Minnesota Department of Transportation

RESEARCH SERVICES & LIBRARY

Office of Transportation System Management

Risk-Based Engineers Estimate

Jennifer S. Shane, Principal Investigator
Department of Civil, Construction, and Environmental Engineering
Construction Management and Technology
Iowa State University

March 2015

Research Project
Final Report 2015-10

To request this document in an alternative format call 651-366-4718 or 1-800-657-3774 (Greater Minnesota) or email your request to ADArequest.dot@state.mn.us. Please request at least one week in advance.

Technical Report Documentation Page

1. Report No. MN/RC 2015-10	2.	3. Recipients Accession No.	
4. Title and Subtitle Risk-Based Engineers Estimate		5. Report Date March 2015	
		6.	
7. Author(s) Jennifer S. Shane, Kelly C. Strong, Ghada M. Gad		8. Performing Organization Report No.	
9. Performing Organization Name and Address Construction Management and Technology Iowa State University 2711 S. Loop Drive, Suite 4700 Ames, Iowa 50011-8664		10. Project/Task/Work Unit No.	
		11. Contract (C) or Grant (G) No. 99004 (C) 3 (WO)	
12. Sponsoring Organization Name and Address Minnesota Department of Transportation Research Services & Library 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes http://www.lrrb.org/pdf/201510.pdf			

16. Abstract (Limit: 250 words)

The review of any bid depends on the reliability of the estimate it is being compared to, making estimates an essential element in the project approval process. Thus, departments of transportation (DOT) should put great effort in the estimates' preparation as under-estimating can lead to project delays, while over-estimating leads to inefficient use of funds. Since delivering more lump sum projects is an Engineering Services Division strategic initiative in MnDOT and since lump sum items are often more difficult to price, it becomes important to develop an effective practice for consistent cost estimating. Risk-based estimating combines both risk management and traditional cost estimating to develop an estimate that includes the risk in the project's cost (Anderson et al. 2007). Risk-based estimating thus serves as an excellent estimating technique that generates reliable estimates. The objective of this research is to:

- Conduct literature review of risk-based estimating.
- Conduct state-of-practice review of risk-based estimating used by DOTs and other construction organizations.
- Based on the state-of-practice and literature review conducted, give recommendations on how these practices can be incorporated into MnDOTs business practice.

The recommendations reached through this research are anticipated to help the MnDOT estimating team get a better understanding of risk-based estimating, and how it could be employed in the MnDOT estimation process.

17. Document Analysis/Descriptors Traffic simulation, Hybrid simulation, Traffic equilibrium, Cubes, Transportation planning, Traffic simulation		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312	
19. Security Class (this report) Unclassified	20. Security Class Unclassified	21. No. of Pages 69	22. Price

Risk-Based Engineers Estimate

Final Report

Prepared by:
Jennifer S. Shane
Department of Civil, Construction, and Environmental Engineering
Construction Management and Technology
Iowa State University

Kelly C. Strong
Colorado State University

Ghada M.Gad
Bowling Green State University

March 2015

Published by:

Minnesota Department of Transportation
Research Services & Library
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

Acknowledgments

The authors appreciate the persistence of Mary Lacho, Nelson Cruz, Alan Rindels, and Jay Hietpas on this project. The authors also appreciate all those who responded to calls for information regarding this subject.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

Executive Summary

The purpose of this research project is to investigate risk-based cost estimating and provide the Minnesota Department of Transportation (MnDOT) with draft guidance for use of identified methods. To achieve this purpose the researchers explored the state of practice of risk-based cost estimating, presented the information to MnDOT personnel, and provided guidance for three identified methods for incorporating risk-based cost estimating in MnDOT practices.

Risk-based cost estimation entails developing probable cost for project components, and the project, based on identified known quantities and costs and contingency developed from a list of identified uncertainties from both opportunities and threats and their potential impact on the project. Examining the state of the practice of MnDOT, other departments of transportation (DOT), and industry use of risk-based cost estimating allowed the researchers to inform the MnDOT personnel about possibilities both within MnDOT and from outside sources.

Through an examination of the state of the practice, the researchers found practices within MnDOT, other DOTs, and other industries. The researchers found that there are some personnel using risk-based cost estimating techniques within the MnDOT. The application of these techniques vary greatly between districts and knowledge is not widespread. There are a number of other DOTs that use risk-based estimating techniques. The use in other DOTs varies depending on the type of project and agency. There is a similar finding in other industries. Knowledge of the concepts is widespread, yet implementation varies depending on project characteristics and the stakeholders involved.

This information was presented to MnDOT personnel in a day long workshop. During this workshop the participants were informed of the state of the practice in each of the areas and the techniques used were also described. There was much discussion among the participants on this topic and at the end of the day three areas for guidance were identified, risk registers, Monte Carlo simulation, and communication.

Chapter 1. Introduction

State transportation agencies' abilities to manage and deliver projects depend on the agency's ability to estimate project costs realistically early in the concept development stage, even before final engineering is completed (AASHTO 2009). Accurate estimates mostly set internal and external expectations (Booz Allen Hamilton 2005). The inability to accurately estimate project costs may lead to delays in project delivery and lack of confidence in the Department of Transportation's (DOT's) abilities to realize their commitments (AASHTO 2009). With accurate estimates, expectations are set for funding, projects are prioritized, a baseline is provided for project control, and a basis for cash flow requirements is formalized over the life cycle of the project (WSDOT 2008a).

Inaccurate estimates are usually a result of poor cost-estimating practices, poor project-management practices, and poor communication between design and construction personnel, and the public. The result is a critical confidence issue in the agency's abilities that can possibly lead to funding rejection (Reilly et al. 2004). The challenge estimators usually face is that the greatest cost and schedule uncertainties are during the planning phases of a project (Figure 1).

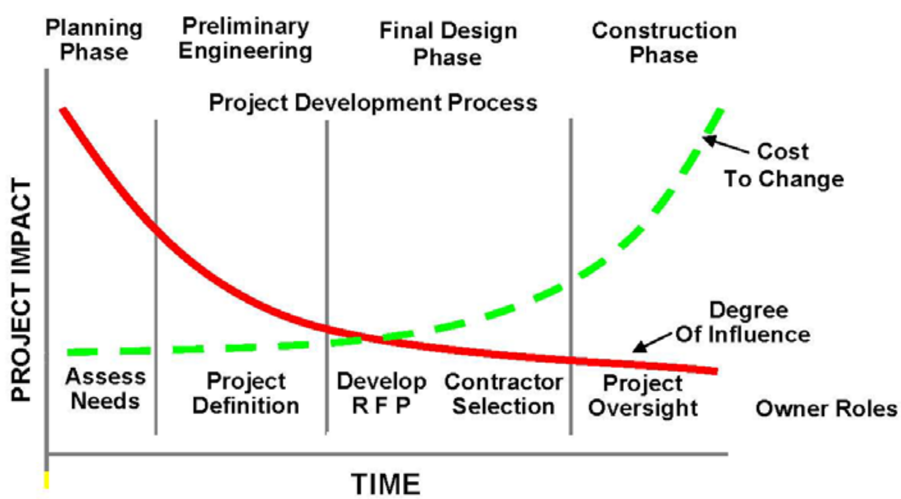


Figure 1. Project Influence Curve (Booz Allen Hamilton 2005)

Using the most accurate information available on project scope, quantities, unit costs, and schedule, estimators forecast the project cost. It is most common, however, that focus is placed on the accuracy of unit cost and quantity estimates (Booz Allen Hamilton 2005).

Two key issues should be considered when developing infrastructure cost estimates, as stated by Reilly et al. (2004):

- "The failure to adequately recognize, for complex infrastructure projects, that any estimate of cost or schedule involves uncertainty, or risk, and that this uncertainty should be incorporated in an estimate

- The need for validation of estimates from the external perspective of qualified reviewers, specifically including experienced construction personnel who understand how the project will be both bid and constructed" (Reilly et al. 2004)

There are many cost estimation methods used that attempt to provide realistic cost and schedule estimates. The most conventional methods are the contingency methods which are used in a deterministic way in which component costs are summed and an overall contingency is then included for uncertainties in cost (Maher and McGoey-Smith 2006). A cost estimation process generally includes five main steps: determining the estimate basis, preparing base estimate, determining risk and setting contingency, reviewing the total estimate, and finally communicating the estimate (Anderson et al. 2006). The actual cost of a project is affected by many variables that can significantly influence the estimated cost. In DOT project estimations, for instance, the one cost number generated represents only one possible scenario based on multiple variables and assumptions (Anderson et al. 2006; Paulsen et al. 2008). It is important to note that those variables and assumptions are not all controllable and quantifiable (Anderson et al. 2006). There are many factors that affect the increase in cost estimates such as an inadequate project scope at the time of planning, insufficient information on the extent of utility relocation requirements, insufficient knowledge of right-of-way costs and locations, required environmental mitigation costs to avoid certain impacts, traffic control requirements, work-hour restrictions, and external financial and economic factors (Anderson et al. 2006; FHWA 2004). Thus, cost estimating is inherently prone to risk (FHWA 2004).

Rather than using a single number to represent project cost, probabilistic approaches that involve simple or complex modeling based on the relationships among cost, schedule, and events related to the project, are used to assess uncertainties and related risks, and translate these risks into costs (Anderson et al. 2006; Molenaar et al. 2010). Such techniques allow uncertainty to be incorporated into the cost estimate giving a cost range and also an associated likelihood for each value within the range (Maher and McGoey-Smith 2006). Cost estimates are comprised of two components: the base cost and the risk (or uncertainty). Base cost is the likely cost of the project if no significant risks occur. It is usually developed using Historical data and/or cost based estimating techniques together with the expert's judgment. After determining the base cost, a list of uncertainties is created of both opportunities and threats to assess the risk in the project. This process replaces the generally defined contingency with explicitly defining risk events and their probability of occurrence and the consequences of each potential risk event (Molenaar et al. 2010).

Each DOT addresses contingency differently; either with a fixed percentage, a sliding scale, or a structural/formal analysis. Although most DOTs factor contingency into their estimates, as per NCHRP Report 98, only one DOT performs a detailed risk analysis. Their cost estimates are created by removing all contingencies from the line items and then cost risks, schedule risks, and opportunities are identified and evaluated. The DOT combines the base cost and the risk assessment and applies critical path methodology and Monte Carlo simulation to generate ranges for expected project cost. Thus, the DOT's method applies contingency factors based on an in depth analysis of possible events and their probability of occurrence. This is in addition to recognizing potential risks early in project development process which enables proactive response to those risks once they occur (Anderson et al. 2009). NCHRP 8-36/Task 72 reported that Maryland state also concluded that "using a risk-based approach to cost estimating will be the easiest to try to implement (improvements to the cost estimating and estimate management process), and also a way to get the most improvement without changing around the whole process."(Paulsen et al. 2008).

There are many reports developed in different highway organizations dealing with cost estimation and risk management. In 2004, the FHWA issued technical guidance for final engineer's estimates called, "Guidelines on Preparing Engineer's Estimate, Bid Reviews and Evaluation" which aimed at outlining recommended procedures for preparing engineer's estimates and for reviewing bids prior to concurrence in award (FHWA 2004).

The AASHTO Technical Committee on Cost Estimating (TCCE) developed the Practical Guide to Cost Estimation to synthesize the current best practices used nationally to help State Transportation Agencies draw from the others' experiences and adopt the practices that are most appropriate for their situation. The guide gave practical guidance on preparing final estimates, including the procedures followed (AASHTO 2013, FHWA 2004). NCHRP 8-36 had a similar objective when they developed a guidebook for cost estimation improvements at DOTs. The objective of the guidebook is to provide insights on how DOTs can implement organizational and cultural changes strategies to improve the accuracy and consistency of project estimates. The guidebook helps DOTs learn from the experiences of other states that are working on improving their cost estimating and estimate management processes and what they are doing to improve them (Anderson et al. 2007).

Under NCHRP 8-49, a guidebook was developed to present approaches to cost estimation and management that can be used to overcome projects' cost escalation and support the development of accurate project estimates throughout the project development process. The guidebook provides strategies, methods, and tools to develop, track, and document more realistic cost estimates during each phase of the process (Anderson et al. 2006).

With transportation professionals' continuous emphasis that Right of Way (ROW) cost estimating and management of ROW estimates are critical to achieving consistency and accuracy in project cost estimates, NCHRP 8-49 undertook a second phase mainly addressing ROW cost estimating. The project developed NCHRP Report 625 guide which presented a practical and effective approach for developing right-of-way (ROW) cost estimates, and tracking and managing ROW cost during all phases of project development (Anderson et al. 2009).

On the same lines, NCHRP 8-60 aimed at an in-depth treatment of methods and tools necessary to implement a specific strategy for risk management. NCHRP Report 658 guidebook was published to provide guidance to state departments of transportation for using specific, practical, and risk-related management practices and analysis tools for managing and controlling transportation project costs. One of the key lessons learned from this project was to communicate cost uncertainty in project estimates by using ranges and/or explicit contingency amounts (Molenaar et al. 2010).

In recognition of the fundamental and strategic importance of cost estimating, Washington State Department of Transportation (WSDOT) developed *Project Risk Management: Guidance for WSDOT Projects* that helps project managers and project teams specifically in WSDOT projects with their risk management. This guide includes a consistent methodology for performing project risk management activities and information on how project risk management fits into the overall project management process at WSDOT. The guide stresses the importance of measuring risks to determine an accurate cost estimate range. It is thus aimed at setting a consistent procedure for identifying the project's uncertainties and risks rather than basing them on the estimator's experience and best judgment (WSDOT 2010). WSDOT has a policy to conduct risk-based estimating workshops for all projects over $10 Million. These workshops aim at helping project managers control scope, cost, schedule, and manage risks for all projects (WSDOT 2010; AASHTO 2009). WSDOT developed the Risk-Based Estimating and Management model for Small Projects tool to make the implementation of risk-based estimating easier (Anderson et al. 2007).

1.1 Disadvantages of Traditional Estimating

Traditional cost-estimating approaches usually develop a best scenario estimate, which is seldom the case in practice (Reilly et al. 2004). It should be noted that a cost estimate should not be one single number. It is very much dependent on the project development phase (WSDOT 2007). As reported by the U.S. Deputy Energy Secretary Bruce Carnes in 2005 (Gabel 2006):

"We have, perhaps too often, taken a best case scenario and then committed to delivering on it, when in order to deliver on it, we have to have seven or eight miracles occur. We're going to be a lot more deliberate and a lot more careful about what we say we can do at what cost and when we can do it."

Traditional deterministic estimating techniques are usually appropriate for predicting costs of projects with small variability. Although this is a quick process requiring minimal resources, it lacks control on risks involved in each cost line item, as risk is not quantified specifically (AASHTO 2009). This approach synthesizes varying underlying assumptions into one estimate for cost based on many sources and data points, which becomes very difficult to control as the project develops (AASHTO 2009, Booz Allen Hamilton 2005).

The actual cost of a project is affected by many variables that can influence the estimated cost significantly. In DOT project estimations, for instance, the one cost number generated represents only one possible scenario based on multiple variables and assumptions (Anderson et al. 2006, Paulsen et al. 2008, AASHTO 2009). It is important to note that those variables and assumptions are not all controllable and quantifiable (Anderson et al. 2006). Those variables can lead to significant variability in the project cost estimate (AASHTO 2009).

There are many factors, such as an inadequate project scope at the time of planning, insufficient information on the extent of utility relocation requirements, insufficient knowledge of right-of-way (ROW) costs and locations, required environmental mitigation costs to avoid certain impacts, traffic control requirements, work-hour restrictions, and external financial and economic factors, that affect the increase in cost estimates (Anderson et al. 2006, FHWA 2004). Thus, cost estimating is inherently prone to risk (FHWA 2004).

1.2 Risk-Based Cost Estimating

Probabilistic estimating captures risk variability associated with those assumptions and characterizes them through a range of estimated costs (AASHTO 2009). Rather than using a single number to represent project cost, probabilistic approaches that involve simple or complex modeling, based on the relationships among cost, schedule, and events related to the project, are used to assess uncertainties and related risks, and to translate the risks into costs (Anderson et al. 2006, Molenaar et al. 2010, Booz Allen Hamilton 2005).

Probabilistic estimating was developed as an improvement to the deterministic cost estimation approach to focus better on key risk items and the effect of project uncertainty on project capital cost. (Booz Allen Hamilton 2005). Probabilistic estimating also allows uncertainty to be incorporated into the cost estimate giving a cost range and also an associated likelihood for each value within the range (Maher and McGoey-Smith 2006).

Cost estimates are comprised of two components: base cost and risk (or uncertainty) (Molenaar et al. 2010, WSDOT 2010). Base cost is the likely cost of the project if no significant risks occur. Base cost is usually developed using historical data and/or cost-based estimating techniques together with the expert's judgment. After determining the base cost, a list of uncertainties is created for both opportunities and threats to assess the risk in the project. This process replaces the generally-defined contingency with explicitly-defined risk events and their probability of occurrence and the consequences of each potential risk event (Molenaar et al. 2010).

Risk-based estimating merges risk management and traditional cost estimating to develop a cost estimate that quantifies risk into the project cost estimate. Risk-based estimating recognizes risks as threats or opportunities together with the variability in the base cost estimate. When risk events reduce project cost, they are considered opportunities, while, when they increase the project cost, they are considered threats. Risks, when triggered, may result in significant cost increases when they are threats or cost savings when they are opportunities (AASHTO 2009, Reilly et al. 2004).

Risk-based estimating, in addition, allows reasonable control over the project cost (not achievable using deterministic cost estimates) by employing the project risk management approach (AASHTO 2009). Figure 2 shows a comparison between traditional and risk-based estimating techniques.

