Estimating preconstruction services costs for highway projects

by

Kate D. Hunter

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Program of Study Committee:
Douglas D. Gransberg, Major Professor
Hyung Seok "David" Jeong
Brent M. Phares

Iowa State University

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ABSTRACT

Preconstruction Services (PCS) is defined as all work completed on a project once it has been authorized for funding and cost related to the project can be charged accordingly, up until construction contract is awarded. Due to the changing nature of State DOT work with increased funding uncertainties and shrinking budgets it is more important than ever to ensure proper allocation of funds for highway projects. Uneducated estimates for preconstruction services or using a fixed percentage across multiple projects can lead to a misallocation of available capital funding in the PCS phase, which may force the need to redistribute funding late in an agency's fiscal year to cover overages and to expend underruns before the authorization expires. Underestimation can lead to inadequate PCS budgets and poor construction documents. In short an educated thought out PCS cost estimate can lead to cost certainty within all aspects of a project.

Firstly the research focuses on developing a framework for a PCS cost estimate focusing on the type of estimate and the factors that affect it. Second, an artificial neural network model is proposed to estimate PCS costs, the research also investigates a method for defining projects to further refine the historic data that is used in the NN model. Finally the research focuses on a method to estimate a design cost contingency.

Two types of estimates were found top-down and bottom-up estimates the difference in the estimate was dependent on the end user and the amount of data available. Three factors complexity, project type and construction cost were found to be the three factors that had a major influence on PCS cost estimate. The NN model produce provided a top-down PCS estimate, the final model provided estimates with a weighted error of 1.4% over 13 projects. Iowa DOT's method of classifying projects based on project complexity was investigated and determined to be an appropriate method for project classification considering project complexity was considered a major influence factor. Finally a method was determined to estimate an appropriate design contingency using design cost estimate accuracy index. All methods and models developed in this thesis are expected to be applied to individual agency's historic data and estimating systems. It is also stressed that models have limitations and should not be used outside the range which it was developed.

CHAPTER 1—INTRODUCTION

The objective of this research is to review the state-of-art in preconstruction services (PCS) cost estimating techniques used within the transportation industry and propose a framework for developing a PCS cost estimate. In doing so, it is important to first focus on how design costs are estimated since those constitute a large proportion of total PCS costs and the preliminary design often dictates what PCSs, like geotechnical investigations and environmental studies, are required to be accomplished to be able to complete the design itself. This thesis has three primary areas of focus:

- Developing a rational method for estimating a contingency for design cost estimate
- Framework for developing a preconstruction services cost estimating model
- Neural network model to determine preconstruction services cost estimate.

The definition of preconstruction services covers a very broad spectrum of project services and includes all work completed on the project from the project conception up until contract award. This process includes effort that may not be assigned to a particular project and also effort for projects that never eventuate.

BACKGROUND

The definition of PCS covers a very broad spectrum of project services and includes all work completed on the project from the project conception up until construction contract award. This process includes effort that may not be assigned to a particular project and also effort for projects that never eventuate.

Standard Definitions

- *Preconstruction Services (PCS)*: All work completed on a project once it has been authorized for funding and costs related to the project can be charged accordingly, up until the construction contract is awarded. A generic project development timeline and a list of included activities for each phase were standardized for this study and are shown in Figure 1.
- *Overhead costs*: The mark-up/amount that accounts for the costs of department of transportation (DOT) staff above the operational level of planners, designers, etc. (i.e. executive and support staff that do not directly work on specific projects).

- *Corridor Projects*: Also referred to as "parent projects'. The term corridor is defined by the US DOT as "a combination of discrete, adjacent surface transportation networks (e.g., freeway, arterial, rail networks) that link the same major origins and destinations. It is defined operationally rather than geographically or organizationally." Corridor projects are usually multi-phased projects which require various preliminary engineering studies such as environmental assessment (acquiring wetland permits, NEPA documents, etc.), and right of way during the early planning stages. These types of projects are represented by project identification number (PIN) and usually fall under Type I category. Thus, a Corridor Project is defined as a group of Single Projects divided either into multiple sections or work types aimed at repairing, preserving and/or improving transportation network associated to a given roadway.
- *Single Projects*: Also referred to as "child projects." Projects that are created from portions Corridor Projects and whose early preconstruction expenses are at some level jointly estimated and recorded within the Corridor Project that spawned it. Single projects are identified by the assign of DOT project numbers for funding purposes. In this type of project, it should be noted that preliminary engineering works might be performed for a particular type of project conducted at the planning stage of multi-phase project and care must be taken to account all works and costs associated with the project.
- *Independent Projects*: Typical projects that are awarded by a DOT on an annual basis. In this type of project, the total preconstruction costs are individually estimated, assigned, and recorded. Thus, Single Projects that do not share any recorded preconstruction service expenses with Corridor Projects will be considered as Independent Projects. Independent Projects are also identified by project numbers.

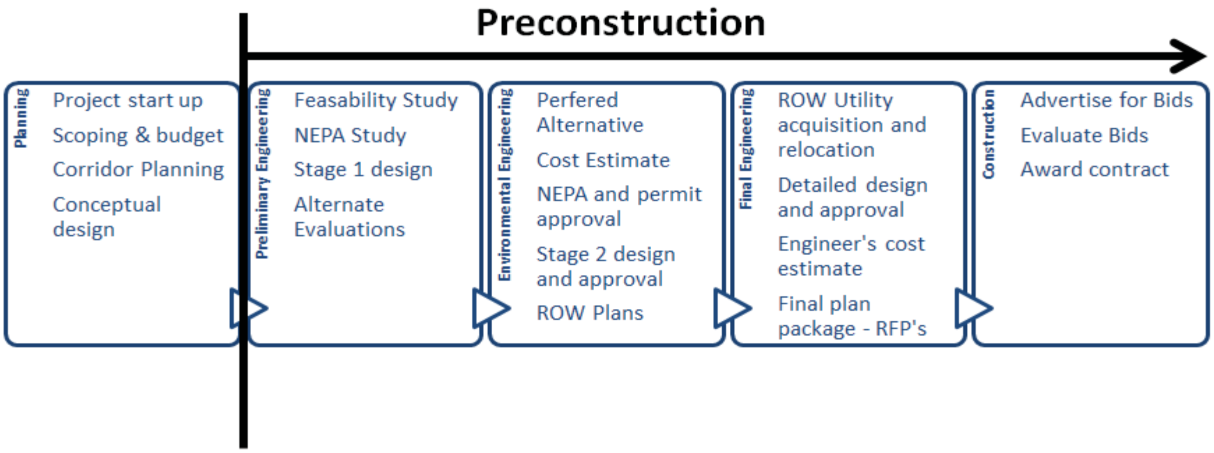

Figure 1: Preconstruction Services Activity Timeline

The projects investigated in this study are termed *"Typical Projects"*. These projects were defined as design-bid-build (DBB) projects within the $2 million – $25 million cost range. The main focus of the case studies will be on these projects. There are also PCS cost data collected from projects that were delivered using design-build (DB) and construction manager/general contractor (CMGC) and it will be used later in the overall research project to provide a comparison of PCS costs. The analysis in this thesis is based entirely upon DBB Typical Projects.

Project Development Timeline

A collection of documents from various agencies on the project development timeline were collected to create a standardized project development process that could be adapted to fit all agencies processes. Table 1 is from NCHRP Report 574: *Guidance for Cost Estimation and Management for Highway Projects during Planning, Programming and Preconstruction* (Anderson et al. 2007). This report focuses on the construction cost estimates through these phases, however it provided definitions of each phase that were then combined with other literature found during the research. The first four activities planning, programming and preliminary design, final design and advertise and bid are the areas of discussed in this research.

Table 1: Preconstruction Services Activity Timeline (Anderson et al. 2007)

Development phase	Typical Activities
Planning	Determine purpose and need, determine whether it's an improvement or requirement study, consider environmental factors, facilitate public involvement/participation, and consider interagency conditions
Programming and Preliminary Design	Conduct environmental analysis, conduct schematic development, hold public hearings, determine right-of-way impact, determine project economic feasibility, obtain funding authorization, develop right-of-way, obtain environmental clearance, determine design criteria and parameters, survey utility locations and drainage, make preliminary plans such as alternative selections, assign geometry, and create bridge layouts
Final Design	Acquire right-of-way, develop plans, specifications, and estimates (PS&E), and finalize pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, and cost estimates
Advertise and Bid	Prepare contract documents, advertise for bid, hold a pre-bid conference, and receive and analyze bids
Construction	Determine the lowest responsive bidder, initiate contract, mobilize, conduct inspection and materials testing, administer contract, control traffic, and construct bridge, pavement, and drainage

Project development processes from the Arizona, Iowa, Ohio, and New York State DOT as well as the Western Federal Lands Highway Division, were synthesized to develop a generalized project development process that can be adapted to individual agencies. These documents can be found in Appendix A of this report. Figure 1 shows the preconstruction timeline starting at the preliminary engineering stage this is designed to coincide with the Statewide Transportation Improvement Plan (STIP) for most agencies. All activities that occur prior to this including initial startup, scoping and budget, corridor planning and conceptual design are considered sunk cost and are included in the project overhead.

Statewide Transportation Improvement Plan

Federal Regulations require that State Departments of Transportation develop a Statewide Transportation Improvement Program (STIP) (CDOT 2013). The STIP contains capital and noncapital transportation projects proposed for funding under Title 23 (highways) and Title 49 (transit) of the U.S. Code as well as all regionally significant transportation projects that require an action by the Federal Highway Administration (FHWA) or the Federal Transit Administration (FTA).

In July 2012, the President signed Moving Ahead for Progress in the 21st Century (MAP-21). The STIP is developed under current federal regulations (Title 23 US Code). Currently, the development of a new STIP is required at least every four years and must contain a minimum four-year listing of Federal-Aid Projects. The STIP must be approved by the FHWA and the FTA.

Federal regulations require each STIP to be fiscally constrained. All federally funded transportation projects must be included in the STIP. In some states it is transportation commission policy to include state funded projects and local projects overseen by the DOT's in the STIP. The STIP was identified as a good baseline for the start of preconstruction services once a project gains funding authorization.

Research by Hollar (2011) looked at the percentage of construction costs that went in to "preliminary engineering." The definition used for *preliminary engineering* it this study was:

> "[P]lanning and design of a highway project for construction. PE begins when a specific highway project first receives funding authorization for planning and/or design activities. The delivery of the construction documents used for solicitation of construction contract bids (known as project letting) marks the end of PE." (Hollar 2011)

This definition is similar to the definition of preconstruction services except it does not include construction contract letting phase. Figure 2 shows the responses from 28 DOTs the percentage ranges from 4% in South Dakota up to 20% in California, Montana, Pennsylvania and Virginia.

Figure 2: DOT reported preliminary engineering cost as a percentage of construction cost (Hollar 2011)

MOTIVATION

The first expenses incurred in all projects are the costs to perform planning, programming, and preliminary engineering. Construction uncertainty is at its absolute highest level, making the practice of setting a budget for PCS costs using a percentage of construction costs merely the act of multiplying an arbitrary number by an estimated figure that will change as project development progresses (Hollar 2011). Hence, in many cases, the budget for developing a given project is effectively more uncertain than the budget for the project itself. To exacerbate the problem, research has proved that 86% of the time the initial construction estimate and subsequent estimates are too low (Flyvbjerg et al. 2002), which means that the budget for PCS costs will also be too low. The cliché "you get what you pay for" becomes active in this situation. The amount of effort that can be applied to quantifying the cost of the project's scope of work is limited by the available budget, and an inaccurate PCS cost estimate becomes a design quality issue, with in-house engineers and DOT preliminary engineering consultants forced to make the time spent on refining the design fit the available budget (Carr and Beyor 2005). The final product is often a set of poorly prepared construction documents detailing a product that is functionally over-designed because the designers did not have the budget to produce a fully optimized design (Gransberg et al. 2007; CMAA 2003).

The state-of-the-practice in PCS cost estimating ranges widely among DOTs. At times the variation is present within a single agency for different types of services and different stages of project development. Issues including the range of design alternatives to be analyzed; the impact of environmental permitting, construction safety, and options for traffic control; as well as construction phasing to meet construction financing and budget constraints all make PCS cost estimating challenging at best and nearly arbitrary at worst. Therefore, the need for standardized guidance for estimating PCS costs is critical for DOTs to meet transparency, accountability, and fiscal responsibility that come with the tighter budget experienced in the past 5 years. Hence, the objective of this research will be to propose a framework for estimating PCS costs.

The issue of accurate estimating of preconstruction service (PCS) costs is essentially tied to the efficient use of available public capital (Janacek 2006). Early estimates conducted during the planning phase often become legislative authorizations and turn into project budgets before the final scope of project work is adequately quantified (Anderson et al. 2007). Additionally, since preconstruction costs are by definition a small portion of the total project delivery cost, they are typically estimated as a standard percentage of estimated construction costs. Hence, if the capital project is underestimated, PCS costs will be similarly underestimated. A 2002 study involving 258 transportation projects collectively valued at $90.0 billion (Flyvbjerg et al. 2002) found that 86% experienced actual costs that were on average 28% higher than estimated. That study concludes that "*underestimation of costs at the time of decision to build is the rule* rather than the exception for transportation infrastructure projects" (Flyvbjerg et al. 2002, italics added). If one applies the USACE (1997) supervision and administration (S&A) rate of 5.6% to Flyvbjerg's sample, the PCS cost would be roughly $5.0 billion, a significant amount of money in any context. Using Flyvbjerg's cost growth would mean that the agencies delivering these projects would be short $1.4 billion in the preconstruction phases of project development. The fact that project scope and quality is defined during the planning and design process leads one to infer that poor estimating accuracy is actually robbing the project of proper resources to complete a thorough preconstruction process and perhaps ultimately results in imperfect construction documents that actually become the basis for construction cost growth after contract award (Molenaar 2005).

A study by Carr and Beyor (2005) reported that consultant design fees have not kept pace with inflation for the past three decades. This creates a situation where "the high-quality professional services rightfully expected by the public will become increasingly difficult [to attain] if the erosion in fees continues unabated into the future" (Carr and Beyor 2005). In essence, this pricing pressure forces engineers to literally furnish the requisite level of design services with a steadily decreasing amount of resources. This could unintentionally induce a bias toward minimizing planning and design activities to maintain necessary project profitability, which in turn would manifest itself in the form of declining quality of construction documents.

This environment is further exacerbated by the recent demand by owners to compress project delivery periods via programs like the FHWA's Everyday Counts (EDC). A survey by the Construction Management Association of America (CMAA 2003) found that the "demand for increasing speed of project delivery is the top reason for decline in construction document quality." The survey also reported that "In their responses to questions about the quality of construction documents, more than half of the owners surveyed responded that these documents often have significant amounts of missing information. Specifically, 45 percent of respondents indicated that construction documents, while sufficient, still had 'significant information needed,' while an additional 12 percent found that documents were typically inadequate because of major information gaps" (CMAA 2003).

A number of studies have looked at the relationship between design quality and subsequent construction contract modifications. Studies by Morgen (1986) and Kirby et al (1988) found that design deficiencies are the major cause of construction contract modifications and that 56% of all modifications are aimed at correcting design deficiencies. Additionally, a study by Burati et al. (1992) found that deviations due to design errors discovered during construction account for 79% of all modification costs and average 9.5% of the total project cost. Thus, past research is showing that improving planning and design quality has the potential to accrue benefits through reducing construction cost growth. A study completed for the Oklahoma Turnpike Authority (OTA) (Gransberg et al. 2006) confirmed this inference and demonstrated for one agency that, to a point, increases in actual construction costs compared to the early estimate were inversely proportional to the amount of money allocated for PCS. Figure 3 comes from that work and illustrates the relationship for OTA DBB bridge projects, specifically for the design fee expressed as a percentage of construction costs. The figure graphically illustrates that, within the limitations of the research, providing adequate funding to properly complete PCS gives the agency more control over the final cost of the project. Said another way, an *accurate PCS cost estimate increases cost certainty* for DBB projects. This conclusion is confirmed by a recent study that found "DB and CMGC display lower cost growths than DBB and therefore *provide greater cost certainty*" (West and Gransberg 2012, italics added).

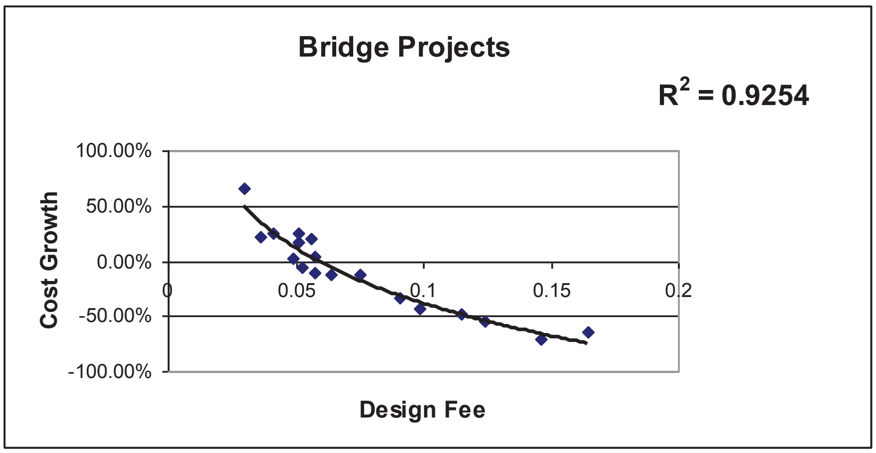

Figure 3: OTA Bridge Projects, Cost Growth from the Initial Estimate versus Design Fee (Gransberg and Lopez del Puerto 2006)

Given the above discussion, developing *a pragmatic system* with which to estimate PCS costs will promote final design quality by reducing construction document errors and omissions (Carr and Beyor 2005; CMAA 2003) and accrue an immediate benefit by enhancing cost certainty for projects delivered using both traditional and alternative delivery methods (Gransberg and Lopez del Puerto 2006; West and Gransberg 2012).

PROBLEM STATEMENT

In the past there has been a substantial amount of research into estimating construction costs for highway projects and there are also a handful of articles about estimating design cost and preliminary engineering for highway project but somehow preconstruction services costs have not been seriously researched. Due to the changing nature of state DOT work with increased funding uncertainties and shrinking budgets, it is more important than ever to ensure proper allocation of funds for highway projects. Uneducated estimates for preconstruction services or using a fixed percentage across multiple projects can lead to a misallocation of available capital funding in the PCS phase, which may force the need to redistribute funding late in an agency's fiscal year to cover overages and to expend underruns before the authorization expires (Hollar 2011).

The main objective of this research is to identify, analyze, and understand the current models for PCS cost estimating. This research is focused on US Department of Transportation (DOT) highway projects, but considers work from other industries.

These objectives are being further explored by focusing on the following questions:

1. *What project characteristics are important to developing an accurate PCS cost estimate?*
2. *What steps must be followed to implement a standardized PCS cost estimating methodology?*

CONTENT ORGANIZATION

This thesis contains three journal articles that comprise chapters 3, 4, and 5. Although each of these chapters contains a stand-alone document, they all focus on aspects of preconstruction services cost estimating for highway projects. The three chapters begin a framework for estimating PCS costs along with the key factors that influence the PCS cost estimates (Chapter 3), then the focus is narrowed to a PCS cost estimating using a neural network (Chapter 4), and finally the focus is narrowed even further to discuss a method for estimating design cost contingency (Chapter 5).

The objective of chapter 3 is to review and analyze current PCS cost estimating methods and propose a framework for developing a PCS cost estimate. The framework is derived from a larger project where detailed case studies were undertaken in nine US state Departments of Transportation (DOT). The paper documents and discusses the project characteristics previously identified for a given project through exploration of the literature and DOT estimating guidance/policy documents. Specifically, the paper seeks to answer the following research question:

What project characteristics are important to developing an accurate PCS cost estimate?

Chapter 4 discusses the use of a neural network to estimate PCS costs. The paper demonstrates the data mining approach used to develop the model and a classification system that can divide projects into like groups to improve the accuracy of the model. This chapter will provide an agency with a framework for implementing a neural network model by building on the influence factors determined in chapter 3.

Chapter 5 was submitted to the Transportation Research Board and was accepted for presentation at the 2014 annual meeting. The purpose of this chapter is to propose a rational method for determining a design cost contingency. This paper focuses on a single aspect of PCS cost estimating, the design cost estimate. The chapter proposes a method for creating a design cost estimate accuracy index from historical budgeted and actual design fee data. The paper demonstrates how the index can be used on future projects to determine an appropriate design contingency.

Chapter 6 details the conclusions reached in the research as well as the limitations that are inherent to those conclusions, and Chapter 7 discusses the important contributions made to the PCS cost estimating body of knowledge and points out future research needs to fill the gaps in that body of knowledge discovered during this project.

CHAPTER 2—APPROACH TO RESEARCH METHODOLOGY AND VALIDATION

There has been a substantial amount of research into estimating construction costs for highway projects. There are also a handful of studies about estimating design cost and preliminary engineering, but no research about estimating preconstruction services costs was found in the literature review conducted for this project. The thesis focuses on sixteen project and nine agency case studies that were collected at the time of this writing, as well as, the relevant analyses and observations made of those case studies. Case studies formed the bulk of the original research conducted in this project and offered examples of PCS cost estimating practices as well as examples of how agencies breakdown available PCS information.

The section begins by discussing the case study data collection protocol and methodology that allowed information to be collected from each agency in a verifiable manner. This section includes a description of case study demographics and the rationale for choosing each case study agency and the accompanying projects. Following the methodology section are condensed synopses of the case study summaries. Detailed case study summaries are contained in the Appendix B.

CASE STUDY PROTOCOL

Case studies were the primary source of data on the PCS cost estimating techniques in this research and are the basis for the practices recommended in this thesis. Since the collection of information via agency interviews and project case studies is the predominant research instrument in the research project, a large amount of time was invested to determine to how best to conduct the case studies, reduce the subsequent data and to capture valuable information.

Construction is a highly social process and is affected by human traits and behavior therefore it is important to utilize social science research methods to ensure social factors do not jeopardize the results (Abowitz 2010). Case study research has been shown to be a powerful research tool to evaluate and analyze emerging business practices such as PCS estimating techniques (Eisenhardt 1991). Case studies are particularly useful in answering questions about how things are done in detail, especially when examining a number of different cases (Yin 2003). The use of the case study method was essential in this research for capturing the unique nature and methods of the differing PCS cost estimating procedures employed by each agency and understanding the rationale behind their chosen methods.

