

Step 5: Use results

Use the knowledge gained by the collected information to make decisions on improving the guidebook. Document how these insights influenced the guidebook revisions. Assess whether the key objectives of the research project have been met. Ask your vetting team the question: Does it fulfill some or all of the outcomes prescribed in within the logic model?

This vetting process can be completed iteratively any number of times until the research team are satisfied that the data collected from the workshops fulfills the research outcomes. It is recommended that a different agency is used each time to ensure the relevance of the Guidebook across the nation.

Case-Study – NCHRP 15-51 guidebook

The research team tested the proposed vetting framework on a Preconstruction Services Cost Estimating Guidebook, a deliverable of the NCHRP 15-51 project. The process was carried out two times at two different agencies, first the Iowa DOT and then at Montana DOT.

Step 1: Engage stakeholders

The NCHRP 15-51 RFP for this project defined the objective of the research to develop a guidance document on cost estimating for PCS. This task was further defined by the research team to the development of a guidebook for ‘’agency implementation of a standardized approach to estimating PCS costs for highway construction projects’’ (Gransberg et al. 2014). This identified the intended users of the research and hence established the stakeholders that would be involved with the evaluation of the produced document. Preconstruction estimating involves staff effort from a broad number of DOT offices. To ensure that the guidebook effectively communicated with all of these people it was decided to hold a workshop at each DOTs main office, in a bid to get the highest possible number of attendees.

Step 2: Create a logic model

A logic model for the entire research project was developed, as shown in Figure 12. This identified the wider situation that prompted the research initially and desired outcomes of the work. It should be noted that creating and evaluating the quality of the PCS Estimating Guidebook is an output of the model, which will then be facilitated to achieve the outcomes.

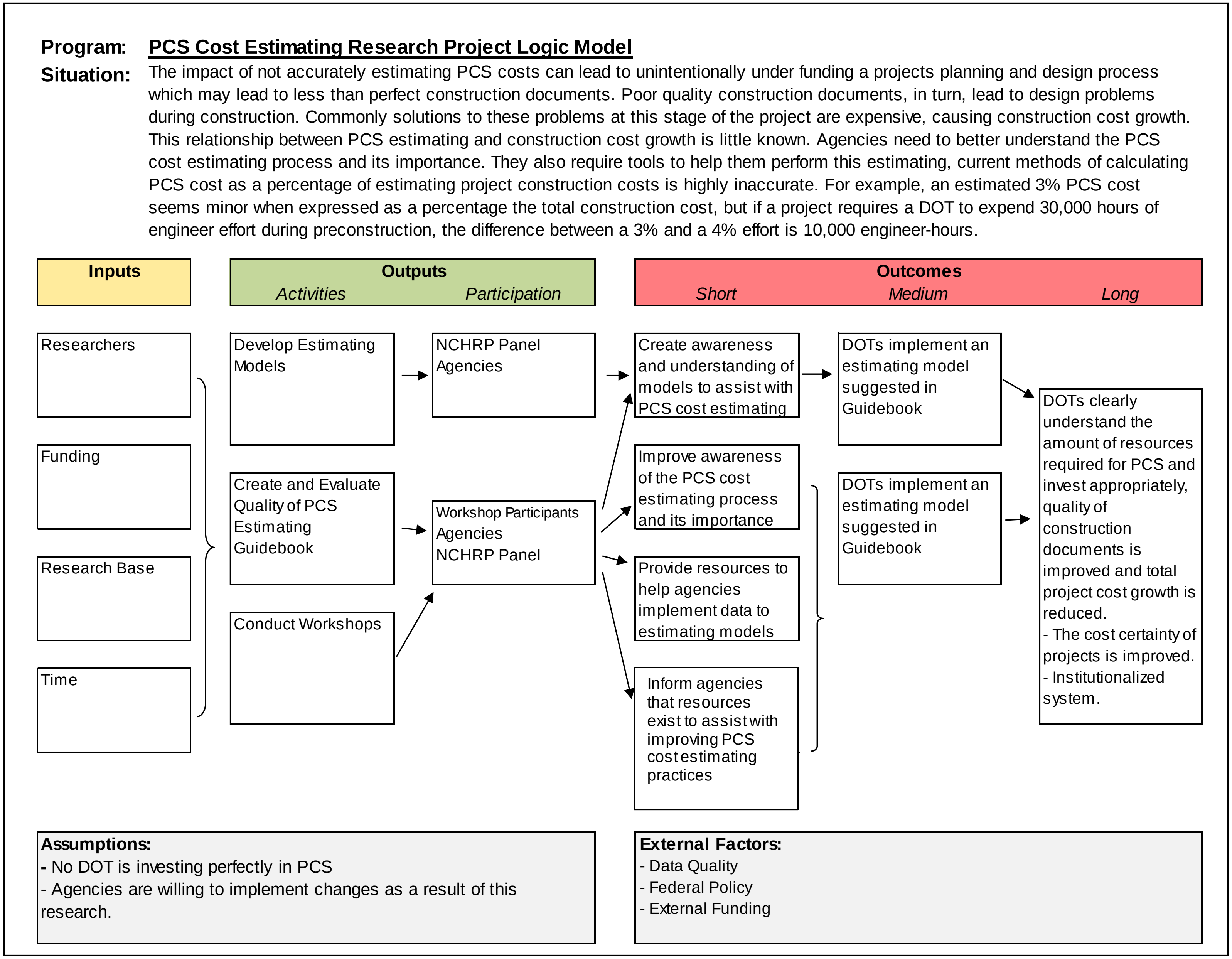


Figure 12. Logic Model for NCHRP 15-51 Project

Step 3: Collect data

The vetting workshops took place over two days and involved upper management, design, construction, and contracting personnel from the two selected DOTs. In Iowa there were 13 participants from various offices, while in Montana there were 21. Two weeks prior to the workshop a copy of the draft PCS Estimating Guidebook was circulated to invited participants.