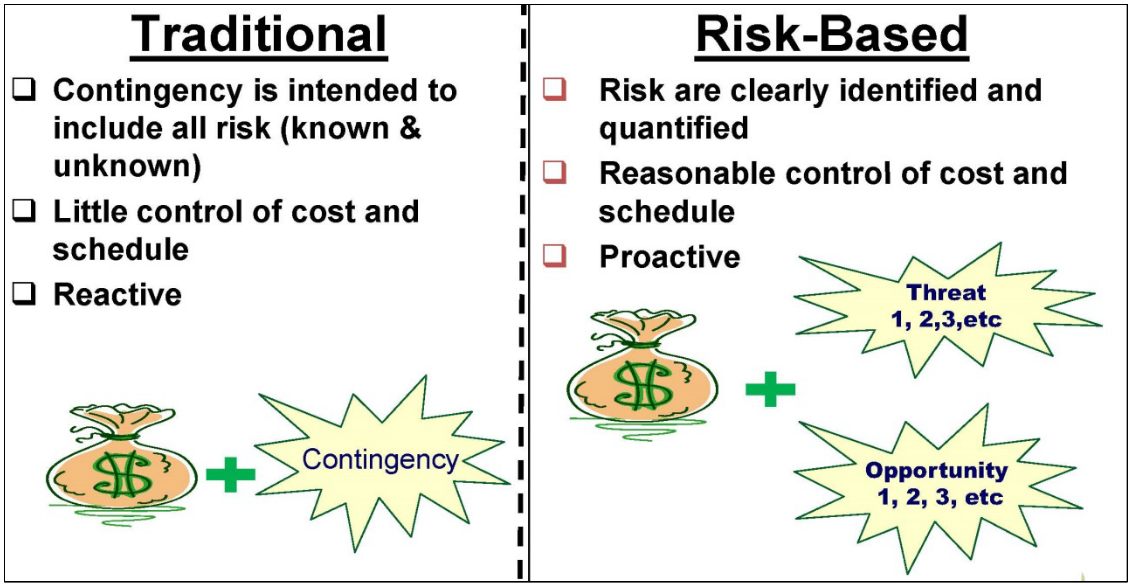


Figure 2. Comparison of Traditional versus Risk-Based Estimating Techniques (Davis et al. 2012)

When a detailed risk-management approach is utilized in developing the project estimate, many benefits are achieved for both the project team and the stakeholders. The project team gains a better understanding of the potential risks and utilizes this information to prioritize the resources and efforts to manage those risks better to achieve the best possible outcome (AASHTO 2009, Long n.d.). The information gathered from this process can also be used for better communications and reporting. Stakeholders benefit by knowing the true forecasted project cost. It is important to note, however, that risk-based estimating is employed for a full risk evaluation given that it creates greater expectations of certainty in public perception of the project cost and thus needs to be controlled continuously (AASHTO 2009).

The amount of effort, time, and resources devoted to risk-based estimating should reflect the size of the project (WSDOT 2010, AASHTO 2009). For major projects, an independent team of experts should be assigned to review the project estimate. For small projects, an experienced estimator can develop an risk-based estimating by obtaining input from the project team (AASHTO 2009).

The Minnesota Department of Transportation (MnDOT) has questioned their use of risk-based cost estimating techniques. Specifically, what techniques, if any, are currently utilized within MnDOT, and after learning what other DOTs do, are there practices that can be implemented at MnDOT?

Chapter 2. Methodology

For the purpose of this research, a state of the practice examination was used to identify organizations that employ risk-based estimating and their current practices, interviews were conducted with MnDOT personal to gain deep understanding of how risk-based estimating is implemented in MnDOT. A workshop with MnDOT employees involved in estimating was conducted to confirm that the research recommendations align with MnDOT business practices and gain feedback from the anticipated implementers of the risk-based estimating technique. Finally, guidance on the implementation of a few select ideas are provided. Figure 3 summarizes the major tasks for this research.

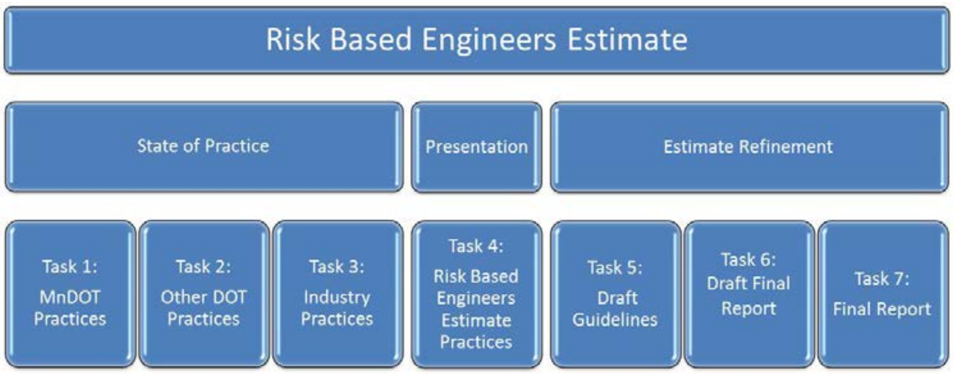


Figure 3. Research Process

2.1 TASK 1: MNDOT PRACTICES

This task aims to explore the current practices within the Minnesota Department of Transportation (MnDOT) regarding the estimation for design-build projects and other projects at approximately 30 percent design. This task included looking at risk, contingency, quantities, and other variables. A closer look at the estimating practices employed at different MnDOT offices offers the opportunity for better communication between the various offices, sharing of ideas and knowledge, and possibly standardizing the estimating methods employed, as applicable.

2.2 TASK 2: OTHER DEPARTMENT OF TRANSPORTATION PRACTICES

For this second project task, the researchers explored current practices at other state DOTs regarding the estimation practices for design-build projects and other design elements at approximately 30 percent design. This work included looking at risk, contingency, quantities, and other variables. This task included collecting and documenting policies and procedures from DOTs across the US.

2.3. TASK 3: INDUSTRY PRACTICES

For this third project task, the researchers explored the current industry practices regarding the estimation practices for design-build projects and other design elements at approximately 30 percent design. This work included looking at risk, contingency, quantities, and other variables. This task included collecting and documenting policies and procedures and requesting suggestions for improvements.

2.4. TASK 4: PRESENTATION/MNDOT WORKSHOP

In Task 4 the research team presented MnDOT personnel with the findings from the first three tasks. From this information MnDOT selected up three ideas/concepts/tools for further investigation to develop guidance specific for MnDOT.

2.5. TASK 5: DRAFT GUIDANCE

During the fifth task the research team developed draft guidance for using the methods selected in Task 4. This guidance does not include tool development nor does it include implementation by MnDOT.

2.6. TASK 6: DRAFT FINAL REPORT

A draft final report is prepared, following MnDOT publication guidelines, to document project activities, findings and recommendations.

2.7 TASK 7: FINAL REPORT

During this task, technical and editorial comments from the review process are incorporated into the document as appropriate. Reviewers will be consulted for clarification or discussion of comments. A revised final report will be prepared and submitted for publication.

Chapter 3. Minnesota Department of Transportation Practices

To achieve the objective for the task, exploring current risk-based estimation practices within MnDOT, structured interviews were conducted with estimating personnel in different MnDOT offices including the Central Office (CO), Minneapolis/St. Paul Metropolitan District, and Districts 1, 7, and 8, as outlined in Table 1.

Table 1. Interviewee information

Office/District	Position	Years of Experience	
		MnDOT	Estimating
Central Office (CO)	State Estimates Engineer	30	5
Minneapolis/St. Paul Metropolitan District	District Estimator	14	4
District 1	Program Support Engineer	30	11
District 7	Engineering Specialist - District Estimator, District Utility Coordinator, and Plans Manager	34	4
District 8	Cost Estimator/GIS Coordinator/ Consultant Contracting Coordinator (40-50/10-15/40-50%)	27	10

Interviews were conducted during July 2013. Some were conducted face-to-face while others were phone interviews. Interviewees were sent the questions prior to the interview (Appendix A). Interview questions included general information about the participant, office's specific estimating development process and role, risk management techniques employed, challenges faced, and suggestions for improvements in the estimating practices. Interviewees were also requested to share the applicable policies, procedures, manuals, and estimating worksheets that are being used at their offices.

3.1 ESTIMATING TECHNIQUES

This section discusses how the different interviewees define the difference in definition and implementation of risk-based estimates, lump-sum estimates, scoping estimates, and estimates done at 30% design. Information covered in this section reflects responses to the following interview questions:

Question 3: How do you do risk-based cost estimates? (if it's done)

Question 4: How do you do lump sum estimates? (for design-build projects and traditional projects)

Question 5: How do you develop estimates for projects that are about 30% design (or less)? What type of estimating is used?

Question 6: How do you define scoping estimates? Are they the same as the 30% design estimates? How do you develop them?

3.1.1 Risk-Based Cost Estimates

Risk-based estimating is defined as the probabilistic estimating that captures risk variability associated with assumptions made and characterizes them through a range of estimated costs. Rather than using a single number to represent project cost, probabilistic approaches that involve simple or complex modeling based on the relationships among cost, schedule, and events related to the project are used to assess uncertainties and related risks and translate the risks into costs.

Based on the interviews conducted, the following bullet items report use of some sort of risk-based estimating, further discussed in this section. However, a more detailed discussion of the different ways they add contingency percentages to address risk factors are discussed in a later section of this document.

- The **CO** only considers risk in design-build at 30% design. In design-bid-build, it should have been accounted for and there is not much risk left.
- In the **Metro** office, there is one PM who employs Monte Carlo simulation on some projects and documents risk. Having mentioned that though, Metro reports that the more time spent by the PM on a cost estimate, employing sophisticated techniques, does not necessarily mean a better estimate.
- The **District 1** office adds a percent contingency and employs a probability and impact matrix. Percent contingency (mostly for paving projects) is evaluated so that, for example, if the pavement has a range of +/- inches, the contingency starts at 20% and then, when more information is obtained, this number is reduced. For more complicated projects, the probability impact matrix is mostly used. It is based on judgment of likelihood and impact. The percentage added is also added to line items.
- In **District 7**, during the scoping process, risks are determined and included in the contingency on the TPCE. The amount of effort in determining, prioritizing, analyzing, and quantifying the risks depends on the complexity of the project and the amount of time that the PM has to complete it.
- **District 8** usually uses a small risk worksheet with percentage-based contingencies. The estimator does their own risk assessment, like adding 5% contingency to the letting total cost and also for posting it. By the time the project is in year 1 and 2 of the STIP, risks would have been retired as they are documented separately so they can be managed. Assumptions and options are all documented (i.e., whether 2 inches or 3 inches was used), as well as the probability and the impact. This is also sometimes done in some line items. However, in regular program projects such as preservations, they are quite simple, so a straight contingency percentage is applied to the estimate. A little higher value is applied for more complex projects. The percentages vary based on how truly stable the scope is, as scope could sometimes be as vague as being communicated verbally. In those cases, assumptions are made, and based on very loose scope definition, a contingency is added knowing that scope could change drastically. Risk registers are also used with some mitigation factors put in. So, the office regularly employs risk management tools to provide better cost estimates.

3.1.2 Lump-sum Estimates (Design-Build and Traditional Projects)

- **CO:** MnDOT design-build projects are not truly lump-sum projects; all projects contain lump sum line items; some of which are percentages of the total cost. The design team is required to submit the items that are included in their lump-sum estimate and the quantities if known. Although the CO looks at bid history values, it gets very dangerous with lump-sum items. Clear and specific information pertaining to the item being estimated is important. Examples of lump sum cost estimates obtained from design functional groups include haul-salvaged material, lighting, mobilization, temporary construction, and traffic control. For those items, the CO requires the designer to give backup information on each line item using a detailed spreadsheet. In some specific cases a functional group may keep track of contractor prices on their own and provide CO with a lump-sum price, one example of this is the lighting functional group. District estimates usually provide the CO with the item quantities used for estimation.

- **Metro:** Length-width-depth (LWD) is a cost/mile estimating technique would be a lump-sum estimate (because it is not possible for the CO to match up bid items to it).
- **District 1:** Lump-sum estimates are usually based on historical grouping. There are not many of these though (for a couple of complex projects a year). Things start to look the same even if they are relatively different (e.g., culverts). LWD (cost/mile) that Metro uses is not used by District 1. For District 1 projects, it is easy enough to do the computation, as most information is known and there is no need for LWD. The Metro office has lots of unknowns compared to District 1.
- **District 7:** For design-build projects, there are basically two major items that they do lump-sum estimates for: earthwork and pavement structure. A percentage for all of the other work included in the project is then added. If the design-build project is urban, a cost for hydraulics based on other related projects (cost per station) could also be added. For traditional projects, lump-sum pay items are quantified a number of different ways. If supplied from a different functional group, district estimators request a breakdown for the lump-sum pay item (such as traffic, specialty items from the CO) or look up previous projects with the same pay item and update the breakdown costs using current costs, or the estimators break down the cost themselves.
- **District 8:** The full estimate also includes some items on a lump-sum basis like signal, railroad crossing, and lighting. They do create some element costs like detailed design of quadrant of ADA compliance, culvert replacement, etc. As close as they get could be called parametric cost estimating (short notice estimate for a local government, special funding, etc.). However, they don’t do those a lot (once every two years or so).

3.1.3 Estimates for 30% (or less) Design Projects

- **CO:** 30% designs are usually design-build. In cases other than design-build (not very common), for example with a 20% design, the CO requested an “independent cost estimate” for a 12 mile project with no information on the Materials Design Recommendation (MDR), earthwork, and drainage, where the consultant was asked to do it independently of the way the district has done it. In this case, quantity for different concepts had a low range estimate and a high range estimate (with comments for the assumptions that were made). Fixed contingency was added for both options (not a range). The CO is not aware if design-bid-build at districts use risk registers.

- **Metro:** Most of the estimates done in Metro are done before getting to a 30% plan complete level, which is four years out, when the project first enters the STIP. Believes that the department would like to get to a point where the plans are 30% complete when they enter the STIP, but there are not enough resources at this time, so this is where the district uses the LWD method.
- **District 1:** Generally computes quantities based on preliminary recommendations from resource groups such as materials, hydraulics, bridges, etc. Prices are bid-based or cost-based. If there are no resource recommendations, historical projects or adjusted cost per mile are used.
- **District 7:** Mostly uses the SEQ at a 30% design estimate but these usually do not get developed until later in the design stages (at least 60%, when earthwork is supposed to be done), especially with more complex projects. Until this stage, the estimating office would depend on the scoping estimate.

3.1.3 Scoping Estimates

- **District 1** explains the difference between scoping and 30% design estimates as follows: "At scoping, the resource groups provide recommendations with limited field investigation, but the project is pretty well defined. At 30%, we would have recommendations from the resource groups and a reduced contingency."
- **District 7** defines scoping estimates as creating a baseline project cost that includes risk and contingency to be used when developing the STIP. On comparing between the scoping and 30% design estimates, the office reported, "If there is no 30% design estimate developed, the scoping estimate is used, which is hopefully being reviewed yearly to lower contingency."

3.2 RISK MANAGEMENT PROCESSES EMPLOYED

This section discusses how the MnDOT estimators incorporate risk in the estimating process and any formal techniques employed. Information covered in this section reflects responses to the following interview questions:

> *Question 7: How is risk, generally, addressed in projects? Is a formal Risk management process employed?*
>
> *Question 8: Are there any specific cost related risk management practices that you employ based on the size/complexity of the project?*
>
> *Question 9: Describe how risk has been incorporated in the estimating practices. Contingency? Specific percentages employed as contingencies in different work items… How does the estimating team generate their assumptions? On what basis?*
>
> *Question 11: Do you track the assumption made throughout the different project development phases? If Yes, how? Who is involved? Are these assumptions carried over into project cost controls during final design and/or construction?*
>
> *Question 14: Who is usually involved in the FHWA CRA/CEVP reviews? How many have you been involved in so far?*

- As reported by the **CO**, for design-build projects, after design-build estimates are produced and bids are received, the CO tries to evaluate their contingency and ask some general questions to the contractor to see what they had in the lump sum. Contingency started as a judgment call between the CO estimating office and the PM, but more guidance has been developed now with resources such as risk and contingency guidance, the risk register, the risk checklist, and the contingency chart. The plan is that, with the next design-build project, a risk register will be developed and used to be more consistent on the contingency assumptions. The CO estimating group also usually holds a risk and contingency meeting with the PM/design team before finalizing the engineer's estimate to make sure that risk and contingencies make sense. For larger projects ($10 to 20 million), 30% design projects, or IDIQ, formal meetings are held. The CO is not involved in bridge estimates (the Bridges functional group provides their bridge estimates).

- The **Metro** office reported that, in some cases, they might do two estimates for two different options where the two estimates are subtracted and the difference is added to the two estimates as a contingency. Percentage of risk, in general, is usually added using the form from the cost estimating technical reference manual or based on judgment. The risk register should be used on projects larger than 20M, as more work is being done on them while, on a simple project, what's being done is good enough.

  The biggest risk in Minnesota is grading (swamp, rock); watershed is another big risk (impervious, ponding, etc.).

  Risks are usually not retired until letting or after.

- **District 1** rarely uses a formal process like risk registers. It would be great to get resource information earlier on riskier projects and to have the PM serve actively and manage risks and own them making it easier to deal with them early. It would also be great to have them early on to manage on a program level rather than on a project level. However, at the program level, we can then retire risks and see what money is left and that all is spent. In the district, the estimating office tries to involve the PM and designer by talking about the risks they may think would occur. Risk registers, percent contingency on paving projects, and the probability impact matrix are used on more-complex projects. The estimating team tries to get resource information early and plan contingent programmatic adjustments ("plan B") for riskier larger projects.

- **District 7** usually identifies risks in the scoping process where it is quantified, and estimated. The PM will also add a small percentage for any unknown risks. A formal risk management process is usually used on large, more-complex projects, especially if there is a value engineering (VE) study. Based on the PM's time, the level of detail entailed in the risk management process is determined.

  On specific measures taken for complex projects, District 7 reported that the percentage of contingency that is used is higher for large complex projects and lower or 0% for small overlay projects.

  Project scoping meetings, which include all functional groups, are also held. Any known risks are identified and discussed in these meetings and are included in the scope and added to the contingency column on the TPCE. An additional percentage (like 5%) will be added for any unknown risks. In addition, specific percentages are employed as contingencies in different work items (a basic mill and overlay may not have any percentage of contingency). There is not any preset specific percentage; it’s a judgment call.

- **Federal Highway Administration (FHWA) Cost Risk Assessment/Cost Estimate Validation Process (CRA/CEVP):** When asked about FHWA CRA/CEVP reviews, all interviewees reported that they are either not involved or unfamiliar with those reviews. The CO reported that the project development team is usually the ones involved, not the estimating office so much (but sometimes they are as experts). District 1 reported that usually the PMs and consultants are involved.

3.3 PRESENTATION OF TOTAL PROJECT COST ESTIMATE TO PUBLIC

This section covers the various ways the different offices present their estimates. Information covered in this section reflects responses to the following interview question:

Question 12: How do you present the total project cost estimate to the public?