The major objection to the use of case studies has been the perceived lack of statistical rigor. Recognizing this criticism, the research sought to generate a defensible, repeatable method to guide the case study process. This method was formalized and recorded in the case study protocol for the project. Creation of the case study protocol was guided by the influential book on the technique written by Yin (2003).

The case study protocol serves to establish the purpose of the case studies and the research questions to be answered by them. Clearly stating the specific information sought by the researchers at the start of this crucial task ensured that all researchers who were conducting case study interviews understood the ultimate goals of the research. The background information for the protocol included key sections, like the two below, to further explore the objective of this research:

1. What project characteristics are important to developing an accurate PCS cost estimate?
2. What steps must be followed to implement a standardized PCS cost estimating methodology?

The most important aspect of the protocol was the field data collection procedures. These procedures standardize the method to conduct all of the case studies and facilitate consistent and comparable results among the case studies. The key research instrument is the structured interview (GAO 1991) based on a standard case study questionnaire. The questionnaire was sent to the participants a week in advance of the interview. Each agency's PCS estimating procedures are unique and the interview process was designed to capture that uniqueness, while generating a standard comparable output. To that end, the questionnaire maximized the use of yes/no questions and matrices of checklists to be complete for every case study. Additionally open-ended questions were crafted to generate in-depth discussion to fill in the details surveys and questionnaires cannot easily capture.

CASE STUDY PROCESS

The case study protocol included a pilot case study to evaluate the efficacy of the process before modifying the case study protocol and completing the remaining cases. The pilot study also served to allow an opportunity to become familiar with the case study protocol for this project and provide comments on it or recommendations for changes. After the pilot study took place with the Montana DOT a few minor adjustments were made to the agency structured interview questionnaire. There were additional explanation boxes added to gain a more in-depth understanding of each agency's PCS processes, also both loss of design effort and geographic factors were added to the matrix concerning the list of factors that influence the PCS estimate. Finally there was the addition of a question about the impact the DOT thought a better PCS estimate would make on the planning process.

The case study protocol for this project mandated a specific sequential order for communications and interactions with project participants that was followed on each case study. First, all interviews with the participating agencies were conducted on site in person at the agency's headquarters to ensure appropriate people were available to answer the questions provided. Other initial inquiries were made via email, but the personal contact was vital to the quality of the information collected in each case study. The personal contact with the key PCS estimating personnel participants provided a champion for the research effort and a specific point of contact for queries during data reduction and interpretation. The participants were not compensated for their time by the research team, making it essential to secure at least one agency staff member who was enthusiastic about assisting with the research effort and was in a position to coordinate with the rest of the agency.

CASE STUDY SELECTION

The research was conducted on a national level therefore it was important to get a fair representation of states considering factors such as population, budget, land area and in-house vs outsource PCS make up. Nine DOTs were selected where data was collected on the agencies PCS cost estimating procedures and some project case study projects were collected. The list of the nine participating agencies has been listed in Table 2 along with their population land area and the DOTs yearly construction budget. Figure 4 shows the geographical distribution of the states.

Table 2: Population and Land area information (US Census Bureau 2014)

Agency	Population (million)	Land area (square miles)	Budget ($ Million)
California	38.3	155,779	$13,000 - $15,000
Colorado	5.27	103,642	$500 – $700
Iowa	3.09	55,857	$400
Maryland	5.93	9,707	$600 – $800
Montana	1.02	145,546	$385
New York	19.7	47,126	$1000
Oklahoma	3.85	68,595	$632 – $790
Rhode Island	1.05	1,034	$300
Utah	2.90	82,170	$1,100

Figure 4: Geographical distribution of the case study states

Nine agencies were interviewed in a structured interview process to determine each agency's overall PCS cost estimating procedure. The interview template is shown in Appendix C. Each agency was also asked to provide 2 – 5 projects for project case studies for the research. The researchers ended with 16 projects from 6 of the 9 agencies.

CASE STUDY AGENCY SYNOPSIS

For full case study reports refer to Appendix B.

Agency: California Department of Transportation – Caltrans

Caltrans collects past project cost data for PCS through engineer's timesheets. Caltrans uses data collected from past projects to estimate the PCS cost for future projects. They also have a system called pipe scan and it is used as a starting point for PCS estimates. Current methods used to estimate PCS costs for a project include a direct estimate of hours as well as the use of an average percent support to cap ratio.

Caltrans performs 90% of PCS in-house and contracts out 10% of PCS. Each district has their own on call contracts with pre-selected qualified architect and engineering consultants. Caltrans can outsource all PCS activities except advertisement for bids, evaluation of bids and award of contract. It is rare for Caltrans to outsource PCS concerning cost estimate, ROW plans, and ROW utility acquisition and relocation.

At Caltrans if there is a loss of funding for a project when it is in PCS phase the project will be terminated, once funding for the project is resumes a new project number is assigned therefore they do not consider loss of design effort these costs will be included in the overhead rate. To improve PCS estimate Caltrans believe they need a better model for historical data analysis, need to do bottom-up estimates. At this stage the project manager does not control the people working on project in the PCS phase, and good scoping documents. Caltrans believes that having more accurate PCS cost estimates would have some impact on the project budget establishment process.

Agency: Colorado Department of Transportation – CDOT

CDOT does not collect past project cost data for PCS. For federally funded projects, CDOT has to submit an independent project cost estimate in which a figure of 10% of the estimated construction cost is used for PCS cost estimate.

CDOT performs 45% PCS in-house and 55% is outsourced by project number. CDOT can outsource all PCS activities except advertisement for bids, evaluation of bids and award of contract. CDOT does not have a policy on the amount of work outsourced however they need to have reasonable justification before outsourcing a project.

Table 3 provides the project data collected for the project case study collected from CDOT.

Table 3: CDOT project data

Project Name	Eagle interchange
Procurement method	CMGC
Project type	Major structure
PCS performance	Consultant
Total project cost	$ 15,100,000.00
Total PCS cost	$ 1,510,000.00
PCS percentage	10%
Complexity	4
Sub-consultants	8
Lanes	4
Plan sheets	515
NEPA Classification	CE
Bridges	2
Highway Classification	Major collector
Length of Project (miles)	0.35

CDOT considers the construction cost of a project to be a major influence on the PCS estimate for in-house projects but only a minor influence if PCS will be contracted out. CDOT are looking to adopt a tool that can help them estimate PCS to offset the loss of experience when they employ young engineers to replace retirees. To improve their PCS estimate they believe they require good tool as well as data that aligns with the systems already in place at the agency. An improved PCS estimate is likely to benefit budget portfolio management as people usually involved with these estimates are often not engineers but planners.

Agency: Iowa Department of Transportation – Iowa DOT

Iowa DOT collects past project cost data for PCS through engineer's timesheets this data is collected and stored mainly for accounting purposes. Iowa DOT does not use data collected from past projects to estimate the PCS costs for future projects. They do not estimate PCS costs for any projects. The Iowa DOT can use both in-house and on call consultants; they do also use other consultants but only for larger less common projects.

Currently Iowa DOT is not estimating PCS cost for projects but may adopt this in the future. To improve these estimates they believe they need to learn how to use the data they already have. Iowa DOT has been capturing PCS hours, and they need a way to organize this data to make it useful in PCS cost estimating. Iowa DOT thinks that having a more accurate estimate of PCS would have a large impact on the planning process for the agency and would allow the agency to better budget staff time. It also would be valuable to know the number of hours per task and to be able to compare these to consultant design hours.

Agency: Maryland State Highway Administration – MSHA

MSHA does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using time tracking software. MSHA uses data collected from past projects along with standard percentages to estimate the PCS cost for future projects. The old system used 15% of the construction cost as preliminary engineering; they now use a curve system on preliminary engineering.

MSHA has a standing contract for a general engineering consultant (GEC). MSHA can perform the entire preconstruction process in-house and it can also outsources all PCS except ROW utility acquisition and relocation, advertisement for bids, evaluation of bids, and award of contract.

MSHA is currently estimating PCS cost for all projects. To improve these estimates they believe they need to develop a historical database of previous estimates. MSHA believes that having more accurate PCS cost estimates would have a large impact on the planning process as they believe that it would provide more efficiency to managing funds.

Table 4 provides the project data collected for the two project case studies collected from MSHA.

Table 4: MSHA project data

Project Name	Taneytown Streetscape	MD 924
Procurement method	DBB	DB
Project type	Reconstruction	Safety
PCS performance		
Total project cost	$ 22,000,000.00	$ 10,000,000.00
Total PCS cost	$ 2,200,000.00	$ 800,000.00
PCS percentage	10%	8%
Complexity	4	4
Sub-consultants	8	2
Lanes	2	4
Plan sheets	354	
NEPA Classification	CE	CE
Bridges	0	0
Highway Classification	Urban other principal arterial	Urban arterial
Length of Project (miles)	2	0.5

Agency: Montana Department of Transportation – MDT

MDT does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets and have a time allocation system per job. MDT does not use data collected from past projects to estimate the PCS cost for future projects. They have a system that records past hours and durations of activities 3-5 years to reconcile with activities to average activity hours. This system has no feedback loop and therefore it is not used to look at past projects or to re access the activity hours in OPX2 (project management tool).

MDT can perform the entire preconstruction process in-house except feasibility study and they can also outsource all PCS except advertisement for bids, evaluation of bids and award of contract this is considered in the construction department. Approximately 20% of the PCS program for MDT is outsourced.

Table 5 provides the project data collected for the five project case studies collected from MDT.

Table 5: MDT project data

Project Name	Alberton - MT	Yellowstone - MT	Richey - MT	Libby - MT	Manchester - MT
Procurement method	DBB	DBB	DBB	DBB	DBB
Project type	Rehabilitation	Bridge replacement	Reconstruction	Rehabilitation	Rehabilitation
PCS performance	In-house	61% in-house 39% consultant	81% In-house 19% Consultant	69% In-house 31% Consultant	In-house
Total project cost	$15,160,216.69	$11,117,526.18	$11,671,335.94	$5,154,041.00	$13,654,704.61
Total PCS cost	$ 326,984.74	$ 1,350,022.32	$ 747,932.55	$ 523,441.08	$ 221,626.30
PCS percentage	2%	12%	6%	10%	2%
Complexity	1	4	3	4	2
Sub-consultants	0	3	1	3	0
Lanes	4	2	2	2	4
Plan sheets	41	113	351	284	258
NEPA Classification	CE	EA	CE	CE	CE
Bridges	6	1	1	0	3
Highway Classification	principal arterial	Urban arterial	Major collector rural	Major collector rural	Principle arterial (freeway)
Length of Project (miles)	9.8	0.7	10.7	5.1	5.4

Currently MDT is estimating PCS cost for all projects using a standard percentage of construction costs. To improve PCS estimates MDT believes they need to introduce function-based estimating, and they also need to determine how to allocate the funds in split corridor projects. MDT also believes that they need to improve how they capture the hours on the time sheets.

Agency: New York State Department of Transportation – NYSDOT

NYSDOT collects past project cost data for PCS through engineer's timesheets. This data is used by project manager to predict an estimate for future projects with similar qualities. NYSDOT uses an in-house system called DPR which contains a selection of tools to estimate PCS hours. NYSDOT are looking at moving to use Primavera P6 in the future.

NYSDOT performs 50% PCS in-house and 50% is outsourced by dollar value and 90% in-house and 10% outsourced by number of projects. NYSDOT does not perform environmental sampling and testing or surveying services, they use on call contracts for these services even if all PCS services are performed in-house. NYSDOT can outsource all PCS activities except advertisement for bids, evaluation of bids and award of contract.

Table 6 provides the project data collected for the two project case studies collected from NYSDOT.

Table 6: NYSDOT project data

Project Name	Western Ave - NYS	I787 NYS
Procurement method	DBB	DBB
Project type	Reconstruction	Bridge rehabilitation
PCS performance	Consultant	In-house
Total project cost	$ 9,700,000.00	$ 28,000,000.00
Total PCS cost	$ 1,280,000.00	$ 1,333,346.08
PCS percentage	13%	5%
Complexity	2	4
Sub-consultants	2	0
Lanes	6	6
Plan sheets	198	648
NEPA Classification	CE	CE
Bridges	0	6
Highway Classification	Interstate	Interstate
Length of Project (miles)	12.1	4.3

NYSDOT does not consider number of plan sheets as an influential characteristic in the PCS estimating due to recent advances in technology and the general move into electronic plans. NYSDOT believes that a major setback to estimating PCS costs is how to estimate inflation as it is difficult if project development occurs over multiple years. NYSDOT believes that to improve their PCS cost estimate they need to move to task based estimating but they are skeptical about whether the time and effort would result in any real value for the agency.

Agency: Oklahoma Department of Transportation – ODOT

ODOT does not record in-house preconstruction services (PCS) hours on a per project basis. Approximately 50% of engineers' time spent on PCS is billed to departmental overhead.

ODOT can perform the entire preconstruction process in-house except right of way acquisition. They can also outsource all PCS except preferred alternative, NEPA and permit approval, final plan package (RFP and RFQ), advertisement for bids, evaluation of bids, and award of contract.

Currently ODOT believes estimating PCS cost would add value to the agency but they have yet to implement a process to do so. To improve PCS cost estimates they believe they need to make direct changes to their projects and agency culture. ODOT believes that it would be difficult to convince all people within the agency to adopt a PCS estimating system.

Table provides the project data collected for the three project case studies collected from ODOT.

Table 7: ODOT project data

Project Name	Garvin - Ok	Beckham -OK	Payne -OK
Procurement method	DBB	DBB	DBB
Project type	Resurfacing	Resurfacing / Bridge rehab	Pavement overlay
PCS performance	In-house	Outsourced	Outsourced
Total project cost			
Total PCS cost			
PCS percentage			
Complexity	4	4	3
Sub-consultants	0	2	2
Lanes	4	4	4
Plan sheets	131	60	50
NEPA Classification	CE	CE	CE
Bridges	6	5	0
Highway Classification	Interstate	Interstate	I 35
Length of Project (miles)	6.5	7.93	5.4

Agency: Rhode Island Department of Transportation – RIDOT

RIDOT does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets. RIDOT does not use data collected from past projects to estimate the PCS cost for future projects. Design costs are estimated by using 15% of total construction cost. However, this is not uniform; smaller projects tend to be of a higher percentage and larger projects tend to be of a lower percentage. This process is not an estimate, but only an educated guess.

RIDOT does contract out PCS. They have several on-call consultants as almost all their design work is outsourced. They use two consultants for highway work, two for bridges, and four for traffic engineering. No single firm is the dominant GEC. RIDOT can advertise for bids, evaluate bids, award contracts, and perform some ROW utilities acquisition and relocation; all other PCS processes are outsourced. RIDOT did not provide data for project case studies.

RIDOT does not see value in estimating PCS cost. Since they are a small organization, they have yet to develop a database to keep track and evaluate the PCS costs. Their priority lies in estimating construction costs. To improve these estimates they believe they need a database to pull scattered records and documentation of PCS into one place. There is a 2 year election cycle so government and legislative representatives change regularly and therefore projects continue to lose and gain importance depending on the political influence. RIDOT believe that having more accurate PCS cost estimates would have no impact on the planning process. They believe that PCS costs have very little impact on the overall program and projects will be executed no matter what the magnitude of PCS costs are.

Agency: Utah Department of Transportation – UDOT

UDOT collects past project cost data for PCS through engineer's timesheets. This data is stored in ePM (electronic project management) and is used by project manager to predict an estimate for future projects with similar qualities. UDOT also performs a direct estimate of hours for PCS work and is compared with the past project cost range as a check.

UDOT performs 25% PCS in-house and 75% is outsourced by dollar value. UDOT can outsource all PCS activities except advertisement for bids, evaluation of bids and award of contract. UDOT tries to decide early on whether the project will be outsourced or performed in-house so that they can set the budget early.

Table 8 provides the project data collected for the three project case studies collected from UDOT.

Table 8: UDOT project data

Project Name	Region 3 - UT	Region 2 - UT	Region 4 - UT
Procurement method	DBB	DB	DBB
Project type	Reconstruction	Continuous flow intersections	Rehabilitation
PCS performance	ROW – Consultants All other PCS in-house	Consultant	In-house
Total project cost	$ 4,200,000.00	$ 48,981,854.37	$ 2,260,000.00
Total PCS cost	$ 277,253.92	$ 3,704,380.09	$ 17,634.00
PCS percentage	7%	8%	1%
Complexity	2	5	1
Sub-consultants	1	4	0
Lanes	6	6	2
Plan sheets	98	115	0
NEPA Classification	CE	EIA	CE
Bridges	0		0
Highway Classification	Rural principal arterial	Major arterial	Major arterial
Length of Project (miles)	2.5	2	8.48

UDOT does not believe they set out to make mistakes therefore they do not consider loss of design effort necessary in estimating PCS. To improve PCS estimate UDOT believe they need to retain, hire or train new experienced staff. UDOT believe that having more accurate PCS cost estimates could have some impact on the planning process and allow them to refine allocation of resources and negotiate with consultants better.

CHAPTER 3—FRAMEWORK FOR DEVELOPING A PRECONSTRUCTION SERVICES COST ESTIMATING MODEL FOR HIGHWAY PROJECTS

Hunter, K.D., D.D. Gransberg and H.D. Jeong, “Framework for Developing a Preconstruction Services Cost Estimating Model for Highway Projects,” *Journal of Management in Engineering,* ASCE (Submitted April 2014) [Peer-reviewed archival journal]

ABSTRACT

Due to recent funding uncertainties in the public sector state departments of transportation (DOT) are experiencing increased pressure to improve efficiency of their cost estimating systems. Preconstruction services (PCS) cost estimating is and area in which there is a need for improvement as guidance and support for agencies in managing PCS costs is lacking. This paper proposes a framework for developing a PCS cost estimate for highway projects, it provides a project development timeline and the types of estimates that will be appropriate at each stage. The paper also establishes the key project characteristics that affect PCS cost of a project identifying project type, complexity and estimated construction cost as most influential factors when estimating PCS costs.

INTRODUCTION

The issue of accurate estimating is essentially tied to the efficient use of available public capital (Janacek 2006). Early estimates conducted during the planning phase often become legislative authorizations and turn into project budgets before the final scope of project work is adequately quantified (Anderson et al. 2007). Additionally, since preconstruction costs are by definition a small portion of the total project delivery cost, they are typically estimated as a standard percentage of estimated construction costs. Hence, if the capital project is underestimated, preconstruction services (PCS) costs will be similarly underestimated. A 2002 study involving 258 transportation projects collectively valued at $90.0 billion (Flyvbjerg et al. 2002) found that 86% experienced actual costs that were on average 28% higher than estimated. That study concludes that “*underestimation of costs at the time of decision to build is the rule* rather than the exception for transportation infrastructure projects” (Flyvbjerg et al. 2002, italics added).

If one applies the US Army Corps of Engineers supervision and administration rate of 5.6% to Flyvbjerg’s sample, the PCS cost would be roughly $5.0 billion, a significant amount of money and *does not include* the design costs. Using Flyvbjerg's cost growth would mean that the agencies delivering these projects would be short $1.4 billion in the preconstruction phases of project development. The fact that a completed construction project's scope and quality was defined during the planning and design process leads one to infer that poor estimating accuracy and the resultant resource shortfall may actually be preventing the project from completing a thorough preconstruction process. It may also ultimately result in imperfect construction documents that actually become the source for construction cost growth after contract award.

As such, this paper's objective is to review and analyze current PCS cost estimating methods and propose a framework for developing a PCS cost estimate. The framework is derived from a larger project where detailed case studies were undertaken in nine US state Departments of Transportation (DOT). Specifically, the paper seeks to answer the following research question:

What project characteristics are important to developing an accurate PCS cost estimate?

The paper will document and discuss the project characteristics previously identified for a given project through exploration of the literature and DOT estimating guidance/policy documents. It will also discuss the underlying motivation for selecting these characteristics via detailed case study interviews. Finally, it will identify and document the possible set of preconstruction services.

BACKGROUND

By definition PCSs are complete when the construction contract has been awarded in design bid build (DBB) and construction manager general contractor (CMGC) contracts and once the design-build (DB) contract is awarded. Unfortunately, defining the point in time where PCS begin is not nearly as simple. Many projects within a state DOT may be started and never move past the initial planning phase due to funding restrictions, political influence, environmental issues or programming priorities. For the purpose of this research, PCS costs start once a project reaches the Statewide Transportation Improvement Program (STIP) or once it has passed the initial planning phase shown in Table 1. All costs incurred for a project before this point are considered sunk costs and are ascribed to the agency overall overhead.

When studying PCS cost estimating it is important to consider what factors influence the PCS cost of a project. Past research on estimating PCS costs is scarce. Much of the cost estimating research in transportation is specifically about construction cost estimating, with some related to design cost estimating (Anderson et al. 2007). Part of the problem is due to the fact that most DOTs complete a great part of the preconstruction project development process using internal personnel. Thus, the budgeting process for DOT staff is different from the process used to establish budgets for construction projects, and the funds typically are appropriated from a different pot of money. Additionally, the management interviews conducted in this study also revealed that there is a concern that systematically collecting the cost data needed for a PCS estimate could result in a publicly accessible document that would expose the agency to criticism for not cost effectively utilizing their personnel budget and political pressure to increase the amount of work that is outsourced (Gransberg and Molenaar 2008).

However as state and federal budgets become tighter and the condition of the nation's highway infrastructure deteriorates, it becomes more critical for public agencies to be able to budget for future projects with greater accuracy. Thus, the business case for investing in systems to estimate PCS costs, a true gap in the body of civil engineering cost estimate knowledge, is becoming more compelling.

New York State DOT developed a model using a commercial spreadsheet / database program to estimate the design hours for each project (Williams 2013). The model allows the DOT to either search similar projects or generate an estimate of total design hours to be expected for a project. The model was developed using a 12 "key" project characteristic chosen by the NYSDOT engineers as defining factors of a project. These were (Williams 2013):

1. Complexity
2. Project type
3. Number of sub-consultants
4. Construction cost
5. Number of lanes
6. Number of plan sheets
7. State Environmental Quality Review (SEQR) classification

8. National Environmental Policy Act (NEPA) classification
9. Predominant bridge type
10. Number of bridges
11. Highway classification
12. Length of project

These characteristics became the input factors in the model the number of plan sheets were used as the independent variable to calculate the total design hours. However cost per plan sheet methodology is becoming obsolete. This is due to the development of technology that permits plans to be produced electronically, making the correlation between number of plan sheets and design fee difficult to measure. Hours are calculated from a simple regression model that is expected to become more accurate as more project data is made available (Williams 2013).