The first day of the workshops consisted of a mixed program of presentations of guidebook material and interactive exercises to apply the concepts of the guide in practice. Participants were divided into groups for the day and worked together to complete each of the exercises. To provide a hands-on experience, laptop computers were provided with loaded software that allowed the groups to physically develop the cost estimating models described in the guidebook. Historical PCS cost data collected from the DOTs was curated into a small database to use in the examples, which also served to make the material more engaging for the participants.

Data to evaluate the quality of the guidebook was collected using observations, survey and a focus group. Observations were made during Day 1 of the workshop. Of particular interest to the research team was each participant's engagement with the material provided. Three members of the research team used an evaluation observation form, in Figure 13, to tally what they observed. Specifically the observers were looking to see if groups were able to relate the new estimating concepts to their prior estimating experience and found value in the information provided. Observations were also made during the exercises to see how well the guidebook aided groups in completing the designated exercises. If the group had to ask additional questions this was noted as it implied that the guide was no comprehensive enough in that particular area.

How often did you see the following behavior?

Participant Engagement	
Behavior	*Number of times seen*
Participants are involved in open discussion	
Participants make conscious effort to complete exercises to the best of their ability	
Participants apply ideas presented in Guidebook to exercises	
Participants are interested in presented materials	
Participants ask questions to clarify material presented	
Participants relate a Guidebook concept to prior knowledge	
Participants are inattentive (eg. checking phones, not focused on speaker)	

Figure 13. PCS Guidebook Evaluation Observation Form

A survey was conducted at the end of Day 1 to measure participant's views on the guidebook and the concepts presented within it. The survey was developed following principles of Taylor-Powell and Renner (2009) and aimed to quantify perceived changes in motivation, knowledge and estimating skills as a result of the guidebook content. A selection of survey questions are displayed in Figure 14. A complete copy of the survey is contained in Appendix B.

1. **To what extent are you more aware of the overall PCS Cost Estimating process during project development as a result of the PCS Cost Estimating Guidebook? (Circle one)**
   a. A Great Deal
   b. Quite a Bit
   c. Somewhat
   d. Very Little
   e. Not at All

2. **Indicate the main things you learned or gained today:**

3. **How will the PCS Cost Estimating Guidebook help you in your work?**

4. **Did you find the Guidebook logical, easy to follow?**
   a. Yes
   b. Somewhat
   c. No

   Comments:

5. **Circle a number to indicate your degree of understanding of these topics AFTER the workshop and BEFORE the workshop.**

My Understanding

	AFTER WORKSHOP			BEFORE WORKSHOP		
	A Lot	Some	Very Little	A Lot	Some	Very little
a. Use top-down models available for PCS cost estimating	1	2	3	1	2	3
b. Creating Functional Level estimates	1	2	3	1	2	3
c. Using a WBS for PCS tasks	1	2	3	1	2	3
d. Developing a PSC cost estimation database	1	2	3	1	2	3

Figure 14. Examples of Vetting Survey Questions

The second day of the workshop involved a focus group with DOT preconstruction personnel and upper management. The purpose of a focus group is to obtain perceptions about a defined topic using a planned discussion (Yu et al. 2006). The workshop focus group involved a structured discussion about the strengths and weaknesses of the guidebook and the realities of implementing its concepts within an agency. It was important for the research team to steer discussion to issues relating to the guidebooks applicability to all national highway agencies and limit focus on just its application to the DOT participating in the vetting. Notes were taken by the research team and conglomerated together to form a master list of feedback points.

Step 4: Analyze and interpret

IOWA DOT VETTING

Observations made throughout the day noted that the participants were very engaged and receptive to the concepts presented. The final survey confirmed this with very positive feedback. From the survey respondents 75% reported that they were ‘quite a bit’ or ‘a great deal’ more aware of the overall PCS cost estimating process as a result of the guidebook, refer to Question 1 of Figure 14. All participants reported a greater understanding of ‘top-down’ data-driven models and how to develop a database. The focus group held the day after the workshop was very positive, there was a general consensus that the guidebook contained very practical approaches that would significantly improve the preconstruction phase of a project.

To summarize the major findings of this vetting were:

- The guidebook is repetitive in some sections, this redundancy should be removed.
- While the guidebook contains many great figures, there is still a lot of text, using call boxes to draw out the important information would make it more readable.
- The business case on Chapter 1 should be aimed at higher management as they are the people who will make a decision on whether these practices are implemented.
- Appendix D, on model development needs to be written less technically.
- The guidebook needs to better explain that implementing these estimating techniques cannot be achieved by one person and that sufficient upfront resources will need to be committed by the DOT to maintain databases and develop models.

As a result of this feedback collected at the Iowa DOT workshop the guidebook was reorganized, redundant text was removed and call-out boxes were introduced. Chapter 1 was revised and Appendix D was modified. This step was essential prior to the Montana workshop as the value to any changes can be observed and vetted.

MONTANA DOT VETTING

Participants were observed being engaged with the workshop and there was lively discussion throughout the day. Groups worked very diligently on the exercises provided and successfully applied guidebook concepts to their solutions. Survey responses at the end of the day recorded 80% of participant being ‘a great deal’ or ‘quite a bit’ more aware of the overall PCS cost estimating process. All participants whose duties involved PCS estimating indicated that they would consider implementing concepts presented in the guidebook, especially using ‘top-down’ estimating models. The focus group held the following day was very encouraging. The group believed the research was very timely but would require a change in agency culture to work effectively.

The major finding of this vetting were:

- Good organization – very methodical
- It steps through process beginning to end very well
- Easy to read
- The paragraph on artificial neural networks it is very vague, could use a little more explanation.
- Could clarify that PCS can be whatever an agency wants – i.e just estimating the preliminary engineering costs or every PCS cost except right-of-way.