- **The CO** presents the EE post-award to the public with all details.
- **Metro** reported this is currently an ongoing discussion.
- **District 1** presents their estimate depending on the project. The letting cost is still most often the number that’s presented.
- **District 7** creates one-pagers, which describe the project, timelines, risks, and costs, for the legislature and the public.
- **District 8** still struggles with how to communicate the estimated number. Letting has always been perceived to be construction, yet it includes other items such as engineering. When reported to STIP, that is basically construction dollars (with no engineering costs, so it’s not TCPE). There is some improvement in this area with the legislature as they are starting to talk about three elements of cost (construction, design, and right-of-way/ROW). They figured there are other items that should be included, so they started to add a percentage for these items. As for reporting ranges, there is resistance to accepting a range. The department policy is to report anything outside of STIP in a range.

3.4 COST ESTIMATING TRAINING FOR MNDOT PERSONNEL

This section covers the various training resources available for MnDOT estimating personnel. Information covered in this section reflects responses to the following interview question:

Question 13: What cost estimating training is available to MnDOT personnel?

- **The CO** stated that they use on-the-job training. Other resources are cost estimate and management training from several years ago, the Cost Estimation and Cost Management Technical Reference Manual, and the MnDOT NCHRP RFP training module. Although those manuals provide good references, the only challenge would be when using different project delivery methods where not a lot of references are available. However, the CO is working on standardizing the estimating practice in this respect to address different project delivery methods.

- **Metro** reported that they conduct training every spring for new PMs. PMs attend a kickoff meeting where they are introduced to the district estimating process.
- **District 1** employs the MnDOT Project Management website (www.dot.state.mn.us/pm/) and the Cost Estimation and Cost Management Technical Reference Manual as training tools.
- **District 7** uses the Risk Management training class offered by ESI International (www.dot.state.mn.us/pm/learning.html). MnDOT Regional Shared Service Centers are also available resources to answer questions or ask for help. The MnDOT Project Management website is also used by District 7 and is full of information together with the Cost Estimation and Cost Management Technical Reference Manual.
- **District 8** uses on-the-job training. A PM training process has been developed; however, cost estimating is not as high on the list.

3.5 CHALLENGES, BARRIERS, AND SUGGESTIONS FOR IMPROVEMENT

Information covered in this section reflects responses to the following interview questions:

Question 15: What are the current challenges in cost estimating practices employed?

Question 16: What barriers do you foresee in implementing a formal, uniform estimating process at MnDOT? How could those barriers be reduced?

Question 17: Do you have any suggestions for improvements in current cost estimating practices?

Question 18: Does MnDOT need a different estimating process for accelerated projects, design-build projects, innovative finance projects, etc.?

3.5.1 Challenges

- **The CO**'s major challenge is the communication between the CO and the various districts and consistency between the estimating practices.
- **Metro**'s major concern is to have statewide consistency on estimating. Employing SEQ does not necessarily ensure better quality.
- **District 1** challenges include program fluctuations. In addition, inflation rates become a challenge given it is difficult to know where to spend the money if projects are overestimated. "Sometimes, overreacting to price fluctuations such as oil could cause the same problem; we have to be careful about not overreacting."
- **District 7 c**hallenges include time, responses/decisions from other functional groups, and PM staffing level.
- **District 8**'s main barrier is resources.

3.5.2 Barriers to Implementing a Formal, Uniform Estimating Process

- **The CO's** major barrier for implementing a formal uniform process is that some offices are attached to the method they're used to, such as districts employing the LWD method.
- **Metro** sees value with the design-build form (developed by the CO) on larger projects, yet it takes time and resources and may not fit best to their projects. In addition, it could be used for design-build projects, yet LWD would still serve as a good check. There should also be more emphasis on VE, risk register, and Form 14.
- **District 1** respondents stated that there is not a magical estimating tool and that a formal, uniform process is not really possible. "There is no tool that can do all the work. It takes work and experience and there is no one easy solution. However, the TCPE form is unified for all districts to report formally."
- **District 7** stated that barriers could be that some estimators/PMs may have more time to utilize all the appropriate forms and templates for a more accurate estimate and others may not. In addition, differences in interpretation can cause differences in estimating uniformly. District 7 also noted differences in geological material throughout the state and location. "Some people use the average bid prices for the latest year and some use the historical prices. Also, estimators don't always think about things that could increase or decrease the cost of an item: plant and pit locations, borrow pits, low versus high quantities, fuel costs, unique pay items, etc."
- **District 8** is not sure whether the complexity and value of cost estimating is truly understood. Upper management thinks tools like Monte Carlo estimation are going to get better estimates; however, that's not what they would necessarily do. There is always a 5 minute or 5 week estimate. The question is how much time spent coming up with an accurate estimate is worth it. "Also, there should be more acceptance of what we can and cannot do. A huge challenge we might face is if design-build and lump sum were to be included. It is not anticipated that those become less statewide unless there is some significant increase in funding that needs to be spent quickly."

3.5.3 Suggestions for Improvements

- **The CO:** Suggests better communication between the different offices and a unified generic estimating tool. The form developed for design-build can be tailored and used on all kinds of projects.
- **Metro:** The risk register should be used on projects larger than 20M as more work is being done on them, while, on a simple project, what's being done is good enough.
- **District 1:** Push to get resource information early for riskier projects so we can do better risk management. Everything should be done year-to-year and better ways to retire and control risks should be employed. In addition, more commitment and education about cost estimating is required.
- **District 7:** Suggests having annual visits with the districts to cover the Project Management website, highlighting some of the forms and templates and answering questions. After visiting the districts, post some of the questions and answers under FAQs on the site. Also

during these visits, have a short demo on how the CO estimators estimate a project for letting. Templates that are in place now should be taken, edited, and updated to generic style. Everyone would be using the same ones. Estimators should be trained on how to estimate certain items or have a location on the web for a reference. It would be nice to have a page either on the project management or estimating sites where estimators or PMs could post unique situations and the results or ask others questions. Someone may have had the same problem, issue, or question and gotten the answer.

- **District 8:** Sees great room for improvement just by comparing notes with other districts. A better job should be done on gathering and storing historical data, and making it usable. Although data is gathered, it lacks information and proper descriptions and includes a lot of peripheral non-important information that makes it lack context. It is not sorted out for estimators. "Line items are not coded so that we know what it is. Looking at final or letting cost versus base: Sometimes there are three or four SPs in one letting, which once mixed up, it's difficult to extract. It would be nice to be able to run a filter for all overlays that were more than one mile to get a proper average. A lot can be done to improve our estimating tools and make less-experienced estimators better by giving better information to start with."

3.5.4 Need for a Different Estimating Process for Accelerated Projects, Design-Build Projects, Innovative Finance Projects, etc.

- **District 1** thinks we need a different estimating process for accelerated projects, design-build projects, and innovative finance projects in terms of risk management. Generally, we just need to come up with a vision and the resources needed to estimate some quantities. Sometimes that's a challenge.
- However, as per **District 7,** there needn't be. The most important aspect would be determination of risks.

3.6 OFFICE RESPONSIBILITIES AND ESTIMATING PROCESS

This section covers the different offices' responsibilities, as reported by the interviewees, and their estimating process development. Information covered in this section reflects responses to the following interview questions:

Question 1: Please explain briefly the project development process and estimates. Please talk about your involvement.

Question 2: Is the estimating process consistent state wide and for all projects?

Question 10: Who is typically involved in the estimating process?

3.6.1 Central Office

- The Central Office (CO) is responsible for the final engineers' estimate (EE) at 100% design prior to letting; they step in at the end of the process. Earlier estimates are done by the different districts. Final EE is placed on every procurement method project let through CO.
- The CO is not involved in the scoping estimate or in risks and how assigned, mitigated, and retired. This may lead to inconsistencies between the different districts, as well as the CO. With all project types, final design estimates are received from districts prior to bidding. Part

of the bidding process is estimating, where the CO reviews plans and develops the final engineer's estimate. This is the estimate used later to compare to the bid prices received.

- Part of the CO role is also bid analysis.
- For design-bid-build projects, communication between different offices is usually less than it is with other project delivery methods. However, the CO also works closely with districts in earlier stages on high profile, large projects, sometimes by providing information/assistance on work bid history, specialty items, and lump-sum estimates at the 60% design phase.
- A cost-based estimating methodology is used employing the American Association of State Highway and Transportation Officials (AASHTO) Cost Estimation System (CES) software. The CO always uses the data on current labor, crew sizes, material cost, pit location, and trucking costs for every job. Although the production rates are from the 1990s, they still use them. All items not included in the CES software, such as traffic and signs, are obtained from bid history.
- The CO adopts Form 14, which is a living document, available online, http://www.dot.state.mn.us/designbuild/DBmanual.html, as the Project Estimate Template, for design-build projects. The form is set up so it can be used for all contracting methods. (Division 2 "Construction" in the "Spec book" was used as the template to develop it.)
- With design-bid-build, the CO has a live data retrieval table where data can be obtained by location.
- The final EE developed are within 10% of low bid most of the time. Outliers are seen more on specialty projects.
- Commenting on alternative project delivery methods employed, indefinite delivery/indefinite quantity (IDIQ) was used for the first time in 2013. There is no mobilization item in those contracts (special IDIQ traffic control items), so they can be pre-priced as applied to different situations (two lane, shoulder, etc.). The remaining items are design-bid-build items, but they are coded to the job as IDIQ because the mobilization, risk, and inflation are buried in every item. Most are about three years in length. The construction manager/general contractor (CMGC) project delivery is currently being used on two MnDOT projects. Risk workshops are held at design milestones. MnDOT is looking at ways to price these risks.

3.6.2 Metro

- The project development/estimating process usually starts in March, with project needs identified. April through June is when the paperwork is prepared. August through September is when projects are presented. October through December is when inflation charts with construction index (CI) incorporated, State Transportation Improvement Program (STIP) description, and a project number are given. Estimates move from STIP to letting with no estimate revisions at 30, 60, or 90% design.
- In Metro, SEQ and length, width, and depth (LWD) sheets, which are based on pavement areas, are used. The estimator fills in the areas with different depths of pavements and then uses an LWD factor (pavement thickness per mile). An LWD factor is an order-of-scale unit cost generated from historical project data to build the major pavement construction items. Other project features that have cost, besides pavement, are also identified and recorded

separately on the same sheet to complete an estimate. The database is searched for items such as mobilization and traffic control. A multiplier is used, which is based on the bid results tracked every year; the construction index is also used to bring it to today's dollars based on data developed from projects based on Metro (basically 24 projects), not statewide. An LWD cost multiplier is selected to closely match project type and scope and is in today's dollars. Then, the Metro office starts to include items that are not included in the multiplier (bridge, water resources, etc.) from other functional groups. Once this estimate is complete, it is reviewed with the project manager and risk is assigned a dollar amount.

- Metro has a scoping database that explains the different decisions made to include/exclude items in a project. Letting results are also reviewed later to figure out any items not included in the estimates (e.g., American Disabilities Act/ADA requirements for curbs).
- Estimators meet with the PM when revising estimates. The PM is included on the estimate starting from the scoping session, when all the needs are documented and related to risk. Thus, when the project starts, the team has a clear idea what the needs are, where more risk was assigned, and what money is left to be used.
- Form 14 is used by Metro only on design-build projects. It should be expanded to projects that are value engineered.
- In general, Metro thinks they are overestimating the engineering cost, which is a percentage added on top of construction cost.
- The STIP includes State Projects (SPs), which are individual projects that might be lumped up into one project that gets let. These require good tracking as, if the baseline of the project changes, the Metro office would document what version it was. Projects usually go through five years and thus there should be five versions with estimates being updated annually to account for inflation, CI, etc. The biggest problem becomes retiring the risk, which is difficult to retire if not documented. Usually, if risk percentage added is higher than 10%, the PM should have reported it. What's documented, however, is very relative to the PM. Each year, PMs present the scoping documents to the scoping committee where they look at them and revise the scope and, then, the estimating office goes back to do it again.
- There is usually a lot of push back from PMs as they set the budget and want the estimator to have it this way.
- Estimates performed at the Metro office are never meant to be a letting tool; it is just an estimate.
- "We learn from history, like in cases when we started with unbonded concrete or roundabouts; our estimates were way off but became better when they became more common types of projects."
- Metro uses the CO Form 14 only for design-build projects. SEQ is a quantity check. The estimates done at the CO are really not estimating given that, by that time, they have full plans and risks are incorporated. More of what is done is just adjusting a unit cost. "I see value with the design-build form on larger projects, yet it takes time and resources." It could also be used for design-bid-build projects, yet LWD would still serve as a good check."
- Ranges are not communicated as the process is always in a rush, yet, every year, "we are

backfilling as there is new money, projects move forward and scope a year out, and never get caught up. For example, the Hastings bridge project moved from 0% to 100% design in six months, where it skipped this whole process and went into being built."

3.6.3 District 1

- In District 1, the estimating office is responsible for district cost estimating and construction project programming through which the initial estimate (scoping estimate) and updates every year, based on general parameters defined by the PM and functional group, are prepared. A worksheet that helps compute quantity is used. Other worksheets are also updated for prices (i.e., recyclable materials). Design at the scoping phase is at 0%.
- The office is also involved in price-based estimating (cost-based). A computation sheet that is cost based on known items is used, especially when we don't have historical data to reference.
- On assumptions made, District 1 reported that they have a scoping process and documents to track assumptions and changes and assumptions are also tracked in the Estimate file.

3.6.4 District 7

- Once the projects are determined, the PM completes the charter, scope, and total project cost estimate (TPCE). The office tracks these documents, completed, signed, and put into the MnDOT Electronic Document Management System (EDMS) by January (March at the latest), so the costs can be incorporated into the STIP. These costs, particularly the contingency, need to be reevaluated yearly. The estimating office is considered the "PM document police." The office also assists PMs if they need a particular cost for an item and will review their estimates, if asked. District 7 rarely does an official planning estimate; they may do rough LWD estimates for planning purposes. Once the projects are determined, the PM will complete the charter, scope, and TPCE.
- On assumption generation, the estimating team generates their assumptions using their previous experience on other projects and discussions at the project scoping meetings. The district estimator reviews all projects and their contingency yearly and requests the PMs update their estimates to either lower the contingency or remove it all together, hopefully either eliminating the assumption or confirming it. In the real world, this does not always happen due to lack of time to investigate or because other functional groups are unable to respond back.
- During the final design and/or construction, sometimes, due to a contingency cap that was placed in the scoping estimate, the quantities may be increased. For example, muck quantities could increase in the plan due to possible lack of borings and uncertainty of muck limits.

3.6.5 District 8

- The district has projects worth $30 million/year for pavement preservation and safety projects (turn lane, signals, realigning, expansion, etc...). Very little expansion is done, although there is a need. Bridges are on average better, yet no large bridge projects.
- There are no design-build projects. It might be anticipated in the future but they mostly work

on small projects.

- Cost estimating is for typical project development (with some peripheral things like county/legislation suggestions), so the focus is on typical projects.
- Most work comes in at scoping (4 year STIP). When projects go in STIP, they are considered scoped and that's when a solid estimate is needed from the office. Other projects planned for 5 to 10 year plans are still vague.
- In the office, the scope is turned into an estimate, from which it is moved to TPCE. Uniform costs that were established by district or corporate are sometimes used by District 8 in developing the cost estimate.
- Once in the STIP, the intent is to re-estimate and update every year, which doesn't necessarily happen. After going into the STIP, there is an "estimate blackout" where reviews are done every year, basically to apply inflation (not true reviewing of estimate). Sometimes, the office returns to the PM when there are major changes and a scope amendment to review the estimate (in years 3 or 4). However, by the time those changes take place, the project has entered into the design process and sort of gets lost. "Those are relatively simple projects that go to the design office with a short time for letting before reviewed. I would say this is fairly true throughout most districts."
- Commenting on the percent design complete at different stages, the office estimated that when it goes to the STIP, it is commonly at 30% design. In simple projects, 50% is a reasonable range and, as jobs get more complex, it goes down to 30%.
- The design is usually complete a couple of months before the letting, making any further review of the estimates impossible.
- The problem faced is due to the influx of changes, especially with low bids. Money left should be picked up and used in other projects. Although the STIP constitutes our basic plan, there are still a lot of outliers.

3.7 TEAM INVOLVED IN ESTIMATING

This section describes who is involved in the estimating process as reported by the different interviewees. In general, they all reported that the estimator, PM, and functional groups are usually involved. District 8, however, reported that the estimating office mostly does it. Sometimes, when some area of expertise is required, they might resort to the functional group like hydraulics, safety, or bridge folks. The PM could be also involved for clarification purposes. In general, though, the same team is usually involved, and the degree of involvement varies from one office to the other.

3.8 ESTIMATING PROCESS CONSISTENCY

There was a general agreement among all interviewees that there are not uniform, consistent estimating practices employed statewide. Although most of them tend to agree there should be, some think that it should be tailored to the needs of the specific district. They all agree that there needs to be better communication and exchange of knowledge and information between all offices.

The CO specifically reported that the estimating process is not consistent statewide. With design-build, the CO dictates the estimating in the Detroit Lakes area of the "design-build project estimate," morphed from Form 14. Form 14 is a living document and available online. The CO sets it up so it can be used for all types of project delivery methods. Although it has been so far used in design-build projects, it can be still used in design-bid-build projects by just removing the preconstruction cost item. The CO does not see the LWD estimating method as a good generic option that could be used as a template compared to Form 14 used in the CO. With LWD, it is always a challenge to develop the estimate from price/mile to a line item. The CO is really aiming at consistency of the format employed. It would be great to have a form to use for all project delivery methods and funding.

Metro also reported that statewide estimating is not consistent. The estimating method used by Metro was an attempt to make the estimating practice in the Metro office consistent. The one consistency that is seen statewide would be the way the estimate should be presented in the SITP. In the STIP, the cost estimate should be presented together with the scoping report and the layout.

The similarities seen with **District 1** are the TPCE report, inflation adjustments, default engineering costs, default supplemental agreement, and cost overrun costs. The base estimates, however, might be prepared differently by different districts. **This was in agreement with District 7 and District 8.**

District 7 reported that every district estimates differently. Some have their estimators do all estimates and others have the project managers do them.

District 8 also reported unfamiliarity with the design-build template developed at the CO ("It seems irrelevant.") In addition, they do not use LWD estimating. Although having tried to work on it a long time ago, they found the LWD process relies on uniformity in the projects and that their projects are not that similar. They also found it depends on sampling of past projects (with historical data, too, it's difficult to use). Most of their jobs have something added so that the similar projects philosophy does not apply and their projects are very small ones.