Another consideration when estimating the PCS cost is the type of estimating method. Two approaches to PCS cost estimating were explored:

- Top-down (macro) estimates produced by an experienced estimator, useful for managers who have limited knowledge of the process to complete the project (Larson and Gray, 2011)
- Bottom-up (micro) estimates usually correlate to a work breakdown structure (WBS). Each activity is estimated by the person who is involved with monitoring the project (Larson and Gray, 2011)

Table 9 has been adapted from Larson and Gray (2011), and shows the project characteristics associated with choosing to do top-down or bottom-up estimates. A top-down estimate is defined as the use of a parametric estimating factor, such as percentage of estimated construction costs, to determine the PCS budget. On the other hand, a bottom-up estimate calculates the number of labor hours estimated for each PCS task, the average labor-hour rate, and rolls the cost up from these detailed estimates of effort.

Table 9: Conditions for preferring Top-Down or Bottom-Up Estimates (Larson and Gray, 2011)

Condition	Top-down	Bottom-up
Strategic decision making	X	
Cost and time important		X
High uncertainty	X	
Internal, small project	X	
Fixed price contract		X
Details needed		X
Unstable scope	X	

METHODOLOGY

A full explanation of the research methodology used to collect case studies is explained in Chapter 2.

Williams et al. (2012) identified 12 project characteristics that are inherent for each project for NYSDOT and can be used to estimate design effort. These characteristics were evaluated by a team of NYSDOT and FHWA personnel so are applicable to the target audience of this research. Most non-design preconstruction activities are similar in composition to design tasks, in that they involve the provision of specialized professional services and are often performed by engineers. Therefore, these characteristics were used as a starting point for identifying the project characteristics important in developing an accurate PCS cost estimate.

Each agency was asked to fill in a matrix identifying which project characteristics had the most influence on the PCS cost estimate. The average ranking for these characteristics were analyzed using a t-test to determine the equality of the means of the responses and categorize the factors in to the three levels of influence.

Question V.1 of the interview was as follows:

How influential do you think the following characteristics are in estimating the overall PCS cost for a "typical Design Bid Build" project? (Interviewer circle the check box)

- *1- No Influence*
- *2-Some Influence*
- *3-Major Influence*

The list of characteristics or influence factors provided was as follows:

1. *Complexity*
2. *Project type*
3. *Number of sub-consultants*
4. *Construction cost*
2. *Number of lanes*
3. *Number of plan sheets*
4. *National Environmental Policy Act (NEPA) classification*
5. *Number of bridges*
6. *Highway classification*
7. *Length of project*
8. *Geographical*
9. *Loss of design effort*
10. *Other*

The same question was also asked in relation to a specific project for the project case study interview - however the influence factors “Loss of Design Effort” and “Geographical” were not considered in the project case study questionnaire.

RESULTS

The following three basic types of estimates were found during the case study interviews (See Table 10):

- Direct estimate of hours
- Standard percentage of construction cost
- Past project cost range

Table 10: Agency PCS estimating methods

Method	Agency
Direct estimate of hours	• California DOT • Utah DOT*
Standard percentage of construction costs	• Colorado DOT • Montana DOT • Rhode Island DOT
Past project cost range	• Maryland State Highway Administration • New York State DOT • Utah DOT*
Do not estimate PCS costs	• Iowa DOT • Oklahoma DOT
* UDOT uses direct estimate for detail and then back-checks the direct estimate with past project cost ranges.	

The level of sophistication used within each department varies, but it can be seen that Utah is the only state currently using two methods and comparing the results. Two states were found to have no formal method to estimate PCS cost.

When the researchers met with the California DOT (Caltrans), two types of projects were used; corridor-level projects (termed parent projects in Caltrans jargon) were used when the costs for planning and scoping are incurred. The parent projects spawn a series of child projects or single projects. This project structure was also found in the Iowa DOT case study data.

When determining the best practice for estimating PCS costs one must consider the estimate's end user, the timing of the estimate and the data available on a specific project type at the time of the estimate. The initial estimate of PCS costs for the corridor project is typically done at the programmatic level. Therefore Table 9 shows that a top-down estimate is more appropriate as it is used essentially for strategic decision making, when there is limited data available on the project and usually an unstable scope. This estimate is useful for allocating program funds, making it valuable to higher level management. When the project moves into the single project phase and it has been assigned funds and enters the STIP, the scope is likely to be better defined and requires a more detailed estimate to set the budget for the project. In this situation, both a bottom-up and a top-down estimate can be used. Once a project reaches this phase it is usually considered the start of the PCS for a project, and it is now much more likely to be funded but is still in the early stages of development. Applying both top-down and bottom-up estimating methods, and comparing the two, helps provide a strong basis for strategic decision making, but also sets a budget for the project manager or PCS staff to adhere to through the PCS phases. As a project is further developed a bottom-up estimate can be used before the project moves into the final engineering phases. This estimate is used as milestone to review the estimate thus far, and also provides a basis for negotiations with consultants if the project is to be outsourced. Independent projects usually arise from a need in a certain area and start at the preliminary engineering phase, but can start later in the PCS process depending on the project characteristics.

Figure 5 shows a flow chart of a standard project development process that shows the three PCS cost estimate milestones described in the previous paragraph. The initial estimate is to be performed before the project reaches the STIP. While the project is still in the corridor phase this estimate is for strategic decision making and encompasses all activities in PCS process. This is likely to be a rough estimate and based on past project experience or a standard percentage of estimated construction cost, and is not likely to involve details or duration of specific activities. Model 2 should be performed once a project reaches the STIP and a project manager is assigned. The model 2 estimate sets the budget for the PCS for the project, and it is recommended that both a top-down and bottom-up estimate is performed so that the two estimates can be compared and act as a check to provide a more accurate estimate. This method is used at Utah DOT where they perform both a direct estimate of hours and use a past project cost range - these are then compared to enhance estimate accuracy. It is recommended that both methods are used at this stage because this estimate will be used for both micro and macro purposes. This estimate sets the budget for the project manager so needs to provide details of the cost, but it will also be used by upper level management for strategic planning. At Caltrans the model 2 estimate also contains a percentage of the planning cost that had already been invested in the project. Once the preliminary engineering and environmental engineering phases have been completed a more accurate estimate of the remaining PCS can be required. This is especially crucial if the project is to be consulted out as it can provide a basis for contract negotiations with consultants for final engineering. In this case a bottom-up detailed estimate is deemed to be more appropriate. This stage should also be used as a review of the model two PCS estimates.

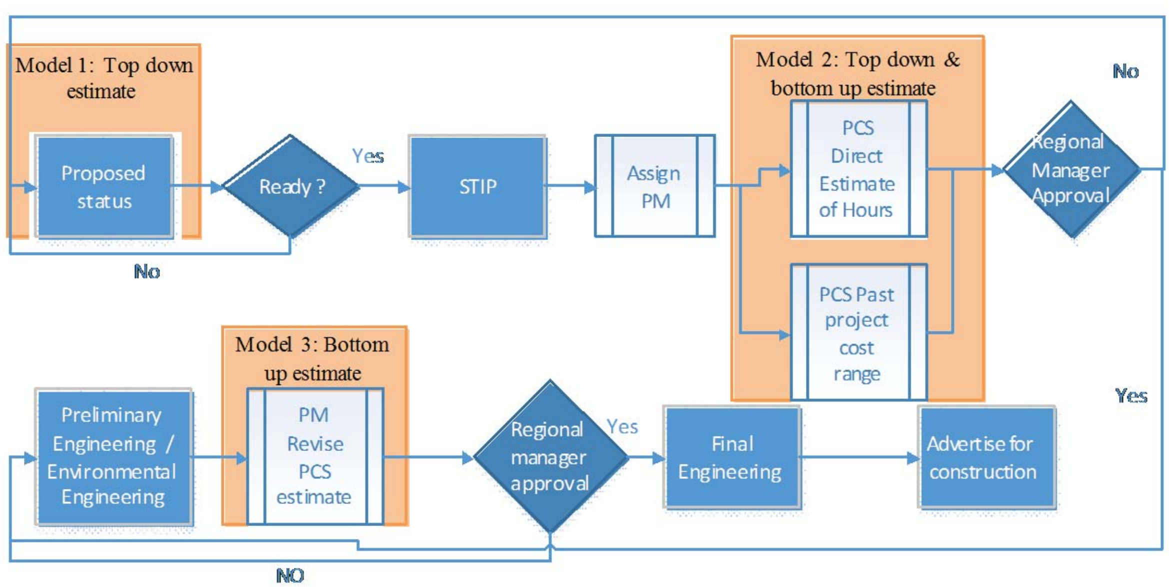

Figure 5: Project development process

The framework provided in Figure 5 can be used as a base timeline for performing PCS cost estimates, and reviewing these estimates to monitor budgets. When developing a PCS cost estimating framework it is also important to determine the project characteristics that affect the estimate. This information allows the user to link a project to past projects with similar characteristics, providing information for an estimate based on past project cost range.

To determine the most influential factors in a PCS cost estimate each agency was asked to fill in a matrix identifying which project characteristics had the most influence on the PCS cost estimate. This question was answered by the DOT representative during the interview and later the same question was answered in the context of a specific project. The mean value of response to each influence factor is given in Table 11 for agency response and Table 12 for the project responses. In these tables the 12 influencing factors are ranked based on the mean response value. It is worth noting that additional factors that were suggested in the other category, such as inflation, expedited project delivery, political issues innovation and new technology, were not included in this analysis.

Table 11: Influence Factors ranked based on mean response values from nine DOTs

INFLUENCE FACTOR	MEAN RESPONSE
Tier 1 [2.56-3.00]	
1. Complexity	3.0
2. Project type	2.89
3. NEPA classification	2.67
4. Construction cost	2.56
Tier 2 [2.00-2.56]	
5. Length of project	2.56
6. Number of bridges	2.44
7. Number of plan sheets	2.33
8. Number of lanes	2.0
9. Geographical	2.0
Tier 3 [1.44-1.56]	
10. Highway classification	1.56
11. Number of sub-consultants	1.44
12. Loss of design effort	1.44

Table 12: Project Influence Factors ranked based on mean response values from 16 Projects

INFLUENCE FACTOR	MEAN RESPONSE
Tier 1 [2.42-2.75]	
1. Complexity	2.75
2. Project type	2.56
3. Construction cost	2.42
Tier 2 [1.92-2.07]	
4. Number of bridges	2.07
5. Length of project	2.06
6. Highway classification	1.94
7. Number of subconsultants	1.93
8. Number of plan sheets	1.92
Tier 3 [1.62-1.81]	
9. NEPA	1.81
10. Number of lanes	1.63

Therefore, the responses summarized in Table 11 represent the importance of influence factors from the point of view of the state DOT. We have categorized the factors into three groups. Tier 1 consists of the factors that DOTs felt had the most influence on the PCS costs. Tier 3 consists of factors that scored on average well below 2.0 and hence were considered to have little to no influence on PCS costs. A statistical analysis was conducted to see the effect of variability of responses to each factor and to see if there are significant differences between factors.

In order to investigate this question we conducted a two-tailed *t*-test for comparison of mean responses. The null hypothesis was that the means for any of the two selected factors were equal. The alternative hypothesis was that the means were not equal. In general, for the factors in each tier of Table 11, one could not reject the hypothesis that the means were equal. This means that the factors within each tier will have more or less the same importance. There are some concerns with using this test for this application. First, the number of data points is only 9. Secondly, the assumption of normality is not realistic. However, the test provides an insight into the effect of variance on the possible values of each factor. The main purpose for conducting these tests was to have a systematic and consistent method to group these factors into the three tiers so that we can concentrate on the most influential factors.

Table 12 gives the project influence factors ranked based on their mean score from 16 projects. The main difference between these factors and factors listed in Table 11 is that the respondent was weighing the influence of each factor against a specific project rather than the whole agency. This table does not include two of the factors listed in Table 11. These were "Geographical" and "Loss of Design Effort."

As can be seen, the most influential factors remain the same in both cases with the exception of NEPA classification, which has been relegated to Tier 3 in Table 12. This is likely because 13 out of 16 projects collected in this study were categorical exclusions and therefore there was little emphasis on NEPA process for these projects. "Number of Lanes" scored higher at the agency level while "Highway Classification" and "Number of Subconsultants" scored significantly higher at the projects level. Overall, while these two tables agree on three out of four most influential factors, in Tier 3 factors there are some differences.

The same statistical approach explained earlier for grouping factors (two-tailed t-test for comparison of means) was applied to the factors in Table 12. The three tiers presented are the outcome of that analysis. In other words, the equality of factor means within each tier could not be rejected statistically. This analysis was based on a sample that varied between 14 and 16 projects because not all respondents scored every influence factor.

As a comparison between the outcome of Table 11 and Table 12, a correlation coefficient was calculated between the ranks of factors in each table. The rank correlation between these factors was calculated as 0.60. A correlation coefficient of 0.64 was also calculated between the scores of factors in the two tables. In both cases, these values show that there is moderate correlation between the results of the two tables.

There seems to be little doubt that the most significant factors at the agency and the project level are the following:

- Project complexity
- Project type
- Construction cost

This is valuable information for developing the parametric estimating model, as these three factors can be used as most influential input variables to estimate the PCS for a project.

Project complexity is a subjective variable making it difficult to incorporate this as in input variable.

One of the controversial characteristics that came from this analysis was the number of plan sheets. While some DOTs still do a lot of their work on paper (i.e. plan sheets), some DOTs like NYSDOT are moving more towards using only digital plans, making the plan sheet metric obsolete. This is also highlighted in the report by Tippett and LaHoud (1991) and Sturts et al. (2005) who stated that "technology is revolutionizing the way engineers work and there is a need to revise the pricing strategies for engineering design services."

Loss of design effort was a characteristic added by the researchers after the pilot study, this was defined as 'Design work completed but not used in the final project due to changes in scope during the design process.' During the PCS phase, this is likely to occur often, especially if the project scope is not well-defined in early phases of the development process. It occurs when there is a change in the scope rendering hours already billed to the project redundant; the work is still a PCS cost to the project and therefore should be accounted for in the estimate. When questioned about this influencing factor, it was clear that this concept was either not fully understood or not considered by state DOTs. It was suggested by several interviewees that incorporating lost design effort into the PCS estimate was inappropriate because it indicates that the agency plans to waste valuable design time. The intent of this factor is to account for typical scope changes/refinements and human error that require reworking of the design. In the final analysis, the issue is moot since none of the case study agencies had a means of tracking lost design effort.

CONCLUSIONS

There are two types of estimates that need to be considered for PCS cost estimating: top-down and bottom-up estimates. The decision to use either of these estimates depends on the end user of the data and the scope definition at the time of the estimate. Figure 2 provides a framework for when to use the estimating methods and at what point in the project development timeline. The type of PCS cost estimating model is also dependent on the available information and project characteristics. The study showed the three factors that had the largest influence on PCS costs were:

- Complexity
- Construction cost
- Project type

If these factors can be identified early on in the project development process, they can be used to determine suitable past projects with similar qualities. These factors can also act as input variables for PCS cost estimating models.

CHAPTER 4— A NEURAL NETWORK APPROACH TO ESTIMATING PRECONSTRUCTION SERVICES COST

Hunter, K.D., D.D. Gransberg and H.D. Jeong, "A Neural Network Approach to Estimating Preconstruction Services Costs," *Journal of Construction Engineering and Management*, ASCE (Submitted April 2014) [Peer-reviewed archival journal]

ABSTRACT

The purpose of this paper is to propose and demonstrate the use of an artificial neural network (NN) in preconstruction services (PCS) cost estimating. PCS cost estimating is becoming more relevant due to the uncertainty in funding for state DOTs as well as the impact of the loss of staff DOTs reducing the experience of the cost estimating staff. A NN model is a computer model that can be trained and change its behavior bases on previous experience. A simple model was developed using a commercial spreadsheet and its internal solver function. The NN model produces a top-down PCS estimate with a weighted error below 2% over the 13 projects. The paper also looks at Iowa DOT's project classification system to determine a suitable way of grouping like projects.

INTRODUCTION

This paper discusses the benefits of using an artificial neural network model to estimate preconstruction services (PCS) costs. Due to recent funding limitations within DOTs, there has been increased pressure to improve cost estimates as a means to more accurately allocate project funding. A study by Government Accountability Office (GAO) reported that "of the 50 departments that completed GAO's survey, 38 indicated that they have experienced constant or declining staffing levels over the past 5 years" (GAO 2008). This has caused an increase in work that is contracted out by an agency having a direct impact on their budget and the ability to estimate these affects is vital.

A poor PCS cost estimate can result in two impacts. Firstly, over estimating PCS costs for a project can lead to inefficient use of program funds and in the case of Federal-aid project, unused funds may be lost to the given DOT as they are redistributed to other states (Hollar 2012). Next, if a project's PSC costs are underestimated, there is insufficient funding to properly complete all PCS activities potentially leading to lower quality construction documents and subsequent construction cost growth (Gransberg et al. 2007).

The purpose of a larger study in which the work described in this paper will be included is to evaluate using multiple PCS cost estimating models in order to select the most appropriate model(s), which will reliably estimate the preconstruction service costs. The three models covered in that research project are briefly explained in this section:

- *Multiple Regression:* A statistical technique that permits the determination of a relationship between a dependent variable, also known as response or outcome variable, and multiple independent variables, which are also usually referred as predictor, explanatory, or regressor variables (Allison 1999). Multiple regression or least squares multiple linear regression, is commonly used by researchers to generate optimal predictions by the combination of multiple variables obtained from historical data or recorded observations (Allison 1999; Ott and Longnecker 2010). By using this method the analyst is able to obtain a quantitative equation that allows DOTs to estimate project PCS cost (dependent variable) based on the characteristics of the projects and others known factors (independent variables).
- *Decision Trees:* This approach is commonly used in industry and research to make decisions that involve a high level of uncertainty (Chelst and Canbolat 2012). These are flowcharts or tree-like graphs that represent algorithms that lead to different outcomes. Decision trees are drawn with a root node at the top by taking all the data and splitting it into branches or decision nodes. This process continues until it reaches a bottom node, or leaf node, based on the values of the independent variables. Thus, in this study, each node in the graph will represent a test on the variable and each branch will represent a possible outcome to this test. The path that determines PCS will depend on the value of the variables for each project and the uncertainty incorporated in the branches of the flowchart, which will be measured from the collected data.
- *Neural Networks*: A neural network is a learning system which has the ability to generalize and learn from data by modeling the neural connections in human brains. Typically a neural network consists of input layer, hidden layer and output layer where different inputs are incorporated by these inputs which are combined to result in single output value through nodes or neurons. Each of these units are then assigned a weight to make its connection through its nodes based on a training process. This method is capable

of modeling non-linear relationships among variables with high accuracy, however it is difficult to determine the internal weights distributed within the network. Berry and Linoff (1997) define neural network as a powerful, general purpose tool readily applied to prediction, classification, and clustering which are sometimes best approached as 'black boxes' with mysterious internal workings.

This content of this paper is confined to reporting the results of the evaluation of artificial neural networks (NN) when applied to PCS cost estimating. It also seeks to identify a project classification system that can separate projects to improve the estimate accuracy when using historic data.

The paper will use a data mining approach that consists of six major functions:

1. identifying the problem to solve,
2. determining the data source,
3. preparing the data,
4. building and training a model,
5. validating the model and
6. implementing the model.

The process to develop a model is the same regardless of the research instrument and the project classification. Figure 6 illustrates the process. Note that identifying potential variables and preparing the data must be separately conducted for each model as each type of project can have different correlation / weight with different types of variables.

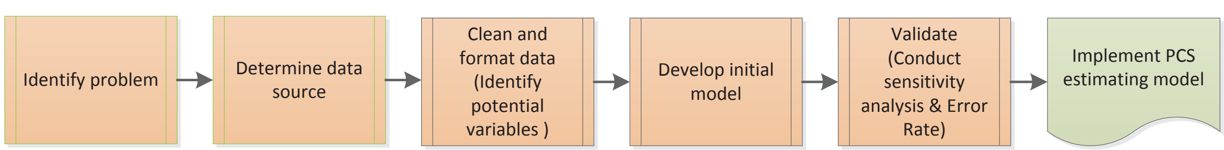

Figure 6: Basic Steps to Develop a PCS Estimating Model

BACKGROUND

Artificial Neural Network

Artificial neural networks (NN) are a mode of computing that "seeks to include the style of computing of the brain" (Aleksander and Morton 1990). In 1992 Moselhi et al. investigated the potential applications of neural networks in construction due to the benefits that they do not just describe behaviors like other artificial intelligence (AI) systems but they mimic them. They are modeled on the adaptable nodes in the human brain and can be trained as through changes in the function of the node by being exposed to examples (Aleksander and Morton 1990). Figure 7 shows a map of a simple artificial NN. There are three types of nodes input nodes, hidden nodes and output nodes the number of each vary depending on the model. The nodes are connected together by weights and along with the transfer function they are used to pass the activation value from node to node (Sayad 2012). The model can be trained by continuously updating the weights until the output is within tolerable limits (Hegazy 1998). Each line in Figure 7 performs a simple sum of the inputs by weight value. A bias node with a value of 1.0 is also added to the input and hidden nodes to facilitate network processing (Hegazy 1998).

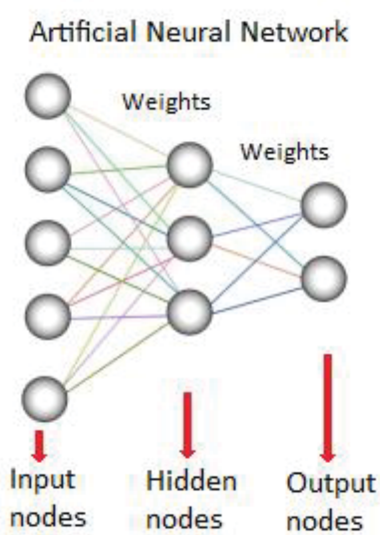

Figure 7: Artificial neural network (Sayad 2012)

One of the trends found in a screening survey completed by 18 state DOTs was that there is an abundance of PCS cost data that currently exists within a typical agency, but DOTs lack reliable tools to organize and convert the data into actionable information. This trend was later confirmed by the agency and case study interviews. In all cases, agency engineers were required to bill their time to specific projects, making the information available within the agency financial accounting system. On some occasions, staff did not think that the hours billed were completely accurate. The Oklahoma DOT responded that approximately 50% of their time was billed to departmental overhead instead of to a specific job. This ‘noise’ in the data is to be expected when working in this environment. When using historical estimating data, it is important to recognize that the noise is there and to try to understand the limitations created by the noise as well as how it may affect the outcome of the estimate. In agencies with a high level of noise, a top-down approach would work better than a bottom-up estimate because of the lack of precise historic labor hour information (Larson and Gray 2011). Employing a NN system that can be trained means DOTs will no longer be as reliant on professional judgment for PCS cost estimating because the trends in PCS costs will be institutionalized in the NN. This capability will become more critical if the recent trend showing DOTs are downsizing continues (GAO 2008). A NN-based PCS cost estimating system is a knowledge management tool that transfers the process to new personnel increasing estimate consistency as DOTs lose experienced mid-career staff to the private sector.