Step 5: Use

The workshops were both an excellent source of information for very specific improvements to be made to the guidebook, as displayed in the bulleted points of major findings. These comments were used to change the wording or structure of some parts of the guidebook and improve its overall quality. It is observed that the list of suggested improvements at the Montana DOT vetting was greatly reduced as a result of incorporating recommendations from Iowa DOT vetting.

The information collected from the workshops was also used to assess whether the guidebook successfully aids the fulfilment of the research project’s short-term outcomes. As shown by the logic model in Figure 4, these outcomes were:

1. Inform agencies that resources exist to assist with improving PCS cost estimating practices
2. Improve awareness of the PCS cost estimating process and its importance
3. Create awareness and understanding of models to assist with PCS cost estimating
4. Provide resources to help agencies implement data to estimating models

The survey were asked participants how the PCS Estimating Guidebook would help them in their work, in 100% of the 34 returned surveys the participant was able to indicate one or more ways the guide would specifically assist them in their role. This indicated to the research team that the guidebook had effectively communicated its resources for improving current PCS cost estimating practices. By doing so our research team deemed that the guidebook had successfully fulfilled the short-term project outcomes.

With 75% and 80% of each workshop reporting their awareness of the overall PCS cost estimating process had increased by ‘a great deal’ or ‘quite a bit’. From this result the research team interprets that the guidebook has improved awareness of the PCS process and its importance.

The positive observations of participants engaging in workshop exercises affirms that the guidebook readers understand the general idea of the multiple PCS estimating models described within the guide. The exercises also demonstrated that the participants could implement data to estimating models from resources within the Guidebook. These observations confirms that the final two short-term outcomes of the research had been met.

Discussion

It is observed that the list of suggested improvements at the Montana vetting was greatly reduced as a result of incorporating recommendations from Iowa before the second workshop. This indicates that the iterative process of completing multiple vettings with different DOTs improves the quality of the guidebook. In the NCHRP 15-51 scenario, just two iterations of the framework were carried out as the research team was satisfied that the improvements identified at Montana were minor and all of the short-term outcomes had been fulfilled. While there may have been added value in completing a third vetting at yet another DOT, this was not considered great enough to warrant the additional investment of time, effort and money.

In addition to the short-term outcomes of the research being fulfilled, the focus group captured each DOTs enthusiasm for the project and positive discussion about how to implement the guidebooks estimating principles within their agency. This was a highly important event as it indicates that the medium-term goals of this research may also be met. A significant validation of the guidebook for the research team.

With the specific recommendations from workshop participants addressed and evidence that all short-term research outcomes are fulfilled by the guidebook, the research team were able to submit a final revised guidebook to the advising NCHRP research panel that they had conclusively proven meet the requirements of the RFP.

A limitation of this study is that the vetting process only focuses on achieving the short-term research outcomes. It would be better to be able to confirm the guidebooks ability to fulfil long-term outcomes and the holistic objectives of the research. However due to the need to instigate new technologies in practice in a timely manner, it is not possible to test the guidebook for years to assess its long-term effect before releasing it to agencies. Researchers must rely on the construct of their logic model and ensure that defined short-term outcomes can progressively lead to the long-term goals of the project.

The research team acknowledges that conducting guidebook vetting requires a significant investment of time and effort. This could be viewed as a disadvantage to evaluating the quality of disseminated guidebooks, however in comparison to circulating a guidebook that causes confusion and push-back from highway agencies, the cost is small. The benefits provided by vetted guidebooks extend beyond their intended users. Research sponsors can be confident that the research delivered is meeting its desired outcomes and highway research as an industry can be assured that society is benefiting from these investments.

Conclusions

In the past five years there has been a discernable preference by members of the AASHTO to require that their sponsored research be disseminated by collecting and synopsizing the salient research project findings in the form of a guidebook that allows the practitioner to immediately implement the research product with minimal or no training. Currently no resources exist for researchers to evaluate the quality of dissemination within the highway industry outside of academic measures like journal impact factors and numbers of citations for a given journal paper.

This paper determines that there is a significant need for a formalized protocol for evaluating highway research dissemination practices. While this study specifically focuses on the vetting of guidebooks, further work is still required to establish vetting processes for other dissemination media.

This paper contributes to the unique field of CEM research methods by providing a vetting framework to qualitatively evaluate whether guidebooks developed as research products effectively communicate their content to the intended users and fulfil their desired research outcomes. A case study of the NCHRP 15-51 PCS Cost Estimating Guidebook established that value was added to the guidebook by iteratively applying the vetting framework. The study also demonstrated how a research team can provide evidence to their sponsor to prove a guidebook meets its research objectives.

The proposed vetting framework has the ability to radically improve the way new research concepts are transferred to industry. Not only will users benefit from better communicated practices that are more easily implementable; research sponsors can also be assured with significant evidence that their investment is bringing positive advancements to the highway industry and that wider society.

CHAPTER 9 - CONSOLIDATED CONCLUSIONS AND LIMITATIONS

Conclusions

Correct investment in preconstruction services is vital to minimize cost growth during construction. Chapter 4 found that public transportation agencies should allocate the necessary manpower and resources in preconstruction phases to achieve the best solution while increasing certainty that their projects will not go over budget in the construction phase. In order to correctly allocate manpower and resources a PCS cost estimate is required early in the project development phase.

Due to the variable nature of PCS it is not always appropriate to estimate the cost using parametric 'top-down' means. It is suggested that estimating PCS with work effort is the most appropriate method as it provides a foundation for highway agencies to estimate costs or schedules. Additionally it provides agency Project Managers a method to allocate resources efficiently during the preconstruction phase. This is valuable for both in-house DOT PCS staff and agency consultant coordinators who must negotiate PCS contracts with external consultants. For in-house staff, a functional level estimate enables future workload to be appropriately managed. In the case of consultant coordinators, a functional level estimate ensures compliance with federal law and aids negotiation processes.