Chapter 4. Other Department of Transportation Practices

4.1 COST-ESTIMATING TECHNIQUES

There are many cost-estimation techniques that are used in an attempt to provide realistic cost estimates. Common estimating methods include parametric estimating, bid-based estimating, and cost-based estimating (Table 2).

Table 2. Different Tools and Techniques used in Cost Estimating (after WSDOT 2007)

Tool \ Technique	Parametric	Historical Based: Bid Pricing	Historical Based: Previous Project	Historical Based: Historical Percentages	Cost Based	CRA/ CEVP
Cost Per Mile	✓					
Standard Item Table		✓	✓	✓		
Spreadsheets		✓	✓	✓	✓	
Ebase		✓				
Unit Bid Analysis		✓	✓	✓		
BidTabs Pro		✓	✓	✓		
Ad and Award Date		✓				
RS Means					✓	
Independent Investigation		✓			✓	
Cost Indices		✓			✓	
Risk Analysis						✓
Internal/External Reviews	✓	✓	✓	✓	✓	✓
Project Cost Estimate File	✓	✓	✓	✓	✓	✓

Parametric estimating, for instance, is used to support development of planning-level estimates in which the project scope definition is still very limited. Both historical cost data and key project parameters are used to calculate various work item costs (WSDOT 2007). Bid-based estimating uses historical data from recently-bid contracts and are adjusted based on project conditions such as location and size (WSDOT 2007). The estimate is based on the concept of comparable work (WSDOT 2008b).

Cost-based estimating relies on a bottom-up approach where labor and equipment, based on estimated production rates, materials, overhead, and profit for each major line item, is estimated (WSDOT 2007, WSDOT 2008b).

One of the most conventional methods is the contingency method, which is used in a deterministic way in which component costs are summed and an overall contingency is then included for uncertainties in cost and quantity (Maher and McGoey-Smith 2006, AASHTO 2009). The contingency percentage applied to the base estimate depends on many assumptions

(AASHTO 2009, Booz Allen Hamilton 2005). It accounts for incorrect quantities or unit costs, unknown conditions, unforeseen requirements, and project risks.

Contingency is applied differently from one agency to another. Common approaches include applying a predetermined percentage to the base estimate for all projects or, based on agency guidance, a specific percentage is geared toward the specific project conditions or, an allowance factor is applied to individual bid items to account for unknown conditions or quantity uncertainty on known items. The estimate is developed without regard to specific risks that compensate for uncertainty in the estimate. Table shows a common sliding scale for contingency percentages based on the project development stage (AASHTO 2009).

Table 3. Sliding-Scale Contingency Percentages (AASHTO 2009)

Project Stage	Contingency Range (%)
Planning	25-40
Preliminary Design	20-35
Design Phase I (30%)	15-30
Design Phase II (60%)	10-20
Design Phase III (90%)	5-10
Final Design (100%)	0-5

4.1.1 Developing Risk-Based Estimates

As previously described, risk-based estimating combines two main components in the project cost estimate (AASHTO 2009, WSDOT 2008c):

- The first component, the **base cost estimate** is developed using traditional cost estimating methods, such as parametric, historic-based, and/or cost-based without contingencies or allowances for the unknowns. This component represents the estimate when the project progresses as planned.
- The second component entails the **risk events component** that might cause the project to turn out differently than planned, using either the independent, cost-validation team approach or the design team, risk-identification approach. The variability in the cost components and the probabilities for the various risks are developed by the estimator.

These two components are then combined to create the total risk-based estimating for the project using simulation techniques such as Monte Carlo (AASHTO 2009) as illustrated in Figure 4.

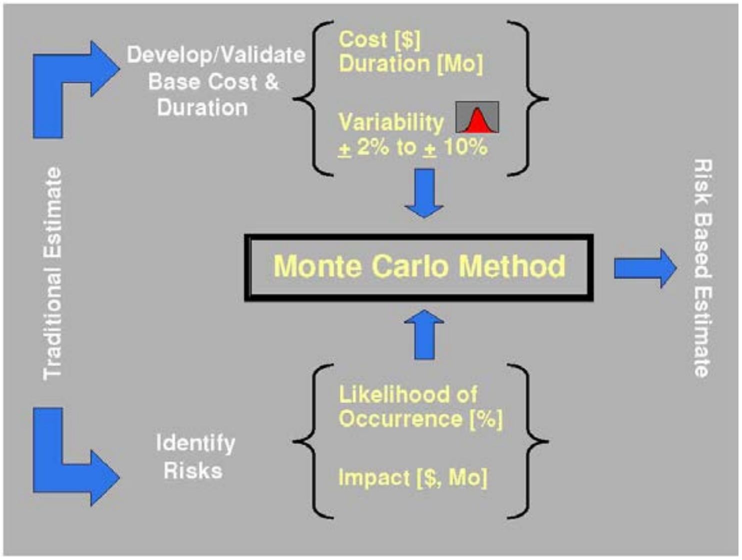


Figure 4. Risk-Based Estimating Schematic (AASHTO 2009)

With risk-based estimating, the following should be noted:

- Risks factored in the cost are based on best current estimates for costs, schedules, construction phasing, and activity sequencing
- Risk identification is dependent on the project team members' expertise, internal and external subject matter experts, risk elicitor, and base cost lead; thus, the experience level of the team should correspond to the magnitude of the project
- A "probabilistic range and shape" for the cost and schedule is developed based on the analysis of the project cost and schedule estimate together with risk assessment
- Risks are ranked based on their impact to project cost and/or schedule, providing the team valuable information to control project costs and manage risks (AASHTO 2009)

4.2 TRANSPORTATION AGENCY RISK-BASED COST-ESTIMATING PRACTICES

This section explores how other DOTs are employing risk-based estimating practices to develop estimates for design-build projects and projects at approximately 30% design. The researchers gathered information on policies and procedures as well as manuals for guidance.

4.2.1 NCHRP and AASHTO Efforts/Guidebooks

In 2006, AASHTO conducted a nationwide survey to investigate best practices for project cost and quality. Survey results showed that agencies acknowledge the challenges associated with developing early and accurate cost estimates. Table shows what different agencies were doing to improve their cost estimating practices (Alavi and Tavares 2009).

Table 4. Agencies Taking Action according to National Survey (Alavi and Tavares 2009)

Actions	Agencies
Developing Cost Estimating Manual	California, Maryland, Minnesota, Virginia, Washington
Developing Systems for Capturing Risk Factors	Florida, Washington
Developing Cost Estimate Training Program or Workshops	Michigan, Virginia, Washington
Establishing Cost Estimating Department	Louisiana, Nevada
Developing Estimate Quality Control Program	Indiana, Maine, Virginia, Washington, Wyoming

Florida and Washington were seen to be the two states developing systems to account for risk factors in their estimating process.

It was also reported in 2006 that, although most state transportation agencies (STAs) factor contingency into their estimates, only one STA (WSDOT) was performing a detailed risk analysis (Anderson et al. 2006). That agency's cost estimates were being created by removing all contingencies from the line items and then identifying and evaluating cost risks, schedule risks, and opportunities. The STA was combining the base cost and the risk assessment and applying critical path methodology (CPM) and Monte Carlo simulation to generate ranges for expected project cost (as explained previously under Developing Risk-Based Estimates).

Thus, the STA's method applies contingency factors based on an in-depth analysis of possible events and their probability of occurrence. This is in addition to recognizing potential risks early in the project development process, which enables proactive response to those risks once they occur (Anderson et al. 2009).

The National Cooperative Highway Research Program (NCHRP) Project 8-36 Task 72 reported that Maryland also concluded that "using a risk-based approach to cost estimating will be the easiest to try to implement (improvements to the cost estimating and estimate management process), and also a way to get the most improvement without changing around the whole process" (Paulsen et al. 2008).

The Transit Cooperative Research Program (TCRP) Project G-7 published in 2005 also reported that when DOTs were asked about the different risk assessment approaches used to develop and evaluate cost estimates and contingencies, only one project (Washington) reported using a probabilistic risk assessment methodology (Booz Allen Hamilton 2005). Several other projects used an informal and/or deterministic approach to manage risks and assign contingencies. Monte Carlo simulation was used in the WSDOT project to establish cost confidence level and identify contingencies. A New York project also performed a risk assessment for line-by-line contingency allocation for known risks.

In general, many guidelines and reports have been published addressing cost estimation practices. The AASHTO TCCE developed a guide to synthesize the current best practices used nationally to help STAs draw from the others' experiences and adopt the practices that are most appropriate for their situation. The guide gave practical guidance on preparing final estimates, including the procedures followed (AASHTO 2013, Anderson et al. 2007).

NCHRP 8-36 had a similar objective when a guidebook was developed for cost estimation improvements at STAs. The objective of the guidebook is to provide insights on how STAs can implement organizational and cultural change strategies to improve the accuracy and consistency of project estimates. The guidebook helps STAs learn from the experiences of other states that are working on improving their cost estimating and estimate management processes and what they are doing to improve them (FHWA 2004).

Under NCHRP 8-49 (Anderson et al. 2007), a guidebook was developed to present approaches to cost estimation and management that can be used to overcome project cost escalation and support the development of accurate project estimates throughout the project development process. The guidebook provides strategies, methods, and tools to develop, track, and document more realistic cost estimates during each phase of the process (Anderson et al. 2009).

With transportation professionals' continuous emphasis that ROW cost estimating and management of ROW estimates are critical to achieving consistency and accuracy in project cost estimates, NCHRP 8-49 undertook a second phase mainly addressing ROW cost estimating. The project developed the NCHRP Report 625 guide, which presented a practical and effective approach for developing ROW cost estimates, and tracking and managing ROW cost during all phases of project development (WSDOT 2009).

On the same lines, NCHRP 8-60 aimed at an in-depth treatment of methods and tools necessary to implement a specific strategy for risk management. The NCHRP Report 658 guidebook was published to provide guidance to state DOTs for using specific, practical, and risk-related management practices and analysis tools for managing and controlling transportation project costs. One of the key lessons learned from this project was to communicate cost uncertainty in project estimates by using ranges and/or explicit contingency amounts (Paulsen et al. 2008).

The TCRP developed a guidebook (Report 138: Estimating Soft Costs for Major Public Transportation Fixed Guideway Projects) for project managers and cost estimators working for transit agencies or other organizations (AECOM et al. 2010). It defines and describes soft costs and provides a new methodology to estimate soft costs of major transit projects over $100 million, based on historical projects in early phases of planning and engineering (AECOM et al. 2010,).

The Guidebook provides information about soft costs, how transit agencies and contractors estimate soft costs, how those estimates fit into the Federal Transit Administration (FTA) New Starts process, and how project characteristics such as guideway length or project delivery method are leading to soft costs being driven up or down in the past. It also presents a Soft Cost Estimation Methodology to estimate project soft costs, based on both the characteristics of the project and the organizational attributes of its sponsor agency (AECOM et al. 2010).

The TCRP study drew some potential improvement strategies from the case studies performed. On best practices to follow when estimating costs at the alternatives analysis, preliminary engineering, final design, and construction phases, the following recommendations were provided (AECOM et al. 2010):

- Use of reasonable starting assumptions. This entails establishing a realistic project scope and schedule based on actual needs given certain known constraints, which can help minimize uncertainties during the estimation process.

- Estimates can be improved significantly through all phases of development using formal estimation manuals, reviews, or validations. Standard estimation procedures can help minimize inconsistencies observed in estimates. It could also reduce the problem of incompatible estimates between projects, missed project elements, and low unit costs.
- Uncertainties should also be communicated with the assumptions of the estimates presented in an easily-understandable way. Assumptions should be documented properly and available for all stakeholders. Having such transparency will produce more reliable estimates. A detailed probabilistic risk assessment can be used in identifying risk factors and quantifying their potential impact on project development. This is in line with the federal requirement of a formal risk assessment process that aims at potentially improving both the reliability and public confidence in project cost estimates. A very good example of a formal risk assessment approach, which is used by Washington, is the Cost Estimate Validation Process (CEVP) (Booz Allen Hamilton 2005).

4.2.2 FHWA

In 2004, the FHWA issued technical guidance for final engineer's estimates called Guidelines on Preparing Engineer's Estimate, Bid Reviews, and Evaluation, which aimed at outlining recommended procedures for preparing engineer's estimates and for reviewing bids prior to award (WSDOT 2010). Based on the continuing trend toward risk applications and extensive research into the subject, Major Project Program Cost Estimating Guidance issued in January 2007 by the FHWA was aimed at the preparation of a total program cost estimate for a major project (FHWA 2007).

A major project, as defined by the FHWA, is as a project that receives an amount of Federal funding and has an estimated total cost greater than $500 million (expressed in year-of-expenditure dollars). This total cost estimate includes construction, engineering, acquisition of ROW, and related costs (Anderson et al. 2006).

The FHWA further developed a process to review cost estimates for major projects (over $500 million dollars) in which it employed an risk-based estimating approach to review the cost and schedule estimates. The aim of this process is to "capture the variability of project risks associated and characterize them through a range of estimated costs." The result of this review is a list of project risks and a cost estimate expressed as a range (AASHTO 2009, Actis 2010).

The key is having reasonable assumptions. The review will verify the accuracy and reasonableness of the total cost estimate reached to develop a probability range for the cost estimate at the current project development stage. It is actually a long-term objective for the FHWA to spread risk-based estimating technology to DOTs so it can be done locally in each DOT (Actis 2010).

The FHWA stresses the importance of addressing uncertainty by conducting risk analysis prior to construction, using risk management approaches to derive contingency values, and reporting cost estimates as ranges. The FHWA outlines the following key principles of risk-based estimating (Actis 2010):

- Transparency of the process
- Project cost estimate should be inclusive of all project costs
- Expressed in year-of-expenditure dollars (assign a realistic inflation rate per year, usually 3 to 4% per year)
- Best information available should be used
- Assumptions and key changes should be documented
- A team of experts should be responsible for developing it
- Project cost estimate should account for risk and uncertainty

4.2.3 Review Process

The review process, developed by the FHWA, is achieved through a formal risk assessment followed by a mitigation workshop where the most critical risk factors are identified and their effect on project cost is quantified, in addition to defining ways to mitigate them (Booz Allen Hamilton 2005). All components of the estimate are reviewed by the team, including but not limited to construction, preliminary engineering, construction engineering, ROW, utilities, railroads, environmental mitigation, public relations, hazardous materials, program management, natural and cultural resources mitigation, third-party costs, and other project-related costs. The project sponsor, from the state DOT, should present how each estimate was developed. The discussion covers quantities, unit prices, contingencies, and assumptions (Actis 2010).

The team determines the risks and identifies them as either being threats or opportunities. They then start quantitatively determining the risk events' probabilities and impacts with input from the project sponsor. It becomes very important to discuss how contingencies are estimated and which costs contingencies are included to ensure risks are not double counted, as contingencies do include risk. As detailed by the FHWA, the team, at its discretion, can handle contingencies in the estimate in two ways: leave the contingency in the estimate and model its uncertainty or eliminate the contingency from the estimate and specifically add risk on an individual basis.

As discussed earlier, once risks, their impacts, and likelihood are identified, they are combined with the base cost estimate using a probabilistic modeling method. The team also reviews the schedule and discusses inflation rates to develop the estimate escalation component. The final estimate is presented in year-of-expenditure dollars. The process is a collaborative one among the FHWA, project sponsor, and team experts. Through this process, consensus on the team findings and recommendations and ultimately on the final estimate is reached. Finally, the FHWA team leader takes responsibility for ensuring that the review and report meets FHWA policies and guidance (Actis 2010).

Washington

In recognition of the fundamental and strategic importance of cost estimating, the WSDOT Strategic Analysis and Estimating Office with contributions from a number of specialists in cost estimating and project development developed a Cost Estimating Manual for WSDOT Projects to provide consistent practices across the agency to enhance methods for meeting this responsibility (WSDOT 2009). Project Risk Management Guidance for WSDOT Projects was also published in 2010 to help project managers and project teams with their risk management efforts by providing a consistent methodology for performing project risk management activities along with techniques and tools for project risk management.

The guidance identifies data requirements for risk analysis input and for output (CPM System data requirements), provides information on how project risk management fits into the overall project management process at WSDOT, and includes guidance on how to proactively respond to risks (WSDOT 2010). The guide also stresses the importance of measuring risks to determine an accurate cost estimate range. Thus, the guidance is aimed at setting a consistent procedure for identifying the project's uncertainties and risks rather than basing them on the estimator's experience and best judgment (WSDOT 2010).

WSDOT Secretary's Executive Order Enterprise Risk Management E 1038.00, Project Management E 103.00, and E 1053.00 were all issued to formalize the efforts of managing risks statewide and to address public concerns about the accuracy of project estimates. Table shows the minimum risk management process required in WSDOT based on different project sizes (WSDOT 2010). Executive Order E 1053 also defines the responsibilities of various project personnel to support the risk management process (WSDOT 2008a).

Table 5. Risk Assessment Level required by Project Size (WSDOT 2010)

<table>
<tr><th></th><th>Project Size ($M)</th><th>Risk Assessment Level</th><th>Notes</th></tr>
<tr><td rowspan="2">Less Formal Risk Assessment</td><td>0 to 10</td><td>Project Team Risk Assessment
Project Management Online Guide (PMOG)
Risk Management Plan
Qualitative Tool</td><td rowspan="2">The Project team assesses each identified risk for its probability of occurrence and its impact on project objectives. Project teams may request assistance from subject matter experts or functional units to assess the risks in their respective fields. The self-modeling 10 to 25 spreadsheet can be used for any project</td></tr>
<tr><td>10 to 25</td><td>Project Team Risk Assessment
Self-Modeling Spreadsheet
Quantitative Tool</td></tr>
<tr><td rowspan="2">More Formal Risk Assessment (Workshops)</td><td>25 to 100</td><td>Cost Risk Assessment (CRA) Workshop
Quantitative Tool</td><td rowspan="2">The team, working collaboratively with independent subject matter experts, reviews and/or validates cost and schedule estimating and identifies, characterizes and analyzes risks. Accomplished in a structured workshop setting. Modeling can be accomplished with off the shelf software or using the self-modeling spreadsheet.</td></tr>
<tr><td>Over 100</td><td>Cost Estimate Validation Process (CEVP) Workshop
Quantitative Tool</td></tr>
</table>

The tools identified in Table are basically dependent on the project size and complexity. They include the following:

- **Project Management Online Guide (PMOG)** that includes a Project Management Plan (fundamental for all project management) and the guide also provides a risk matrix suitable for smaller, less complex projects. This guide was developed in 2005.
- **Risk Management Plan spreadsheet** template (found on the WSDOT Strategic Analysis and Estimating Office/SAEO website). This Excel-based self-modeling tool for quantitative risk analysis was developed by Dr. Ovidiu Cretu in 2006. With the tool, only 25 risks could be modeled and only two risks could create dependencies with the schedule (Long n.d.). Project design engineers can enter risks and determine the quantitative impact on the project total cost estimate. This spreadsheet should be used on all projects, specifically those not meeting the limits of cost risk assessment (CRA) or CEVP (Berends 2006).

