NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
(NCHRP)

PROJECT 8-60

# Research Report for Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs

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**The University of Colorado**
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TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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# Summary

Project cost escalation is a serious problem faced by many State Highway Agencies (SHAs). The consequences of a failure to deliver individual projects and programs within established budgets is a detrimental effect on later programs and a loss of faith in an agency's ability to wisely use the public's money. Highway design and construction projects can be extremely complex and are often fraught with uncertainty. However, engineers, project managers, and cost estimators often overlook or fail to recognize project uncertainty early in the project development process. As a result they do not communicate project uncertainty and its effect to stakeholders. A comprehensive risk management approach can help project teams identify, assess, mitigate, and control project risks. Among the benefits of a comprehensive risk management approach is the ability to generate range estimates early in the project development process and to establish justifiable contingencies. It may even be possible to reduce contingency amounts during the project development process as identified risks are eliminated by designers who are now aware of the impacts of their decisions.

This Research Report documents the process for the development of a Guidebook that presents a systematic process to apply risk analysis tools and management practices to aid SHA management in controlling project cost growth. The Guidebook addresses risk identification, assessment, analysis, mitigation, allocation, and tracking and control in a manner that is systematically integrated into the organizational structure and culture of SHAs.

The Guidebook was developed as an extension to NCHRP Report 574, *Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*. That research presented a strategic approach to cost estimating and cost estimate management. However, the research team and the NCHRP research panel members identified the need for more detailed tools and management practices in the area of risk analysis and risk management practices. These needs were recognized to be particularly crucial for the long-range transportation planning, priority programming, and preconstruction stages of the project development process.

As in initial effort of this Guidebook, the research team conducted a survey of current SHA risk management practices. The survey revealed that while risk is indeed inherent in every capital transportation project, only three of the 48 state agencies responding to the survey had formal, published project risk management policies or procedures. Additionally, the survey found that only eight of the 48 responding agencies have a formal published definition of *contingency*. Without a formal definition for contingency, agencies have a difficult time consistently calculating contingencies appropriate to project conditions. Therefore, this Guidebook is an imperative to support SHA efforts to control project cost escalation.

Given the current state of practice, the research team employed an approach to developing the Guidebook that included a critical review of the literature, in-depth case studies with leading agencies (both inside and outside of the transportation sector), and a thorough industry validation of the work. The research team gathered and annotated more than 80 papers and reports on risk and risk management. In reviewing these articles and reports, the research team identified important research terms and sought risk management methods and tools to assist in cost

estimating, estimating contingency, or risk management related to cost control. Following the literature review the team closely analyzed eight in-depth case studies. The case studies were with Caltrans as an agency, the Caltrans San Francisco-Oakland Bay Bridge project, the Washington State Department of Transportation (WSDOT), the United States Department of Energy (US DOE), the Federal Highway Administration (FHWA), the Federal Transit Administration, the New York Metropolitan Transit Agency, and the Ohio DOT. The research team used the knowledge gained from industry surveys, the literature review, and the case studies to develop the initial Guidebook. The Guidebook was then tested with the WSDOT, Minnesota DOT (Mn/DOT), and the Colorado DOT and reviewed by the NCHRP Panel. The resulting Guidebook is founded on industry practice and was validated through industry review.

The risk management framework described in this Guidebook is based on best practices used in the design and construction industry. In the Guidebook, these practices are adapted to the unique needs of highway project development. The overall framework of the Guidebook includes three main elements:

1. **Risk Management Process**
   - Risk identification, assessment, analysis, planning and mitigation, allocation, and monitoring and control
2. **Project Development Phases**
   - Planning, programming, and design
3. **Project Complexity**
   - Project type, technical complexity, and management complexity

The interaction of the risk management process with the project development process and with project complexity is shown schematically in Figure 1.


**Figure 1: Risk Management Process Framework**
*(varies by project development phase and complexity)*

Of particular note in Figure 1 is the fact that the overall risk management process is cyclical. As a project evolves, some risks will be resolved or diminished, while others may surface and thus be added into the process. The five fundamental risk management steps can be applied throughout the project life cycle. The extent of application of each step varies as the methods and tools used to support these steps are influenced by the project development phase and project complexity. The process is scalable from small and non-complex projects to large and complex projects. There are five imperative steps to managing project risk.

1. *Risk identification* is the process of determining which risks might affect the project and documenting their characteristics using such tools as brainstorming and checklists.
2. *Risk assessment/analysis* involves the quantitative or qualitative analysis that assesses impact and probability of a risk. Risk assessment assists in deriving contingency estimates. Quantitative and qualitative risk analysis procedures are applied to determine the probability and impact of risks.
3. *Risk mitigation and planning* involves analyzing risk response options (acceptance, avoidance, mitigation, or transference) and deciding how to approach and plan risk management activities for a project.
4. *Risk allocation* involves placing responsibility for a risk to a party – typically through a contract. The fundamental tenants of risk allocation include allocating risks to the party that is best able to manage them, allocating risks in alignment with project goals, and allocating risks to promote team alignment with customer-oriented performance goals.
5. *Risk monitoring and control* is the capture, analysis, and reporting of project performance, usually as compared to the risk management plan. Risk monitoring and control assists in contingency tracking and resolution.

Lessons learned from the development of this Guidebook can be summarized in five keys to success for risk analysis tools to control project cost.

1. *Employ all steps* in the risk management process.
2. *Communicate cost uncertainty* in project estimates through the use of ranges and/or explicit contingency amounts.
3. *Tie risks to cost ranges and contingencies* as a means of explaining cost uncertainty to all stakeholders.
4. *Develop risk management plans* and assign responsibility for resolving each risk.
5. *Monitor project threats and opportunities* as a means of resolving project contingency.

# Chapter 1: Introduction

## *1.1 Introduction*

Highway design and construction projects can be extremely complex and fraught with uncertainty. Engineers and construction managers must coordinate a multitude of human, organizational, technical, and natural resources. Quite often, the engineering and construction complexities are overshadowed by economic, societal, and political challenges. The outcome of these challenges has too often been significant cost escalation. Project cost escalation has a detrimental effect on a state highway agency's (SHA) ability to program and deliver projects.

Project cost escalation is a major problem for SHAs. In completing NCHRP Project 8-49, "Procedures for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction," members of this research team and the NCHRP research panel identified the need for more detailed tools in the area of risk analysis and risk management, particularly in the long-range transportation planning, priority programming, and preconstruction stages of the project development process. The following unique challenges were identified in the previous research and included in the project statement. Each challenge was addressed to achieve systematic integration of risk management into the cost estimating and cost management process:

- Develop consistent definitions for "cost escalation," "risk," and "uncertainty";
- Develop guidance for consistent application of contingency to risk management and cost estimation;
- Develop systematic and uniformed approach for documenting and tracking risk;
- Identify appropriate timing of risk management procedures given various levels of project complexity during the different project development phases;
- Address policy, political, and communications issues;
- Determine appropriate organizational structures and required organizational commitment to achieve a risk management culture; and
- Develop performance measurements and accountability tools that can exist within transportation agency organizational structures.

This research provides a Guidebook of risk analysis tools and management practices to aid in controlling project costs. The Guidebook addresses risk identification, assessment, analysis, mitigation, allocation, and tracking and control in a manner that is systematically integrated into the organizational structure and culture of our nation's SHAs.

## *1.2 Cost Escalation and Cost Containment*

The problem of project cost exceeding SHA estimated cost is a major performance issue for many SHAs. The ramifications and effects that result from differences between early project cost estimates and the bid price or the final project cost are significant. This fact is illustrated by the media coverage and political response to bids for the Wilson Bridge in Washington, D.C., the San Francisco-Oakland Bay Bridge East Span, and to the cost increases on the Central Artery/Tunnel project in Boston (National Academy of Engineering 2003). These problems are

pervasive in the transportation industry as a whole on projects both large and small. A study of 258 infrastructure projects spanning a time period of more than 70 years found that project costs are underestimated in approximately 90 percent of the projects, and actual costs average 28 percent higher than estimated based on this sample (Flyvbjerg, et. al 2002). Although highway projects fared better than rail and fixed-linked projects, the sample still displays an increase in project costs of more than 20%. As a result of both higher bids and project cost growth, estimating for projects over $10 million was a topic of review by the Federal House Subcommittee on Transportation Appropriations (Federal-Aid 2002). Clearly, additional guidance would assist in better estimating procedures for our SHAs.