Current practices indicate most DOTs form functional level estimates, however Chapter 5 found that approaches used vary widely and there are few formal tools or processes in place to support the development of a PCS estimate. In a comprehensive survey of 29 highway agencies, the estimating approaches which reported using a CSBS and an historical database were identified as the most effective. Both of these methods create a standardized approach that are not dependent on experienced judgment. These conclusions from Chapter 5 were used in Chapter 6 to show how the tools can go hand-in-hand, with the structure of a CSBS allowing organized collection of data, such as the work effort hours for specific work tasks.

Consistency is an important quality of successful cost estimating. As such, providing a framework or process to facilitate a uniform approach to estimate PCS costs is highly beneficial. The 3-Point estimating methodology, contained in Chapter 6, better recognized the number of work effort hours required for a project and provided more consistent estimate development across multiple estimators. These attributes allow better allocation of resources to the PCS phase across an agency.

Finally, it was determined in Chapter 8 that there is a significant need for a formalized protocol for evaluating highway research dissemination practices. A systematic approach to vetting highway guidebooks lead to improved communicability of research concepts to intended industry users and provided research sponsors with evidence that their investment is bringing positive advancements to the highway industry and that wider society.

Limitations

Limitations are the characteristics of design or methodology that impact or influence the application or interpretation of a study's results (Rukwaru 2015). There are a number of limitations that affect the authority of the conclusions drawn in Chapter 4. First, the data comes from four agencies, and as such, only applies to those agencies. The results cannot be generalized to other agencies. Secondly, as found by Hunter and Gransberg (2014), each agency has its own definition as to what PCS costs are accounted for in the consultant design fee.

The synopsis of current state of functional-level estimating practice, in Chapter 5, is limited to the 47 survey responses that were received from SCOD committee members. While the responses came from the 29 different state DOTs, they do not provide a complete picture of all estimating approaches used across the nation. It must also be noted that the survey responses were self-administered, and the results may be prone to personal biases. To mitigate this, care was taken by the research team to author survey questions that were unambiguous and concise.

In Chapter 6, the conclusions about 3-Point estimation as an effective approach for allocating resources is limited to the two case-studies performed at Iowa DOT and cannot be generalized for all projects or across other transport agencies. Further case studies are required to validate this methodology for all highway agencies.

A limitation of the study in Chapter 7 is that the vetting process only focuses on achieving the short-term research outcomes. This thesis is being published prior to any long-term outcomes occurring. It would ideal to be able to confirm the guidebooks ability to fulfil long-term outcomes and the holistic objectives of the research. However, due to the need to instigate new technologies in practice in a timely manner, it is not possible to test the guidebook for years to assess its long-term effect before releasing it to agencies. Researchers must rely on the construct of their logic model and ensure that defined short-term outcomes can progressively lead to the long-term goals of the project.

CHAPTER 10 - CONTRIBUTIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Contributions

The primary contribution of this research is the development of a functional level PCS cost estimating framework to help agencies improve the quality of a project's final design documents but enhance their ability to control cost and schedule growth during project delivery, detailed in Chapter 7. This is the first ever formalized 'bottom-up' estimating methodology for PCS costs. The framework facilitates the contributions of concepts developed within Chapters 5 and 6, detailed further below.

The research first presents the case for estimating PCS costs and then more specifically why a 'bottom-up' functional level estimating approach need to be established for highway agencies. Functional level cost estimating of PCS is not being completed by all highway agencies, and there is no formalized process for all highway agencies. Chapter 5, for the first time, proposes a formalized approach to functional level PCS cost estimating using a CSBS. The CSBS proposed in Chapter 5 provides a structured method to organize PCS work tasks for which to develop an estimate from.

Further in Chapter 5, it was recognized that utilizing historical project information is an important action for improving the accuracy of new PCS cost estimates. Currently few DOTs invest effort in recording this data at all or if they do it is rarely in a useful format. The CSBS presented in this Chapter 5 contributed a method that agencies can use to document PCS data for future use.

Chapter 6 leverages the CSBS work in Chapter 5 to introduce a 3-Point estimating approach for PCS cost estimates. This has not been shown in any literature for highway projects, nor is it completed at any highway agency. It is a tool that can be used in practice to overcome the challenges of losing experienced staff and current poorly documented historical data.

Finally, Chapter 7 contributes to the unique field of CEM research methods by providing a vetting framework to qualitatively evaluate whether guidebooks developed as research products effectively communicate their content to the intended users. This framework also can assess whether a research project is fulfilling its desired research outcomes. This research was motivated by the lack of literature in this field and aims to fill that void. The framework has the ability to radically improve the way new research concepts are transferred to industry. Not only will users benefit from better communicated practices that are more easily implementable, research sponsors can also be assured with significant evidence that their investment is bringing positive advancements to the highway industry and that wider society.

Recommendations for Future Research

In order to fully implement formalized functional level estimating practices, future research is needed to address the barriers to utilizing organized historical data in an effort to aid estimates. The construction industry has benefited from added estimate accuracy established with historical data. There is no reason the preconstruction phase could not also benefit from adopting some of these practices if a correct implementation framework was developed.

The 3-Point estimating methodology, introduced in Chapter 6, was only validated at the Iowa DOT. It is recommended that further case studies are carried out to investigate its application for other DOTs. Many agencies face the challenge of losing experienced staff and having limited historical project data (if any) to aid better PCS cost estimation.

The PCS cost estimating framework proposed in Chapter 7 has only been validated piecewise. Further research observing its full application within agencies and quantifying its impact on consultant negotiations and design quality would be the logical next step to support this concept in industry.