- **CRA workshops** for smaller projects between $25M and $100M were developed in 2004. The CRA workshop is very similar to the CEVP workshop yet less intense (Berends 2006). These workshops aim at helping project managers control scope, cost, and schedule, and manage risks for all projects (Molenaar et al. 2010, WSDOT 2010, AASHTO 2009, WSDOT 2008a).
- **CEVP workshops** for larger projects over $100M were developed in 2003 by Reilly et al. (2004) and are discussed in detail in the next subsection. Table shows a comparison between CRA and CEVP. Figure 5 shows the workshop flowchart.

Table 6. Comparison of CRA and CEVP Workshops (WSDOT 2010)

	CRA - 1 to 2 Day Workshop	CEVP - 3 to 5 Day Workshop
Subject Matter Experts	Internal and local	Internal and external
Timing (when to hold)	Anytime. Typically updated when design changes or other changes to the project warrant an updated CRA.	Best to start early in the process, major projects are typically updated as needed.
General	An assessment of risks with an evaluation and update of costs and schedule estimates.	An intense workshop that provides an external validation of cost and schedule estimates and assesses risks.

Note: Workshops are orchestrated by the Cost Risk Estimating Management (CREM) unit of the Strategic Analysis and Estimating Office in HQ in collaboration with the project manager. The project manager submits a workshop request and works with the CREM unit to ascertain the type of workshop required and candidate participants. See WSDOT Guidelines for CRA-CEVP workshops for more details.

Cost Estimate Validation Process (CEVP)

WSDOT started tackling this issue in February 2002 when CEVP was developed as a groundbreaking tool that can identify and quantify anticipated risks that can have an impact on project cost or schedule (Booz Allen Hamilton 2005, Gabel 2006). In 2003, CEVP was first implemented on approximately 12 WSDOT mega projects.

CEVP was originally presented as a methodology to review and validate cost estimates and conduct a risk and opportunity analysis for capital projects to obtain the best possible information about the probable project cost ranges (Booz Allen Hamilton 2005, Reilly et al. 2004). It is a probabilistic-based evaluation method of a project cost and schedule estimate (Reilly et al. 2004).

Using CEVP involves an intense workshop in which the project team and subject matter experts (top engineers and risk managers) review the project details to identify cost and schedule risks. CEVP includes both the validation of the project base cost, along with identification of high cost and schedule risk drivers, which enables the development of risk management plans early in the project. (Reilly et al. 2004).

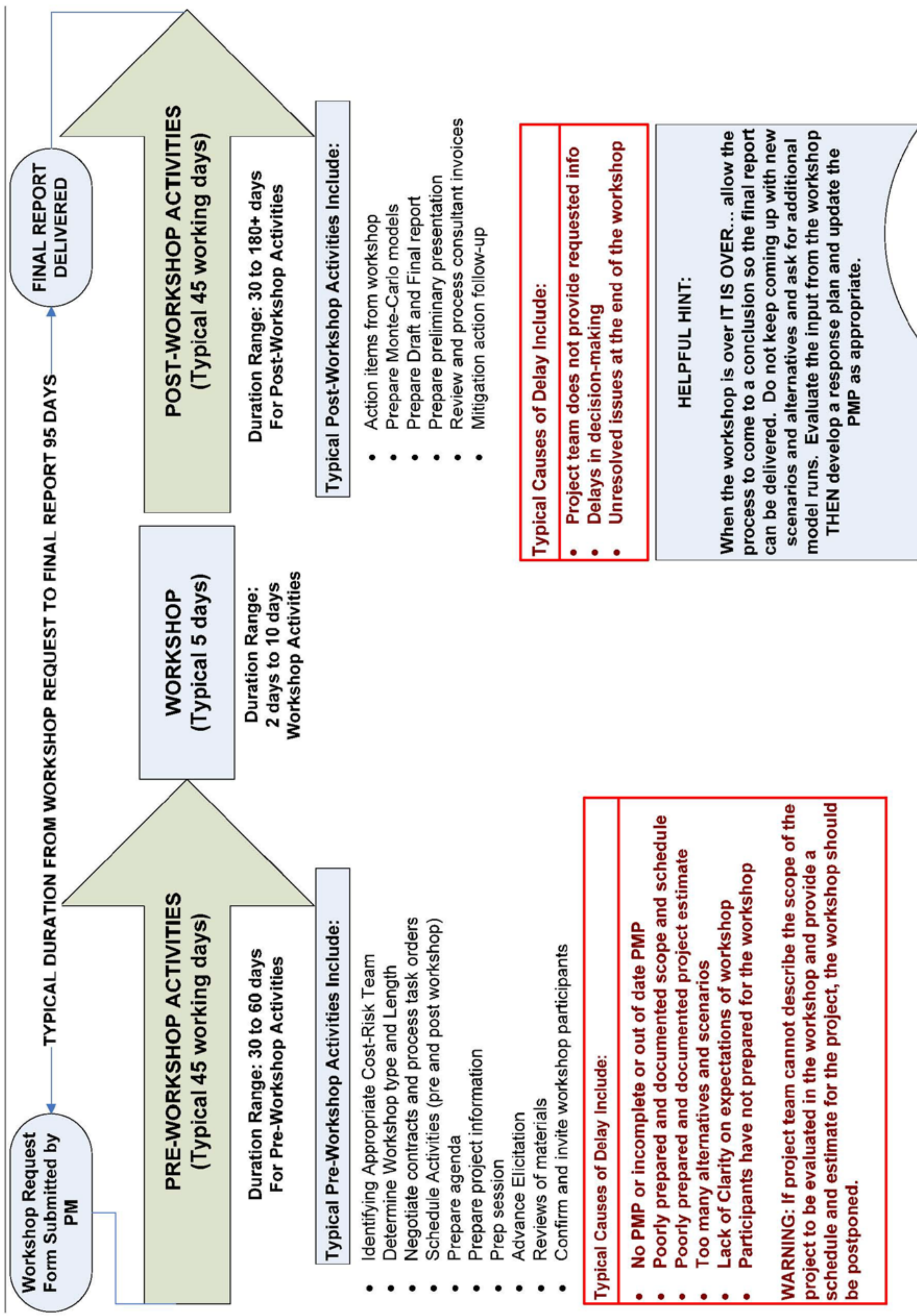


Figure 5. Simplified Workshop Timeline (WSDOT 2010)

CEVP development identified five main strategic issues that need to be taken into consideration (Reilly et al. 2004). First, as shown in Figure 6, “A future cost estimate is not a number; it is a range of probable costs” (Reilly et al. 2004).

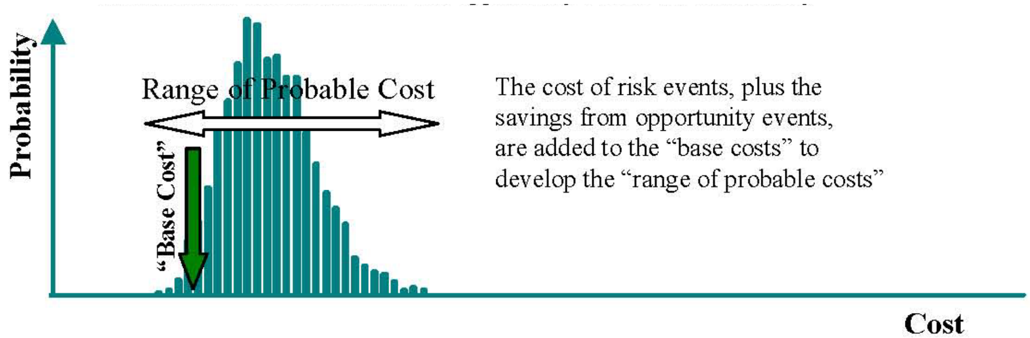


Figure 6. Future Cost Estimate as a Range of Probable Costs (Reilly et al. 2004)

Second, peer review and collaborative assessment are key to providing unbiased estimates (Reilly et al. 2004, Gabel 2006). Third, cost and schedule uncertainty should be both acknowledged and included in the estimation process. Fourth, risk descriptors and quantification should be diligently and practically developed. Finally, and most importantly, the output should be presented in an easily understandable way to the public (Figure 7) (Reilly et al. 2004).

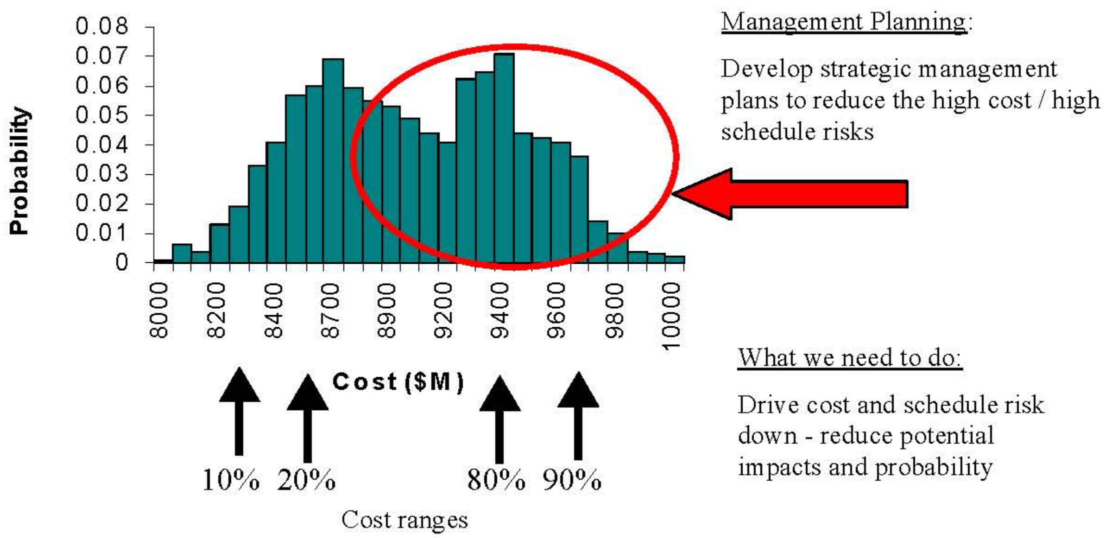


Figure 7. Range of Probable Costs with Risk Mitigation Targeted to the High-Cost Risk Events (Reilly et al. 2004)

The process involves a workshop where input is obtained from the project team and other independent subject matter experts. The workshop starts with the review and evaluation of the project team estimate. The CEVP methodology involves the following steps (Reilly et al. 2004):

1. **Assemble Relevant Project Data and Involve the Project Team:** The project team should assemble all plans, exhibits, and project documents to define the scope and timeframe of the project.
2. **Define the Project Flowchart:** In this stage, a project flowchart is developed based on the major activities and their schedules.

3. **Critically Evaluate the Project Cost Estimate to Determine Base Cost:** The project team prepares the base cost estimate together with other costs that represent the uncertainties. Subject matter experts (SMEs) then review and evaluate the estimate, which could range from conducting a full detailed audit to only a reasonableness evaluation assessment.
4. **Define and Assess Uncertainty Events:** This step involves explicitly addressing the uncertainty, described as either a threat or opportunity. Experts start developing the risk list (risk register) in a workshop setting. Relationships among the risk events could also be addressed through correlation. The likelihood and impact of each risk occurrence is also assessed.
5. **Integrate Base + Uncertainty Costs in a Probabilistic Model:** At this stage, a probabilistic model is developed for quantifying the uncertainty in the project cost and schedule. The rate of inflation is also taken into consideration in the model.
6. **Analyze Results and Write CEVP Report:** Results from the previous step are presented as cost and schedule probability distributions with supporting tabulations of characteristic statistics. An example of one developed by WSDOT is shown in Figure 8.

SR 167, Tacoma to Edgewood New Freeway Construction

Project Description:

The project completes SR 167 from Puyallup to the Port of Tacoma.

The new facility provides a six lane freeway including HOV lanes from SR 161 near Puyallup to Interstate 5 and four lanes between Interstate 5 and SR 509 near the Port of Tacoma.

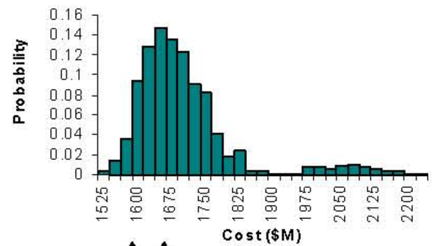
Project Schedule:

Estimated Construction Start: 2005

Estimated Completion: 2012 - 2013

Inflation escalation is to year 2008, the approximate mid-point of construction.

CEVP Profile/Result:



Best Current Cost Range (BCCR)

There is a **10%** chance the cost is less than **$ 1.59 Billion**

There is a **50%** chance the cost is less than **$ 1.67 Billion**

There is a **90%** chance the cost is less than **$ 1.78 Billion**

Benefits this project would provide:

- Completing this freeway link will help relieve congestion in the lower Puget Sound region by offering commuters, travelers, and shippers an alternative to Interstate 5, especially providing a key link for movement of freight to and from the Port of Tacoma.
- SR 167 will reduce congestion and improve safety on local roads while providing system continuity between the SR 167 corridor and Interstate 5.

Some events that could impact project cost or schedule:

This project requires the acquisition of large amounts of property in a corridor where land is rapidly developing. Delays in acquiring new properties will result in significant cost increases to the project.

This project will be constructed near the Puyallup River, Hylebos Creek, Wapato Creek, wetlands and wildlife habitat. Environmental permitting and mitigation requirements may change significantly between now and construction, tending to increase costs and cause delays.

This project includes a major new interchange where Interstate 5 and SR 167 connect. The design of this interchange assumes Federal Highway Administration (FHWA) approval of a number of design features. If not approved by FHWA, changes in the design would result in increased cost and time for the project.

Only a few contractors are qualified to pursue construction projects this large. Less competition may result in higher contractor prices and thus higher project costs.

If all identified risks occur, the cost of the project will be on the high end of the probability curve.

Washington State Department of Transportation

Figure 8. CEVP One-Page Summary (Reilly et al. 2004)

California

The California DOT (Caltrans) Project Risk Management Handbook: A Scalable Approach just published in June 2012 aims at establishing and nurturing a culture of risk management with the DOT (Caltrans 2012). The handbook addresses the implementation of risk management approaches in different areas, including cost estimates, in more detail than in the 2007 version (Caltrans 2012, Caltrans 2007). The handbook suggests that risk management requires implementation based on the project size (Table 7).

Table 7. Risk Management Requirements by Scalability Level (Caltrans 2012)

Scalability Level	Estimated Cost (Capital and Support)	Risk Management Requirements
	Minor A, Minor B, and other projects less than $1 million	Risk register encouraged
1	Less than $5 million	Risk register
2	$5 million to $100 million	Risk register with qualitative analysis
3	Greater than $100 million	Risk register with quantitative analysis

The levels differ in qualitative and quantitative analysis processes. Level 3 (projects greater than $100 million dollars) quantifies risks in probabilistic forecast terms of cost and time while Levels 1 and 2 do not. The handbook details how risk management practices can be employed at Level 3 to quantify risk and generate a cost estimate range (Caltrans 2012).

Florida

The Florida DOT (FDOT) Executive Workshop held in July 2012 pointed out the importance of risk-based estimating and how the FDOT team has been conducting workshops to develop in-house expertise on risk-based estimating. The team has a draft procedure and a training course for the risk analysis modeling and tracking software and requirements for a risk contingency plan (FDOT 2012).

FDOT also organized and conducted 2012 Design Training Expo training to emphasize using risk-management techniques in developing cost estimates. In-house training and pilot workshops on various projects in FDOT have been conducted to implement this approach (Davis et al. 2012).

Montana

In 2009, the Montana DOT (MDT) issued a report entitled Highway Project Cost Estimating and Management (Alavi and Tavares 2009). The purpose of this report was to develop a document to determine the best practices of efficient highway cost estimating for MDT. The report recommended the development of a comprehensive system for capturing risk factors. MDT has adopted the project Risk Management Plan spreadsheet, developed originally by WSDOT, to manage cost uncertainties. With the help of WSDOT, a draft set of Risk Management Guidelines was published in November 2012 to provide MDT project guidance on how to manage costs through identification and management of risks (MDT 2012).

Chapter 5. Industry Practices

In the construction industry, the accuracy of cost estimates is fundamental to project success for both owners and contractors. Contractors usually bid in a competitive bidding setting where they estimate a total bid price based on the available project information and anticipated risks. The bid price is a sum of the cost estimate and a mark-up.

An owner's cost estimating approach is usually risk neutral with an acceptable estimate that has a same probability of overrun and under-run. The reason is, with some project cost overruns and under-runs, they will balance out.

However, contracting organizations use a more conservative, risk-adverse attitude, which anticipates each project will generate profit to their company; thus, they specify a higher probability that the project will not exceed their estimate. This, of course, increases the required contingency and project cost to owner (Henley 2012).

These basic assumptions about differences in contractor and owner attitudes toward risk may be overstated. A recent survey conducted in the US aerospace industry found that the average desired confidence levels for owners and contractors were relatively close, ranging from 65 to 68% (GAO 2009).

5.1 ESTIMATING TECHNIQUES

In a study of cost-estimating practices, Akintoye and Fitzgerald (2000) identified that "standard estimating procedure" was the highest-ranked technique employed overall by contractors in the United Kingdom (UK). Standard estimating procedure was defined as the costs of construction, as established by the estimate, in addition to allowances for overhead and profit (Akintoye and Fitzgerald 2000).

Historical data, if available to contractors, are usually broken down to a common cost-coding structure that can be retrieved easily and used for planning of future projects and developing accurate cost estimates. However, escalation in prices has driven companies to study and adopt cost-estimation models to obtain more accurate and cost-aggressive methods (Hall and Delille 2012).