Uncertainty and risk are major drivers of cost escalation throughout project development. State highway agencies need guidelines that comprehensively describe risk-related analysis tools and management practices for estimating and controlling transportation project cost. Inadequate estimating invariably leads to misallocation of scarce resources. If estimates are consistently high, compared to bid costs and ultimately final costs, fewer projects will be authorized than could have been performed with the resources available, resulting in loss of benefits. If estimates are consistently low, more projects can be authorized than can be fully funded, resulting in project slowdowns, scope changes, and performance shortfalls, and generally higher costs and reduced benefits. If estimates are neither consistently high nor low, but still inaccurate, the estimated benefit/cost ratios will not be correct and the most beneficial projects may not be authorized, while less beneficial projects are authorized. All of these conditions result in misallocation of funds and a loss in benefits to the public.

Substantial value results from providing risk assessment, cost estimating, cost management, and cost containment techniques at the earliest stages in the project development process. Cost engineering research has illustrated that the ability to influence and manage cost is greatest at the earliest stages in project development ("Pre-Project Planning: Beginning…", 1994). A project management oversight function definitely has the ability to help manage the process – *especially in the area of cost containment* – but it is imperative to examine the problems and solutions for cost-risk analysis and management practices at the earliest stages of the project. To neglect the earliest stages of the project development process will diminish the practical application of this research.

> *Risk assessment, cost estimating, cost management, and cost containment techniques must be implemented at the earliest stages of the process – even if the transparency of uncertainty in the engineering and political process is difficult to define and manage.*

## 1.3 Research Problem

The research problem is clear. State highway agency engineers and management need a comprehensive set of risk analysis and management practices to combat this issue of cost escalation and achieve cost containment. The cost escalation problem is faced by every state highway agency, transit agency, and metropolitan planning organization in the country as projects evolve from concept in the long-range planning process, are prioritized for programming, and are subject to detailed development prior to construction. *This research addresses the need for more in-depth research and guidance on the application of risk-related*

*management practices and analysis tools for controlling project costs.* This need is manifested in current approaches to cost management and cost control processes that do not take a systematic approach to risk analysis and management to promote consistency and accuracy of costs over the project development process.

This research is not suggesting wholesale changes to the cost estimating process, but rather it is suggesting a more rigorous step of risk identification and estimation of contingencies in the project estimating process. This research provides a Guidebook with a clear and concise collection of practices to assist agencies in identifying and managing risk, estimating and managing contingency, and ultimately controlling transportation project costs.

## 1.4 Research Objectives

The transportation industry problem of accurately estimating project cost and achieving cost containment will be addressed by accomplishing the following main objective:

> *To develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs.*

This main objective is addressed through a focus on the following sub-objectives:

1. Development of a Guidebook that seamlessly integrates with the strategies, methods, and tools defined in the NCHRP 8-49 Guidebook for Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction.

2. Develop a Guidebook that provides a plain language approach to selecting appropriate tools and practices that support a systematic approach to risk management.

3. Develop a Guidebook that is applicable to all phases of project development.

4. Develop a Guidebook that is applicable to all projects, but which recognizes the affects of project size and complexity.

The resulting Guidebook is a “how to” manual for risk analysis and risk management practices. It contains clear step-by-step guidance on why, when and how to apply proven industry methods and tools. When applied throughout the industry, the Guidebook creates a common vocabulary and set of practices that will promote learning and the exchange of new tools and innovations throughout our nation’s state highway agencies.

## 1.5 Scope of Work

Accomplishment of the project objective required the following tasks:

**Task 1: Current Practice Review and Definition Development**
A comprehensive review was conducted of the literature, recent and ongoing research results, applicable federal requirements and guidance, and current practice relative to risk management as it applied to cost estimation and cost control. An annotated summary of information was

prepared for use in the Guidebook. Definitions of cost escalation, risk, and contingency, as well as other important terms were created.

**Task 2: Risk Categorization, Identification, Quantification, and Assessment Review**
A review of current practice in defining and categorizing risk, identifying and quantifying risk, and assessing the degree of uncertainty in transportation project-cost estimation was conducted and documented.

**Task 3: Risk Tools and Practices Review and Documentation**
A review and documentation was conducted for an array of well-established risk analysis tools and management practices. Information was obtained from practitioners and stakeholders on issues associated with using risk analysis and management for project-cost control.

**Task 4: Case Studies of Effective Application**
Based on information obtained in Tasks 1 through 3, the research team prepared a series of case studies that demonstrated effective application of risk-analysis tools and management practices in controlling project costs during the planning, priority programming, and preconstruction phases of transportation projects. Issues that required additional attention to improve current practice were identified.

**Task 5: Preliminary Guidebook Outline**
Based on the results of Tasks 1 through 4, the research team developed a preliminary outline of the Guidebook, including a proposed glossary of terms related to risk analysis tools and management practices to control transportation project costs.

**Task 6: Prepare Interim Report**
The research team prepared an interim report that documented the work performed and findings from Tasks 1 through 5. The team presented the interim report and proposed necessary revisions to the work plan at a meeting with the project panel.

**Task 7: Detailed Annotated Guidebook Outline and Appropriate Presentation Materials**
Based on panel decisions at the Task 6 meeting, a detailed annotated outline and sample sections of the Guidebook was prepared and the research team developed appropriate presentation materials for practitioner-review sessions in Task 8. The outline and presentation materials were submitted to the panel for review and were approved.

**Task 8: Professional Practitioner Review**
The team presented the annotated outline of the Guidebook developed in Task 7 to selected professional practitioners at review sessions to obtain input and feedback and to gauge reactions to the format and content of the Guidebook.

**Task 9: Draft Guidebook**
Based on the input and feedback received in the Task 8 review sessions, the team developed the draft Guidebook.

**Task 10: Submit Guidebook and Research Report**
A final Guidebook and Research Report were prepared and submitted to the panel review and approval.

## *1.6 Framework for Research Approach*

Successfully achieving a research objective requires a rigorous research framework. The framework provides a basis for the proposed research methodology. In this way, the research is conducted in a systematic and rigorous manner. Thus, the end result and subsequent product is developed based on a solid research approach and, at the same time, is described in a manner that is readily implementable by transportation agencies.

The overall framework that the research approach followed included three main elements listed below and shown here in Figure 1.1.

1. **Risk Management Process**
   - Risk identification, assessment, analysis, planning and mitigation, allocation, and monitoring and updating
2. **Project Development Phases**
   - Planning, priority programming, and preconstruction
3. **Project Complexity**
   - Project size, technical complexity, and management complexity


**Figure 1.1: Research Framework**
*(varies by project development phase and complexity)*

The interaction of these steps in the risk management process with the project development process and project complexity is shown schematically in Figure 1.1. Of particular note is the fact that that the overall risk management process is repetitive and cyclical. As the project evolves, some risks will be resolved, mitigated, or fully realized, while others may surface and thus be added. The five fundamental risk management steps are repeatedly applied throughout the project life cycle, but the methods and tools to complete these steps are dependent on the

project development phases and project complexity. The Guidebook consciously and directly addresses the interaction of these important elements.

## 1.7 Reader's Guide to the Report

The research report is organized around the research tasks. To aid in the readability of the report and to better explain the final research approach, the report presents the case studies in Task 4 are prior to the tools in Task 3 because many of the final tools were discovered in the case studies. Additionally, the report groups the Guidebook development tasks into one chapter. Chapter 2 presents the state-of-practice results from Task 1. Chapter 3 presents the risk identification, categorization, quantification, and assessment review from Task 2. Chapter 4 presents the case studies from Task 4. Chapter 5 presents the risk tools from Task 3. Chapter 6 presents the Guidebook development and testing from Tasks 7, 8 and 9. Chapter 7 summarizes the research results. The appendices of the report contain the references, definitions, annotated bibliography, case studies, and state-of-practice questionnaire.