As described in Chapter 8, there are many forms of research dissemination. This article was only focused on vetting the quality of highway guidebooks. As pressure continues to mount for better quantification of the societal impacts of scientific research, more work is required to create vetting procedures to ensure the quality of other types of research projects and their selected dissemination media.

REFERENCES

AbouRizk, S.M., Halpin, D.W. and Wilson, J.R. (1994). "Fitting beta distribution based on sample data." *Journal of Construction Engineering and Management,* 120(2), 288-305.

Abowitz, D. and Toole, T. (2010). "Mixed Method Research: Fundamental Issues of Design, Validity, and Reliability in Construction Research." *J. Constr. Eng. Manage.* 136, SPECIAL ISSUE: Research Methodologies in Construction Engineering and Management, 108–116.

Adrangi, B. and Harrison, W. (1987). "Effort estimation in a system development project." *Journal of Systems Management,* 38, 21-23.

Alavi, S. and Tavares, M.P. (2009). *Highway Project Cost Estimating and Management*, Report No. FHWA/MT-08-007/8189. Montana Department of Transportation, Helena, MT.

American Association of State Highway and Transportation Officials (AASHTO). (2008). *Guide to Estimating Environmental Costs*. American Association of State Highway and Transportation Officials. Washington, D.C.

American Association of State Highway and Transportation Officials (AASHTO). (2013). *Practical Guide to Cost Estimating, First Edition,* American Association of State Highway and Transportation Officials, Washington, DC.

American Association of State Highway and Transportation Officials (AASHTO). (2008). *Guide to Estimating Environmental Costs*. American Association of State Highway and Transportation Officials. Washington, D.C.

American Association of State Highway and Transportation Officials (AASHTO). (1996). *Guide for Contracting, Selecting and Managing Consultants in Preconstruction Engineering.* American Association of State Highway and Transportation Officials. Washington, D.C.

Anderson, S., Molenaar, K. and Schexnayder, C. (2007). *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction*. Transportation Research Board of the National Academies, Washington, D. C.

Association for the Advancement of Cost Engineering (AACE) International. (2012). *Skills and Knowledge of Cost Engineering, 5th Ed*. AACE International, Morgantown, WV.

Bashir, H. A., and Thomson, V. (2001) "Estimating effort and time for design projects." *Canadian Society of Value Analysis Conference*.

Bode, J. (2000)." Neural networks for cost estimation: simulations and pilot application." *International Journal of Production Research*, 38(6), 1231-1254.

Brooks Act (1972). Public Law 92-582, 40 U.S.C. 541 et seq.

Brown, J. T. (2002). "Controlling costs using design quality workshops." AACE Transactions, Washington, D.C., pp. CSC.10.1–CSC10.9.

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

Burati, J. L., Farrington, J. J., and Ledbetter, W. B. (1992). "Causes of quality deviations in design and construction." *J. Constr. Eng. Manage.*, 118(1), 34–49.

Carr, P. G., and Beyor, P. S. (2005). "Design Fees, the State of the Profession, and a Time for Corrective Action." *Journal of Management in Engineering*, 21(3), 110-117.

Chau, K. W. (1995a). "Monte Carlo simulation of construction costs using subjective data." *Construction Management and Economics*, 13(5), 369-383.

Chau, K. W. (1995b). "The validity of the triangular distribution assumption in Monte Carlo simulation of construction costs: empirical evidence from Hong Kong." *Construction Management and Economics*, 13(1), 15-21.

Cheng, C. P., Lau, G. T., Law, K. H., Pan, J. and Jones. A. (2009) "Improving access to and understanding of regulations through taxonomies." *Government Information Quarterly* 26, No. 2, 238-245.

Cochran, J., Crocker, J., Kingsley, G. and Wolfe, P. (2004) "Best practices in consultant management at state departments of transportation." *Transportation Research Record: Journal of the Transportation Research Board*, 1885, 42-47.

Colorado Department of Transportation (CDOT). (2013) *Project Development Manual*. Denver, CO.

Construction Management Association of America (CMAA) (2003). "Speed, communication, and commissioning issues are top owner concerns, FMI/CMAA survey finds." http://cmaanet.org/owners_survey.php, (Jun. 24, 2006).

Cooksy, L. J., Gill, P., and Kelly, P. A. (2001). "The program logic model as an integrative framework for a multimethod evaluation". *Evaluation and program planning*, 24(2), 119-128.

Crosset, J., and Hines, L. (2007). *Comparing State DOTs' Construction Project Cost and Schedule Performance - 28 Best Practices from 9 States*, American Association of State Highway and Transportation Officials. Washington, D.C.

Davis, K. A., and Songer, A. D. (2003). "Individuals' resistance to technological change in the

AEC industry." *Proc., 2003 Construction Research Congress,* K. R. Molenaar and P. S. Chinowsky, eds., ASCE, Reston, Va., 8.

Department of Transportation. (2002). "Information Dissemination Quality Guidelines." https://cms.dot.gov/regulations/dot-information-dissemination-quality-guidelines (Sept. 4, 2015).

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

ESRC (2015). "Research Ethics Framework (REF)." *Ecomonic and Social Research Council, Swindon.* http://www.esrc.ac.uk/_images/framework-for-research-ethics_tcm8-33470.pdf (Sept. 8, 2015).

Federal Highway Administration (FHWA). (2006) "Design-Build Effectiveness Study," *Final Report to Congress as Required by TEA-21. Federal Highway Administration* http://www.fhwa.dot.gov/reports/designbuild/designbuild0.htm (Aug 30, 2014).

Federal Highway Administration (FWHA). (2015a) "Transportation Research Funding." *Federal Highway Administration.* https://www.fhwa.dot.gov/research/about/funding.cfm (Oct. 10, 2015).