In a review of 50 years of empirical cost-estimate accuracy research, Hollmann (2012) showed "an ongoing failure to effectively address the reality of project cost uncertainty and… a lack of good historical data with causal information." The paper argues that, although project estimators understand the reality of failed ineffective methods used and are aware of reliable practices that quantify project cost uncertainty, they still continue to use the ineffective methods causing serious project overruns and bringing up even ethical issues of why they still use ineffective estimating approaches.

Hollmann argues that, although there is extensive use of risk registers and brainstorming sessions, risk quantification is still dominated mostly by estimator bias. Worst case scenarios and reliable risk analysis techniques should at least be considered in preparing estimates. Estimators should seek to improve their estimates and practices based on past outcomes (Hollmann 2012).

In another study, 462 projects completed in a 20 year interval (1988 to 2008) were used to quantify industry metrics for estimate accuracy by comparing estimated costs at different stages of project development/definition to actual costs (Ogilvie et al. 2012). Accuracy was defined in this study as "an indication of the degree to which the final cost outcome of a project may vary from the single point value used as the estimated cost of the project."

Results of the study showed there is a greater level of variability in estimate accuracy compared to industry expectations (presented in the Association for the Advancement of Cost Engineering/AACE International Recommended Practice 18R-97 (AACE 2011)). This study also showed that projects with a completed definitive project scope have less estimate variability (Ogilvie et al. 2012).

In practice, estimation is more probabilistic than deterministic and traditional estimating techniques fail to provide probability of overruns. A method that could be used, which is based on historical data yet provides a probabilistic analysis, is historical data-driven range estimating.

Using the historical data from previous similar projects, the cost is adjusted to the time and place of the project being estimated. The cost is then represented as a probability distribution, which is simulated to develop a total cost with ranges and confidence levels (Figure) (Evrenosoglu 2010).

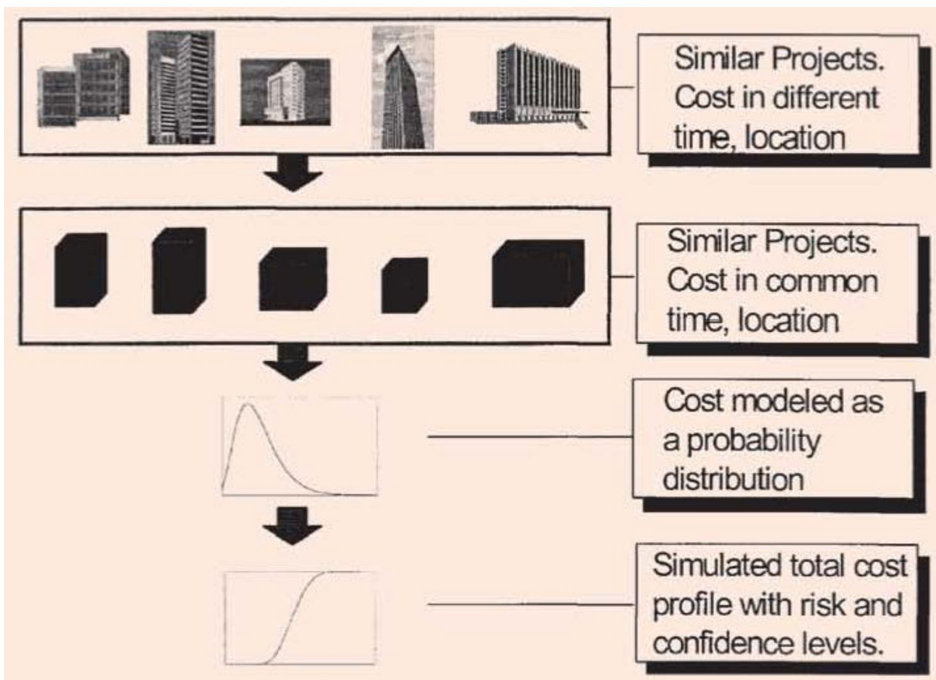


Figure 9. Historical Data-Driven Probabilistic Range Estimating (Evrenosoglu 2010)

Globally, there has a move toward more robust risk-based estimating techniques. The Highways Agency in England developed a Highways Agency Risk Management (HARM) program that models uncertainties of estimates for cost and time ensuring realistic budgets particularly for publicly-financed projects. In the Netherlands, two agencies were formed called Public-Sector Comparator and Public-Private Comparator (PSC/PPC) with dedicated staff to support project teams in risk management identification and quantification using probabilistic techniques (Molenaar et al. 2006).

Another study conducted in the UK revealed that the most important factors affecting the contractor's cost-estimating practice include complexity of the project, technological requirements, project information, contract requirements, project duration, and market conditions (Akintoye 2000).

Many studies have attempted to investigate US industry practices in cost estimating. In 2008, The Society of Cost Estimating and Analysis (SCEA) and Space Systems Cost Analysis Group (SSCAG) conducted a cost-risk survey to investigate how companies in the US aerospace industry develop and apply cost-risk analysis to aid in project decisions, identify and investigate the trends of the cost-estimating tools and methods utilized, and emphasize the importance of assessing cost risks.

The survey included 17,000 respondents from many engineering disciplines, including civil engineering. The sample encompassed 26% US government, 54% industry, 13% consultant, and 5% university. In general, the study concluded that, in comparison to a similar survey conducted in 1998, “Cost risk analysis is more broadly applied by both government and industry” (Black 2008).

The key motivations for cost-risk analysis are project size, obvious risk, and customer direction. Black (2008) found that 40% of the survey respondents reported risk is related to all project types while the other 60% related it to factors like project complexity, technical risks, schedule risks, customer requirements, and value of project.

Another interesting result showed that 90% of cost risk analyses are integrated into the baseline estimate. The key benefits of cost-risk analysis, as reported by the survey respondents, included likelihood of success, better cost control, customer requirements met, and better business decisions.

The most popular tools used to perform cost risk analysis were Crystal Ball and @Risk; a decreasing trend was observed in the use of Excel-based tools compared to the survey conducted in 1998. It was also observed that statistical cost analysis based on history has increased significantly compared to team-consensus subjective judgments. When asked whether risk analysis tools were becoming highly-specialized, the percentage responding yes in the 2008 survey was lower than that reported in a similar survey administered in 1998.

Another interesting trend seen in this survey is that the training provided to estimators is increasing dramatically compared to 10 years earlier. As for integration of cost-risk analysis into the risk-management project process, only 25% had mature systems incorporating the analysis, tracking, and managing of risks and supporting the decision-making. Sparse historical data and limited functional support were reported as the major constraints in performing cost-risk analysis (Black 2008).

AACE International developed multiple guides to help in estimating and incorporating risk into the process. Recommended Practice (RP) No. 40R-08 was developed to guide in the selection and development of risk-quantification and contingency estimating methods by providing principles that any estimating method should follow (AACE 2008a). Another AACE guide, RP No. 41R-08, was developed to introduce range estimating as a method of probabilistic cost estimating that utilizes Monte Carlo analysis techniques (AACE 2008b). The desired level of confidence is determined in the RP based on many companies’ successful efforts to determine project risk and contingency using range estimating.

Range estimating utilizes Monte Carlo sampling to rank critical risks (threats and opportunities), which develops a range for the total project estimate and defines how contingency would be allocated on the different critical items. It is important in the RP to determine the critical items affecting the project outcomes and to apply ranges only to them. A critical item is defined as "one whose actual value can vary from its target, either favorably or unfavorably, by such a magnitude that the bottom line cost (or profit) of the project would change by an amount greater than its critical variance." The critical variance of the bottom line cost is shown in Table (AACE 2008b).

Table 8. Bottom Line Critical Variances (AACE 2008a)

Bottom Line Critical Variances		
Bottom Line (Cost or Profit)	Conceptual Estimates (AACE Classes 3, 4, 5)	Detailed Estimates (AACE Classes 1,2)
Cost Δ	± 0.5%	± 0.2%
Profit Δ	± 5.0%	± 2.0%

Another important factor to consider is linking the items that are strongly dependent on each other and not treating each one separately. In addition, the item's magnitude is not as important as the effect of its change on the bottom line, given that some smaller magnitude items may be more critical than larger ones. In a typical project, there are 10 to 20 critical items (AACE 2008a).

AACE RP 18R-97 is another recommended practice that provided guidelines for classes of estimates through the project development/definition process, also referred to as the front-end loading (FEL) process, for process industries (AACE 2011). The document provides a guide on the expected range of accuracy in each estimate class as shown in Table .

Table 9. Cost Estimate Classification Matrix for Process Industries (AACE 2011)

	Primary Characteristic	Secondary Characteristic		
Estimate Class	Maturity Level of Project Definition Deliverables (% of complete definition)	End Usage (Typical purpose of estimate)	Methodology (Typical estimating method)	Expected Accuracy Range (Typical variation in low and high ranges)*
5	0 to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20 to -50% H: +30 to +100%
4	1 to 15%	Study or feasibility	Equipment factored or parametric models	L: -15 to -30% H: +20 to +50%
3	10 to 40%	Budget authorization or control	Semi-detailed unit costs with assembly-level line items	L: -10 to -20% H: +10 to +30%
2	30 to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5 to -15% H: +5 to +20%
1	65 to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3 to -10% H: +3 to +15%

* The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

The information in the table shows how estimates develop from high-level approximations to more-detailed estimates as a project moves through the different project-definition phases (AACE 2011).

Many organizations develop their own standardized-estimating techniques that are communicated to the entire project team to generate better cost estimates in an efficient manner. The Hartsfield-Jackson Atlanta International Airport, for example, has adopted a firm set of standards for estimates resulting in higher-quality estimates and timely acceptance of estimates by airport management. Adhering to these standards avoids unnecessary rework and allows a small number of estimators to review and accept estimates in a timely fashion (Kraus 2012). To be implemented properly, the standards should include the following practices:

- Communication to appropriate parties before the estimating process begins
- Effective estimate planning including estimate organization
- Support tools such as software
- Documentation included in the estimate to generate mutual understanding
- Continuous transfer of quantities from scope documents to quantity takeoff to estimate all with appropriate documentation of changes made during the estimating process
- Documentation of all source of costs, including breakdown of cost and a list of items where costs could not be documented
- Reference of other alternative sources
- Review of the estimate by qualified personnel not involved in preparation of the original estimate
- Source of data, including accurate quantity take-offs and visual (Kraus 2012)

A quality approach to the cost-estimating process is suggested by Hollmann (2012). The approach foresees the four stages of planning, execution, verification, and improvement. It includes key elements that can enhance cost-estimate predictability. The approach suggested is applicable to all projects in every phase. However, the detail level and diligence used during the cost-estimating process vary depending on the project's strategic importance, project phase, total project value, and estimate purpose.

The process includes three steps: planning, execution, and control. Planning aims at aligning the team on the activities to be included in developing the estimate, such as purpose, inputs, scope, deliverables, and formats. The planning stage results in "quality from the beginning of the estimating process," as opposed to corrective actions and reviews.

The next step is execution, where the estimate, together with the supporting documents, are prepared. This step is based on inputs from the previous planning phase where input deliverables were identified by the team. In this step and according to project needs, some special activities may be conducted to obtain additional information for cost-estimating tasks such as market surveys. It is important to support all estimating activities performed in this step with comprehensive documentation. Proper documentation shouldn't be viewed as a waste of time given that it assures the estimate is traceable and transparent, making the final estimate understandable and easily communicated to management and reviewers.

The last step, control, involves verification and improvement, which is a quality assurance step before presentation of the estimate. The verification of the estimate could be done by an independent cost estimate review internally or externally to verify the estimate and suggest areas of improvement (Hollmann 2012).

Contractors, as well as owners, are always faced with challenges to implementing quality estimates as Hollmann defines it (2012), which include limited resources and time pressures, third-party review activities that are not effective, underestimation of the importance of good early planning, early alignment on requirements and expectations, and, finally, supporting documentation for the estimate. The use of a structured-estimating process helps solve the time-pressure problem as the process becomes systematic with properly-identified roles and responsibilities. It also helps develop quality estimates, which in turn facilitate the management decision-making process (Hollmann 2012).

Understanding the importance of proper scope definition in generating good conceptual estimates, a study conducted by Serpell (2011) developed a project-scope modeling methodology based on historical project scopes, using the most-relevant information and application of case-based reasoning (CBR).

CBR is “a reasoning model that incorporates problem solving, understanding, and learning.” It is based on modeling human reasoning and thinking and works based on past-experience cases. This approach was validated on 17 completed construction projects with known final costs, producing accurate estimates with an acceptable level of accuracy. The scope generated provided a reasonable work breakdown structure that can be used for various planning purposes (Serpell 2011).

In addition, it was noted in another study that changes made at each step of exploring new alternatives during the conceptual phase should be documented properly (Uppal 2011). Uppal suggested a two-step procedure. During the conceptual stage, the project scope should be developed and changes should then be recorded thereafter during preliminary estimating and engineering developments should then be tracked and reflected on the estimates. To achieve this, there should be a person responsible for tracking changes and documenting them in a standardized format. A decision parameter list can be developed as a standard format listing all parameters, such as technical reports, meetings, and group discussions, used to make decisions (Uppal 2011).

The movement to formal risk-based estimating techniques has a significant impact on how bidders prepare their proposals in the US. In a proposal submitted in 2012 on the Co-Development, Multi-Modal I-70 Mountain Corridor Project, one bidder proposed a risk-management program for both cost and schedule management (HDR Engineering 2012). The team implemented a proprietary process that combines Cost Risk Assessment (CRA) with Value Engineering (VE) called CRAVE (Figure 10).

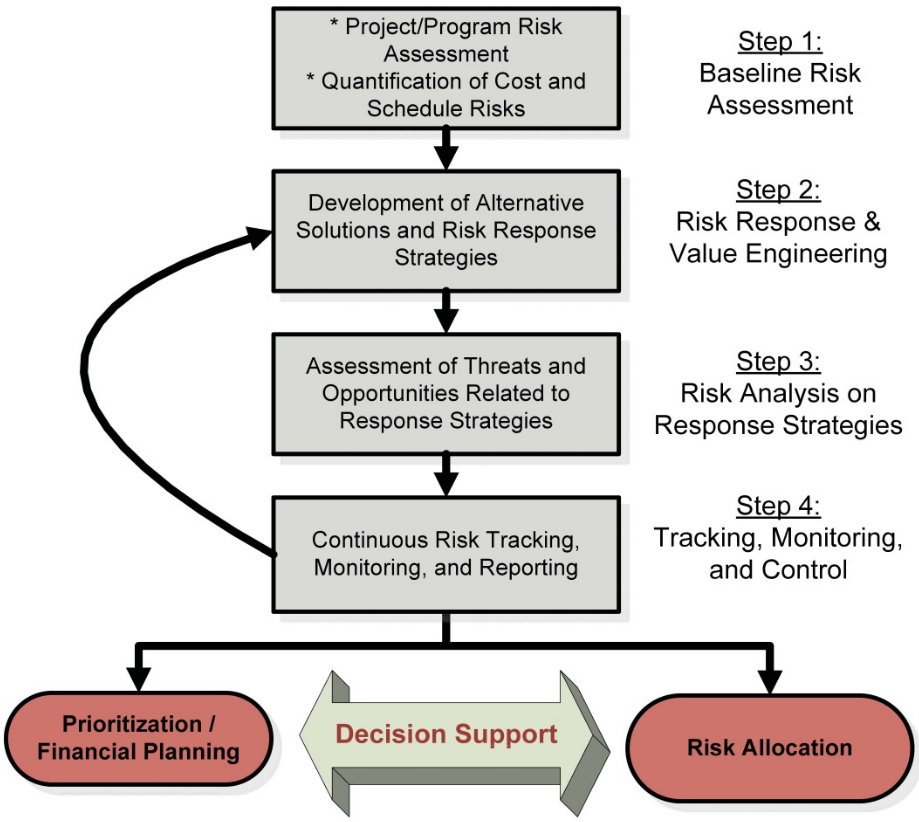


Figure 10. The CRAVE Process (HDR Engineering 2012)

The process presented provides a systematic approach for identifying, assessing, and controlling risks. Through workshops involving all team members, risks are identified, quantified, and managed through an early planning process. Mitigation measures are also proposed for anticipated threats.

Figure 3 shows the four-step CRAVE process that aims at managing important project factors such as project cost and schedule, in addition to helping in financial planning and risk allocation. Through this process, a risk-management plan is developed to guide the team throughout the project on handling project uncertainties and risks (HDR Engineering 2012).

5.2 ESTIMATING TOOLS AND SOFTWARE PACKAGES

Many tools and software packages are used by contractors to help in the cost-estimating process. These vary tremendously between contractors—from paper and pencil, to spreadsheets, advanced specialized software packages, on-screen digitizing systems, and three-dimensional (3D) computer-aided drawing (CAD) parametric estimating software (Samphaongoen 2009).

5.2.1 Excel Spreadsheets and Specialized Estimating Programs

The most popular tool used in estimating is Excel spreadsheets (Samphaongoen 2009, Law and Robson 2009). Spreadsheets have replaced manual calculations due to their increased accuracy and the considerable time savings, estimated to be one-third the time taken to do manual calculations (Law and Robson 2009).

A survey of 365 Pennsylvania home-building contractors conducted in 2009 to investigate information-technology utilization in estimating found significant differences in the information technology used for estimating costs based on firm size. The study compared the use of computerized-estimating software versus a manual-estimating system. Larger firms utilized more advanced estimating software compared to smaller ones. However, small firms employing computerized-estimating procedures are using the same software as the large firms. Smaller firms are more likely to rely on paper and pencil calculations (Law and Robson 2009).

Law and Robson (2009) also showed that spreadsheets are the most popular computerized estimating resources, while specialized estimating software is used less. Although spreadsheets are the most popular, the problem with using them is the lack of readily-available links to unit cost databases (Kraus 2012).

Other specialized estimating programs are being used increasingly with additional options such as storing information in databases and reporting resources (Law and Robson 2009, Samphaongoen 2009). The use of such programs allows the estimators access to past project performances and historical data, which in essence improves the estimate. This is analogous to having an experienced versus an inexperienced estimator with no previous knowledge.

Feedback from such databases obtained from historical projects form the basis of the contractor's experience as the knowledge they gain from multiple past projects provides feedback in refining the estimating process and thus helps in the decision-making process (Law and Robson 2009). The database included in the software might include labor, equipment, and material cost databases (Samphaongoen 2009).