## 1.8 Conclusion

Highway design and construction projects can be extremely complex. If uncertainty in project estimates and management is not properly analyzed and managed, costs will escalate. This research report describes the development of a Guidebook under NCHRP Project 8-60 "Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs." It describes the methodological approach and research results that were used to develop the final Guidebook. The Guidebook contains tools and management practices in the area of risk analysis and management practices, particularly for the long-range transportation planning, priority programming, and preconstruction stages of the project development process. The Guidebook structure provides guidance for executive, program, project, and discipline-level managers to implement risk analysis and management practices in a strategic manner to create change in SHA management procedures and cultures.

# Chapter 2: State-of-Practice Review

## *2.1 Introduction*

The goal of Task 1 was to describe the current state of practice and develop definitions for risk analysis and cost control. During this task, the team conducted a thorough literature review and a survey of state highway agencies regarding current risk management practice as it applies to cost estimation and cost control. The goal of the literature review and survey was to help determine current industry practices to be used in supporting the appropriate sections in the Guidebook and to develop the comprehensive set of definitions. This chapter presents the methodology for the literature review and the state of practice summary. It presents the results as they relate to the project development phases, agency estimating organizations, cost escalation, uncertainty and estimate development, highway cost estimating/management practice, and contingency estimates. It then presents cost estimating and risk management definitions. It concludes with a description of the risk management process.

## *2.2 Literature Review Methodology*

The literature review involved researching, gathering, reading, note taking, and processing information and literature relating to risk management practice in relation to cost estimating and cost control. The literature review was not limited solely to the transportation sector as other sectors of construction (e.g., industrial and environmental remediation) are more advanced in the discipline of risk management. Searches were performed with the following resources:

- The general Internet, including Yahoo and Google;
- Academic and research search engines including Transportation Research Information Services (TRIS) and Engineering Village 2;
- Research institutions including the Construction Industry Institute (CII) and Transportation Research Board (TRB);
- Societies with journal and conference publications including the American Society of Civil Engineers (ASCE) and the Association for the Advancement of Cost Engineering International (AACEI); and
- Government publications including both federal and state, United States General Accounting Offices, and state Department of Transportation research departments.

Keywords used during these searches include:

- risk;
- risk management;
- cost control; and
- contingency.

Each document gathered by the team was read and information relevant to the research compiled. The search identified summaries of a number of past research efforts. In such cases, the team attempted to obtain the original work rather than use the summary. This cross referencing of literature helped to identify the most important research and literature.

The research team has gathered and annotated more than 80 papers and reports (Appendix B). In reviewing these articles and reports, the research team defined important research terms and looked for risk management methods and tools to assist in cost estimating, estimating contingency, or risk management related to cost control. More specifically, the team identified methods and tools that focus on conceptual or long-term estimates, but not at the exclusion of engineer's estimates.

## 2.3 State-of-Practice Survey Methodology

The state-of-practice survey was administered via email and through an on-line questionnaire. The goal of the survey was to help determine the current industry practices for assessing uncertainty and estimating contingencies. An initial questionnaire was sent to the NCHRP panel and the final questionnaire was constructed based on feedback from the panel. The team applied a number of lessons learned concerning successful techniques for administering web surveys via email. The TCRP Synthesis 69, "Web Based Survey Techniques" (Spitz et al. 2006) and the book "Conducting Research Surveys via E-Mail and the Web" (Schonlau et al. 2002) were relied upon heavily in the creation of the survey.

The state-of-practice web survey is included in Appendix K.

Survey contacts were solicited from the following groups: AASHTO Technical Committee on Cost Estimating; Transportation Estimators Association (TEA); AASHTO Trns•port Users Group (TUG); AASHTO Trns•port Task Force; AASHTO Subcommittee on Construction; AASHTO Standing Committee on Planning; and the AASHTO Subcommittee on Design. A brief description of each group and the total number of contacts who were asked to participate in the survey are:

The AASHTO Technical Committee on Cost Estimating is comprised of approximately 19 members from various Departments of Transportation. The objectives and scope of this AASHTO committee are to:

- create an AASHTO position regarding a recommended policy on best practices for how to develop estimates; and
- prepare written policies/guidelines for cost estimating at all stages of project development.

The Transportation Estimators Association (TEA) is comprised of members from various Departments of Transportation. The objectives of the TEA are to:

- improve cost estimating techniques and publish guidelines used by transportation estimators (cost based, historical based and parametric);
- develop innovative new cost estimating techniques;
- disseminate experiences in cost estimating and new practices through yearly meetings;
- publish a newsletter to transportation cost estimators; and
- sponsor a yearly cost estimating workshop.

The AASHTO Trns•port Users Group (TUG) is comprised of approximately 50 members from various Departments of Transportation. The objectives of the TUG are to:

- provide a forum for a unified voice to direct the course of Trns•port, hereinafter called the products, or any products which may supersede these products;
- provide cooperative technical support of the products;
- provide input to the Product Management Task Force on product effectiveness, product deficiencies, and needed product enhancements;
- define product training and support needs;
- prioritize maintenance, enhancements, and support needs; and
- submit recommendations to the Product Management Task Force.

The AASHTO Subcommittee on Construction is comprised of approximately 79 members from various Departments of Transportation. The objectives of the AASHTO Subcommittee on Construction are to:

- prepare, publish and keep current (1) guide specifications for construction; and (2) a manual of construction practices and methods;
- coordinate the practices of the several Member Departments regarding construction procedures;
- operate a forum for the exchange of information regarding such procedures;
- effect liaison with other operating subcommittees in a concerted effort to reduce construction cost, promote quality in construction, provide coordinated plans and specifications, mitigate traffic impacts, advocate environmental sensitivity in construction, and promote safety for both the construction workers and the traveling public;
- encourage economical electronically supported business practices for construction related programs; and
- promote the best practices for administering construction contracts with all stakeholders.

The AASHTO Committee on Planning is comprised of approximately 94 members from various Departments of Transportation. The objectives of the Standing Committee on Planning are:

- investigate, study, and report on planning activities including such activities as urban and statewide transportation systems planning;
- corridor and site planning for individual facilities;
- review and evaluate methods used or proposed for use for acquiring and applying the information essential to transportation planning;
- promote and encourage an effective liaison between state transportation officials and appropriate levels of government; and
- review national problems, existing and proposed policies, Federal guidelines, and regulations pertaining to transportation.

The AASHTO Subcommittee on Design is comprised of 283 members from various Departments of Transportation. The Subcommittee on Design objectives are:

- investigate available data and pursue studies to develop and keep current appropriate publications pertaining to principles, methods, and procedures of transportation facility design, including but not limited to geometric, aesthetic elements, and pavements;
- investigate, develop, and keep current recommended practices for the design of facilities to integrate safety features;

- recommend and promote design practices which will protect and enhance the quality of the environment, provide a forum for the exchange of practices and experience in the field of transportation facility design; and
- give due consideration to the effect of all design features on economic and energy resources.

The results of this survey have been incorporated into following section and throughout the remainder of this report.

## *2.4 State-of-Practice Summary*

This section describes the state of practice based on both the literature review and a survey of state highway agencies. Results from these two sources of information are presented separately in some cases and together when the literature supports the survey results.

### 2.4.1 Project Development Phases

Project estimates are made at various times during project development. Different types of estimates will occur during different phases of project development. An estimating technique must fit the information available at the time the estimate is developed. Thus, certain types of estimates are common during the different project development phases. For example, conceptual estimating is commonly used in planning and early in the programming phase of a project.