Federal Highway Administration (FWHA). (2015b) "Corporate Master Plan for Research and Deployment of Technology and Innovation." *Federal Highway Administration.* https://www.fhwa.dot.gov/legsregs/directives/policy/cmp/03077.htm (Sept. 8, 2015).

Federal Transit Administration (FTA). (2015). "Procurement Object Types." *Federal Transportation Administration.* http://www.fta.dot.gov/12831_6189.html#BM6_4. (Nov. 13, 2014)

Fellows, R. and Liu, A. (2008). *Research Methods for Construction*. Blackwell, UK.

Flanagan and Stevens (1990) Risk analysis. In Brandon, P.S. (ed.) *Quantity Surveying Techniques: New Directions.* Oxford, BSP Professional Books, 121- 38.

Florida Department of Transportation (FDOT) (2015). *Negotiation Handbook, Professional Services Contracts.* Florida Department of Transportation. Tallahasse, FL.

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

General Services Administration (2015). *Code of Federal Regulations,* Part 172-Administration of Engineering and Design Related Service Contracts. 23 CFR Section 172.7.

Gibb, A.G.F., and F. Isack. (2001) "Client drivers for construction projects: implications for standardization." *Engineering Construction and Architectural Management,* 8(1), 46-58.

Gransberg, D.D. and Molenaar, K.R. (2008). "Does Design-Build Project Delivery Affect the Future of the Public Engineer?" *Transportation Research Record: Journal of the Transportation Research Board*, National Academies, 2081, 3-8.

Gransberg, D.D., Lopez del Puerto, C. and Humphrey, D. (2007). "Relating Cost Growth from the Initial Estimate Versus Design Fee for Transportation Projects," *Journal of Construction Engineering and Management*, ASCE, 133(6), 404-408.

Gransberg, D.D., Jeong, H.D., Lopez del Puerto, C., and Hunter, K.D. (2014) *Preconstruction Services Estimating Guidebook*, Interim Research Report, NCHRP Project 15-51.

Grant, J., Brutscher, P-B., Kirk, S., Butler, L., and Wooding, S. (2009) "Capturing research impacts. RAND Europe/Higher Education Funding Council for England." *Rand Corporation.*

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). "Toward a conceptual framework for mixed-method evaluation designs." *Educational Evaluation and Policy Analysis*, 11, 255-274.

Grubbs, F.E. (1962). "Attempts to validate certain PERT statistics or picking on PERT." *Operations Research*, 10, 912–915.

Hatry, H. (1996). *Measuring program outcomes: a practical approach*, United Way of America. Washington, D.C.

Healy, T. L. (1961). "Activity subdivision and PERT probability statements." *Operations Research*, *9*(3), 341-348.

Hollar, D. (2011). *Predicting Preliminary Engineering Costs for Highway Projects.* North Carolina State University, Raleigh, NC.

Hunter, K.D. and Gransberg, D.D. (2014) "Comparative Analysis of Two Models for Estimating Highway Project Design Costs," *Compendium*, 2014 Transportation Research Board Annual Meeting, Paper 14-3967, National Academies.

Iowa Department of Transportation (Iowa DOT). (2007). *Negotiated Contracts for Architectural, Engineering, and Related Professional and Technical Services*. Policy No. 300.12, Policies and Procedures Manual. Ames, IA.

Jacome, M.F. and Lapinskii, V. (1997). "NREC: risk assessment and planning of complex designs." *IEEE Design & Test of Computers*, 14, 42-49.

Janacek, J. (2006). "Construction costs going through the roof?" *Presentation, 2006 Public Works Officer Institute*, Los Angeles, California.

Kirby, J. G., Furry, D. A., and Hiks, D. K. (1988). "Improvements in design review management.” *J. Constr. Eng. Manage.*, 114(1), 69–82.

Lane, J., & Bertuzzi, S. (2011). Measuring the results of science investments. *Science, 331*(6018), 678-680.

Larson, E.W., and Gray, C.F. (2011). *Project Management the Managerial Process,* 5th Ed. McGraw Hill, New York.

Liu, J., Shahi, A., Haas, C., Goodrum, P., and Caldas, C. (2014). ”Validation Methodologies and Their Impact in Construction Productivity Research.” *J. Constr. Eng. Manage.*, 140(10), 0401446.

Lucko, G. and Rojas, E. (2010). ”Research Validation: Challenges and Opportunities in the Construction Domain.” *J. Constr. Eng. Manage.* 136, SPECIAL ISSUE: Research Methodologies in Construction Engineering and Management, 127–135.

MacCrimmon, K. R., and Rayvec, C. A. (1964). “An analytical study of the PERT assumptions.” *Operations Research*, 12(1), 16–37.

Macilwain, C. (2010). “Science economics: What is science really worth.” *Nature* 465(7299), 682-684.

Malcolm, D. G., Roseboom, J. H., Clark, C. E., and Fazar, W. (1959). “Application of a technique for research and development program evaluation.” *Operations Research, 7*(5), 646-669.

Mark, M. M., Henry, G. T., and Julnew, G. (2002). *Evaluation: An integrated framework for understanding, guiding and improving policies and programs*. San Francisco: Jossey-Bass.

Marquart, J. M. (1990). A pattern-matching approach to link program theory and evaluation data. In L. Bickman, *Advances in program theory. New directions for program evaluation* (pp. 93-107). Vol. 47. San Francisco: Jossey-Bass.

Mathison, S. (1988). “Why triangulate?” *Educational Researcher*, 17(2), 13-17.

McCawley. P. F. (no date). “The Logic Model for Program Planning and Evaluation.” *Univesity of Idaho Extension*. Moscow, ID. https://www.d.umn.edu/~kgilbert/educ5165-731/Readings/The%20Logic%20Model.pdf (Sept. 5, 2015).