A NN model is a top-down estimating model and provides an overall estimate for PCS cost but no details as to how the output was generated. That's why these NNs are often referred to as "black box" systems. As shown in Figure 5 this system would work best at the very early stages of the project development process as the Model 1 estimating system. It could also be used alongside a bottom-up estimate shown in Model 2. The NN can be used as the back check of the Model 3 direct estimate based on the project work break down structure (WBS).

Highway Project Classification

One of the challenges encountered in developing a PCS cost estimating model is classifying highway projects into categories and identifying what is a typical DOT project. Each DOT has their own set of technical jargon that accompanies their various data collection, cost estimating systems and project development processes. In some of the case studies, use of different terminology was found between elements within an agency. Project classification is key to improving the accuracy of the NN model. Although the model can be trained, it utilizes past project data to train it. This means that the estimate is based on previous projects in the database, and therefore, the estimate is only valid for projects within the same range. In other words, estimating the PCS cost for a new interstate interchange project with a model that is built from resurfacing project data would not provide a valid estimate.

As shown in Figure 6, steps 1 and 2 identify the problem and determine the data source has been completed. The problem is estimating PCS costs, and the data being used for this paper is the project data provided collected from the case study projects. The four remaining steps to developing a PCS cost estimating model are as follows:

1. Identify potential independent variables based on the availability of data in DOT records, clean and prepare the data by applying appropriate methods for reliable model development
2. Develop an initial model by using the potential variables and employing the research tools
3. Validate the developed models using internal validation (by partitioning data into training and validation data set and conducting sensitivity analysis)
4. Implement the validated models into new projects based on variables with significant impact on preconstruction service costs.

Prior to implementation, of any model it must be validated by comparing the outcomes with actual collected data and evaluated by comparing its performance with other existing PCS estimating methods.

Cleaning Data

This paper explores the project classification system used by the Iowa DOT as a guide for differentiating between project types. Before a cost estimating system can be set up, the data needs to be sorted and cleaned to ensure that the results are as accurate as possible. In this situation, the old adage "garbage in equals garbage out" applies. The data needs to be sorted into categories to avoid misuse of the model.

The data categories provide a basis for the number of models that need to be developed to satisfy the estimating requirements for each category. Iowa DOT utilizes the following two types of classification systems;

1. geometry based classification
2. project complexity classification.

Geometry based classification categorizes projects into four classes;

1. point-based,
2. line-based,
3. polygon-based or multi-line projects and

4. special projects

For the purpose of data collection, special projects are be integrated with geographical information system interfaces. Figure 8 shows the project classification for the geometry based system.

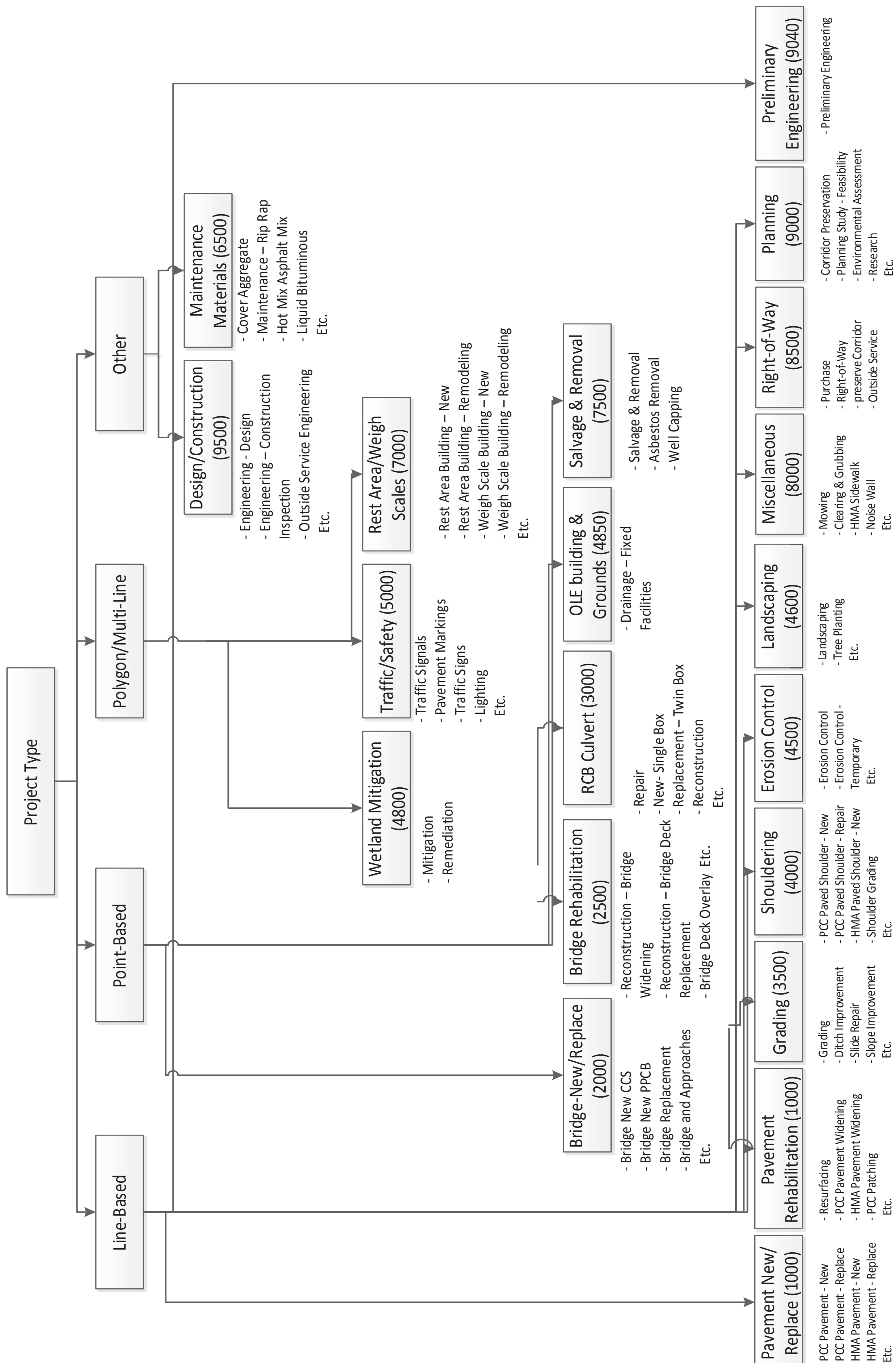

Figure 8: Geometry-Based Project Classification

The second classification categorizes projects into Type I, II and III projects in a decreasing order of complexity where Type I projects require major changes such as new construction, bridge replacement, relocation etc., Type III projects are repair, replacement or operational improvement type projects. The complexity classification is determined from five criteria:

1. location,
2. grade,
3. lanes,
4. ROW,
5. Public access and private access.

For instance, Type I projects are complex projects such as interstate projects that consist of interchanges and roads that features new alignment with complete new grade lines and may incorporate addition of new lanes and acquisition of substantial right of way. Table 13 shows these classifications along with applicable project groups and corresponding work types.

The complexity based project classification system is more adaptable to the data available from other DOTs. Project complexity was also found to be one of three most influential characteristic on the PCS cost estimate. Determining projects into groups by their complexity rating can minimize the error this factor could introduce. Another defining factor that could be used is National Environmental Policy Act (NEPA) classification systems. Each project must be assessed to determine whether it is a categorical exclusion (CE), environmental assessment (EA) or an environmental impact statement (EIS). These ratings are usually related to project complexity and there are specific guidelines on how to determine the classification of each project whereas project complexity classification is more subjective.

From the project influence analysis discussed in Chapter 3, NEPA classification was in the top tier when considering the overall agency program. However, when rated on an individual project basis, it was relegated to Tier 3 (little to no influence). This is likely because 13 out of 16 projects collected in this study were categorical exclusions (lowest level of documentation required); therefore the NEPA classification had little effect on the PCS cost estimate for these projects.

Table 13: Project Classification Based on Complexity (Iowa DOT, 2012)

Project Type	Criteria	Description	Applicable Project Groups	Corresponding Work Types
Type I Major Change	Location	New alignment or relocation along major portion of highway section	- New Construction - Relocation - Bridge Replacement (Major Crossing)	- Grading - Pavement: New/Replace - Right of Way - Bridge: New/Replace
	Grade	Complete new grade lines, or very small segments of existing grade line		
	Lanes	2-lanes, change from 2-lanes to multi-lane (divided/undivided) or ROW acquitted for multi-lane construction		
	ROW	Substantial right of way (ROW) acquisition		
	Public Access	Restricted to interchange locations or limited at-grade connections for freeway or expressway system or minor or no adjustment		
	Private Access	Restricted to use of frontage roads or points of public access for freeway or expressway system or changes with limitations on number & location in areas of ROW acquisition		
Type II Minor Change	Location	Use existing grade location	- Reconstruction - Rehabilitation - Restoration - Bridge Replacement - Intersection Improvement	- Grading - Pavement Rehabilitation - Right of Way - Bridge: New/Replace - Pavement: New/Replace - Traffic/Safety
	Grade	Use existing grade lines		
	Lanes	Remains the same in number but will normally be widened		
	ROW	Usually requires some additional right of way		
	Public Access	Remains the same or involves minor adjust		
	Private Access	Could involve changes with limitations on number & location in areas of ROW acquisition, but not frontage roads		
Type III Repair, replacement or Operational Improvement	Location	No change	- Rehabilitation - Restoration - Maintenance - Bridge Replacement - Bridge Repair - Bridge Rehabilitation - Safety Improvement	- Pavement Rehabilitation - Bridge Rehabilitation - Right of Way - Bridge: New/Replace - RCB Culvert - Traffic/Safety - Shouldering
	Grade	No change requiring ROW, excepted in isolated circumstances		
	Lanes	No change, width may change and turning lanes may be added		
	ROW	No additional ROW required except at isolated locations		
	Public Access	Remains the same		
	Private Access	Remains the same		

METHODOLOGY

Figure 9 show the methodology adopted to develop the PCS cost estimate.

Figure 9: Research Methodology

The methodology for the interviews and case studies has been described in chapter 2 of this thesis. Chapter 3 describes in detail how the researchers developed the NN model input variables. Tables 3-8 in chapter 2 show the data collected for individual projects that are used in this study.

Project Influence Factors

Input variables were tested for significance, and the results are presented in Chapter 3. The results of the influence analysis broke the factors down into 3 tiers as shown in Table 14. All the factors investigated became input variables for the neural network.

Table 14: Project Influence Factors ranked based on mean response values from 16 Projects

INFLUENCE FACTOR	MEAN RESPONSE
Tier 1 [2.42-2.75]	
1. Complexity	2.75
2. Project type	2.56
3. Construction cost	2.42
Tier 2 [1.92-2.07]	
4. Number of bridges	2.07
5. Length of project	2.06
6. Highway classification	1.94
7. Number of subconsultants	1.93
8. Number of plan sheets	1.92
Tier 3 [1.62-1.81]	
9. NEPA	1.81
10. Number of lanes	1.63

A simple NN was created to estimate preconstruction services cost for highway projects. The NN was created following the methodology proposed by Hegazy et al. (1998). A data solver add-in for a spreadsheet was used to train the model with the appropriate weight matrices. A brief summary of the model is provided in Figure 10, for the procedure duplicated the full methodology found in the paper “Neural Network Model for Parametric Cost Estimation of Highway Projects” (Hegazy et al. 1998). A step by step summary of the methodology on how to set up a NN model in a spreadsheet is shown in Figure 11.

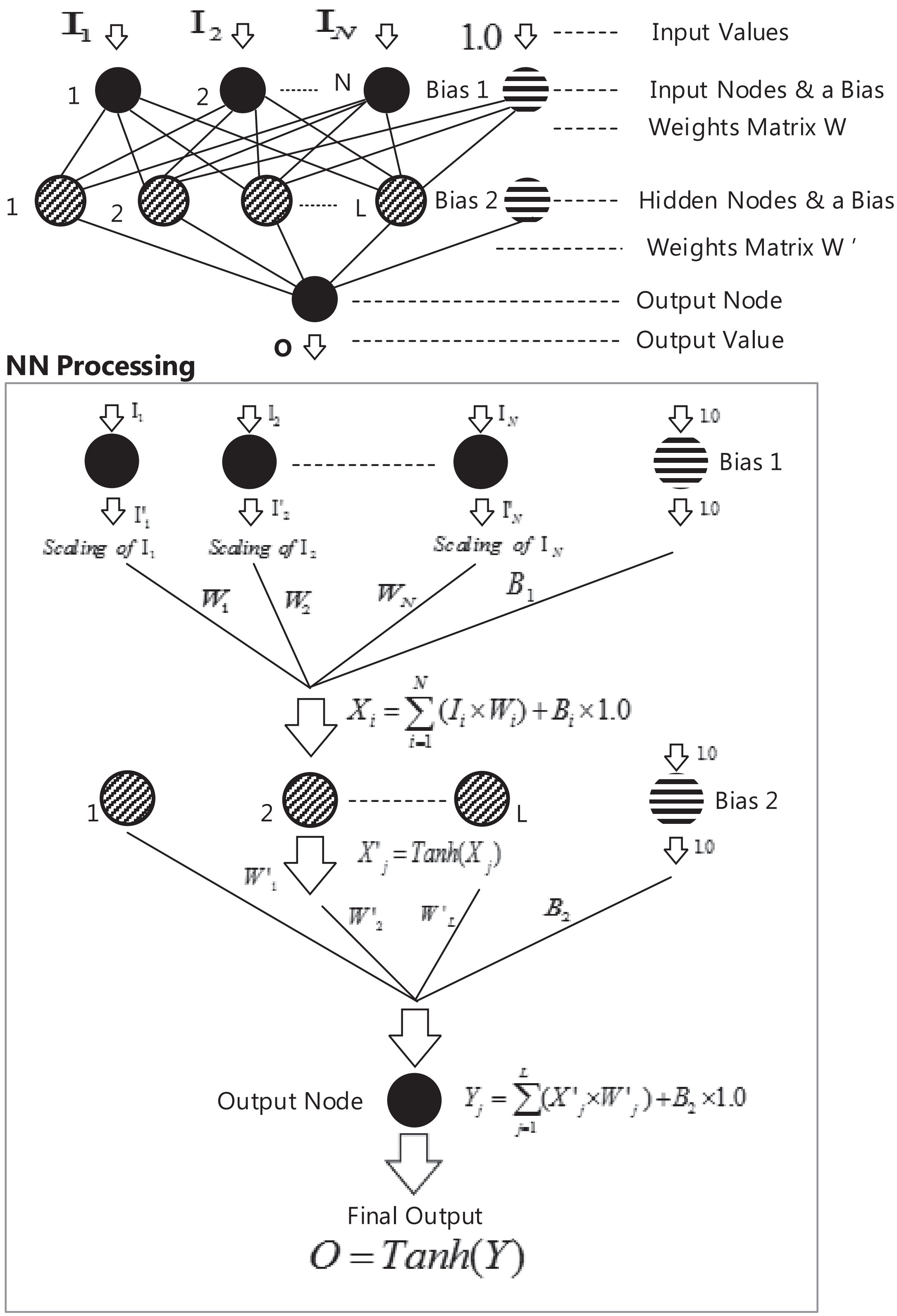

Figure 10: Schematic Diagram of NN (adapted from Hegazy 1998)

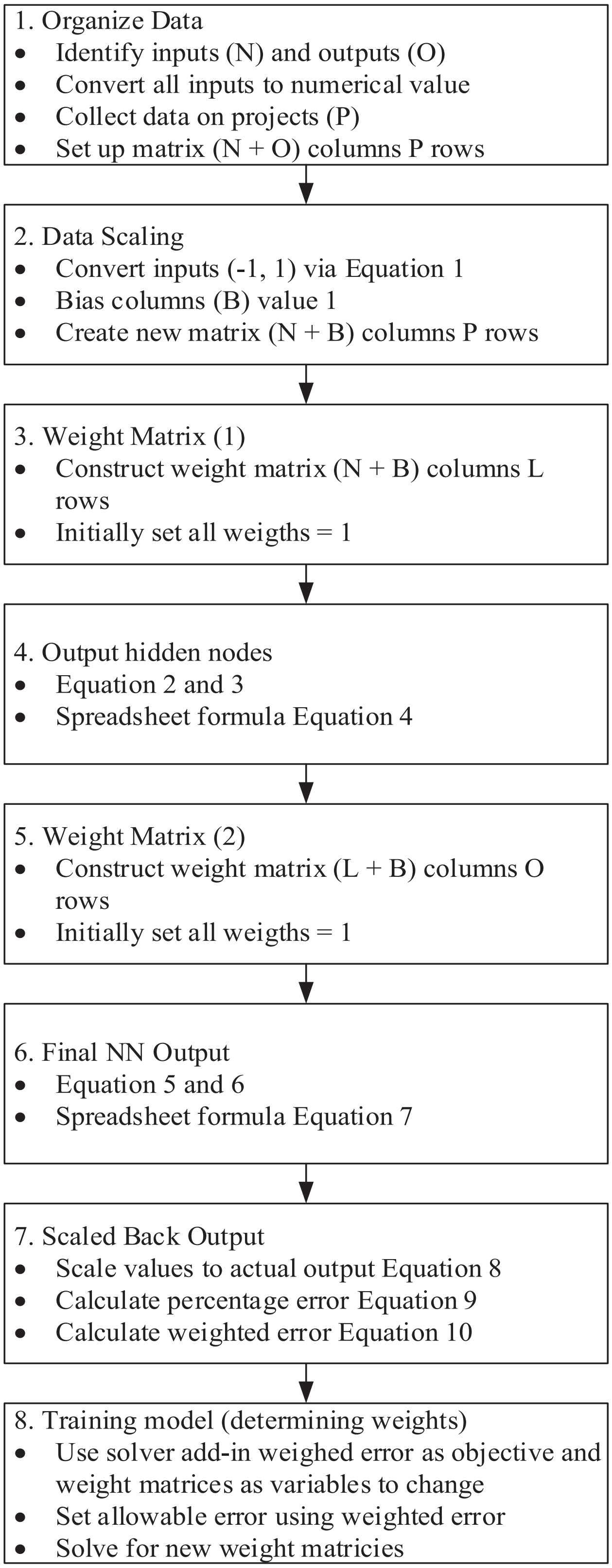

Figure 11: Methodology for building a NN in a spreadsheet

$$Scaled\ Value = \frac{2 \times (unscaled\ value - minimum\ value)}{(maximum\ value - minimum\ value)} - 1 \qquad \text{Equation 1}$$

$$X_j = \sum_{i=1}^{N} (l_i \times W_{ij}) + B_{1j} \times 1 \qquad \text{Equation 2}$$

$$X_j' = \tanh(X_j) \qquad \text{Equation 3}$$

$$L_1 = TANH(SUMPRODUCT(I_1{:}\,I_N + B_1, W_1{:}\,W_{N+1}) \qquad \text{Equation 4}$$

$$Y = \sum_{j=1}^{L} (X_j' \times W_{ij}') + B_2 \times 1 \qquad \text{Equation 5}$$

$$Output(O) = \tanh(Y) \qquad \text{Equation 6}$$

$$O = TANH(SUMPRODUCT(L_1{:}\,L_L + B_2, W'_1{:}\,W'_{L+1}) \qquad \text{Equation 7}$$

$$Estimate = \frac{(O + 1)(maximum\ output - minimum\ output)}{2} \qquad \text{Equation 8}$$

$$Error = \frac{(O - actual\ output)}{actual\ output} \times 100 \qquad \text{Equation 9}$$

$$Weighted\ Error = 50\%(testing\ error) + 50\%(training\ error) \qquad \text{Equation 10}$$

In the model developed to estimate PCS cost there were ten input values (N=10) for each project, these values came from the influence factors shown in Table 14. The diagram show in Figure 7 shows a multiple output NN the model developed for here used a single output the PCS cost estimate (O=1). The number of hidden nodes is set to equal one half of the total input and output nodes (Hegazy et al. 1994). In the PCS cost estimating model there was five hidden nodes (L=5) All values must be in a numerical format the input values and their numerical assignments are listed below:

- I_1 = Project Cost
- I_2 = Project type (1= Major Structure, 2=Reconstruction, 3=Bridge rehabilitation, 4= Continuous flow intersection, 5=Rehabilitation, 6=Safety)
- I_3 = NEPA Classification (1 = Categorical exclusion, 2= Environmental Assessment, 3= Environmental Impact statement)
- I_4 = Project Complexity (scale 1(basic project) 3(standard project) 5(complex project))
- I_5 = Number of sub-consultants
- I_6 = Number of lanes

- I_7 = Number of plan sheets
- I_8 = Number of Bridges
- I_9 = Highway Classification (1=principal arterial, 2= urban arterial, 3= rural major collector, 4=rural principal arterial, 5=interstate)
- I_{10} = project length (miles)

Due to the limited number of project case studies available in this study, the model was trained with 10 projects then tested with the remaining 3. There was not actual PCS cost data for Oklahoma DOT projects, therefore these were not used in the model. It is important to continually add data to the system and update the weights as more data becomes available. This will continually improve the model and train it to provide better estimates as more data is added to the database.

RESULTS

The key to a NN is training the model, which adjusts the weight matrices to produce estimates within the allowable error. The effectiveness of the model is measured by the weighted error shown in Equation 10.