An understanding of project development phases is critical in selecting appropriate risk analysis tools or management practices, and for communicating the results of the risk analyses. Because each transportation agency has subtle differences in the terms used to describe the phases of project development, the NCHRP research team and Panel found it necessary to create a standard set of terms for the NCHRP Report 574. The project development phases and their descriptions, as presented in Figure 2.1 and discussed in Table 2.1 respectively, these were adapted from a National Cooperative Highway Research Program Synthesis on *Statewide Highway Letting Program Management* (Anderson and Blaschke 2004) and then tested thoroughly through the Guidebook validation process. The Planning, Programming/Preliminary Design, and Final Design phases are depicted as overlapping in Figure 2.1. This overlapping indicates the cyclical nature of these three phases, as projects are developed and move to construction. Refer to Appendix A for formal definitions of the project development phases used in the Guide.

**Table 2.1. Development Phases and Activities (Anderson and Blaschke 2004)**

| Development Phases | Typical Activities |
|---|---|
| Planning | Purpose and need; improvement or requirement studies; environmental considerations; right-of-way considerations; schematic development; public involvement/participation; interagency conditions. |
| Programming (a.k.a. scoping, definition) | Environmental analysis; alternative selections; public hearings; right-of-way impact; design criteria and parameters; project economic feasibility and funding authorization. |
| Preliminary Design | Right-of-way development; environmental clearance; preliminary plans for geometric alignments; preliminary bridge layouts; surveys/utility locations/drainage. |
| Final Design | Right-of-way acquisitions; PS&E development – final pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/final drainage design, final cost estimates. |

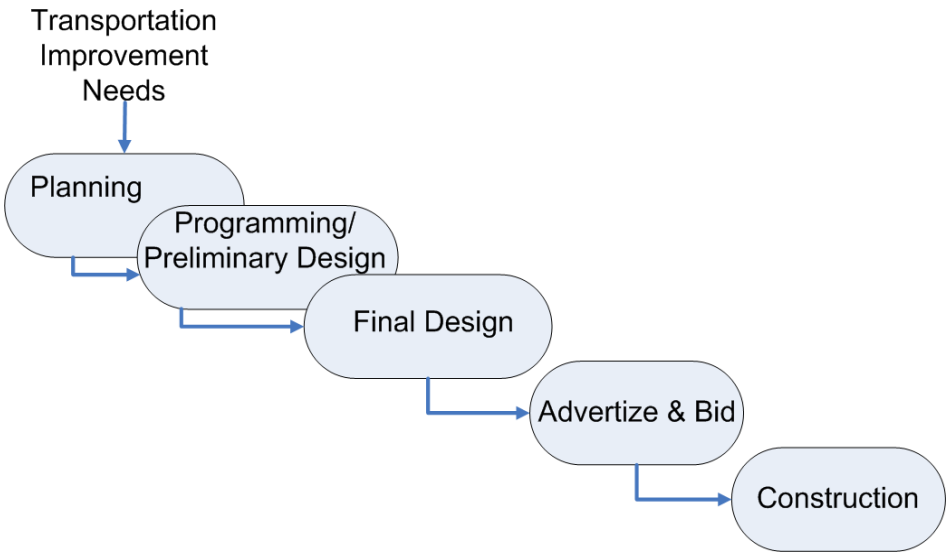


**Figure 2.1: Typical Project Development Phases for Highway Projects**

Significant value can result by providing risk assessment, cost estimating, cost management, and cost containment techniques at the earliest stages in the project development process. A key step identified in the NCHRP Report 574 involves the setting of a baseline estimate for cost and schedule control. Baseline estimates are typically set as the project enters the priority programming phase or the State Transportation Improvement Program (STIP). Ideally, projects at this stage would be scoped with a high level of certainty, but in practice, scope definition can vary greatly at this stage. An understanding of risk and the associated contingency estimate at this stage of the process is a key to controlling cost escalation.

### 2.4.2 Agency Estimating Organizations

An understanding of how agencies organize to conduct cost estimates throughout the project development process is essential to developing a Guidebook of risk management practices to control transportation project costs. Initial discussions with agencies found that they organize for estimating using two very different approaches. The first approach is to have a separate estimating section that is solely responsible for the estimates. The second is to have planners/designers and project managers perform the estimates. Agencies also use a combination of these two approaches. Table 2.2 provides a summary of the results.

**Table 2.2. Agency Estimating Organization**

| Project Development Phase | Separate Section | Planners/Designers and Proj. Managers | Both |
|---|---|---|---|
| Planning | 2% | 63% | 35% |
| Programming and Preliminary Design | 0% | 65% | 35% |
| Final Design | 4% | 44% | 52% |

* 49 of 52 agencies reporting.

As a whole, only about one third of the agencies have a separate estimating section to support designers and managers in the planning and programming and preliminary design stages. This number rises to over one half for the final design stage. This decentralized estimating function in the early stages of planning and project development implies that the risk management function must also be decentralized, or at least not solely dependent upon a central risk management unit.

For the planning phase, Illinois is the only state agency that uses a separate estimating section. The majority of the state agencies, 31 of the 48 that responded, leave the responsibility of estimating up to the planners at this stage. The remaining 16 state agencies use both methods as a combined effort. These planners could be internal agency planners, consultants and/or metropolitan planning organizations depending upon the agency and the project.

For the programming and preliminary design phase none of the respondents use a separate estimating section. Once again, the majority of the state agencies, 32, rely solely on the designers and project managers to develop the cost estimates. The same 16 states use both methods for a combined effort.

For the final design phase, both Mississippi and Wyoming use a separate estimating section. At this stage in project development, only 21 of the 48 state agencies rely solely on the designers and project managers and the majority use both a separate section and the designers and project managers for estimates.

The survey asked for the names of separate estimating sections. Table 2.3 provides a listing of the estimating section names to provide a sense of who is supporting the planners, designers, or project managers with their estimating tasks.

**Table 2.3. Agency Estimating Sections**

| State | Separate Sections |
|---|---|
| Arizona | Contacts and Specifications Section |
| California | Structure Estimates |
| Connecticut | Office of Contract Development/Estimating |
| Georgia | Estimating Section |
| Illinois | Bureau of Design and Environment |
| Iowa | Department of Contracts |
| Kentucky | Construction Procurement Estimating Branch |
| Minnesota | Engineering Cost Data and Estimating Unit |
| Nebraska | Highway Estimating Section |
| New York | Estimating Section |
| North Carolina | Estimating Section |
| Ohio | Office of Contracts and Estimates |
| Oregon | Estimating Unit |
| South Dakota | Project Development Unit |
| Tennessee | Conceptual Design and Estimates |
| | Program Development |
| | Construction Estimating |
| Virginia | Scheduling and Contracts Division |
| | Final Cost Estimating Section |
| Washington | Strategic Analysis and Estimating Office |
| Wyoming | Contracts and Estimates Section |

### 2.4.3 Cost Escalation

The problem of project cost exceeding the SHA estimated cost is a major performance issue for many SHAs. As discussed in Chapter 1, the ramifications and effects that result from differences between early project cost estimates and the bid price or the final project cost are significant. Inadequate estimating invariably leads to misallocation of scarce resources. If estimates are consistently high, compared to bid costs and ultimately final costs, fewer projects will be authorized than could have been performed with the resources available, resulting in a loss of benefits.

Construction projects have a long history of cost escalation (Federal-Aid 2003, Flyvbjerg 2002). NCHRP Report 574 documented the factors that lead to project cost escalation through a large number of studies and research projects as described in the literature (Anderson, et al. 2007). The factors driving cost escalation of project cost were divided into internal and external. Factors that contribute to cost escalation and are controllable by the SHA are internal, while factors existing outside the direct control of the SHA are classified as external. This arrangement of factors is shown in Table 2.4, these factors are numbered for reference only and do not suggest a level of influence. The factors are fully explained and referenced in NCHRP Report 574.