McSkimming, J., Peck, B., Hoy, B., and Carr, S. (2005). “The quality of design documents: What can the cm do?” *CMAA forum on quality of design documents.* http://cmaanet.org/user_images/forum.quality_of_design_documents_-_mcskimming.pdf (Jan. 5, 2015).

Mendez, V. (2010). “Every Day Counts: Innovation Initiative.” *Federal Highway*

Administration, Washington, D.C.

Millar, A., Simeone, R.S., and Carnevale, J.T. (2001). “Logic models: a systems tool for performance management.” *Evaluation and Program Planning,* 24, 73-81.

Molenaar, K. R. (2005) “Programmatic cost risk analysis for highway megaprojects.” *J. Constr. Eng. Manage.*, 131(3), 343–353.

Montana Department of Transport (MDT). (2010). *Consultant Services Manual*. Helena.

Morgen, E.T. (1986). *Claims by the Federal Government Against Its A/E – Guidelines for Improving Practice*. Office for Professional Liability Research, Victor O. Schinner and Co., Washington, D.C.

Nelson, J. (2015). Iowa DOT. Personal communication with the author, July 21, 2015.

Office of Management and Budget (OMB) (2001). Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility and Integrity of Information Disseminated by Federal Agencies. https://www.whitehouse.gov/omb/fedreg_reproducible (Sep. 12, 2015).

OmniClass Construction Classification System. (2015). “A Strategy for Classifying the Built Environment.” http://www.omniclass.org. (Jul. 15, 2015).

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

Orszag, P., and Holdren, J. (2010). “Science and Technology Priorities for the FY 2012 Budget.” *Memorandum for the Heads of the Executive Departments and Agencies.*

Oxford Dictionary (2015a). “Definition of Validate in English.” *Oxford Dictionary,* http://www.oxforddictionaries.com/us/definition/american_english/validate (Oct. 5, 2015).

Oxford Dictionary (2015b). “Definition of Dissemination in English.” *Oxford Dictionary,* http://www.oxforddictionaries.com/us/definition/american_english/dissemination (Oct. 7, 2015).

Pleguezuelo, R. H., Pérez, J. G., and Rambaud, S. C. (2003). “A note on the reasonableness of PERT hypotheses.” *Operations Research Letters*, *31*(1), 60-62.

Project Management Institute. (2013). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*. Project Management Institute, Incorporated.

Rukwaru, M. (2015). *Social Research Methods: A Complete Guide*. Eureka Publishers. Nairobi.

Schexnayder, C., Knutson, K., and Fente, J. (2005). ”Describing a Beta Probability Distribution

Function for Construction Simulation." *J. Constr. Eng. Manage.*, 131(2), 221–229.

Snyder, R (2015). Montana DOT, personal communication with author, July 25, 2015.

Stokes, D. E. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation,* Brookings Institution Press, Washington, D.C.

Sutherland, W. J., Goulson, D., Potts, S. G., and Dicks, L. V. (2011). "Quantifying the impact and relevance of scientific research." *PloS one*, 6(11), e27537.

Swanson, L. A., and Pazer, H. L. (1971). "Implications of the underlying assumptions of PERT." *Decision Sciences*, 2, 461–480.

Taylor, J. and Jaselskis, E. (2010). "Introduction to the Special Issue on Research Methodologies in Construction Engineering and Management." *J. Constr. Eng. Manage*. 136, SPECIAL ISSUE: Research Methodologies in Construction Engineering and Management, 1–2.

Taylor-Powell, E. and Henert, E. (2008). *Developing a logic model: Teaching and training guide.* University of Wisconsin Extension. Madison, WI.

Taylor-Powell, E. and M. Renner (2009). *Collecting Evaluation Data: End-of-Session Questionnaires.* University of Wisconsin Extension. Madison, WI.

Taylor-Powell, E., Steele, S., and Douglah, M. (1996). *Planning a program evaluation*. University of Wisconsin Extension. Madison, WI.

Transportation Research Board (TRB). (2001). *The Federal Role in Highway Research and Technology - Special Report 261.* National Academy Press. Washington D.C.

Transportation Research Board (TRB). (2015). "Mission and Services." http://www.trb.org/AboutTRB/MissionandServices.aspx. (Aug. 7, 2015.)

United States Census Bureau. (2014). *State and Country Quick Facts* http://quickfacts.census.gov/qfd/index.html. (Jan. 2014.)

University of Wisconsin Extension (UWex) (2002). *Enhancing Program Performance with Logic Models.* University of Wisconsin Extension, Madison, WI.

University of Wisconsin Extension (UWex) (2006). "Program Development & Evaluation." http://www.uwex.edu/ces/pdande/evaluation/index.html (Sept. 1, 2015).

Utah Department of Transportation (UDOT) (2013). *Consultant Services Manual of Instruction*. Salt Lake City, UT.

West, N.J.N., Gransberg, D.D., and McMinimee, J. (2012). "Effective Tools for Projects Delivered Using the Construction Manager/General Contractor Method," *Transportation Research Record: Journal of the Transportation Research Board*, National Academies, 2268, pp.33-42.

Williams, T. P., Parker, N., and Klotz. J. (2013). "Development of an Estimating Tool for Transportation Project Design Effort." *Presented at 92nd Annual meeting of the Transportation Research Board*, Washington, D.C., 2013.

Wilmot, C. G., Deis, D. R., Schneider, H. and Coats Jr, C. H. (1999). "In-House Versus Consultant Design Costs in State Departments of Transportation." In *Transportation Research Record: Journal of the Transportation Research Board*, Washington, D.C., 1654, 153-160.

Yin, R. K. (2008). *Case Study Research: Design and Methods*. Sage Publications, New York,

Yu, A. T. W., Shen, Q., Kelly, J., and Hunter, K. (2006). "Investigation of critical success factors in construction project briefing by way of content analysis." *J. Constr. Eng. Manage.*, 132(11), 1178–1186.