Initially the values of the 5 by 11 and 1 by 6 weight matrices were set to 1. Table 15 shows the output results of this analysis. The weighted error is 99.57 %, which exceeds the acceptable limit. After the solver simulation was completed, the model is trained as described in step 8 Figure 11 using the weighted error as the objective cell to minimize its value. Constraints were set on the error values. The maximum error for the 10 training projects was set at 2% and the maximum error for the testing cells was set at 3%. The simulation was run and new weight values were created. The final PCS cost estimates shown in Table 15 were all within the previously mentioned constraints and the weighted error was reduced to 1.4%.

Table 15: Results of NN analysis

	Before Training		After Training	
Actual PCS Cost	Estimate	Error	Estimate	Error
$ 2,200,000.00	$ 18,950.23	99.14%	$ 2,156,000.00	2.00%
$ 800,000.00	$ 18,917.15	97.64%	$ 784,000.00	2.00%
$ 326,984.74	$ 19,283.07	94.10%	$ 320,445.05	2.00%
$ 1,350,022.32	$ 18,902.44	98.60%	$ 1,323,021.88	2.00%
$ 747,932.55	$ 18,971.17	97.46%	$ 732,973.90	2.00%
$ 523,441.08	$ 18,917.35	96.39%	$ 512,972.26	2.00%
$ 221,626.30	$ 18,890.64	91.48%	$ 226,058.83	2.00%
$ 277,253.92	$ 18,888.98	93.19%	$ 282,799.00	2.00%
$ 3,704,380.09	$ 3,704,355.83	0.00%	$ 3,703,639.06	0.02%
$ 17,634.00	$ 18,871.44	7.02%	$ 17,986.68	2.00%
$ 1,510,000.00	$ 83,511.06	94.47%	$ 1,509,993.91	0.00%
$ 1,280,000.00	$ 94,265.66	92.64%	$ 1,318,400.00	3.00%
$ 1,333,346.08	$ 3,704,356.45	177.82%	$ 1,333,352.90	0.00%

	Before Training	After Training
Average Training error	77.50%	1.80%
Average Testing error	121.64%	1.00%
Weighted Error	99.57%	1.40%

Table 15 shows the analysis output in both dollar values and as a percentage of error from actual PCS costs for each project. As future projects are completed within an agency, they should be added to the database and used as further training projects to maintain current PCS cost estimates. There needs to be a constant feedback loop and continual adjustment of weight values to avoid inflation or cost differences affecting the final estimate.

The input variables that were used in the model are not fixed and. they should be altered to fit the individual agency data and processes. To implement this method an agency should determine its input variables by completing an influence analysis of project PCS costs as described in Chapter 3 (Table 14). Input parameters should also be regularly assessed to ensure they are still relevant to PCS cost estimate. For example, NYSDOT suggested they are moving away from using plan sheets to fully electronic construction documents. Thus, plan sheets will no longer be a suitable parameter for use in the future. Another example is found in the Rhode Island DOT where PCS costs vary whether a project is bordering the sea, bordering a fresh water body, or not near water at all, making an input factor related to its geographical location logical for that agency's PCS cost model.

CONCLUSIONS

Hegazy (1998) provides a detailed methodology to create a simple NN model that can be built in a spreadsheet and this paper has demonstrated the application Hegazy's methodology to produce a PCS cost estimate. After training the NN model, the between predicted and actual project PCS cost was reduced from 99.6% to 1.4%. This leads to the conclusion that NNs are well suited for use in PCS cost estimating as they can be trained and easily adjusted as new data becomes available.

Iowa DOTs project classification process was also investigated and found to provide a comprehensive three level classification system to define a project based on its complexity. Project complexity was shown in Chapter 3 to have a major influence on the PCS cost estimate. Therefore it is concluded that projects can be classified using the Iowa DOT classification system.

Finally it is recommended that each project complexity type should have its own NN-based PCS cost estimating model compiled of like projects to improve estimate accuracy. As with all models that require historic data the model is only valid within the parameters in which it was created and must be continually revised and updated to ensure the output remains current.

CHAPTER 5 – RATIONAL METHOD TO DETERMINE A DESIGN COST CONTINGENCY FOR CONSULTANT DESIGNED HIGHWAY CONSTRUCTION PROJECTS

Hunter, K.D. and D.D. Gransberg, "Comparative Analysis of Two Models for Estimating Highway Project Design Costs," *2014 Transportation Research Board*, Paper 14-3967, National Academies, January 2014, pp. 1-18.
[Peer-reviewed full-paper proceedings article]

ABSTRACT

The purpose of this paper is to propose a rational method for determining a design cost contingency. The contingency in design is to account for risks such as scope creep and lost design effort throughout the process. In design of transportation projects, the required function of a project is usually well-defined but the amount of time required needed to complete the design are difficult to quantify. The proposed method to calculate design contingency can be used by an agency to augment its current method to estimate consultant design fees. This paper details a method for creating a design cost estimate accuracy index from historical budgeted and actual design fee data. The index can be used on future projects to determine an appropriate design contingency. The paper demonstrates the validity of the proposed method by example comparing the data from 26 actual projects from 9 different agencies with published design fee curves from the American Society of Civil Engineers and the Institute of Professional Engineering New Zealand, using linear regression. Since coefficients of determination (R^2 values) exceeded 0.95, the paper concludes that the use of the design contingency will enhance the accuracy of design fee estimates.

INTRODUCTION

Design is defined by the Oxford English Dictionary as "a plan or drawing produced to show the look and function or workings of a building, garment, or other object before it is made" (Oxford 2013). It is difficult to set a dollar value to the creativity, foresight and technical skill that are required to solve a given engineering problem because design is the creation of intellectual rather than physical property (Sturts et al 2005). This is issue has long plagued engineers and their clients. The traditional remedy in construction estimating is to include a contingency, which by definition is "a provision for an unforeseen event or circumstance" (Oxford 2013). The objective of the research is to develop a method to determine an appropriate contingency for highway construction project design fee estimate being designed by external design consultants. The proposed approach assumes that an agency will already have its own unique method for estimating consultant design fees as well as data for budgeted and actual design fees from past projects. It then relies on the historic data to develop an index that measures the accuracy of past estimates and establish a logical means to calculate a contingency for a given project based on a fee that is a function of the ratio of the design cost to the budgeted construction cost.

Design costs occur in the preconstruction services phase of a project and are not always accurately recorded in the public sector making it more difficult to form an estimate without past data and experience available. As design costs are usually a small portion of the total project cost, conventional wisdom holds that it is unnecessary to conduct a detailed design cost estimate that accounts for all the uncertainty (Brown 2002). An inaccurate design cost estimate in the Preconstruction Services (PCS) phase typically does not directly affect the total project cost as much as an inaccurate estimate of the construction cost of the project. The design fee contingency tends to be a small percentage of the total project costs, making its value seem inconsequential. However if the design estimate requires 40,000 hours 5% of this is 2,000 hours, this extra time available for design could drastically change the project outcomes. Recent research has shown that failing to adequately fund the design phase can result in increased construction cost growth (Gransberg et al 2007). The cost growth can be attributed to designers cutting corners to get the design finished in the time allocated and supplying incomplete construction documents. If designers know there is extra time available for design this will be used to complete work to an appropriate standard without the risk of not getting paid. Accounting for uncertainty when a consultant design fee is established is every bit as important has accounting for uncertainty in estimating the construction cost. Additionally, having a direct estimate of the expected fee and a reliable contingency gives the agency a starting point for negotiations with consultants, and it will also allow them to more efficiently allocate funds throughout the program.

BACKGROUND

From the literature it can be seen that there are a wide variety of methods for estimating design costs for transportation projects. This variation stems from diversity in the states, their funding, policy, regulations and local preferences. As a result, any method for determining an appropriate design contingency based on past project experience must be able to be applied to a variety of estimating models to be of practical value. At the outset of design fee negotiations, a number of satisfactory design solutions to a given design problem exist, making it difficult to estimate the financial value of these services when the details of the end product are unknown. Struts et al. (Struts et al 2005) commented that "expertise, creativity, and quality are difficult to quantify," and therefore there is a large component of uncertainty in the design process. There must be provisions to address uncertainty to ensure the client gets the best product and can make alterations to the final scope of work as necessary.

Design Fee Impact on Construction Project Cost Performance

In highway projects, the design cost ranges from approximately 1.5% to 5% of the estimated construction cost (Struts et al 2005). The low overall value of design costs has in the past deterred Departments of Transportation's (DOT) from investing any more time than necessary to estimate the design cost and little if any, time to established necessary contingencies (Williams et al 2013). The upshot is that inaccurately estimated consultant design fees create an unintentional cap on the amount of design effort that can be expended on a given project (Carr et al 2005) and actually impact the quality of the construction documents (McSkimming et al 2005).

In traditional design-bid-build project delivery, poor design quality leads to increased construction cost because the project's owner warrants the quality of the construction documents. Any errors, omissions, and quantity inaccuracies discovered after award of the construction contract must be paid for by contract modifications, which usually increase the final cost of the project (Beemer 2005). More importantly, the design documents "literally define the level of required construction quality and as such, are extremely important to a transportation project's ultimate success" (Gransberg et al 2007). Research completed by Morgen (Morgen 1986) and Kirby et al (Kirby et al 1988) found that design deficiencies were the primary driver for construction contract changes and that "56% of all modifications are aimed at correcting design deficiencies." Another study by Burati et al (Burati et al 1992) found that changes resulting from design errors identified after construction contract award accounted for 79% of all change order costs and average 9.5% of the total project cost.

Carr and Beyor (Carr et al 2005) reported that design fees have lagged construction inflation for the past three decades. Underfunding project design contracts results in a conundrum where "the high-quality professional services rightfully expected by the public will become increasingly difficult [to attain] if the erosion in fees continues unabated into the future" (Carr et al 2005). Pricing pressure leads engineers to a point where they must provide the necessary level of design with diminishing resources, and may induce a bias toward minimizing design analyses and cross-checks to maintain project profitability, which would be seen in declining quality of construction documents. This issue is further exacerbated by the recent focus on accelerating project delivery in official programs like the Federal Highway Administration's Every Day Counts initiative (Mendez 2010). Janacek (Janacek 2006) sums up this issue succinctly when he states: "Don't try to squeeze that extra quarter point from their [design] fee. For every dollar you spend up front on design and planning you will save 10 to 20 fold down the line"

Estimating Design Fees

The 2012 update of ASCE Manual No. 45 states that there are five methods for charging for design services (ASCE 2012):

1. Multiplier: Salary cost times multiplier, plus direct nonsalary expense;
2. Hourly: Hourly billing rate, plus reimbursable expenses and a "not to exceed: amount for specific services;
3. Per diem: Fixed charge per day;
4. Cost plus, fixed fee ; and
5. Lump sum or fixed price.

The first four methods are variable cost methods as the price the client will pay varies depending on the actual amount of work (ASCE 2012). The fifth method, lump sum or fixed fee, is a single factor and is useful if there is a well-defined project scope. When an agency outsources design, there is commonly a defined, but general, scope of work. However, as the project is yet to be designed, that scope is conceptual and both the owner and the consultant must estimate the design effort to achieve the necessary functional requirements. By adding a contingency the need to request authorization for additional funds to complete the design process is avoided. Without a contingency, there exists a strong bias against requesting additional funding (Flyvbjerg et al 2002). If a contingency is not used during the design those funds can then be released.

Contingencies

When estimating project design cost, the scope is articulated in functional terms, but the design details are unknown. Nevertheless, current practice tends toward negotiating a lump sum design fee, which unintentionally implies a level of certainty that may not be dependable (Gransberg et al 2007, Williams et al 2013). Some agencies will only use variable cost methods to allow for the uncertainty; however it is important to have a known range for funding authorization. A design estimate is the expected value of design and a contingency can be included in the estimate to account for the higher end of the possible cost range for the project (Mak et al 2000). In public works, the project's contingency is effectively to account for the risks associated with both the design process and the construction project. However, in many cases, it is calculated as an arbitrary percentage. For example, the US Army Corps of Engineers requires a 5% contingency (US Army Corps of Engineers 197) and the Riverside County California DOT uses 10% (Riverside County 1999) to be added to project cost estimates before design commences.

Figure 12 shows the project development process, how the risk is allocated, and how the contingency can be retired as the project progresses and risks are realized. Most of the research conducted about contingencies pertains to construction cost contingencies; however an argument can be made that Figure 12 shows that the construction contingency is greater in the design stage where the unknowns are much greater and as such, a design contingency is warranted for the very same reason.

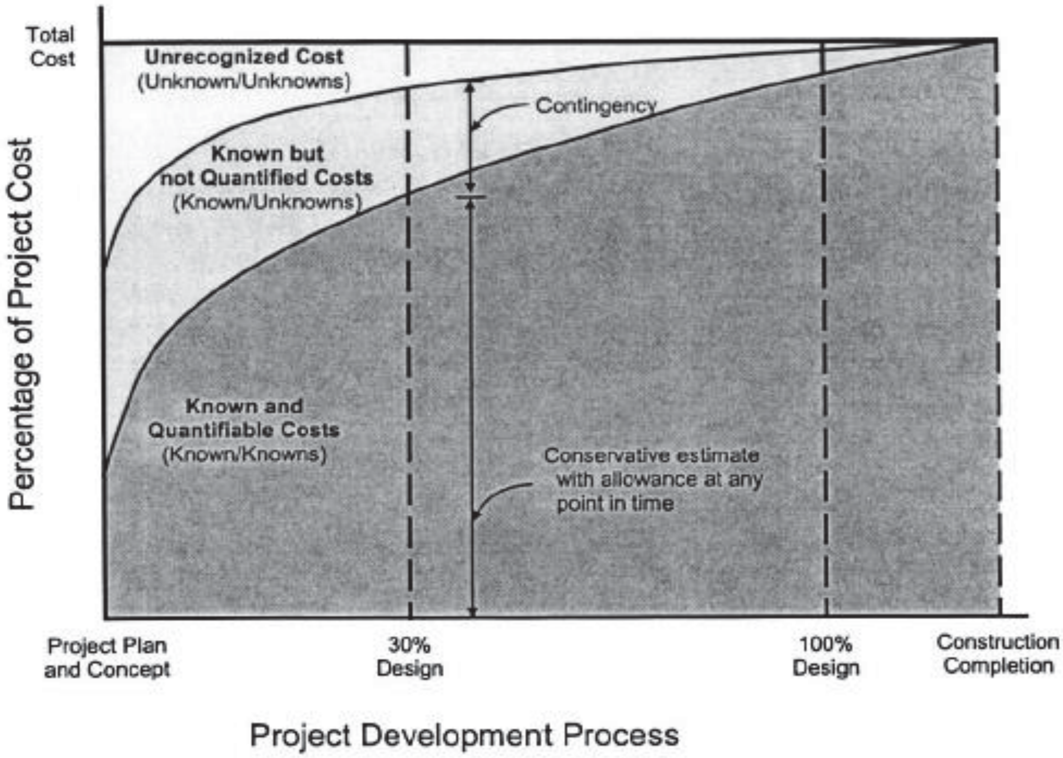

Figure 12: Conceptual components of a cost estimate (Molenaar et al. 2005)

Design Fee Estimating Approaches

Two approaches for estimating design cost have been identified in this study, an estimate of hours and an estimate producing a fee percentage of construction cost. Another method to estimate design fee is cost per plan sheet. This was not included in the analysis because this method is becoming obsolete. This is due to the development of technology that permits plans to be produced electronically making the correlation between number of plan sheets and design fee difficult to measure. New York State DOT developed a model using a commercial spreadsheet/database program to estimate the design hours for each project (Williams et al 2013). The model allows the DOT to either search similar projects or generate an estimate of total design hours to be expected for a project. The model was developed using a 12 "key" project characteristic chosen by the NYSDOT engineers as defining factors of a project, these were (Williams et al 2013):

1. Complexity
2. Project type
3. Number of sub-consultants

4. Construction cost
5. Number of lanes
6. Number of plan sheets
7. State Environmental Quality Review (SEQR) classification
8. National Environmental Policy Act (NEPA) classification
9. Predominant bridge type
10. Number of bridges
11. Highway classification
12. Length of project

These characteristics became the input factors in the model the number of plan sheets is used as the independent variable to calculate the total design hours. Hours are calculated from a simple regression model that is expected to become more accurate as more project data is made available (Williams et al 2013).

It has been suggested that using labor-hours as an estimating tool could cause a misrepresentation of the total work performed (Sturts et al 2005). Due to the advancement in available technology and computer aided design the labor-hours can be significantly reduced but the value of the design could be increased (Sturts et al 2005). This was also suggested by Carr and Beyor (2005) where they found that the design fees are not keeping up with the inflation of construction prices. Another study (Gransberg et al 2007) found that if the design fee of a project is too low, it can lead to major cost growth in the construction process due to incomplete construction documents. The issue of under-estimating the reasonable cost of the necessary design effort must be considered when using past project data to estimate direct hours and make adjustments if necessary.

Three regression models were considered by the researchers in this study one at a state level, American Council of Engineering Companies of Texas (TCEC); a national model American Society of Civil Engineers (ASCE) fee curve model; and an international model Institute of Professional Engineers New Zealand (IPENZ) design fee curve. The three alternatives furnish three different perspectives on the topic.

The American Council of Engineering Companies of Texas (TCEC) released a formula to estimate a fee for consultant design of a transport project. The formula uses a number of technical factors related to the project to determine the percentage of design fee estimate. Table 16 shows all the factors that are considered. The estimator must determine the appropriate value for each factor for each individual project. The formula is as shown in Equation 11 (TCEC 2005):

$$F = \frac{12\,(1 + C)}{0.1\,\left(\frac{P}{A}\right)} \qquad \text{Equation 11}$$

Where: F = Engineering fee as a percent of construction cost

C = Sum of fee factors (See Table 16)

A = Cost index factor = CCI current/CC11993

CCI = Engineering News Record construction cost index

CC11993 = 3484.85 (Dallas, Texas - March 1993)

P = Construction cost in millions of dollars

Table 16: TCEC Table of Technical Factors (TCEC 2005)

Technical Factors	**Factor Values**
1. Level of information required on plans/drawings	-0.20 to 0. 1 0
2. Project requirement a. scope of services b. rehab vs. grass roots project c. interface with other contracts/consultants d. numerous disciplines required e. alteration/modification of existing facility f. complexity of project	-0.20 to 0.33
3. Existing data, e.g. preliminary engineering report as-constructed drawings/specifications	-0.35 to 0.20
Owner Controlled Factors	**Factor Values**
1. Risk/liability (base standard of risk limited to fee)	-0.10 to 0.10
2. Time required for owner review/approvals (2 weeks standard)	0.0 to 0.20
3. Number of submittals/owner reviews	Add 0.05 for each submittal in addition to preliminary and final
4.Schedule for completing work - fast-track vs. reasonable schedule	0.0 to 0.20
5. Payment schedule - 30 days after receipt of invoice	0.01 for each late 30-day period
6. Owner requested subconsultant's	0.05 to 0.15 of the value of the subcontract
7. Owner participation in project/partnering	0.0 to 0.20
8. Construction inspection limiting participation of engineer	0.05 to 0.20
External Factors	**Factor Values**
1. Coordination with other entities	0.0 to 0.12
2. Environmental regulations	0.0 to 0.12
3. "Not-in-my-back-yard"/citizen's involvement	0.0 to 0.20
4. Governmental constraints	0.0 to 0.20

This estimate considers a variety of technical factors to either increase of decrease the estimated fee depending on project conditions. The table incorporates all 12 of the factors specified in ASCE Manual No.45 (ASCE 2012) of factors influencing project design cost. Unfortunately, the projects used in the analysis below did not contain sufficient detailed information to accurately analyze the data using this method. Therefore, only the ASCE and IPENZ models are included in the analysis.

The American Society of Civil Engineers (ASCE) published design fee curves in the 2002 edition of Manual 45. These curves displayed a range of design fees versus construction costs. In the 2012 edition of the manual it was noted that the fee curves were followed as absolute fee estimates, which was not ASCE's intention. As a result, the 2012 data did not contain the fee curves (ASCE 2012). Figure 13 shows the total fee percentage versus new construction cost this graph used the cost data from the 2012 edition of the Manual 45 and the line representing the fee curve has been added in by the researchers to mimic the curves in the 2002 edition. This curve was used to determine the percentage of construction cost that would be the design fee.

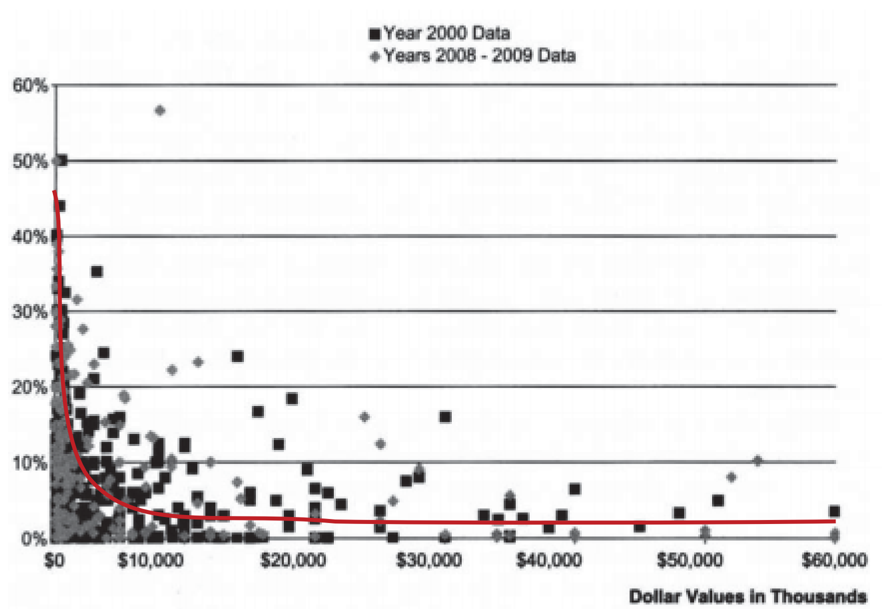

Figure 13: Total design fee percentage versus new construction cost (ASCE 2012)

The Institute of Professional Engineers New Zealand (IPENZ) and the Association of Consulting Engineers New Zealand (ACENZ) also developed a guideline for estimating consulting engineering services fees as a percentage of the estimated construction cost (IPENZ 2004). This is a common method for estimating design cost as the construction cost tends to be easier to quantify than design (Sturts et al 2005). The curves were developed using data from past projects and provide a “best practice” for estimating consultant fees however individual project interpretation is encouraged. It is noted in the guideline that the fee estimate includes project estimates, economic studies, alternative evaluations and schedule of quantities if the required services for a particular project is different an adaptation of the fee is required.