**Table 2.4. Project Cost Escalation Factors (Anderson et. al, 2007)**

| | Cost Escalation Factor |
|---|---|
| **Internal** | 1. Bias<br>2. Delivery/Procurement Approach<br>3. Project Schedule Changes<br>4. Engineering and Construction Complexities<br>5. Scope Changes<br>6. Scope Creep<br>7. Poor Estimating<br>8. Inconsistent Application of Contingencies<br>9. Faulty Execution<br>10. Ambiguous Contract Provisions<br>11. Contract Document Conflicts |
| **External** | 1. Local Concerns and Requirements<br>2. Effects of Inflation<br>3. Scope Changes<br>4. Scope Creep<br>5. Market Conditions<br>6. Unforeseen Events<br>7. Unforeseen Conditions |

The cost escalation factors in Table 2.4 illustrate the challenges and uncertainties that SHAs face as they develop cost estimates. Many of these factors can be controlled through diligent project management and strict project cost control policies. However, many of the factors (e.g., project schedule changes, effects of inflation, unforeseen events, etc.) do not occur on each project and should therefore not be incorporated into a base estimate. On any given project, many of these escalation factors should be managed through contingency and risk management practices.

### 2.4.4 Uncertainty and Estimate Development

Uncertainty and risk play a major role in cost escalation throughout project development. Cost estimating methods and tools must relate and adapt to the various phases of project development. When estimating costs on large highway projects, this becomes even more profound (Merrow, et. al 1988). *In the long-range planning and priority programming stages of project development, estimators have very little information with which to work and the information is often fraught with uncertainty.* The Association for the Advancement of Cost Engineering International (AACEI) defines a Cost Estimate Classification System with five classifications for estimates. This system provides an expected range of accuracy for each phase as shown in Table 2.5. A Class 5 estimate is based upon the lowest level of project definition, and a Class 1 estimate is closest to full project definition and maturity.

**Table 2.5. AACEI Generic Cost Estimate Classification Matrix (adapted from AACEI 1997)**

| **Estimate Class** | **Level of Project Definition** Expressed as % of complete definition | **End Usage** Typical purpose of estimate | **Methodology** Typical estimating method | **Expected Accuracy Range** Typical +/- range |
|---|---|---|---|---|
| Class 5 | 0% to 2% | Screening or Feasibility | Stochastic or Judgment | +100 to -50 |
| Class 4 | 1% to 15% | Concept Study or Feasibility | Primarily Stochastic | +75 to -40 |
| Class 3 | 10% to 40% | Budget, Authorization, or Control | Mixed, but Primarily Stochastic | +40 to –20 |
| Class 2 | 30% to 70% | Control or Bid/ Tender | Primarily Deterministic | +20 to –10% |
| Class 1 | 50% to 100% | Check Estimate or Bid/Tender | Deterministic | +10 to –5% |

Although Table 2.5 is generic for the construction industry and the terminology does not directly coincide with the highway project development process, it can be used to convey a few key concepts. First, it describes a number of end usages for estimates, which relate to the strategies described later in this report. Second, it describes the methodological approach to the estimate as either *stochastic* or *deterministic*, depending upon the level of design and information available. This is an important concept and a change for the highway industry. In data collection for the NCHRP Report 574, the research team found that the Federal Highway Administration and state highway agencies currently rely almost exclusively on deterministic estimates at all stages of project development. A stochastic estimate models uncertainty in project costs and produces a range of cost for the total estimate whereas a deterministic estimate relies on mean (or most likely) values and produces one value for the total estimate. According to AACEI, stochastic estimates should be used instead of deterministic estimates for long-range planning and priority programming as the AACEI would consider these to be Class 5 to Class 3 estimates.

Two fundamental figures are shown here as a basis for describing the need for risk-based cost estimating techniques. More generally, at any stage in the development of a transportation project, cost estimates will be composed of three types of information, which can be termed as the “Known/Knowns,” (known item with quantifiable costs), the “Known/Unknowns,” (known item but costs not quantified) and the “Unknown/Unknowns” (as yet unrecognized items and costs) as shown in Figure 2.2. Comprehensive cost management and containment strategies must be employed to properly control these types of information. All too often, if the cost of an item is not known, it is not included in early project cost estimates. At other times items, such as right of way or construction engineering costs, are often left out entirely from early estimates. The three types of information also require different methods and tools to define and quantify their possible contribution to a cost estimate at any particular time in the project development process. Traditional methods take a deterministic, conservative approach to project cost

estimating, and then add a cost contingency that varies depending on the stage of project definition, experience and other factors. This approach tends to fall short of the needs for contemporary assessment and management of uncertainty.

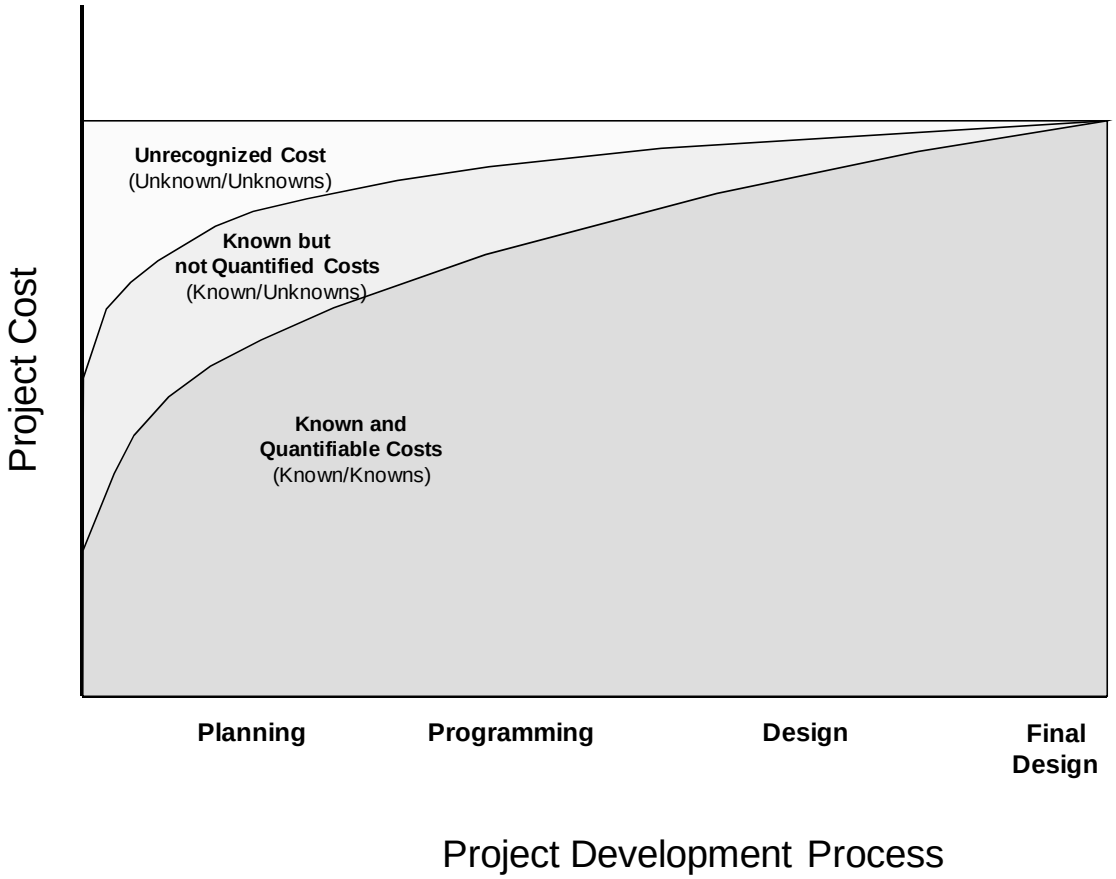


**Figure 2.2. Conceptual Components of a Cost Estimate**

Figure 2.3 depicts how identifying, quantifying and managing cost uncertainty relates to management of the cost of major projects. In this figure two primary points that apply to situations where the project scope is unchanged and where an estimate includes uncertainty are illustrated. The first point is that there should be a reduction in the range of cost uncertainty as a project proceeds from concept to completion. The reduction in estimated cost is a result of better defining cost variables and eliminating uncertainty as cost factors are finally incorporated in the project plan. The second point is that, if the problems (or risks) included in the early stages of a cost estimate do materialize, then a higher range of the cost estimate will be expected. In contrast, when risk management and other cost control processes are used effectively to capitalize on opportunities, a lower range of expected costs will likely result.