5.2.2 Cost-Estimating Technology Advancements

Other more-advanced technologies include digitizing tablets that use software packages to digitize the owner's paper-based blueprints to obtain length, perimeter, or area quantities. The software package might also have estimating software that, after having the quantities, the estimator can use to estimate the item price. This differs than the on-screen digitizing system in that it works with computer graphic files or scaled CAD documents, not with paper blueprints.

Another emerging technology that is advancing rapidly in cost estimating is the use of 3D CAD models. Using such models, estimators can visualize the project in a 3D environment, digitally extract and transfer data and, thus, speed up the cost-estimating process (Samphaongoen 2009).

5.3 CONCLUSIONS

The accuracy of cost estimates is fundamental to project success for both owners and contractors. From the studies reviewed, traditional estimating that relies on historical data with no proper causal information has failed to address and include project uncertainties into cost estimates. In practice, estimation is probabilistic rather than deterministic and traditional estimating techniques fail to account for overrun probability.

The researchers looked at different methods that have been proposed and implemented in the industry such as historical data-driven range estimating and risk-based estimating techniques. The key advantages in those estimating techniques compared to traditional estimating are that they provide better cost control, satisfy customer requirements, and assist in making better business decisions. AACE International has developed multiple guides to help in estimating and incorporating risk into the process.

Another important finding of this research is the emphasis on standardizing the estimating process within different organizations to generate better cost estimates in an efficient manner. The implementation of such standard practices should be fostered by effective communication to the entire team, estimate planning, software support tools, documentation of estimate and scope changes to generate mutual understanding, and review of estimates by qualified personnel who are not involved in preparation of original estimates.

Chapter 6. Draft Guidance

Based on the workshop conducted in February 2014 there are three areas of guidance regarding risk-based engineer's estimates for the Minnesota Department of Transportation. These areas are regarding the use of risk registers, use of Monte Carlo simulation, and communication. In addition to these recommendations there are a number of best practices and resources that can be found in sections 4 (Other Department of Transportation Practices) and 5 (Industry Practices) of this report. Additionally, a recently published *Guide for the Process of Managing Risk on Rapid Renewal Projects* may be consulted for additional best practices (Golder et al. 2014)

6.1 RISK REGISTERS

During the review of the state of practice it was found that there are a number of ways that MnDOT, other DOTs, and other industries are conducting risk analysis. One common method is to develop a risk register. A risk register is a listing of the identified risks for a specific project along with other information about the risk often including a description of the risk, cost impacts, schedule impacts, likelihood of occurrence, risk type, owner of the risk, and status. MnDOT has a form for the risk register hosted by the Office of Project Management. It seems that to develop the risks in the risk register, by project managers and others identifying the risks, a risk checklist is used. A risk checklist is also available from the Office of Project Management. During the workshop it became apparent that many of the participants representing a number of different offices and districts use their own version of the risk checklist.

6.1.2 Developing Base Cost Estimate

The base estimate is developed utilizing traditional estimating techniques without including risk. The objective is to develop a value without contingencies included, assuming the work will be completed as planned (Molenaar et al. 2010, AASHTO 2009, Reilly et al. 2004). At this stage, risks are documented as either threats or opportunities, to be used as input into the risk elicitation. The major aim is to minimize or eliminate any hidden or explicit contingency, whether in the unit prices and/or quantities. Allowances can be made for items that are known but not fully quantified; thus, when such an estimate is reviewed, adjustments can be made if necessary with the reason for change documented clearly, allowing the project team to track the changes made and their justifications (AASHTO 2009).

This step allows structuring the project for the risk assessment by defining project scope, strategy, and assumptions as the basis for the risk assessment model. Through this stage, the team starts to gain a very good understanding of the construction techniques assumed and to discover areas of concern/risks, which can be discussed in the next step. In summary, in the base cost estimating step, the team accomplishes the following tasks:

- Reviews project assumptions
- Reviews project cost and schedule based on the information available (update unit prices and quantities)
- Captures unknown cost of miscellaneous items
- Removes contingencies (AASHTO 2009)

6.1.3 Incorporating Risk into the Cost Estimate

The next four subsections walk through the four steps of risk management (identification, analysis, response, and monitoring and control) and their implementation in risk-based estimating. A critical concept in employing risk-management steps is to understand what are the project knowns and unknowns.

Known items have some degree of uncertainty due to the unit bid price and quantities variance and the level of design completed. Unknown items, on the other hand, are defined by risks events. In addition, some potential risks may not be captured in the risk identification process and those are defined as unknown-unknowns. Unknown-unknowns may be considered and defined additionally as a percentage of all identified risks.

In risk-based estimating, uncertainty is defined as a symmetric variance in the base cost and schedule (AASHTO 2009). It is important to note that estimate development is not the last step in risk-based estimating; the use of risk-based estimating implies controls will be present during subsequent project phases.

6.1.4 Risk Identification

Risk identification includes determining which risks might affect the project and documenting their characteristics. This could be conducted by a risk elicitor with a good understanding of risk analysis and its impacts. The main aim is to identify the key risky events, estimate how likely they are to occur, and estimate why and by how much the risky events may affect the base estimate.

Risk is defined in explicit terms separating cause and effect. The process of risk identification is iterative, as new risks become known and existing risks may change as the project progresses. The project team should be involved in this process as it helps them develop and maintain a sense of ownership and also responsibility for risks and their cost control strategies (AASHTO 2009).

Ultimately, a comprehensive, non-overlapping risk register is developed defining each risk as a threat or an opportunity (Roberds and McGrath 2006). The risk identification process, as referenced by AASHTO (2009), should include the following seven segments:

1. **Risk Status:** Where the status of the risk event is defined. A specific risk may start at one status and its status may change as the project is developed further. The team has the following three status scenarios to choose from:
    - Active, when the risk is being actively monitored and controlled
    - Dormant, when the risk is low priority but may become high priority in the future
    - Retired, when the risk is dismissed for any reason
2. **Risk Identification Number**: A unique number assigned to the risk for tracking purposes.
3. **Date Identified and Project Phase:** The date and phase of the project when the risk was first identified. Typically, projects are broken into different phases: Preliminary Engineering, ROW, Acquisition, and Construction. These phases can vary based on agency and the level of detail necessary for the project.

4. **Functional Assignment:** Defines the project delivery functions that are impacted by the risk, such as planning, design, ROW, environmental, engineering services, and construction.
5. **Summary Description**: Defines whether the risk is a threat or opportunity:
   - If the risk outcome provides negative impact to the project (higher cost and/or longer duration), the risk is a threat
   - If the risk outcome provides positive impact to the project (lower cost and/or shorter duration), the risk is an opportunity
6. **Detailed Description of the Risk Event:** A clear description of the potential risk event is very important for the team to manage the project risks. Coming up with a description that is Specific, Measurable, Attributable, Relevant, and Time-bound (SMART) will result in a good detailed risk description.
7. **Risk Trigger:** Addresses the symptoms and warning signs that may indicate the likelihood of threatening risk events to occur. This helps in determining when to implement the risk response strategies to keep the risk from occurring (AASHTO 2009).

A bottom-up risk assessment could be employed that entails a flow chart of the sequence of major project activities and could be used for integrated cost and schedule analysis (Roberds and McGrath 2006).

2. Risk Analysis

Risk quantitative analysis involves numerically analyzing the risk probability and impact of the risk on the project if it occurs (AASHTO 2009, Roberds and McGrath 2006, Actis 2010). Depending on the design level, it is recommended to add 2 to 10% of the base value and use a representative probability distribution.

The Project Evaluation and Review Technique (PERT) Beta3 is the most commonly used distribution. It is defined by three points: "Min (Lowest), Max (Highest), and Most Likely, where the MOST LIKELY in the case of variability in the base represents the base median value" (AASHTO 2009). Common distributions such as Triangular, PERT, Minimum Extreme, and Maximum Extreme could be also selected by the team to better represent the risks (AASHTO 2009, Actis 2010).

Using risk quantitative analysis, the probability of the project meeting its cost objectives could be estimated numerically. This is done through simultaneous evaluation of the impact of all identified and quantified risks resulting in a probability distribution of the project's cost based on project risks. In this step, the factors to which the risk probability and impact are sensitive are also identified using the following guidelines as reported by AASHTO (2009):

- How likely is it that a risk event will occur?
  - Lowest value = 0; the risk event cannot occur
  - Highest value = 1; the risk event will definitely occur
  - Middle value = 0.5
- Risk occurrence likelihood (It is important to be "approximately right" without wasting time being "precisely wrong"):

- Very Low = 5%
  - Low = 25%
  - Medium (as likely as not) = 50%
  - High = 75%
  - Very High = 95%
- Define range and shape, if a risk event occurs: the expert team provides a three-point estimate:
  - Range, which includes the lowest reasonable value (MIN) and the highest reasonable value (MAX)
  - Shape, which is defined by the "Best-Guess" (the expert's median guess)

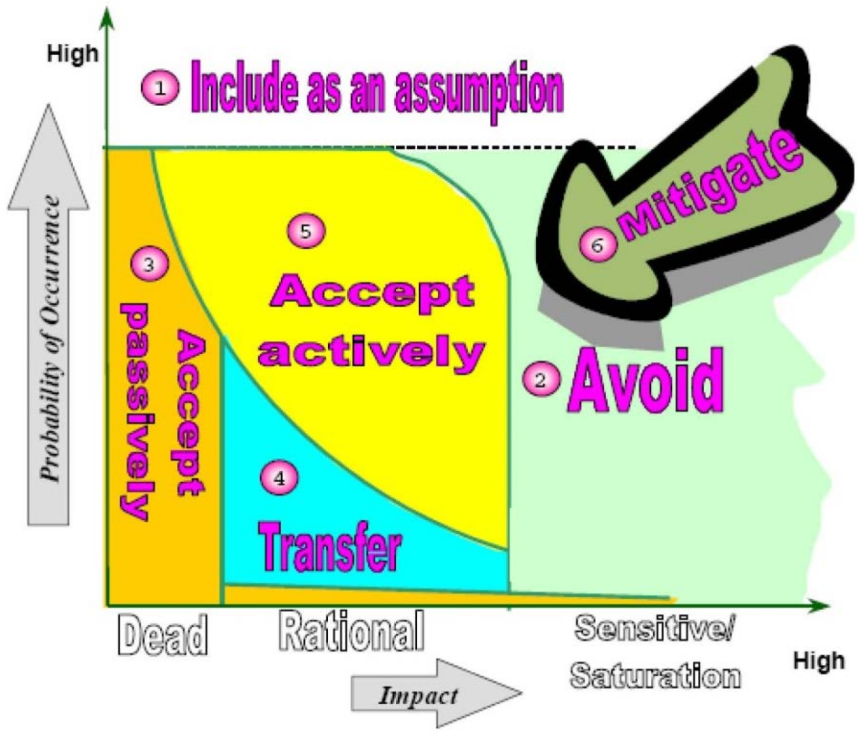
3. Risk Response

Based on the risk items evaluated in the risk analysis step, risk response strategies focus on the high-risk items. The team identifies the best strategy for managing those risks by determining specific actions. Table below shows different response strategies employed depending on whether the risk is defined as a threat or an opportunity.

Table 10. Risk Response Strategies (WSDOT 2010)

Threats	Opportunities
1. Avoid	1. Exploit
2. Transfer	2. Share
3. Mitigate	3. Enhance
4. Accept	

Figure 11 illustrates response strategies employed for threat risk events (WSDOT 2010).



1. If a risk has an extremely high probability of occurrence, it may be best to assume the condition as part of the base.

2. Risks (threats) with high impacts, can over a given limit, wreck a project; these risks must be avoided.

3. Insignificant risks can be accepted, passive response.

4. Between avoidance and acceptance we can take other actions such as mitigation or for risks with low probabilities we may want to transfer them.

5. For risks (threats) above a certain probability we may choose to accept actively by mitigating and/or preparing contingency plans in the event of its occurrence.

6. All risks (threats) should be mitigated where practical and cost-effective.

Figure 11. Risk Response Planning Chart for Threats (Piney 2002)

Threat risk response strategies could include the following (WSDOT 2010, AASHTO 2009):

- **Avoidance**, by basically eliminating the risk. This could be achieved by changing plan, changing scope, adding time, or adding resources. Such a strategy would require management approval (AASHTO 2009). In essence, the risk is either removed or the plan is changed. It is not always possible to employ this technique (AASHTO 2009).
- **Transference**, by transferring the risk's financial impact. This could be achieved by contracting part of the work out. It should be noted, though, that the risk should be transferred to the party best able to control and reduce that risk.
- **Mitigation**, by reducing the probability and/or impact of the risk event to an acceptable range. This could be achieved by many different methods that are project- and risk-specific. Although risk mitigation could be potentially costly and time consuming, it could be better than the consequences of the unmitigated risk.

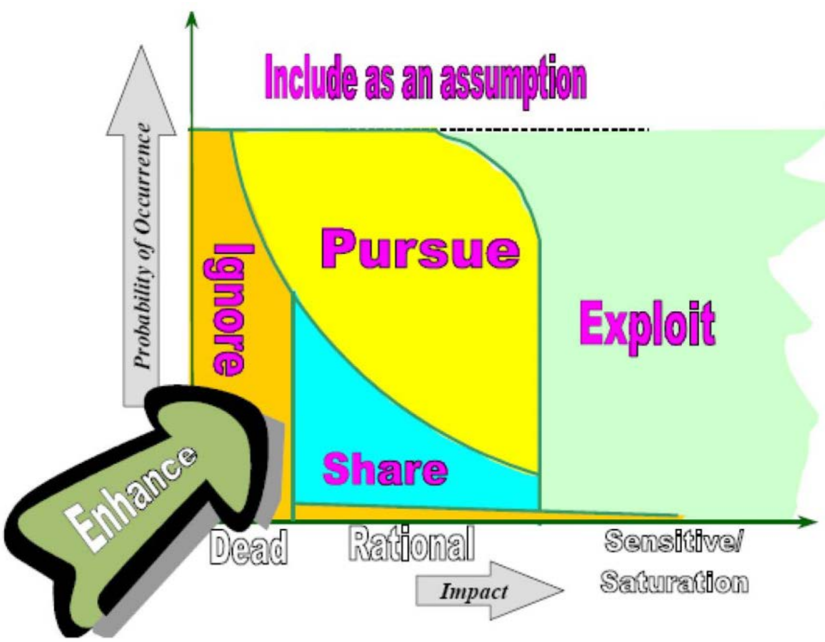
- **Acceptance**, by deciding to accept specific risks and their impacts on the cost and schedule. Acceptance strategies do not change the project plan to deal with a risk or identify any response strategy other than agreeing to address the risk if it occurs (AASHTO 2009). Responding to the risk, in this case, may prove to be not cost effective (WSDOT 2010).

  Acceptance could be either active or passive. Active acceptance involves establishing a contingency reserve including time, money, or resources to handle the threat or opportunity. The team develops a contingency plan that will be executed when risk triggers occur. Passive acceptance requires no action; the project team deals with the risk events as they occur. A work-around or recovery plan is implemented once the risk event occurs (not the trigger) (AASHTO 2009).

Figure 12 illustrates response strategies employed for opportunity risk events (WSDOT 2010).

Opportunity risk response strategies include the following (WSDOT 2010, AASHTO 2009):

- **Exploit** is the opposite of avoidance (WSDOT 2010). This is basically eliminating the uncertainty of the event happening, making it definitely happen. This could be achieved by, for example, securing talented resources that may become available for the project or providing better quality (WSDOT 2010, AASHTO 2009).
- **Share**, by giving ownership to a third party that can best capture the opportunity to benefit the project. This can be achieved by forming risk-sharing partnerships, joint ventures, etc.
- **Enhance**, by increasing the probability and/or positive impacts of the event. This could be achieved by maximizing key drivers and triggers of those risk events.
- **Acceptance** (refer to threats) (AASHTO 2009)



1. If a risk has an extremely high probability of occurrence, it may be best to assume the condition as part of the base.

2. Risks (opportunities) with high impacts; these risks should be exploited.

3. Insignificant risks can be accepted, passive response.

4. Between exploit and accept we can take other actions such as enhance and/or share opportunity risks.

5. Risks (opportunities) above a certain probability we may choose to accept actively by preparing plans in the event of its occurrence –how will we take advantage of a fortunate occurrence?

6. All risks (opportunities) should be enhanced where practical and cost-effective.

Figure 12. Risk Response Planning Chart for Opportunity Risks (Piney 2002)

4. Risk Monitoring and Control

Risk monitoring and control identifies and designates specific parties to take responsibility for each risk response. The aim is to track the identified, residual, and new risks, and to ensure the implementation of the risk response plans together with evaluating their effectiveness. Risk monitoring and control also ensures that this becomes a continuous process during the project lifecycle, where risks are tracked whether new risks develop or anticipated risks occur or disappear. The owner of each risk plan reports periodically to the project manager on plan effectiveness, unanticipated effects, and midcourse corrections that should be taken to mitigate risk (AASHTO 2009).

Project risk reviews are scheduled regularly during the course of the project to repeat the risk management steps (1 through 3). Project risk is also an agenda item in all project meetings. Risk ratings and prioritization commonly change during the project life cycle. This mainly assures that, if an unanticipated risk emerges, or a risk's impact is greater than anticipated, planned response strategies are revised accordingly to control the risk. Risk control, thus, involves choosing alternative response strategies, implementing contingency plans, taking any corrective actions required, and re-scoping the project (AASHTO 2009).

6.1.5 Suggested Guidance

While risk checklist are useful, project teams should not feel limited to the identified risks. The project team should consider each project individually and brainstorm risks that may be associated with the specific project that is not represented in any checklist.

Risk checklists from across MnDOT should be collected regularly and the checklist that is available through the Office of Project Management should be updated to reflect the current state of the checklists across the state. One place to accumulate a number of risks is annually reviewing risk registers from across the state to provide updated checklist. The checklists may be divided into categories to make it easier to use.

Risk registers should be reviewed regularly and the number of each risk should be counted. An identified risk may only rarely appear in some districts and many more times in another, but based on the frequency it may be helpful to add the risk to the risk checklist as a way to communicate that this is a risk to be considered.

When updating a risk register, project teams should be sure to update all categories for the previously identified risks. Also, project teams should brainstorm and consider new risks that need to be added to the risk register.

Project teams should consider risks beyond the cost, schedule, technical/scope risks, but should also consider risks associated with financing and risks outside of the MnDOT.

Risks should not only be tied to the cost of the project but also to the schedule of a project.