The method divides projects up into nine different types each type has a sub types to define the project. Figure 14 shows the fee guideline for the class of project in the analysis, the graph used by the researcher in this study. The graph relates the project complexity and degree of urbanization to the design effort required. From Figure 14 it can be seen that the there is a logarithmic relationship between the construction cost and design fee (IPENZ 2004). The costs are all recorded in New Zealand dollars however as the design cost is measured as a percentage the graphs were directly translated to US dollars. Due to the accuracy of the project data it was assumed all projects were state highway projects and all fees were calculated using Figure 14.

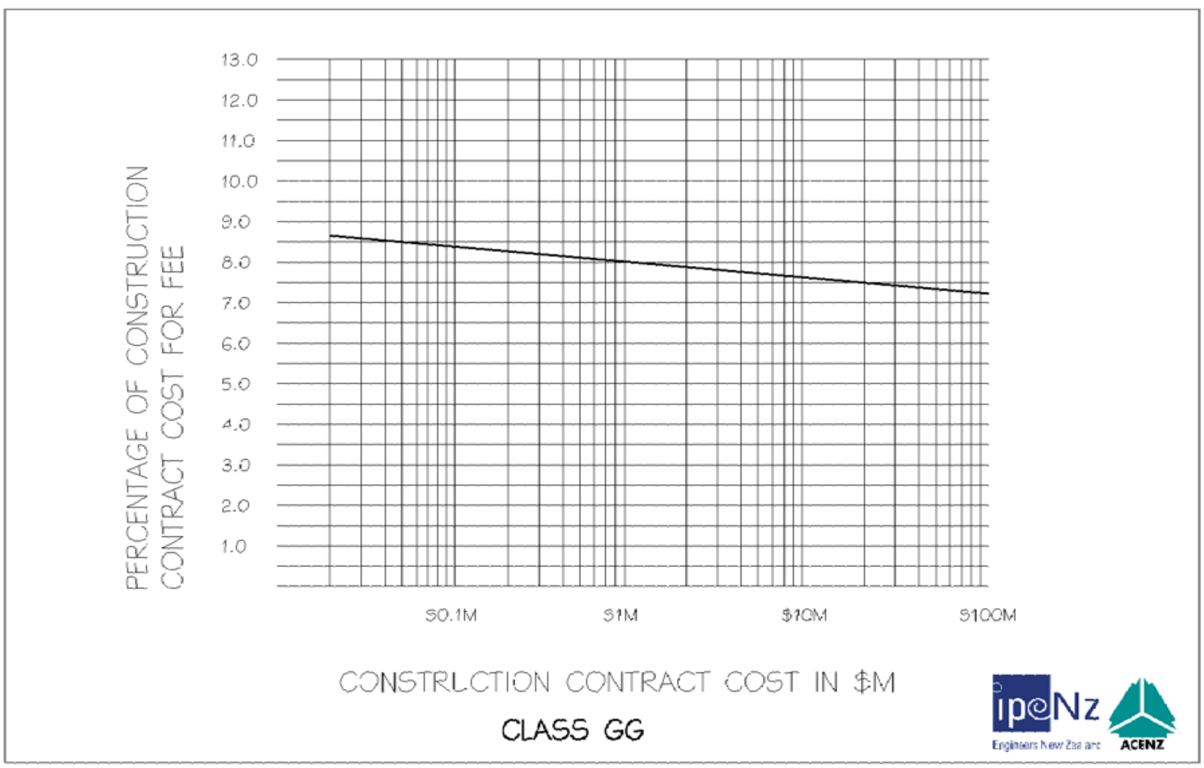

Figure 14: State Highway Road, Shape Correction, Pavement Rehabilitation, Bridge and Urban Bridge Fee Guideline (IPENZ 2004).

METHODOLOGY

The purpose of this research is to develop a method to determine an appropriate contingency when producing a design cost estimate using an individual agency's traditional estimating model. Initially, a database of past projects performed by consultant design was collected with cost data including budgeted design cost (cost at award) in both dollar value and percentage of budgeted construction cost. Table 17 is the database of projects used in the research it consists of 26 projects from 9 different DOTs and encompassed a variety of projects including roads, bridges, sound walls and intelligent transportation systems. For each project a complementary database was created using a cost estimating model that expresses design cost as a percentage of construction cost. Both the ASCE and IPENZ models were used. Figure 15 is a projection of the three datasets. The difference in the budgeted and estimated cost represents contingency required as it consists of the known unknowns shown in Figure 12.

Table 17: Database of projects used estimate

Agency	Budgeted Design Cost (in thousands)	Budgeted Construction Cost (in thousands)
Roads		
Colorado Department of Transportation	$ 1,800.00	$ 16,200.00
Colorado Department of Transportation	$ 2,320.00	$ 26,680.00
Florida Department of Transportation	$ 93.36	$ 1,073.64
Florida Department of Transportation	$ 375.00	$ 2,500.00
Florida Department of Transportation	$ 568.37	$ 4,598.66
Georgia Department of Transportation	$ 909.00	$ 27,400.00
Maryland Department of Transportation	$ 1,000.00	$ 17,635.00
Maryland Department of Transportation	$ 880.00	$ 8,059.00
Pennsylvania Department of Transportation	$ 350.00	$ 17,252.00
Pennsylvania Department of Transportation	$ 647.00	$ 9,825.70
Washington State Department of Transportation	$ 2,000.00	$ 15,000.00
New Jersey Department of Transportation	$ 1,300.00	$ 7,116.00
Pennsylvania Department of Transportation	$ 117.21	$ 7,117.00
Bridges		
Florida Department of Transportation	$ 129.53	$ 1,489.55
Delaware Department of Transportation	$ 147.00	$ 588.00
New Jersey Department of Transportation	$ 400.00	$ 2,400.00
New Jersey Department of Transportation	$ 360.00	$ 1,700.00
New Jersey Department of Transportation	$ 200.00	$ 2,900.00
Pennsylvania Department of Transportation	$ 150.00	$ 3,346.00
Pennsylvania Department of Transportation	$ 50.00	$ 3,429.00
Pennsylvania Department of Transportation	$ 27.00	$ 531.00
Florida Department of Transportation	$ 130.00	$ 1,142.47
Pennsylvania Department of Transportation	$ 350.00	$ 8,450.00
Other		
Florida Department of Transportation	$ 750.00	$ 6,500.00
Maryland Department of Transportation	$ 1,000.00	$ 17,586.00
North Carolina Department of Transportation	$ 3,200.00	$ 12,630.00

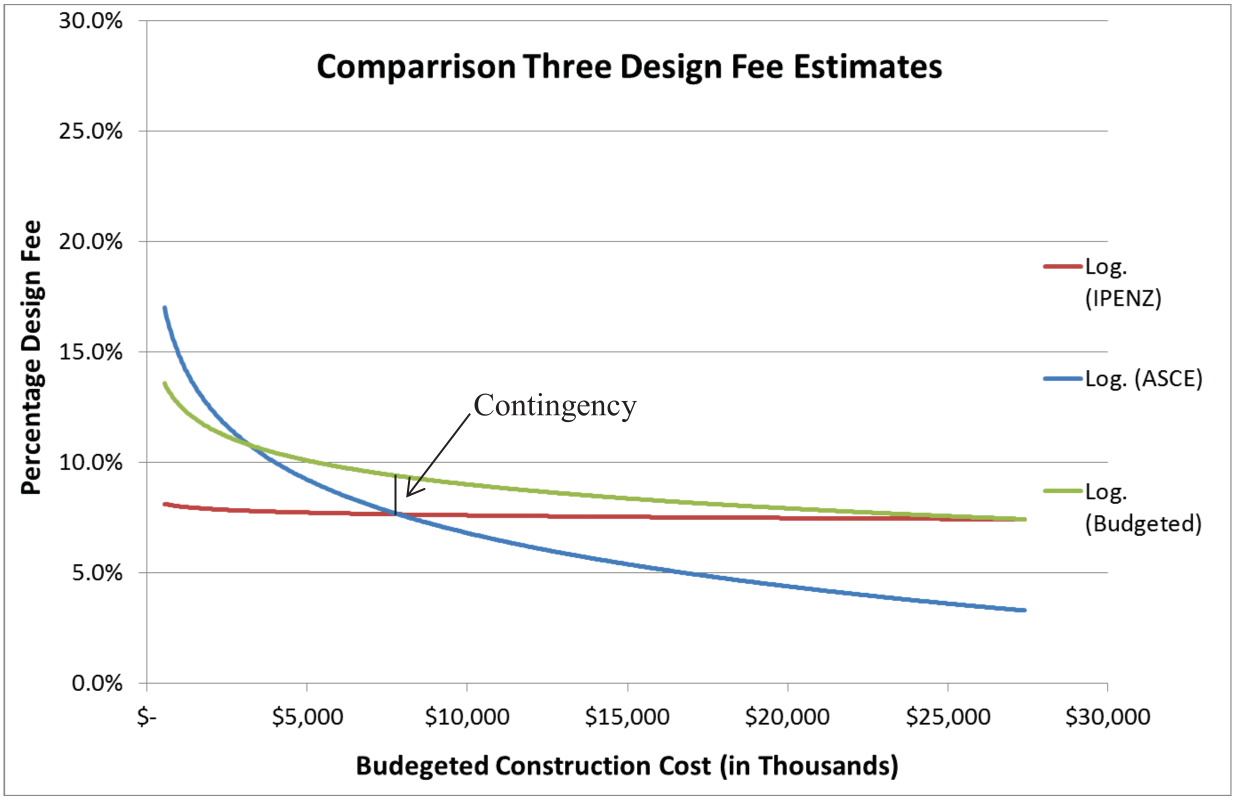

Figure 15: Comparison of three design fee estimates

Proposed Contingency Estimating Method

This method is intended to be used with a variety of design cost estimating models. The database is used to find the absolute difference of each of the estimated design cost for each project and the budgeted design cost (both as a percentage of budgeted construction cost) and divide by the budgeted design cost. This will become the design cost estimate accuracy index (DCEAI) shown in Equation 12.

$$DCEAI = \frac{|BDC\% - EDC\%|}{BDC\ (\$Millions)} \qquad \text{Equation 12}$$

DCEAI – Design cost estimate accuracy index

BDC% - Budgeted design cost as a percent of construction cost

EDC% - Estimated design cost as a percent of construction cost

BDC – Budgeted Design Cost ($Millions)

The DCEAI represents the percent per million dollars variation of the budgeted and the estimate. This is plotted on a scatter graph against the budgeted design cost and the best fit trendline with the highest coefficient of determination (R^2) for the data set is found. Figure 16 shows that for both the ASCE and IPENZ model a power equation was the best fit curve for both.

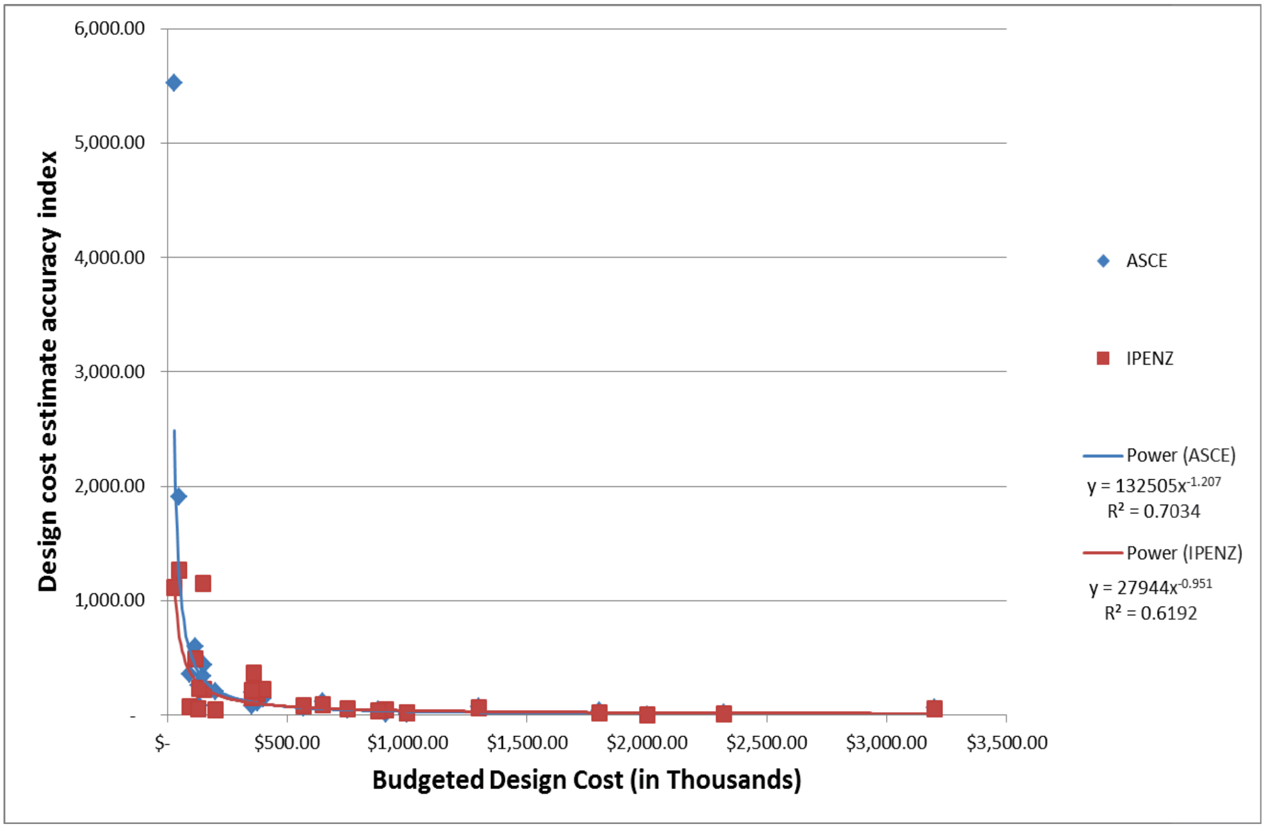

Figure 16: Design cost estimate accuracy index trend plot

For a given estimated construction cost both ASCE and IPENZ methods were used to determine a budgeted design cost percentage, which was converted to a budgeted construction cost. The equation of the trendline is used to determine the DCEAI for a project of any size with in the available data range. In the above example the data on included projects with a maximum budgeted design cost of \$3.25 million and a budgeted construction cost of \$27.5 million. The model is only validated within this cost range if more data was available the model could include a greater cost range.

For any given budgeted construction cost the estimated design cost is extrapolated from the design cost model. The equation from the graph in Figure 16 is used to determine the DCEAI for a given the estimated design cost.

$$DCEAI_{ASCE} = 132505 \times BDC^{-1.207}$$

$$DCEAI_{IPENZ} = 27944 \times BDC^{-0.951}$$

The DCEAI is multiplied by the budgeted design cost to generate the design contingency for the project. Figure 17 shows the design contingency for both the ASCE and IPENZ models it is noted that the models contingency are progressing in opposite directions, this represents the difference in accuracy of the two models are the project cost increases. Both models display a very strong logarithmic relationship as the R^2 values in each case is above 0.99 shows that the contingency amounts when added to the design fee from the ASCE and IPENZ curves almost exactly match the actual design costs. To insure that this result is not viewed to be more definitive that it is, the reader must keep in mind that the model is retroactive and would be expected to have a high correlation.

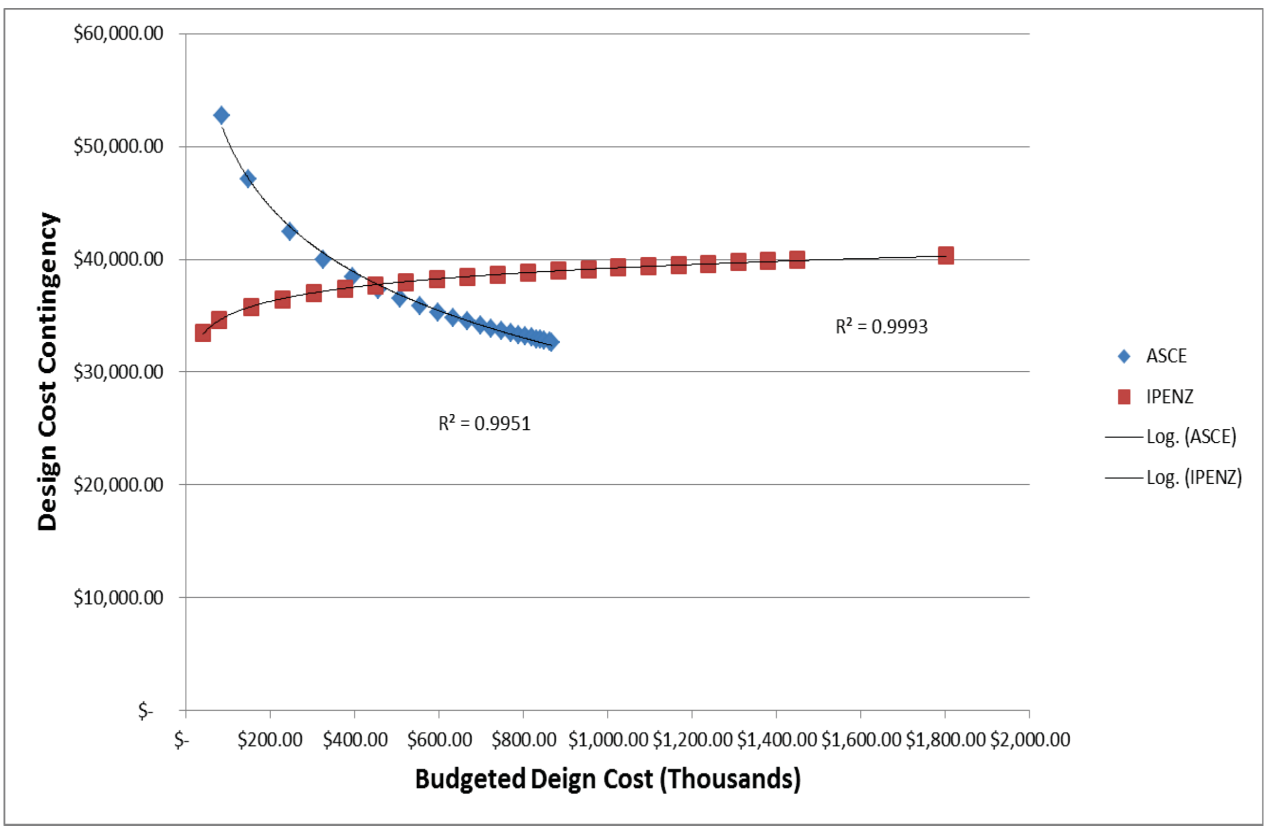

Figure 17: The results of the design contingencies for ASCE and IPENZ design fee curves

CONCLUSIONS

All good estimates have a contingency built in to account for the uncertainty of the tasks to be performed. The method provided in this study is meant to furnish a means to calculate the required construction contingency for design cost estimate as an alternative to choosing a random number or using an arbitrary percentage. An index that relates the variation in design estimate to budgeted design cost for projects to calculate a contingency design of future projects.

The model can only be used within ranges of the budgeted cost data used to develop it. As budgeted cost database increases the accuracy of curves and design cost estimate accuracy index is expected to increase improving the contingency estimate. The implementation of this method will also encourage DOTs to accurately record design cost data for projects into the future. In the example there was a strong correlation between the design cost estimate accuracy index and the budgeted design cost confirming that the method is acceptable and proving the relationship exists. In the future this method should be tested with a larger dataset over a wider range of project sizes. The model concluded that the contingency for the two estimating methods tested progressed inversely exposing the difference in the estimating methods. It is expected that agencies will apply the method using individual estimating techniques to determine the applicable contingency for each project. Agencies must remember that estimates need to be tailored to individual project and the demands of each contract and that the contingency is for unknown unknowns not for known activities.

CHAPTER 6—CONSOLIDATED CONCLUSIONS AND LIMITATIONS

CONCLUSIONS

There are two types of estimates that need to be considered for PCS cost estimating: top-down and bottom-up estimates. The decision to use either of these estimates depends on the end user of the data and the scope definition at the time of the estimate. Figure 2 provides a framework for when to use the estimating methods and at what point in the project development timeline. The type of PCS cost estimating model is also dependent on the available information and project characteristics. The study showed the three factors that had the largest influence on PCS costs were:

- Complexity
- Construction cost
- Project type

If these factors can be identified early on in the project development process, they can be used to determine suitable past projects with similar qualities. These factors can also act as input variables for PCS cost estimating models.

Hegazy (1998) provides a detailed methodology to create a simple NN model that can be built in a spreadsheet and this paper has demonstrated the application Hegazy's methodology to produce a PCS cost estimate. After training the NN model, the between predicted and actual project PCS cost was reduced from 99.6% to 1.4%. This leads to the conclusion that NNs are well suited for use in PCS cost estimating as they can be trained and easily adjusted as new data becomes available.

Iowa DOTs project classification process was also investigated and found to provide a comprehensive three level classification system to define a project based on its complexity. Project complexity was shown in Chapter 3 to have a major influence on the PCS cost estimate. Therefore it is concluded that projects can be classified using the Iowa DOT classification system.

Finally it is recommended that each project complexity type should have its own NN-based PCS cost estimating model compiled of like projects to improve estimate accuracy. As with all models that require historic data the model is only valid within the parameters in which it was created and must be continually revised and updated to ensure the output remains current.

All good estimates have a contingency built in to account for the uncertainty of the tasks to be performed. The method provided in this study is meant to furnish a means to calculate the required construction contingency for design cost estimate as an alternative to choosing an arbitrary number or percentage. An index that relates the variation in design estimate to budgeted design cost for projects to calculate a contingency design of future projects.

As budgeted cost database increases the accuracy of curves and design cost estimate accuracy index is expected to increase improving the contingency estimate. The implementation of this method will also encourage DOTs to accurately record design cost data for projects into the future. In the example there was a strong correlation between the design cost estimate accuracy index and the budgeted design cost confirming that the method is acceptable and proving the relationship exists. In the future this method should be tested with a larger dataset over a wider range of project sizes. The model concluded that the contingency for the two estimating methods tested progressed inversely exposing the difference in the estimating methods. It is expected that agencies will apply the method using individual estimating techniques to determine the applicable contingency for each project. Agencies must remember that estimates need to be tailored to individual project and the demands of each contract and that the contingency is for unknown unknowns not for known activities.