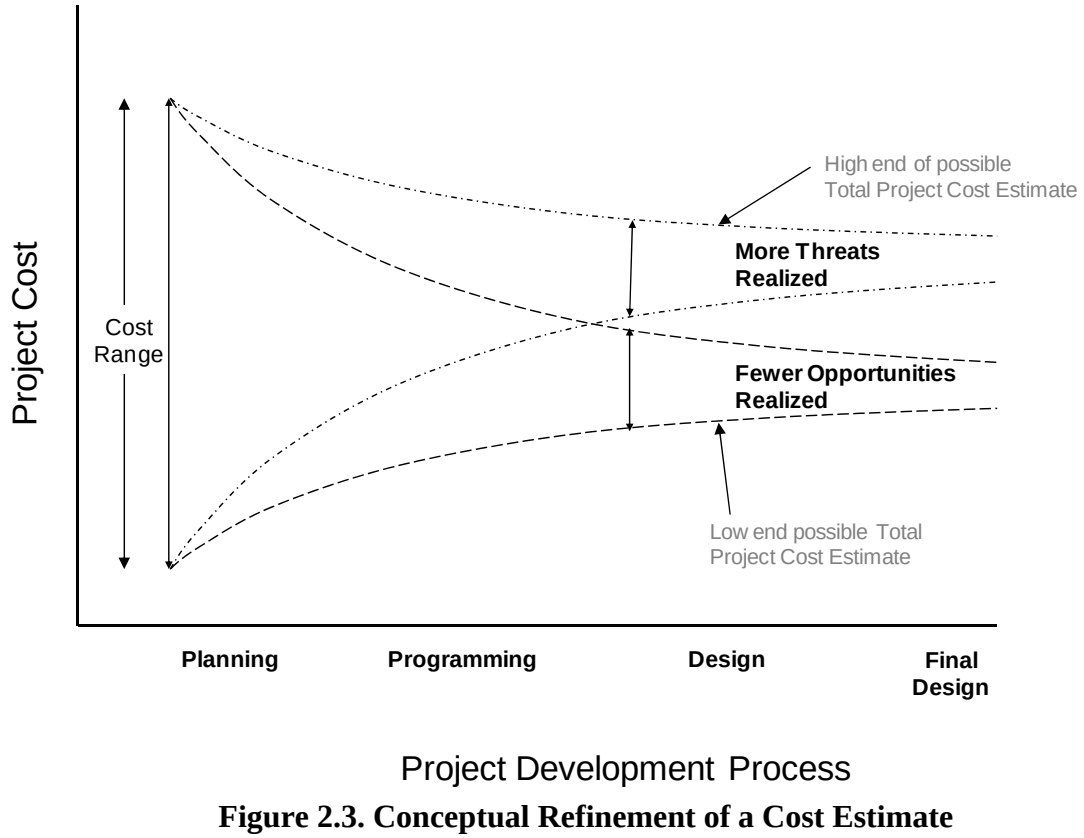


**Figure 2.3. Conceptual Refinement of a Cost Estimate**

### 2.4.5 Highway Cost Estimating and Cost Management Practice

The cost escalation factors and issues of uncertainty in cost estimates described in the preceding sections necessitate disciplined cost estimating and cost management procedures. The foundation for achieving accurate and consistent cost estimates is a structured estimate development process. Yet in many agencies there exist "stove pipe" divisional structures that lead to a failure in communicating important project information affecting scope, design, and cost. While these agency structures may not in and of themselves be the direct cause of the project cost escalation problems, they deprive management at all levels of the ability to adequately address the foundational problems that drive program and project cost increases.

As described in NCHRP Report 574, cost estimating and cost estimating management processes can be described in terms of a number of steps. In fact, a relatively small number have been found to adequately describe each of these two processes. These cost estimating and cost management steps have been found to be scalable to different elements within the process and to different types of estimates. This report will rely on these steps as a basis for discussion of the highway cost estimating and cost management process.

Cost estimating is described in terms of four basic steps. The four steps and a brief description of each step are provided in Table 2.6. The descriptions are general in nature and are considered applicable to the estimating process across each project development phase.

**Table 2.6. Cost estimating process (Adapted from NCHRP Report 574).**

| Cost Estimating Step | Description |
|---|---|
| Determine estimate basis | Document project type and scope including<br>• scope documents;<br>• drawings that are available (defining percent engineering and design completion);<br>• project design parameters;<br>• project complexity;<br>• unique project location characteristics; and<br>• disciplines required to prepare the cost estimate |
| Prepare base estimate | Prepare estimate, including<br>• documentation of estimate assumptions, types of cost data, and adjustments to cost data;<br>• application of appropriate estimating techniques, parameters, and cost data consistent with level of scope definition;<br>• coverage of all known project elements;<br>• coverage of all known project conditions; and<br>• check to ensure that estimate is consistent with past experience. |
| Determine risk and set contingency | Identify and quantify areas of uncertainty related to<br>• project known's and unknowns;<br>• potential risks associated with these uncertainties; and<br>• appropriate level of contingency congruent with project risks. |
| Review total cost estimate | Review estimate basis and assumptions, including<br>• methods used to develop estimate parameters (e.g., quantities) and associated costs;<br>• completeness of estimate relative to project scope;<br>• application of cost data, including project-specific adjustments;<br>• reconciliation of current estimate with the baseline estimate (explain differences); and<br>• preparation of an estimate file that compiles information and data used to prepare the project estimate. |

While these steps and their descriptions could be shown in greater detail, the four steps are sufficient for purposes of providing guidance on cost estimating. The four steps must be implemented in each of the project development phases. However, the manner in which these steps are performed varies depending on the project development phase. These variations are reflected in the methods and tools that are implemented during each project phase. The performance of each step is supported by historical databases, input from different project disciplines (e.g., planners, roadway, structures, right-of-way, utilities, and environmental), and input from third parties such as Metropolitan Planning Organizations, environmental agencies, local agencies, and the public. The types of information provided through databases and diverse entities, which impact estimating, also varies depending on the project phase.

Cost estimating management can likewise be described by a number of steps. Five steps and a general description of each step are provided in Table 2.7. Again, the descriptions are general and are considered applicable to the cost estimating management process across each project development phase. Implementation of these steps varies by project phase.

Similar to the cost estimating steps, these cost estimating management steps and their descriptions could be shown in greater detail, but five steps are sufficient for purposes of providing guidance on cost estimating management. The required number of steps performed in each phase varies. The timing and the manner in which the steps are performed also varies depending on the project phase. These variations are reflected in the strategies, methods, and tools that are implemented during each project phase.

NCHRP Report 574 described these cost estimate and cost estimate management steps in detail. The Guidebook on risk analysis tools and management practices to control transportation project costs is written as a standalone document, but it relies heavily upon and remains consistent with the NCHRP Report 574 framework. The risk Guidebook expands primarily upon Step 3 – Determine Risk and Set Contingency of the cost estimating steps. It also integrates with the cost management steps, with a particular emphasis on Step 2 – Determine Estimate Communications Approach and Step 5 – Adjust Cost Estimate. All of these ties are made primarily through using risk analysis to estimate contingency needs in the early project development phases and retire the contingency thoughtfully in the later stages of project development.