There should be a clear process for retiring risks and returning available funding back to the district pool of funds. Retiring risks and associated funds should not indicate that there is additional funding for the project, but should be returned to the program.

Require risk registers for level 3 and 4 projects. Risk registers for level 1 and 2 projects may be done at a program level.

Estimators should refer to the expanse of knowledge and documentation that has been developed on risk-based estimating from the AASHTO TCCE and under the research reports of NCHRP 8-36 and NCHRP 8-49 (AASHTO 2013, Anderson et al. 2007, FHWA 2004). These documents detail suggested practices on preparing estimates and approaches to cost estimating and management.

The following key principles should be taken into consideration when conducting risk assessment (Roberds and McGrath 2006):

- Anticipate all possible outcomes
- Take a comprehensive look at the entire project to anticipate any large risks that could occur before construction
- Define the baseline scope, strategy, and cost and schedule estimates before including risk
- Reach a balanced decision between the project team's perspective and independent subject-matter expertise
- Stay focused on the key issues, not every detail
- Continue to follow up, monitor, and update as risks change and sometimes are resolved as the project progresses
- Continue to develop and maintain documentation such as the risk register and the risk management plan/implementation program

6.2. MONTE CARLO SIMULATION

Monte Carlo simulation is a specific tool that is used to simulate the cost of a project through a number of iterations through a computer program to predict the cost, and possibly schedule, of a project based on the identified cost and risks of a project. The user of a Monte Carlo Simulation can determine a base cost of a project by identifying known characteristics, or pieces, of a project and selecting a probable cost. The user then identifies a number of risks and for each risk determines a possible impact and the likelihood of the risk actually happening. Using a computer program, the user then runs a number of simulations. Each simulation is different, with different risks occurring while other risks do not occur. The number of occurrences depends on the identified likelihood of the risk happening. MnDOT is conducting Monte Carlo simulations on some projects, and does have the capability in-house.

Once risks, their impacts, and likelihood are identified, they are combined with the base cost estimate and used as input to a computerized probabilistic modeling tool. Inputs, also called assumption curves, can be correlated. Correlations can be used in situations where the unit price increases as quantity decreases. Correlations are also used when two risks with separate assumption curves are dependent (Actis 2010).

Monte Carlo simulation is the most commonly used probabilistic modeling tool in project risk analysis; it consists of running thousands of plausible cases and summarizing the results to determine a cost range. It is a computerized probabilistic calculation that uses random number generators to draw samples from different probability distributions (AASHTO 2009).

This type of modeling is also available as add-on packages (such as Crystal Ball) to spreadsheets such as Excel or to scheduling software such as Primavera. The result is an estimate of the cost of all identified risks taking into account the interactions of risks and the probability that they will occur simultaneously (AASHTO 2009).

Monte Carlo provides detailed, illustrative output models for the risk effects on the project cost, which would be too complex for common analytical methods. Cost estimate confidence ranges are shown on a histogram or cumulative graph. Moreover, sensitivity analysis could also reveal the impact of specific risk events on the project cost. With such an output, cost is no longer communicated to the public as a single number (leading to accountability problems if it changes). It is instead communicated as a range of potential costs dependent on risks, which can be understood by the public.

However, Monte Carlo method implementation requires knowledge and training including having appropriate inputs from the project team (probability distribution information, mean, standard deviation, and distribution shape). These inputs are somewhat subjective given they are purely based on the team judgment for each item. It is important to try to select the different distribution shapes based on historical data, if available, to remove the bias (AASHTO 2009).

6.2.1 Suggested Guidance

Communicate with MnDOT personnel what Monte Carlo Simulation is and how it can be used. There are a number of people who have misconceptions about the process and the amount of information that is needed to produce a useful simulation.

Hold a training session or webinar about Monte Carlo Simulation that is hosted by MnDOT personnel using it on their projects so other MnDOT personnel are updated on the techniques used in-house and can use on their own projects.

Monte Carlo simulations should be run multiple times during the project development process. The first should be early in the planning/scoping process. While much may not be known, many design decisions still need to be made, this process will provide a backbone for later simulations and help the user determine which risks need to be addressed as well as a likely cost of the project. Use throughout the project will also help identify and manage the contingency for a project.

Monte Carlo simulation can be used very early in project development by using the knowledge about a project as well as what is likely to happen on the project. The users can use engineering judgment to make assumptions about the project that can then be updated in later simulation runs as the development process progresses.

6.3 COMMUNICATION

Communication is essential for success of an organization. It seems that techniques that are being used within MnDOT are not always communicated to the entire organization. Communication might be beneficial to other districts and offices.

6.3.1 Suggested Guidance

Develop an annual meeting for estimators, project managers, and others involved in the cost estimating process together. At this meeting participants from across the state should be allowed to present to the group as a whole and interact individually to exchange ideas and experiences with estimating. This network opportunity will allow for a transfer of knowledge and lessons learned. This meeting can also include a training aspect, such as Monte Carlo Simulation used by some project managers and estimators. This can include new ideas or refreshment on previously covered materials. Topics may include when a risk has passed when and how to release contingency and not just how to use a tool but how to manage the tool.

For communication between annual meetings develop a forum for the exchange of ideas. A web blog or some sort of web group, like an internal social media application, may be helpful. This will allow for people to communicate immediate needs and ideas and not have to wait for the next group meeting at the annual conference.

References

AACE (2008a). *AACE International Recommended Practice No. 40R-08. Contingency Estimating – General Principles. TCM Framework: 7.6 – Risk Management*. Last accessed Oct. 24, 2013. www.aacei.org/rpsfree/40R-08.pdf.

AACE (2008b). *AACE International Recommended Practice No. 41R-08. Risk Analysis and Contingency Determination using Range Estimating. TCM Framework: 7.6 – Risk Management*. Last accessed Oct. 24, 2013. www.aacei.org/rpsfree/41R-08.pdf.

AACE (2011). *AACE International Recommended Practice No. 18R-97. Cost Estimate Classification System – As Applied In Engineering, Procurement, and Construction for the Process Industries. TCM Framework: 7.3 – Cost Estimating and Budgeting*. Last accessed Oct. 24, 2013. www.aacei.org/rpsfree/18R-97.pdf.

AASHTO Technical Committee on Technical Estimating (July 2009). A Practical Guide to Estimating. American Association of State Highway and Transpiration Officials. http://design.transportation.org/Documents/TCCEReport-APracticalGuidetoEstimating.pdf

AASHTO Technical Committee on Cost Estimating (2013). Practical Guide to Cost Estimating. American Association of State Highway and Transportation Officials.

Actis, C. M. (2010). FHWA Risk Based Cost Estimate Reviews. 2010 Capacity Building Workshop for Cost Estimation and Cost Management. August 11-13, 2010. Minneapolis, MN.

AECOM, Donald Schneck, LLC, Ali Touran, Raul V. Bravo + Associates, Inc., and Sharp & Company (2010). *TCRP Report 138: Estimating Soft Costs for Major Public Transportation Fixed Guideway Projects*. Transit Cooperative Research Program. Washington, DC.

Akintoye, A. (2000). “Analysis of Factors influencing project cost estimating practice.” *Construction Management and Economics*, 18(2), pp. 77-89.

Akintoye, A., and Fitzgerald E. (2000). “A survey of current cost estimating practices in the UK.” *Construction Management and Economics*, 18(2), pp. 161-172.

Alavi, S., and Tavares, M. P. (2009). *Highway Project Cost Estimating and Management*. Montana Department of Transportation (FHWA/MT-08-007/8189). Helena, MT. February 2009.

Anderson, S., Molenaar, K., Schexnayder, C. (September 2006). *Guidance for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction.* Final Report for NCHRP Report 574. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w98.pdf

Anderson, S., Molenaar, K. and Schexnayder, C. (2007). *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects during Planning, Programming and Preconstruction,* Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_574.pdf

Anderson, S., Molenaar, K., and Schexnayder, C. (2009). *NCHRP Report 625: Procedures Guide for Right-of-Way Cost Estimation and Cost Management.* Transportation Research Board of National Academies. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_625-2.pdf

Berends, T. (2006). Risk Based Estimating Tools at WSDOT: Self-Modeling Spreadsheet, CRA, CEVP. Washington State Department of Transportation. 2006 TEA Conference.

Black, H. M. (2008). U.S. Aerospace Industry Cost Risk Analysis Survey. SCEA/ISPA 2008 Joint Annual Conference. Industry Hills, CA. June 24-28, 2008.

Booz Allen Hamilton Inc. (2005). *TCRP Web-Only Document 31 (Project G-7): Contractor's Final Report*: *Managing Capital Costs of Major Federally Funded Public Transportation Projects.* Transit Cooperative Research Program. Washington, DC. November 2005.

Caltrans (2007).*Project Risk Management Handbook: Threats and Opportunities.* California Department of Transportation. Office of Statewide Project Management Improvement (OSPMI). Sacramento, CA. May 2007.

Caltrans (2012). *Project Risk Management Handbook: A Scalable Approach.* California Department of Transportation. June 2012. Last accessed Oct. 24, 2013. dot.ca.gov/hq/projmgmt/documents/prmhb/PRM_Handbook.pdf.

Davis, G., Lieblong, K., and Quigley, R. (2012). Risk Analysis Process Training. 2012 Design Training Expo, Lake Buena Vista, FL. Last accessed Oct. 24, 2013. dot.state.fl.us/structures/designExpo2012/Presentations/CRA%20Team%20-%20Risk%20Analysis%20Process%20-%20presented.pdf.

Evrenosoglu, F. B. (2010). "Modeling Historical Cost Data for Probabilistic Range Estimating." *Cost Engineering Journal*, 52(5), May 2010. pp. 11-18.

FHWA (January 2004). *Guidelines on Preparing Engineer's Estimates, Bid Reviews and Evaluation.* http://www.fhwa.dot.gov/programadmin/contracts/ta508046.pdf

FHWA (2007). *Major Project Program Cost Estimating Guidance.* Federal Highway Administration. Innovative Program Delivery. Jan. 2007. Last accessed Oct. 23, 2013. fhwa.dot.gov/ipd/pdfs/project_delivery/major_project_cost_guidance.pdf

FDOT (2012). Executive Workshop Minutes. Tallahassee, FL. Florida Department of Transportation July 18, 2012. Last accessed Oct. 22, 2013. dot.state.fl.us/publicinformationoffice/executiveboardmeeting/archworkshop/Workshop%20Minutes%20July%202012.pdf.

Gabel, M. (2006). The WSDOT Cost Estimate Validation Process: Risk Based Estimating at WSDOT: CRA and CEVP. Washington State Department of Transportation Cost Risk and Estimating Management. 2006 TRB Conference. Jan. 24, 2006. Washington, DC.

GAO (2009). *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*. United States Government Accountability Office. Applied Research and Methods. March 2009.

Golder Associates Inc., Molenaar, K., Loulakis, M., Farragut, T. (2014). *Guide for the Process of Managing Risk on Rapid Renewal Projects*. Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R09-RW-2.pdf

Hall, N. A. and Delille S. (2012). "Cost Estimation Challenges & Uncertainties Confronting Oil and Gas Companies." *Cost Engineering Journal*, 54(3). May/June 2012. pp. 14-24.

HDR Engineering, Inc. (2012). *Co-Development, Multi-Modal I-70 Mountain Corridor Project, Part 1-Technical Proposal*. Aug. 15, 2012.

Henley, G. (2012). *Road to Success. Appendix 3.4.5: Project Cost Estimate and Contingency*. International Pipeline and Offshore Contractors Association. Last accessed Oct. 24, 2013.wiki.iploca.com/display/rtswiki/Appendix+3.4.5+-+Project+Cost+Estimate+and+Contingency

Hollmann, J. K. (2012). "Estimate Accuracy: Dealing with Reality," *Cost Engineering Journal*, 54(6), November/December 2012. pp. 17-27.

Kraus, W. E. (2012). "Mr. Owner's Estimate Is Not Satisfactory — Why Not?" *Cost Engineering Journal*, 4(13), May/June 2012. pp. 4-13.

Law, M. D., and Robson, G. S. (2009). "An Investigation into Computerized Estimating Software Used in Accounting for Cost Estimates by Residential Builders." *Review of Business Information Systems*, 13(2).

Long, B. (no date). Self-Modeling Spreadsheet and Informal Workshop Training. Washington State Department of Transportation. Last accessed Oct. 24, 2013. wsdot.wa.gov/publications/fulltext/CEVP/SMSSTrainingWorkbook.pdf.

Maher, M. L. J. and McGoey-Smith, A. D. (2006). *Risk-Based Cost and Schedule Estimation for Large Transportation Projects,* Association for European Transport and contributors http://euromedtransport.org/Fr/image.php?id=1561

MDT (2012). *Draft-Risk Management Guidelines: Managing project costs through identification and management of risks*. Montana Department of Transportation. November 2012. Last accessed Oct. 24, 2013. mdt.mt.gov/other/roaddesign/external/report_templates_guidance/risk_manual_mdt_draft.pdf

Molenaar, K. R., J. E. Diekmann, D. B. Ashley, and American Trade Initiatives, Inc. (2006). *Guide to Risk Assessment and Allocation for Highway Construction Management*. U.S. Department of Transportation Federal Highway Administration in cooperation with: the American Association of State Highway and Transportation Officials and the National Cooperative Highway Research Program. Washington, DC. October 2006.

Molenaar, K., Anderson, S. and Schexnayder, C. (2010). *NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practice to Control Transportation Project Costs.* Transportation Research Board of National Academies.http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_658.pdf

Ogilvie A., Brown, R. A., Biery, F. P., and Barshop, P. (2012). "Quantifying Estimate Accuracy and Precision for the Process Industries: A Review of Industry Data." *Cost Engineering Journal*. 54(6). November/December 2012. pp. 28-38.

Paulsen, C., Gallivan, F., Chavez, M. and Venner, M. (July 2008). *NCHRP 8-36/Task 72: Guidelines for Cost Estimation Improvements at State DOTs*, Transportation Research Board of the National Academies. http://www.statewideplanning.org/_resources/235_NCHRP-8-36-72-guidelines.pdf

Piney, C. (2002). Risk Response Planning: Selecting the Right Strategy. Fifth European Project Management Conference, PMI Europe.

Reilly, J., McBride, M., Sangrey, D., MacDonald, D., and Brown, J. (2004). "The Development of CEVP - WSDOT's Cost-Risk Estimating Process." *BSCE CEVP Paper*. FINAL DRAFT. Feb.

22, 2004. Last accessed Oct. 22, 2013. wsdot.wa.gov/NR/rdonlyres/F3C8DCB6-08B4-4CCF-B7A0-2A8494D28466/0/040223BSCEfinalpapersubmitted.pdf.

Roberds, B., and McGrath, T. (2006). Quantitative Cost and Schedule Risk Assessment and Management for Large Infrastructure Projects. Golder Associates, Inc. Redmond, WA.
Samphaongoen, P. (2009). A Visual Approach to Construction Cost Estimating. Master's Thesis. Marquette University.

Scheduling the Next Generation Project Management Institute College of Scheduling (PMICOS) Conference April 23-26, 2006. Orlando, FL. Presentation slides dated May 9, 2006.

Serpell, A. F. (2011). “Modeling Project’s Scopes for Conceptual Cost Estimating.” *Cost Engineering Journal*. 52(8). Aug. 2010. pp. 24-31.

Uppal, K. B. (2011). “Pitfalls of Early Estimates and Scope of Work.” *Cost Engineering Journal*. 53(4). Apr. 2011. pp. 18-23.

WSDOT (2007). Cost Estimating Fundamentals. Washington State Department of Transportation. Olympic Region Design & Construction Conference 2007. Feb. 7, 2007. Last accessed Oct. 24, 2013. wsdot.wa.gov/NR/rdonlyres/55FE5BF8-D8E5-439B-93C1-13A09A9C85F5/30267/2007ORDC6.pdf.

WSDOT (2008a). Project Risk Management and Risk Based Estimating. Secretary’s Executive Order Number: E 1053.00. Washington State Department of Transportation. December 10, 2008. Last accessed Oct. 22, 2013. wsdot.wa.gov/publications/fulltext/cevp/1053policy.pdf

WSDOT (2008b). Division 8: Contract Estimate. *Washington State Department of Transportation Plans Preparation Manual*. M 22-31. pp. 1-7.

WSDOT (2008c). CEVP/CRA History. Washington State Department of Transportation. Last accessed Oct. 22, 2013. wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/history.htm.

WSDOT (July 2009). *Cost Estimating Manual for WSDOT Projects.* http://www.wsdot.wa.gov/publications/manuals/fulltext/M3034/EstimatingGuidelines.pdf

WSDOT (July 2010). *Project Risk Management Guidance for WSDOT Projects.* http://www.wsdot.wa.gov/publications/fultext/cevp/ProjectRiskManagement.pdf

Appendix A

MnDOT Risk-Based Estimating Project Interview Questions

MnDOT Risk-Based Estimating Project Interview Questions

Name:
Position:
Years of experience:

- MnDOT:
- Estimating:
- Other related experience:

1. Please explain briefly the project development process and estimates. Please talk about your involvement.
2. Is the estimating process consistent state wide and for all projects?
3. How do you do risk-based cost estimates? (if it's done)
4. How do you do lump sum estimates? (for design-build projects and traditional projects)
5. How do you develop estimates for projects that are about 30% design (or less)? What type of estimating is used?
6. How do you define scoping estimates? Are they the same as the 30% design estimates? How do you develop them?
7. How is risk, generally, addressed in projects? Is a formal Risk management process employed?
8. Are there any specific cost related risk management practices that you employ based on the size/complexity of the project?
9. Describe how risk has been incorporated in the estimating practices. Contingency? Specific percentages employed as contingencies in different work items… How does the estimating team generate their assumptions? On what basis?
10. Who is typically involved in the estimating process?
11. Do you track the assumption made throughout the different project development phases? If Yes, how? Who is involved? Are these assumptions carried over into project cost controls during final design and/or construction?
12. How do you present the total project cost estimate to the public?
13. What cost estimating training is available to MnDOT personnel?
14. Who is usually involved in the FHWA CRA/CEVP reviews? How many have you been involved in so far?
15. What are the current challenges in cost estimating practices employed (HQ & district)?
16. What barriers do you foresee in implementing a formal, uniform estimating process at MnDOT? How could those barriers be reduced?
17. Do you have any suggestions for improvements in current cost estimating practices?
18. Does MnDOT need a different estimating process for accelerated projects, design-build projects, innovative finance projects, etc.?