LIMITATIONS

For every research study, there are limitations. In Chapter 3, the limitations of the research were that the results of interviews with nine DOTs. As explained in the methodology the states were chosen to provide a variety it was observed that cost estimating practices vary greatly among DOTs and within each agency.

The limitations in Chapter 4 deal with the case studies themselves. In Chapter 4 there were 16 case study projects collected and used in the NN model. It must be stressed that the model is only valid within the data that it was built. This is why it has been suggested that projects are classified by their complexity and separate models are built for each type. It is also important that each DOT choses input factors that affect the PCS cost in their state.

Chapter 5 provided a methodology to estimate the design cost contingency for a project not a direct estimate. This methodology need to be applied to historic data and estimating systems of a specific agency to render it valid for use. The method can only be used to estimate the contingency within the range of historic data used to construct the model. The data used in this study was from nine agencies and provides only a demonstration of the method not actual results. The model can only be used within ranges of the budgeted cost data used to develop it.

CHAPTER 7—CONTRIBUTIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

CONTRIBUTIONS

Chapter 3 provided the base for this research because it synthesized the current practices in the industry and set up a framework for estimating PCS costs. Chapter 3 also determined the factors that are considered to have a major influence on PCS costs. These were complexity project type and construction cost. Previous research in highway cost estimating related predominantly to construction cost estimating with some about design cost estimating. This research presents the case for estimating PCS cost and Chapter 4 presents a method to do this using and artificial NN model, the first time NNs have been applied to PCS cost estimating. Chapter 5 proposed a method to estimate design cost contingency which to the author's best knowledge has never been addressed by any past research. The interviews in this project indicated that a design contingency was a very small part of the total project costs and therefore, it was considered trivial, which supplies the answer to why no previous research has been conducted on the topic. As described in Chapter 5, the concept that underfunding design merely creates a bias to poor quality construction documents which in turn have been proven by past research to be the root cause of construction cost growth.

RECOMMENDATIONS FOR FUTURE RESEARCH

Chapter 3 came up with 3 models for PCS cost estimates at different stages of the project development process. Further investigation into the models one and three shown in Figure 5 and how they all relate to each other is required.

This research provides a NN model that can be easily produced to estimate PCS costs. Future research could be conducted to access the validity of estimating methods such as multiple regression and decision tree analysis compared to NN. Further analysis could be done using a database of projects divided into complexity groups within one DOT to further validate the conclusions in chapter 4. It would also be useful for future research to investigate the effect of different association functions on the NN model.

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APPENDIX A—PROJECT DEVELOPMENT PROCESSES

The following 4 figures are project development processes from 4 different transportation agencies. The project development processors were synthesized to create a generalized project development process for the preconstruction services phase of a project.

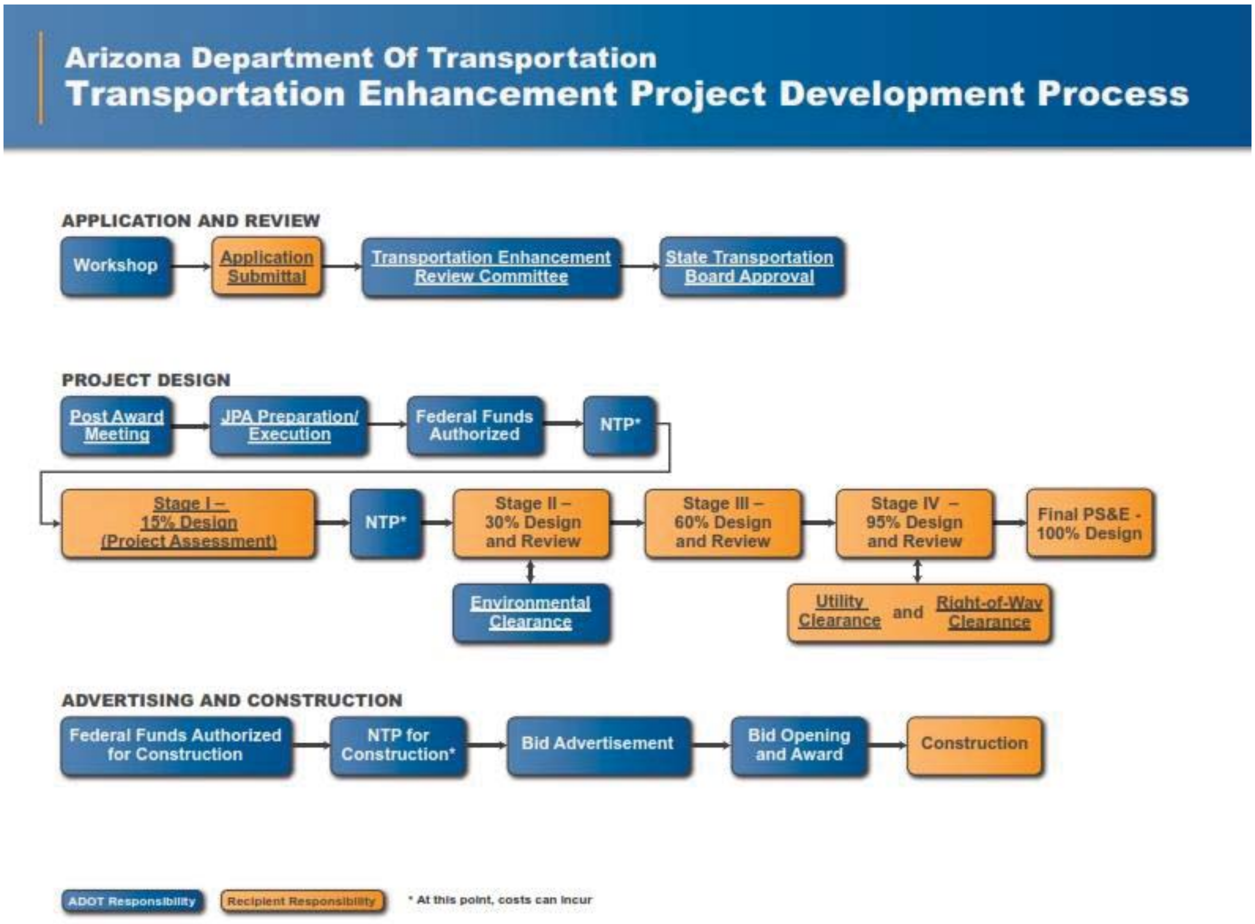


Figure A-1. Arizona DOT project development process (ADOT 2014)

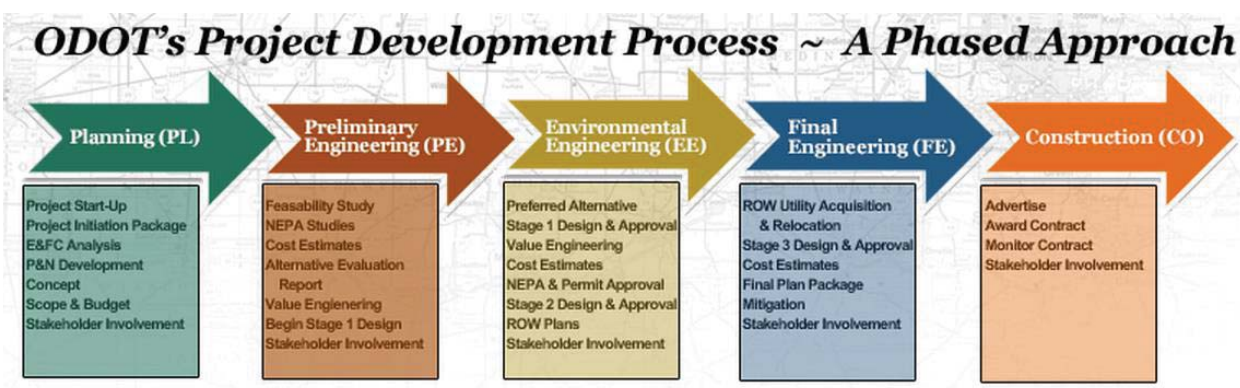


Figure A-2. Ohio DOT project development process (Ohio DOT 2014)

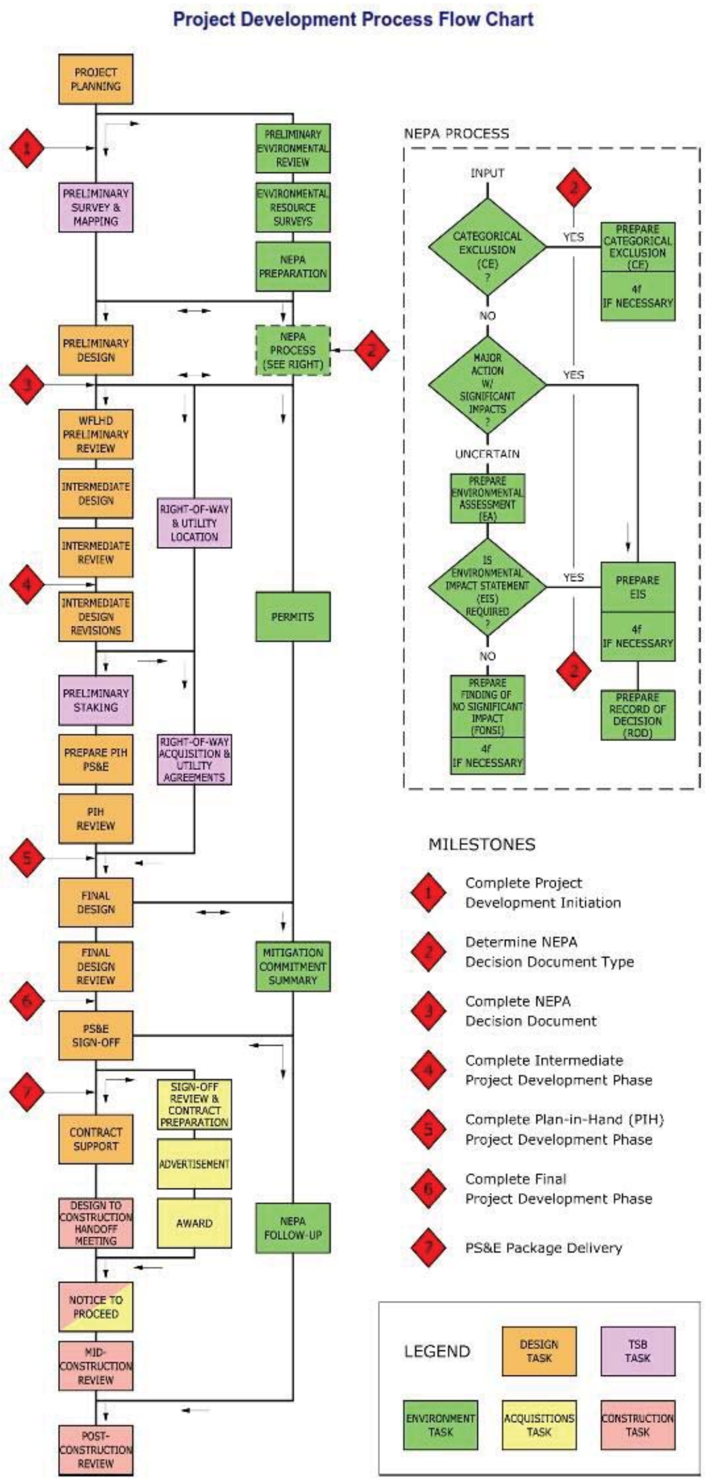
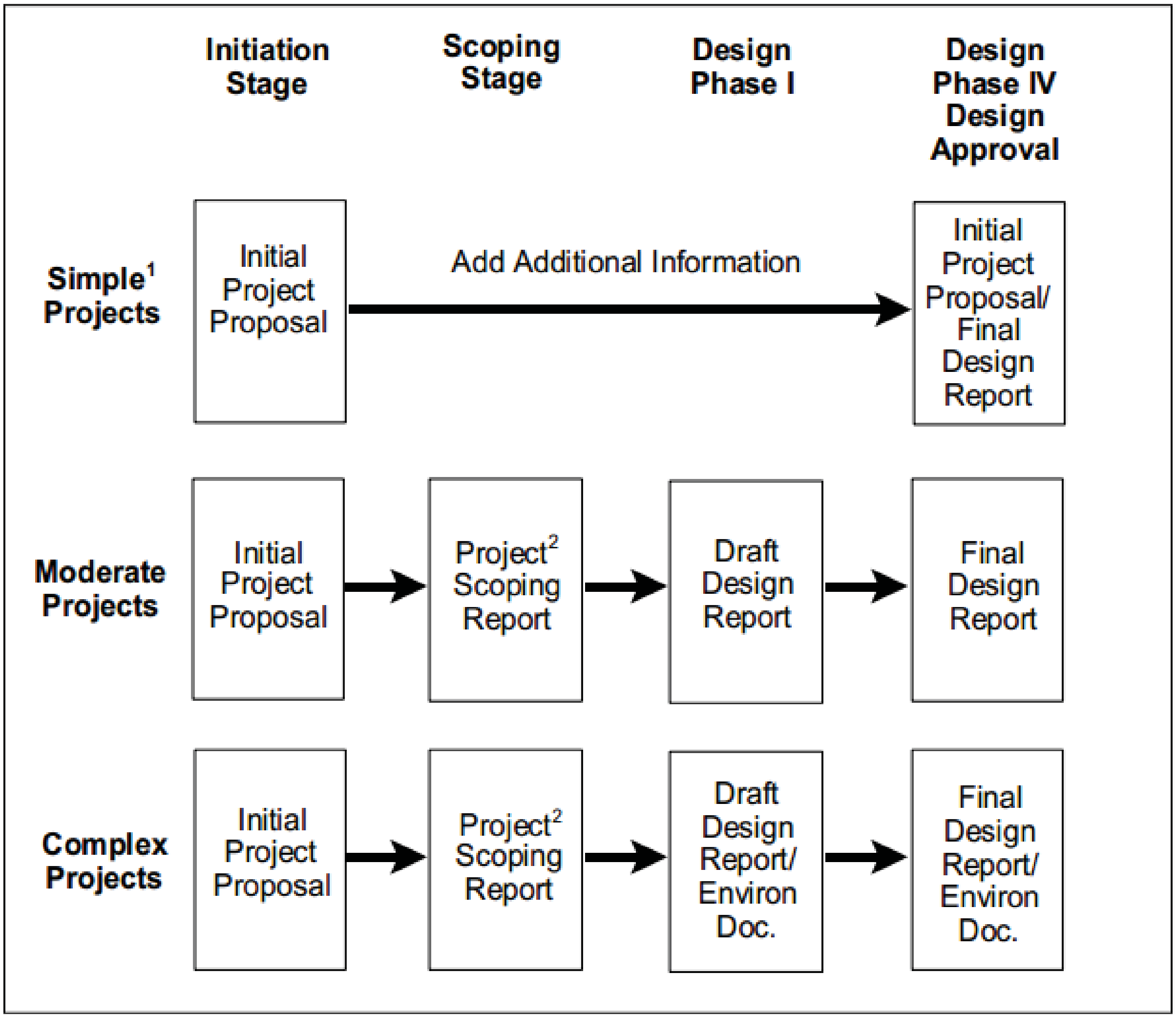


Figure A-3. Western Federal Lands Highway Division project development process (WFLHD 2007)

Exhibit 2-2 Project Documentation For Simple, Moderate, and Complex Projects



Notes:

1. For simple projects, activities may occur during the Scoping Stage and Design Phase I. However, separate reports are not required and the appropriate documentation will be included in the Initial Project Proposal/Final Design Report.
2. The Project Scoping Report is a first draft of the draft design report or draft design report/environmental document.

Figure A-4. New York State DOT project development process (NYSDOT 2004)

APPENDIX B—CASE STUDY WRITE UPS

The following is a full write up of the nine agency case study interviews on preconstruction service (PCS) cost estimating practices. All write ups are completed with the same template so they can be easily compared. Chapter 2 of the report contains a synthesized version of these case studies.

Agency: Caltrans

Location: Sacramento, California

General information: Caltrans yearly construction budget is approximately $13-$15 Billion and they are awarded approximately 364 construction projects per year. Approximately 60% of all annual projects are federally funded with the remaining 40% non-federally funded. Project monetary size ranges from $50 thousand to $3.5 Billion. The average monetary size of a new construction project is $2 - $5 Million.

In-House data collection: Caltrans does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets. The data recorded on these times sheets is rated a 3 out of 5 on the scale of accuracy. Caltrans does allocate in-house overhead cost to a specific project. These costs are allocated as a % annual rate with a functional rate at 35% - 40% and an administrative rate at 20%-30%. Caltrans uses data collected from past projects to estimate the PCS cost for future projects. However, the PIPE scan system is used as a starting point. Current methods used to estimate PCS costs for a project include a direct estimate of hours as well as the use of an average % support to cap ratio.

Outsourcing data collection: Caltrans contracts out 10% of PCS work. They have a standing contract for a GEC. Each district has their own separate on call staff. Caltrans can perform the entire preconstruction process in-house and they also outsource all PCS except advertisement for bids, evaluation of bids, and award of contract. It is rare for Caltrans to outsource PCS concerning cost estimate, ROW plans, and ROW utility acquisition and relocation.

Caltrans performs 90% PCS in-house and 10% is outsourced. The main reason why they outsource PCS is due to policies, staff availability, as well as special expertise. Caltrans does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for CALTRANS are;

- Complexity
- Project Type
- Construction costs
- Number of plan sheets
- NEPA classification
- Length of project

The minor influences in the PCS cost for this agency:

- Number of lanes
- Number of bridges
- Geographical

The characteristics that have no influence in the PCS cost for this agency:

- Number of sub-consultants
- Highway classification
- Loss of design effort*

* Start a new project if no funding so loss of design effort is not considered

PCS estimate improvements: Currently Caltrans is already estimating PCS cost for all projects. To improve these estimates they believe they need a better model for historical data analysis, need to do bottom-up estimates, project manager does not control the people working for them, and good scoping documents. Caltrans already has a system that captures PCS cost information. IT makes it hard to buy a new program off the shelf, and Caltrans believes that a new program needs to fit current systems and data. They believe that having more accurate PCS cost estimates would have some impact mainly on the budget process.

Researcher's observations: The biggest thing is it will be hard to convince people to use the system

Agency: Colorado Department of Transportation (CDOT)

Location: Denver, Colorado

General information: CDOT yearly construction budget is approximately $500 - $700 million and they award approximately 180 construction projects per year. 85% -90% of all annual projects are federally funded. Project monetary size ranges from $150 thousand to $100 million. The average monetary sized of a new construction project is $1.5 - $1.6 million.

In-House data collection: CDOT does not record in-house preconstruction services (PCS) hours on a per project basis. Whether the cost is recorded depends on the type of the project. For federally funded projects they need to submit and independent project cost estimate in this case 10% is assumed. For bridge enterprise and larger projects the will collect all costs. They record these hours using the engineer's timesheets. The data recorded on these times sheets is expected to be 60% accurate. CDOT does allocate in-house overhead cost to a specific project. Their current organizational indirect rate of 20% is evaluated every year and distributed across the multiple phases of the project. CDOT does not use data collected from past projects to estimate the PCS cost for future projects. They use standard percentages of estimated construction cost to estimate PCS hours.

Outsourcing data collection: CDOT does contract out PCS. They have a standing contract for geotechnical and environmental consultants (GEC). CDOT can perform the entire preconstruction process in-house. Or they can outsource all PCS except advertisement for bids, evaluation of bids, and award of contract.

CDOT performs 45% PCS in-house and 55% is outsourced (by number of projects). The main reason why they outsource PCS is due to staff availability and special expertise. They do not have and regulations on how much they can or shall outsource. They have to have justification to outsource projects. CDOT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process. The decision to whether outsource or not is mainly based on the availability of staff and in-house capabilities.

The major influences in the PCS cost for CDOT are;

- Complexity
- Construction costs*
- NEPA classification
- Political elements (i.e. high visibility project)
- Schedule drivers

The minor influences in the PCS cost for this agency:

- Project type
- Number of sub-consultants
- Construction cost*
- Number of plan sheets
- Number of bridges
- Highway classification
- Length of project
- Geographical

The characteristics that have no influence in the PCS cost for this agency:

- Number of lanes
- Loss of design effort

* CDOT considers construction cost a major influence for in-house projects but only some influence for consultant projects.

PCS estimate improvements: Currently CDOT is looking to adopt a system of estimating PCS cost for larger projects. To improve their PCS cost estimates they believe they need good tools as well as good data. It is currently all guesstimates. It is an artistic process and loss of experience with younger engineers. They need a data collection effort to figure out the number of hours. If there was a system available that would capture PCS cost information, they would consider adopting such a program depending on how the model aligns with other systems CDOT uses. CDOT believes that having more accurate PCS cost estimates could have a moderate impact on the planning process. It would really help with budget portfolio management. People involved in PCS cost estimating are not usually engineers. This position is usually left up to planning or environmental people. Project cost planner rough idea relies on past information use it more for construction cost.

Researcher's observations: When you hire a consultant you need to negotiate the number of hours.

Agency: Iowa Department of Transportation (Iowa DOT)

Location: Ames, Iowa

General information: Iowa DOT yearly construction budget is approximately $400 Million and they award approximately 500 – 600 construction projects per year.

In-House data collection: Iowa DOT does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets. The data recorded on these times sheets is rated a 4 out of 5 on the scale of accuracy. Iowa DOT does not allocate in-house overhead cost to a specific project. The Iowa DOT does not use data collected from past projects to estimate the PCS cost for future projects. They do not estimate PCS cost for a project.

Outsourcing data collection: Iowa DOT does contract out PCS. The Iowa DOT can use both in-house and on call consultants they do also use other consultants but only for larger less common projects, they do not have overall GEC contracts. Iowa DOT can perform the entire preconstruction process in-house and it also outsources all PCS except advertisement for bids, evaluation of bids and award of contract.

The main reason why they outsource PCS is due to staff availability, special expertise and timeline for design. They do not have and regulations about how much it can or shall outsource however they cannot exceed the annual budget for outside services. The Iowa DOT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for Iowa DOT are;

- Complexity
- Project Type
- Construction costs
- Number of plan sheets
- NEPA classification
- Length of project

The minor influences in the PCS cost for this agency:

- Number of lanes
- Number of sub-consultants
- Number of bridges
- Geographical – (Soils on west side of state)

The characteristics that have no influence in the PCS cost for this agency:

- Highway classification

PCS estimate improvements: Currently Iowa DOT is not estimating PCS cost for projects but it is looking to adopt this in the future. To improve these estimates they believe they need to learn how to use the data they already have. Iowa DOT has been capturing PCS hours for a few years now and they need a way to organize this data so that is useful in PCS estimating. If there was a system available to help capture agencies PCS cost Iowa DOT would consider adopting it.