**Table 2.7. Cost estimate management process (adapted from NCHRP Report 574).**

| Cost Estimate Management Step | Description |
|---|---|
| Obtain appropriate approvals | Obtain management authorization to proceed by<br>• review of current project scope and estimate basis;<br>• securing of approvals from appropriate management levels;<br>• approval of current estimate, including any changes from previous estimate; and<br>• release of estimate for its intended purpose and use. |
| Determine estimate communication approach | Communication approach is dependent upon the stakeholder who is receiving the information, but should consider<br>• mechanism for communicating the cost estimate for its |

| Cost Estimate Management Step | Description |
|---|---|
| | intended purpose;<br>• level of uncertainty to be communicated in the estimate given the information upon which it is based, and ;<br>• mechanism to communicate estimate to external parties. |
| Monitor project scope and project conditions | Identify any potential deviation from the existing estimate basis, including<br>• changes to scope;<br>• changes due to design development<br>• changes in project risks<br>• changes due to external conditions<br>• the nature and description of the potential deviation; and;<br>• whether the deviation impacts the project budget and/or schedule (potential increase or decrease). |
| Evaluate potential impact of change | Assess potential impact of change, including<br>• cost and time impact of the deviation;<br>• risk impact on project contingency; and<br>• recommendations as to whether to modify the project scope, budget, and/or schedule due to change. |

## 2.4.6 Contingency Estimates

### 2.4.6.1 Definition of Contingency

Contingency is the primary tool that estimators and project managers use to manage risk and uncertainty in project estimates. The dictionary defines contingency as a future event that is possible but cannot be predicted with certainty. In this study, contingency is defined as the *estimate of costs associated with identified uncertainties and risks, the sum of which is added to the Base Estimate to complete the Project Cost Estimate. Contingency is expected to be expended during the project development and construction process.*

Unfortunately, the word contingency does not have universal meaning. According to the AACE International, contingency is defined as an amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, and/or effect are uncertain and that experience shows will likely result, in aggregate, in additional costs (AACEI 2007). According to the Cost Engineers' Notebook, contingency is a cost element of an estimate to cover a statistical probability of the occurrence of unforeseeable elements of cost within the defined project scope due to a combination of uncertainties, intangibles, and unforeseen/highly unlikely occurrences of future events, based on management decisions to assume certain risks (for the occurrence of those events) … contingency reflects a management allowance to avoid project cost overruns (within the parameters of risk assumed) to ensure that the owner is not required to re-appropriate additional funds (AACEI 1995). Ford (2002) states contingency funds are established such that emergencies are resolved by providing funds for future unforeseen

expenses; completion is assured by the project deadline by accelerating progress; value is added to the constructed facility, typically by implementing design and scope changes; and contingency savings are maximized. Bent (2001) defines the contingency as the amount that historical experience indicates must be added to the completed estimate so that the total estimate has an equal chance of falling above or below the actual cost. Bent goes on to establish that contingency is usually a function of the following:

- design definition (such as process, utilities, facilities, and revamp);
- estimating methods (database and level of detail);
- estimator experience (type project/same industry);
- time frame and schedule probability;
- new technology and prototype engineering;
- remoteness of jobsite, infrastructure requirements and logistics;
- engineering physical progress at time of estimate; and
- material commitment at time of estimate.

The transportation industry generally agrees that contingency is necessary, but there is inconsistency concerning what is included in a contingency amount and how it should be calculated. As seen in Figure 2.4, only 8 of the 48 responding agencies have a formal published definition of contingency. Without a formal definition for contingency, agencies will have a difficult time consistently calculating appropriate contingencies. This research will need to promote a formal definition and constant application of contingency for it to be successful.

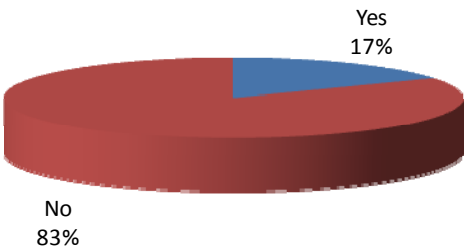


**Figure 2.4 Published Definition for Contingency Pie Chart (48 of 52 State Agencies Responding)**

Although no two definitions for contingency are the same, there are many similarities that can be seen among them. Moselhi (1997) pointed out that it is possible to highlight the most common elements and essential characteristics of contingency as follows:

- it covers unforeseen elements of cost within a defined project scope;
- it is associated with the risk of exceeding an established target cost with a certain probability of occurrence. At a set probability of occurrence, the higher the risk undertaken the higher the amount of contingency required, and vise versa;

- it is a function of uncertainty, for example, the higher the project definition, the lower the amount of contingency required. The amount of contingency is considered to be approximately equal to or slightly higher than the probable… accuracy of the cost estimate;
- it is intended to cover additional costs arising from incomplete design, construction accidents and breakdowns, regulatory risk, estimating inaccuracies, technological change, abnormal construction start-up problems;
- it is not intended to cover profit, changes in scope, escalation, overhead, cash allowance, or human error, that is, cost differences owing to negligence, faulty inference, and/or double booking.

As can be seen above, the various definitions still leave room for interpretations for the use and ownership of contingency.

### 2.4.6.2 Contingency versus Estimating Allowances

The difference between contingency and estimate allowances must also be established. As previously stated, an allowance is an amount included in the base estimate for items that are known but the details of which have not yet been determined. These are considered to be part of defined project scope costs. Allowances are perhaps best described through examples. One such estimating allowance is Material Take-Off (MTO). This allowance is meant to describe the materials that are not shown on early drawings but will be shown on later drawings as the details are developed. The drawings for which estimates are made are usually not 100 percent, so the estimators and engineers must account for this by applying a MTO allowance. Another such allowance is the Mechanical and Specs Allowance or the Design Development Allowance. This allowance is intended to account for minor mechanical and electrical changes that occur during the engineering of more complete drawings (Ripley 2004).

### 2.4.6.3 Estimation of Contingency

Regardless of how contingency is defined, a proper understanding of how to estimate contingency is critical. According to a recent publication (Burroughs & Juntima 2004), the primary concern of most project control systems is proper contingency cost estimation. Contingency estimation methods range from a predetermined percentage for all projects to probabilistic risk-based approaches. Each method has its advantages and disadvantages; some are quick and easy, but less accurate, others take extended amounts of time and create answers that are too complex to interpret.

Four of the most common techniques to set contingency are predetermined percentage, expert's judgment, quantitative risk analysis and regression analysis. Predetermined percentage is the simplest form of contingency setting. The process calls for a set percentage to be allocated for the whole project. The percentage can vary between different types of projects, but the overall reason this method is so widely used is its ease of use and consistency. The disadvantage to this method is its failure to account for the complexity of the project, level of definition, and the technology or methods required to construct the project. More importantly, there is no description of what this type of contingency application really covers in terms of project specific risks and other uncertainties (e.g., estimate variation).

The next method, expert judgment, allows for professionals to determine a percentage based on certain risk drivers and the base estimate of the specific project. The expert judgment method allows for a much more subjective approach based on individuals' experience and expertise. When using this method to estimate contingency, the risks are identified and a predetermined contingency is set based on the level of project definition and the level of risk.

The quantitative risk analysis technique uses a probabilistic or statistically-based approach. The process measures the probability of occurrence and magnitude of impact of risks and then estimates their implications on project objectives. Risks are characterized by probability distributions of possible outcomes. This process uses quantitative techniques such as simulation and decision tree analysis. A simulation uses a project model that translates the uncertainties specified at a detailed level into their potential impact on objectives that are expressed at the level of the total project. Project simulations use computer models and estimates of risk at a detailed level, and are typically performed using the Monte Carlo technique.

A related, less frequently used method is to employ regression analysis to set contingency. Regression analysis is a statistical technique for estimating the equation that best fits sets of observations of a response variable and multiple explanatory variables in order to make the best estimate of the true underlying relationships between these variables. The goal is similar to that of quantitative risk analysis only the quantitative number is based off of historical data of key variables that drove cost estimates, not probability distributions. Regression analysis is not covered in this Guidebook because it was not found to be prevalently in use.

### 2.4.6.4 State Highway Agency Techniques for Estimating Contingency

The lack of a formal definition does not imply that agencies do not set contingencies in their estimates. Approximately four out of five agencies stated that they apply contingency in at least one phase of the project development process. Agencies set contingency by three primary methods: 1) use of a standard predetermined contingency by percent; 2) use of a unique project contingency set by individual estimators; and 3) use of formal risk analysis and associated contingency.

The first method of setting contingency used by SHAs is a standard predetermined contingency across all projects. Sixteen of the 48 state agencies use some form of a standard predetermined contingency on their projects. When a standard contingency is applied exceptions can be made for a number of different reasons, including: phase in the project development process, project type, project complexity, market conditions, geographic region, and estimated project value.