APPENDIX A - ESTIMATING CONSULTANT/DESIGN EFFORT HOURS FOR PCS CONTRACTS SURVEY

Investigators: Dr. D. Gransberg, Emily Craigie

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Feel free to contact Emily on ecraigie@iastate.edu if you have any questions about the study or about this form.

Introduction

The purpose of this study is to learn more about current practices for estimating Consultant/Design Effort Hours for Preconstruction Service Contracts among different State Departments of Transportation. You are being invited to participate in this study because you are involved in some capacity with preconstruction services estimation within your agency. If you do not have any personal knowledge on your agencies formal procedure for estimating these costs please do not complete this survey.

Description of Procedures

If you agree to participate, you will be asked to:

· Complete a survey about the standard procedures used by your agency to estimate consultant effort hours that are used to negotiate a professional service contract.

Personal details will not be recorded however the type of role that you hold and the name of your agency will be recorded. This allows the research team to assess the level of experience participants in this survey have. Knowing the name of the agency gives an indication of the how many different agencies respond across the nation and their geographic location.

The survey will take approximately 5 minutes to complete.

You can withdraw from the study at any time, refuse to answer or skip questions that you are not comfortable answering. There are no foreseeable risks from participating in this study.

Thank you for your assistance!

1. **Do you agree to participate in this survey?**
   - ☐ Yes
   - ☐ No

2. **Please name the agency that you work for:**

3. **What is your role within your agency?**

4. **Does your agency policy require an independent cost estimate for hours of design effort to be completed prior to negotiating a professional service contract with a consultant?**
   - ☐ Yes
   - ☐ I do not know
   - ☐ No

5. **Do you (or a member of your staff) typically develop an independent cost estimate before the consultant fee proposal is obtained?**
   - ☐ Yes
   - ☐ I do not know
   - ☐ No

6. **Does your agency provide a tool or process to aid you with creating the independent cost estimate? For example a spreadsheet or software.**
   - ☐ Yes, we have a standard process or tool used by all preconstruction departments
   - ☐ No, but individuals have developed their own personal tool/spreadsheet that they use
   - ☐ No

7. **Please name and describe the tool or process used for estimating hours of design effort:**

8. Is there a particular reason why an independent estimate is not made prior to negotiation?

- ☐ Lack of time and/or staff to complete an estimate for every contract
- ☐ It does not add value to the negotiation process
- ☐ We are confident using past experience and professional judgment when evaluating consultant fee proposals
- ☐ Another reason (not listed above)

9. Does your agency use a Work Breakdown Structure to assign effort to individual design/consultant tasks?

Note: A Work Breakdown Structure (WBS) divides a project (in this case a consultant contract) into phases and work tasks. Each specific task can then be assigned a level of effort (number of hours) needed to complete it. The final estimate is the total work hours for all tasks.

- ☐ Yes
- ☐ I don't know
- ☐ No

10. Does your agency use organized historical data to aid forming the independent cost estimate?

- ☐ Yes, we have a database or spreadsheets where we can compare hours of design effort for specific tasks
- ☐ No, but we may check previous projects that are similar to get an idea of hours of design effort
- ☐ No

11. Please elaborate of why your agency does not develop an estimate?

APPENDIX B - FEEDBACK SURVEY FOR NCHRP 15-51 GUIDEBOOK VETTING

1. **What department do you work in?**

2. **To what extent are you more aware of the overall PCS Cost Estimating process during project development as a result of the PCS Cost Estimating Guidebook? (Circle one)**
   a. A Great Deal
   b. Quite a Bit
   c. Somewhat
   d. Very Little
   e. Not at All

3. **Indicate the main things you learned or gained today:**

4. **How will the PCS Cost Estimating Guidebook help you in your work?**

5. **Which of the following will you <u>consider</u> doing as a result of this workshop:**

	Yes	Maybe	No	Why?
a. Use a Top-Down estimating model	__	__	__	____________________
b. Create Functional Level estimates	__	__	__	____________________
c. Create a WBS for PCS tasks	__	__	__	____________________
d. Establish a template to collect data	__	__	__	____________________
e. Collect data on historical projects	__	__	__	____________________
f. Developing a PCS cost database	__	__	__	____________________
g. Other________________________	__	__	__	____________________

6. Did you find the Guidebook logical, easy to follow?

a. Yes

b. Somewhat

c. No

Comments:

7. Circle a number to indicate your degree of understanding of these topics AFTER the workshop and BEFORE the workshop.

My Understanding

	AFTER WORKSHOP				**BEFORE WORKSHOP**		
	A Lot	Some	Very Little		A Lot	Some	Very little
a. Use 'top-down' models available for PCS cost estimating	1	2	3		1	2	3
b. Creating Functional Level estimates	1	2	3		1	2	3
c. Using a WBS for PCS tasks	1	2	3		1	2	3
d. Developing a PSC cost estimation database	1	2	3		1	2	3

8. Would you feel confident using the Guidebook to set up your own 'top-down' model with your own data? (assuming you have sufficient good quality data)

a. Yes

b. Maybe

c. No

Comments:

9. What did you like about the PCS Cost Estimating Guidebook?

10. What needs to be changed about the Guidebook to make it more user friendly?

11. Additional comments about the workshop/Guidebook:

APPENDIX C – INSTITUTIONAL REVIEW BOARD EXEMPTION DOCUMENT

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 7/24/2015

To: Dr. Douglas Gransberg
394 Town Engineering

CC: Emily Craigie
2711 South Loop Drive, Suite 4700

From: Office for Responsible Research

Title: NCHRP Project 15-51 Preconstruction Services Cost Estimating Guidebook

IRB ID: 15-366

Study Review Date: 7/24/2015

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.