Iowa DOT think that having a more accurate estimate of PCS would have a large impact on the planning process for the agency. Would allow the agency to budget staff time would be good to know the number of hours per task and to compare these to consultant design hours.

Researcher's observations:

Iowa DOT wants to capture costs that are useful to each area, can't be useful to both planning and design. Would like a model that is split up by function or by office.

Agency: Maryland (MSHA)

Location: Annapolis, Maryland

General information: MSHA yearly construction budget is approximately $600-800 Million and they award approximately 300 – 350 construction projects per year. Project monetary size ranges from $1Million to $150 Million. Average monetary size of a new construction project is approximately $25 Million.

In-House data collection: MSHA does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using time tracking software. The data recorded on these times sheets is rated a 4.5 out of 5 on the scale of accuracy. MSHA does allocate in-house overhead cost to a specific project. The MSHA uses data collected from past projects along with standard percentages to estimate the PCS cost for future projects. The old system used 15% of the construction cost as preliminary engineering, they now use a cure based system on preliminary engineering.

Outsourcing data collection: MSHA does contract out PCS. They have a standing contract for a GEC. MSHA can perform the entire preconstruction process in-house and it also outsources all PCS except ROW utility acquisition and relocation, advertisement for bids, evaluation of bids, and award of contract.

The main reason why they outsource PCS is due to staff availability and special expertise. They do not have regulations on how much they can or shall outsource. The MSHA does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for MSHA are;

- Complexity
- Project Type
- Construction costs

The minor influences in the PCS cost for this agency:

- Number of sub-consultants
- Number of lanes
- Number of plan sheets
- National Environmental Policy Act (NEPA) classification
- Number of bridges
- Length of project

- Geographical
- Loss of design effort
- Innovation
- New Technology
- PDM

The characteristics that have no influence in the PCS cost for this agency:

- Highway classification

PCS estimate improvements: Currently MSHA is already estimating PCS cost for all projects. To improve these estimates they believe they need to develop a historical database of previous estimates. MSHA believe that having more accurate PCS cost estimates would have a large impact on the planning process as they believe that it would provide more efficiency to managing funds.

Researcher's observations: Historical projection is incorporated into project factors

Agency: Montana Department of Transportation (MDT)

Location: Helena, Montana

General information: MDT yearly construction budget is approximately $385 Million and they award approximately 80 – 100 construction projects per year.

In-House data collection: MDT does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets and have a time allocation system per job. The data recorded on these times sheets is rated a 4 out of 5 on the scale of accuracy. MDT does allocate in-house overhead cost to a specific project; they allocate this using an indirect rate which they apply to all projects. It is approximately 9-11% but has been as high as 18%. The MDT does not use data collected from past projects to estimate the PCS cost for future projects. They have a system that records past hours and durations of activities 3-5 years to reconcile with activities to average activity hours. This system has no feedback loop and therefore it is not used to look at past projects or to re access the activity hours in OPX2 (project management tool).

Outsourcing data collection: MDT does contract out PCS. MDT can perform the entire preconstruction process in-house except feasibility study and it also outsources all PCS except advertisement for bids, evaluation of bids and award of contract this is considered in the construction department.

The main reason why MDT outsources PCS is due to staff availability, special expertise and also to transfer risk of design liability. They do not have and regulations about how much they can or shall outsource however there is an unwritten rule that approximately 20% of the program is outsourced. The MDT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for MDT are;

- Complexity
- Project Type
- Number of lanes
- Number of plan sheets
- NEPA classification
- Number of bridges

- Length of project
- Geographical
- Loss of design effort
- ROW and utilities

The characteristics that have no influence in the PCS cost for this agency:

- Number of sub-consultants
- Construction costs
- Highway classification

PCS estimate improvements: Currently MDT is already estimating PCS cost for all projects. To improve these estimates they believe they need to get to function based estimating and also need to determine how to allocate the funds in split corridor projects. MDT also believe that they need to improve how they capture the hours on the time sheets.

Agency: New York State Department of Transportation (NYSDOT)

Location: Albany, New York

General information: NYSDOT yearly construction budget is approximately $1 billion and they award approximately 300 – 350 construction projects per year.

In-House data collection: NYSDOT does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets. The data recorded on these times sheets is rated a 4.5 out of 5 on the scale of accuracy. NYSDOT does allocate in-house overhead cost to a specific project. The NYSDOT uses data collected from past projects to estimate the PCS cost for future projects. They use an in-house system called DPR which contains a selection of tools to estimate PCS hours. NYSDOT are looking to move to primavera P6 software resource allocation model to help estimate hours PCS.

Outsourcing data collection: NYSDOT does contract out PCS. When design for a project is performed in-house they use on call contracts for the environmental sampling and testing and survey services but they do not have overall GEC contracts. NYSDOT can perform the entire preconstruction process in-house except services stipulated above and it also outsources all PCS except advertisement for bids, evaluation of bids and award of contract.

NYSDOT performs 50% PCS in-house and 50% is outsourced by dollar value and 90% to 10% by project number. The main reason why they outsource PCS is due to staff availability and special expertise. They do not have and regulations about how much they can or shall outsource however they have quarterly meetings with consultants to ensure there is enough work in the industry. Design staff for NYSDOT are unionized. Most consultant work for NYSDOT happens in the southern region in and around New York City and Long Island. The NYSDOT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for NYSDOT are;

- Complexity
- Project Type
- Construction costs
- Number of lanes
- NEPA classification
- Number of bridges
- Length of project
- Geographical

- Inflation

The minor influences in the PCS cost for this agency:

- Highway classification

The characteristics that have no influence in the PCS cost for this agency:

- Number of sub-consultants
- Number of plan sheets*

The NYSDOT also noted that loss of design effort is considered rare they had problems when they shifted to preservation mode 3 years ago. A lot of reconstruction was shifted later in program (~10 years) and preservation was adopted.

* Electronic plan sheets mean that you can produce more but it no longer directly reflects the level of work put into the design like it did in the past when cad and other modeling software wasn't used.

PCS estimate improvements: Currently NYSDOT is already estimating PCS cost for all projects. To improve these estimates they believe they need to get to task estimating however they are skeptical about whether the time, effort and cost of this would be add any real value to the agency. NYSDOT believe that having more accurate PCS cost estimates could have some impact on the planning process the believe that they may possible be able to have more projects but the current number already within ~10% and having a more accurate estimate will not make the process cheaper so is not likely to affect the agency.

Agency: Oklahoma State Department of Transportation (ODOT)

Location: Oklahoma City, Oklahoma

General information: ODOT yearly construction budget is approximately $632-$790 million and they are awarded approximately 364 construction projects per year. Approximately 60% of all annual projects are federally funded with the remaining 40% non-federally funded. Project monetary size ranges from $50 thousand to $25 million. The average monetary sized of a new construction project is $1.7 million.

In-House data collection: ODOT does not record in-house preconstruction services (PCS) hours on a per project basis. Approximately 50% of the time it is billed to overhead.

Outsourcing data collection: ODOT does contract out PCS. ODOT can perform the entire preconstruction process in-house except right of way and they also outsource all PCS except Preferred alternative, NEPA and permit approval, final plan package (RFP and RFQ), advertisement for bids, evaluation of bids, and award of contract.

The main reason why they outsource PCS is due to staff availability and special expertise. They do not have any regulations on how much they can or shall outsource. The ODOT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for ODOT are:

- Complexity
- Project type
- Construction cost
- Number of bridges
- Length of project

The minor influences in the PCS cost for this agency:

- Number of sub-consultants
- Number of plan sheets
- National Environmental Policy Act (NEPA) classification
- Highway classification

The characteristics that have no influence in the PCS cost for this agency:

- Number of lanes

PCS estimate improvements: Currently ODOT believes estimating PCS cost would be valuable but have yet to do so. To improve PCS cost estimates they believe they need to made direct changes to their projects. If a system that would capture PCS cost information was available, ODOT might choose to adopt it. ODOT believes that having more accurate PCS cost estimates would have minimal impact on the planning process within their program.

Researcher's observations: Will be hard to convince people to use the system.

Agency: Rhode Island Department of Transportation (RIDOT)

Location: Providence, Rhode Island

General information: RIDOT yearly construction budget is approximately $300 million.

In-House data collection: RIDOT does record in-house preconstruction services (PCS) hours on a per project basis. They record these hours using the engineer's timesheets. The data recorded on these times sheets is rated a 4 out of 5 on the scale of accuracy. RIDOT does not allocate in-house overhead cost to a specific project. The RIDOT does not use data collected from past projects to estimate the PCS cost for future projects. Design costs are estimated by using 15% of total construction cost. However, this is not uniform; smaller projects tend to be a higher percentage and larger projects tend to be a lower percentage. This process is just an educated guess.

Outsourcing data collection: RIDOT does contract out PCS. They have several on-call consultants as almost all their design work is outsourced. They use two consultants for highway work, two for bridges, and four for traffic engineering. No single firm is the dominant GEC. They have only two persons in the area of historical and heritage issues and four in environmental groups. This workforce is inadequate in performing the required studies in an appropriate time. RIDOT can advertise for bids, evaluate bids, award contracts, and perform some ROW utilities acquisition and relocation. All PCS processes are outsourced except those stipulated above.

The main reasons why they outsource PCS are due to staff availability and having better control over consulting engineers easier to terminate / not extend consultant contract contracts than employees. RI DOT engineers are unionized. RIDOT rely heavily on federal funds (roughly two thirds of the transportation budget comes from federal) which are subject to approval; can't guarantee jobs. They do not have and regulations on how much they can or shall outsource. Engineering staff for RIDOT are unionized. The RIDOT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process.

The major influences in the PCS cost for RIDOT are:

- Complexity
- Project type
- Number of plan sheets

The minor influences in the PCS cost for this agency:

- Construction cost
- Number of lanes
- National Environmental Policy Act (NEPA) classification
- Number of bridges
- Highway classification
- Length of project
- Geographical
- Loss of design effort

The characteristics that have no influence in the PCS cost for this agency:

- Number of sub-consultants

During Mr. Farhoumand's 26 years with RIDOT, there has been just one new road project and one major relocation of a major road (I95). New roads are a rarity!

One clarification regarding the characterization of "Geographical" above. Coastal projects need extra permits compared to non-coastal projects, hence more "difficult."

PCS estimate improvements: RIDOT does not see value in estimating PCS cost. Since they are a small organization, they have yet to develop a database to keep track and evaluate the design costs. Their priority lies in estimating construction costs. To improve these estimates they believe they need a database to pull scattered records and documentation of PCS into one place. If there was a system RIDOT would probably not consider adopting it because drivers of these costs tend to be out of the control of the agency. There is a 2 year election cycle so government and legislative representatives change regularly and therefore projects continue to lose and gain importance depending on the political influence. Also they will get built regardless of preconstruction; it is the construction cost that causes the most difficulties. RIDOT believe that having more accurate PCS cost estimates would have no impact on the planning process. They believe that PCS costs have very little impact on the overall program and projects will be executed no matter the PCS costs.

Agency: Utah Department of Transportation (UDOT)

Location: Salt Lake City, Utah

General information: UDOT yearly construction budget is approximately $1,100 million.

In-House data collection: UDOT does record in-house preconstruction services (PCS) hours on a per project basis they charge hours to a PIN (project identification number). They record these hours using project management software called ePM. The data recorded on these times sheets is rated a 4 out of 5 on the scale of accuracy, sometimes staff will bill to overhead instead of a project. UDOT does not allocate in-house overhead cost to a specific project however they do charge to a management line item and all staff costs included benefits etc. The UDOT uses data collected from past projects to estimate the PCS cost for future projects. They use a past project cost range as well as a direct estimate of hours to determine the PCS hours. These estimates are project dependent.

Outsourcing data collection: UDOT does contract out PCS. UDOT uses on call contracts for most outsourced work but they can only use up to $40,000/consultant/project if more work need to be outsourced they will advertise for contracts. UDOT can perform the entire preconstruction process in-house except region 4 (Southern reigion) cannot do ROW, hydraulics and signal design services. UDOT outsources all PCS except advertisement for bids, evaluation of bids and award of contract.

UDOT performs 25% PCS in-house and 75% is outsourced by dollar value. The main reason why they outsource PCS is due to staff availability and special expertise they also choose to outsource to strengthen the economy and expedite project delivery. They do not have policy or regulations about how much they can or shall outsource however they must always keep the in-house staff busy first. The UDOT does not compare the cost of performing PCS in-house versus consulting out as part of the outsourcing decision process they are aware that this will cost more but are limited by staff. UDOT try to decide early on whether the project will be outsourced or performed in-house so that they can set the budget early. PCS for simple projects will usually be performed in-house this decision is made at the program level. Occasionally UDOT will put design staff to work with the consultant on an outsourced project to get experience. The staff at UDOT has reduced from 3500 in 2000 to 1530 now.

The major influences in the PCS cost for UDOT are;

- Complexity
- Project Type
- NEPA classification
- Number of bridges

The minor influences in the PCS cost for this agency:

- Highway classification
- Construction costs
- Number of plan sheets
- Number of lanes
- Length of project

The characteristics that have no influence in the PCS cost for this agency:

- Number of sub-consultants
- Geographical
- Loss of design effort

The UDOT does not believe it sets out to make mistakes therefore they do not consider loss of design effort necessary in estimating PCS.

PCS estimate improvements: Currently UDOT is already estimating PCS cost for all projects. To improve these estimates they believe they need to have more experience. New project managers do not have a good feel for the number of hours, required training and time on job needed to produce an accurate estimate. UDOT is happy with their current cost estimating system and they would prefer to refine their own system than adopt another system. UDOT believe that having more accurate PCS cost estimates could have some impact on the planning process allow them to refine allocation of resources and negotiate with consultants better.

Researcher's observations:

UDOT has a positive work environment that keeps them moving forward and allows UDOT to try new and innovative things, constantly pushing to get better results.

APPENDIX C—AGENCY AND PROJECT INTERVIEW TEMPLATE

Appendix C contains the structured interview template used to interview each of the nine agencies. This is followed by the project case study interview template.

STRUCTURED INTERVIEW:

I. Agency and Interviewee General Information:

1. Interviewee name:
2. Interviewee job position in the agency:
3. Interviewee telephone number:
4. City and state in which the respondent agency is headquartered:

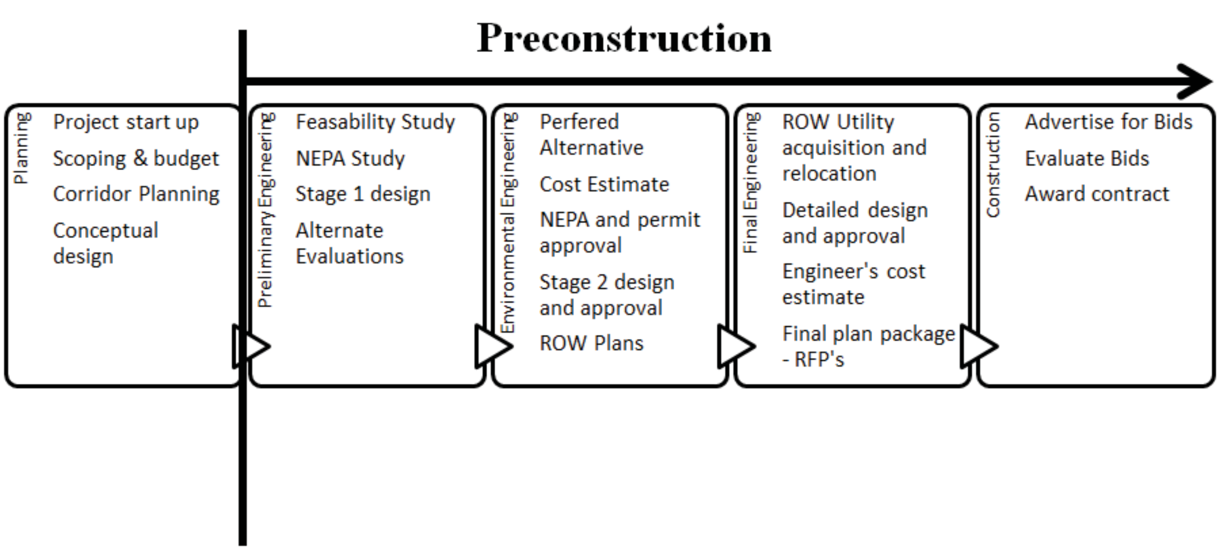
    A. Name of Agency:

5. What type of organization do you work for?

    ☐ State DOT; ☐ Other public transportation agency; ☐ Other: {explain}

6. Annual construction budget:
7. Approximate average annual number of awarded construction projects:
8. Approximate average annual number of federally funded projects:
9. Approximate average annual number of non-federally funded projects:
10. Project monetary size range: $ to $
11. Average monetary size of a new construction project $

II. Preconstruction Services Project Development Process



III. Agency In-House data collecting:

1. Do you record in-house PCS hours on a per project basis.
   ☐ Yes ☐ No

   If yes continue. If No go to next section

2. How do you record these hours?

☐ Engineer's timesheets ☐ Time allocation system per job
☐ Time tracking software ☐ Other {explain}

3. How accurate do you think the hours are?

   1- Not Accurate — 2 — 3 — 4 — 5- Very Accurate

4. Do you allocate in-house overhead costs to an individual project?
   ☐ Yes ☐ No
   If yes how do you allocate these costs?
5. Do you use the data to determine PCS cost estimate for future projects?
   ☐ Yes ☐ No
   If yes continue. If No go to next section

6. What method do you use to estimate PCS costs for a project

☐ Trns.port Software; ☐ Standard percentage of estimated preconstruction cost ;

☐ Direct estimate of hours; ☐ Past project cost range; ☐ Don't know; ☐ Other {please specify}

IV. Agency Outsourcing Preconstruction Services Make Up:

1. Does your agency contract out PCS work?
   ☐ Yes ☐ No
   If yes continue. If No go to next section:

2. Do you have a standing contract for a general engineering consultant (GEC)?
   ☐ Yes ☐ No

3. What services do you contract out?

	In-house	GEC	Other Consultant
Feasibility Study			
NEPA Study			
Stage 1 Design			
Alternate Evaluations			
Preferred alternative			
Cost Estimate			
NEPA and Permit Approval			
Stage 2 Design and Approval			
ROW Plans			
ROW Utility Acquisition and Relocation			
Detailed Design and Approval			
Engineer's Cost Estimate			
Final Plan Package (RFP and RFQ)			
Advertise for Bids			
Evaluate Bids			
Award Contract			
Approximate percentage			

4. If your agency contracts out PCS why do you do it?

☐ Regulations ☐ Staff availability ☐ Special expertise

☐ Policy ☐ Transfer risk of design liability ☐ Other: {explain}

5. Do you have limitations or guidelines on how much you can or shall outsource?

☐ Yes ☐ No

If yes please explain:

6. Do you compare the cost of in-house resources to the cost of consulting out as part of the outsourcing decision process?

☐ Yes ☐ No

If yes please explain:

V. Preconstruction Cost Components:

2. How influential do you think the following characteristics are in estimating the overall PCS cost for a "typical Design Bid Build" project? (*Interviewer circle the check box*)
   - 1- No Influence
   - 2-Some Influence
   - 3-Major Influence

	1	2	3
Complexity	☐	☐	☐
Project type	☐	☐	☐
Number of sub-consultants	☐	☐	☐
Construction cost	☐	☐	☐
Number of lanes	☐	☐	☐
Number of plan sheets	☐	☐	☐
National Environmental Policy Act (NEPA) classification	☐	☐	☐
Number of bridges	☐	☐	☐
Highway classification	☐	☐	☐
Length of project	☐	☐	☐
Geographical	☐	☐	☐
Loss of design effort	☐	☐	☐
Other	☐	☐	☐

VI. How to improve PCS cost estimates:

1. What is your agency current stance on estimating PCS cost?
   - ☐ Already estimating PCS cost
   - ☐ Looking to adopt it in the future
   - ☐ Believe it would be valuable
   - ☐ Do not see value for my agency
   - ☐ Other: {explain}
2. What do you think your agency needs to do to improve their PCS cost estimate?
3. If there was a system available that would capture PCS cost information would your agency consider adopting it?

   ☐ Yes ☐ No ☐ Maybe
4. If you were able to more accurately estimate the PCS cost what would be the impact on planning process?

   1- No Impact 2-Some Impact 3 – Large Impact
5. Is there anything you would like to add that you think would be valuable to the researchers in this study?

PROJECT CASE STUDY INTERVIEW:

VII. Project General Information:

1. Project name:
2. Project type: DBB DB CMGC Other
3. Project description:
4. Total monetary size of project:
5. Total Cost of PCS for project:
6. Breakdown of the PCS cost for the project (if available)

	In-house	GEC	Other Consultant
Feasibility Study	$	$	$
NEPA Study	$	$	$
Stage 1 Design	$	$	$
Alternate Evaluations	$	$	$
Preferred alternative	$	$	$
Cost Estimate	$	$	$
NEPA and Permit Approval	$	$	$
Stage 2 Design and Approval	$	$	$
ROW Plans	$	$	$
ROW Utility Acquisition and Relocation	$	$	$
Detailed Design and Approval	$	$	$
Engineer's Cost Estimate	$	$	$
Final Plan Package (RFP and RFQ)	$	$	$
Advertise for Bids	$	$	$
Evaluate Bids	$	$	$
Award Contract	$	$	$
Total percentage			

7. Complexity of project:

1- Basic project   2   3 Typical project   4   5- Very complex

8. Number of sub-consultants:

9. Number of lanes:

10. Number of plan sheets:

11. NEPA Classification

12. Number of bridges:

13. Highway Classification:

14. Length of project:

15. How much influence did the following factor have on the PCS cost for this project?

	No influence	Minor influence	Major influence
Complexity	☐	☐	☐
Project type	☐	☐	☐
Number of sub-consultants	☐	☐	☐
Construction cost	☐	☐	☐
Number of lanes	☐	☐	☐
Number of plan sheets	☐	☐	☐
National Environmental Policy Act (NEPA) classification	☐	☐	☐
Number of bridges	☐	☐	☐
Highway classification	☐	☐	☐
Length of project	☐	☐	☐
Other	☐	☐	☐