The second method of setting contingency used by SHAs is a unique project contingency that is set by engineers, estimators or project managers. The majority of agencies responding to the survey indicated that they used this method. Many different tools are used to determine the contingency in this manor, including: engineering judgment; statistical analysis of historic data; and correlation of historic data with current market prices.

The third method of setting contingency used by SHAs is the identification of specific risks and assignment of the associated contingency. California, Maryland and Washington stated in their survey responses that they use a combination of a formal risk analysis and a unique project

contingency. Additionally, the FHWA stated that they use this method. The research team is aware of other agencies using this method on a project-by-project basis (e.g., Colorado, Florida, Minnesota, New York and Texas), but the survey respondents did not respond positively to this question. Tools for determining contingency through a risk analysis include: use of expected values through statistical analysis of historic data for assigning cost to risks; use of expected values through engineering judgment for assigning cost to risks; Monte Carlo or simulation methods, influence diagramming, and probability or decision trees. This third method is a primary focus of this research and it is explored in great detail in the Guidebook.

State agencies can apply contingency at an individual project level or a program level. Applying contingency at a program level means that the contingency is spread across projects (e.g., as set-aside amounts in a State Transportation Improvement Program). Depending on the phase of project development, state agencies can choose to apply contingency using one or both of these methods. Over one half of state agencies surveyed apply contingency at a project level for all three development phases. Only one state agency applies contingency at solely a program level, regardless of developmental phase. Just less than one in five agencies use a combination of project and program contingencies (19% at the planning and programming and preliminary design phases, and 16% at the final design phase). The remaining survey respondents stated that their agencies do not apply contingency in their estimate (26% at the planning phase and 21% at the programming and preliminary design phase and 21% at the final design phase).

Numerous states provided examples of how they estimate contingency through reference to their cost estimating or design guides. Examples from Caltrans, Florida, Maryland, Montana, Nevada, Ohio, and Washington follow.

*California*[1]

The California State Department of Transportation (Caltrans) has different definitions for contingency based on the phase of the project. The Caltrans Project Risk Management Handbook defines contingency as the amount of money or time needed above the estimate to reduce the risk. The Caltrans Project Development Procedures Manual (PDPM) states that contingency factors for project planning cost estimates vary depending on the cost estimate type and those contingency factors are intended to compensate for the use of limited information. The percentage goes down as the project becomes more defined and thus there are fewer unknowns. As stated in the PDPM, contingencies are not intended to take the place of incomplete design work. Project alternatives and their associated cost estimates must be thoroughly compiled by diligently using all of the available data, modifying that data with good judgment and using past cost estimating experience so that the cost estimates can be used with confidence. Table 2.8 shows the contingency breakdown based on type of estimate.

[1] This summary of the Caltrans process was written primarily from the survey response. An in-depth case study of the Caltrans risk management process is provided in Appendices C and D.

**Table 2.8. Caltrans Sliding-Scale Contingency**

| Estimate Type | Contingency |
|---|---|
| Planning Estimates | 25% |
| General Plan Estimates | 20% |
| Marginal Estimate-Final PS&E | 5% |

*Florida*

Florida does not have a formalized definition of contingency. However, they do employ both program and project contingencies. They have a program contingency that is applied across the board for all projects. Each District, based on their respective available funds, sets the contingency amount. This contingency is a general catchall, but includes project changes, additional projects added to the program, cost increases and supplemental agreements (change orders). There is also a project contingency (known as project unknowns) that is used to cover scope additions/refinements and bid unit price escalations. Table 2.9 provides Florida's general guide for determining the project unknown factor in each estimate.

**Table 2.9. Florida Sliding-Scale Contingency**

| Project Phase | Project Unknown Factor |
|---|---|
| Initial Cost Estimate | 25% |
| Design Scope of Work | 20% |
| Design Phase I (30%) | 15% |
| Design Phase II (60%) | 10% |
| Design Phase III (90%) | 5% |
| Design Phase IV (100%) | 0% |

*Maryland*

Maryland does not have a formal definition of contingency, but it does have a guidance by project phase to use as estimates are developed. The agency sets the guidance, but the engineers/project managers have discretion based upon the level of engineering completed for a category. The survey response stated that the estimator's discretion is based on a general risk analysis of how confident they are that the cost estimate includes the entire project scope. The general percentages of contingency can be seen in the Table 2.10.

**Table 2.10. Maryland Sliding-Scale Contingency**

| Project Phase | Contingency |
|---|---|
| Planning | 35-40% |
| Programming and Preliminary Design | 25-35% |
| Final Design | 0-25% |

*Montana*

The Montana DOT provided a formal definition for contingency. Contingency means an event that may occur but is not likely or intended. It is a possibility, condition of chance, for which there must be a plan of action (or additional money). Montana considers contingency and risk in terms of quantifiable and non-quantifiable outcomes. Contingency is an amount added to the project cost to account for the effects of incorrect quantities or unit costs, the possibility of unknown conditions or events, unforeseen project requirements, and other project risk. They did not provide a standard set of contingency percentages to cover the identified risk.

*Nevada*

The Nevada DOT did not provide a formal definition for contingency. However, they have a published procedure that documents a sliding scale for contingency at three levels. Table 2.11 lists these percentages and an explanation from the Nevada DOT follows.

**Table 2.11. Nevada Sliding-Scale Contingency**

| Project Phase – Level of Design Confidence | Contingency |
|---|---|
| Preliminary Design – *Design Level 1* | 15% |
| Intermediate Design – *Design Level 2* | 10% |
| Final Design – *Design Level 3* | 3% |

During the course of a project's development the division establishes a level of confidence for the project data called a design level. These levels indicate to design management, in very general terms, how much confidence they can have in project information currently available to them. The design team must keep the accuracy of the schedule and estimate compatible with the design level of the project.

During preliminary design the confidence level is at *Design Level 1*. The project schedule should be based on the work breakdown structure template for the appropriate project type. The schedule should be maintained using historical data from previous projects of similar nature, conversations with major project contributors and the judgment of experienced project management professionals. A project coordinator should be able to predict the quality assurance review submittal date to within three to six months. At this level the design team should maintain the estimate using rough estimating techniques, the best information readily available and 15% for contract contingencies. The design team should always develop its own estimates and not rely on previous attempts.

During the intermediate design the confidence level is upgraded to *Design Level 2*. The schedule should be correlated with the final scope to include all remaining tasks and be maintained using work-hour estimates, detailed conversations with major project contributors and the judgment of experienced project management professionals. A project coordinator should be able to predict the QA review submittal date to within one to three months. At this level the estimate should reflect costs for all work being contemplated and the design team should have rough calculations to back the costs up. There should be few, if any, lump sum "guesstimates" at this level. All items of work should be identified, the associated units of work should be incorporated into the engineer's estimate, and the contract contingencies should be set to 10%.

During final design the confidence level is changed to *Design Level 3*. The schedule should be based on the actual work hours needed to complete the remaining work and guaranteed delivery dates from major project contributors. A project coordinator should be able to predict the QA review submittal date to within one to three weeks. At this level, the estimate should be based on actual units of work, the associated quantities should reflect checked calculations, and contract contingencies should be set to 3%.

*Ohio*[2]

The survey respondents from the Ohio DOT believe that reasonable contingencies should be built into the total project budget estimate. Although contingencies are not included for the final engineer's estimate, a contingency based on different levels of design completion are included in the project's total cost estimate. For example, at the beginning of the detail design, a design development contingency around 30% may be appropriate. As the actual design approaches completion, the design development contingency should approach 0%. These contingencies may be developed based on previous historical data for similar type and size projects.

The Ohio DOT also emailed the research team a copy of their Excel-based Procedure for Construction Budget Estimating. It has multiple areas that address risk and contingency including Design Contingency, Constructible Risk/Contingency, and Inflation Contingency. A process for determining each of these three contingency values is described in the procedure. Figure 2.5 shows a sliding-scale contingency from the procedure from planning/concept through PS&E for major projects.

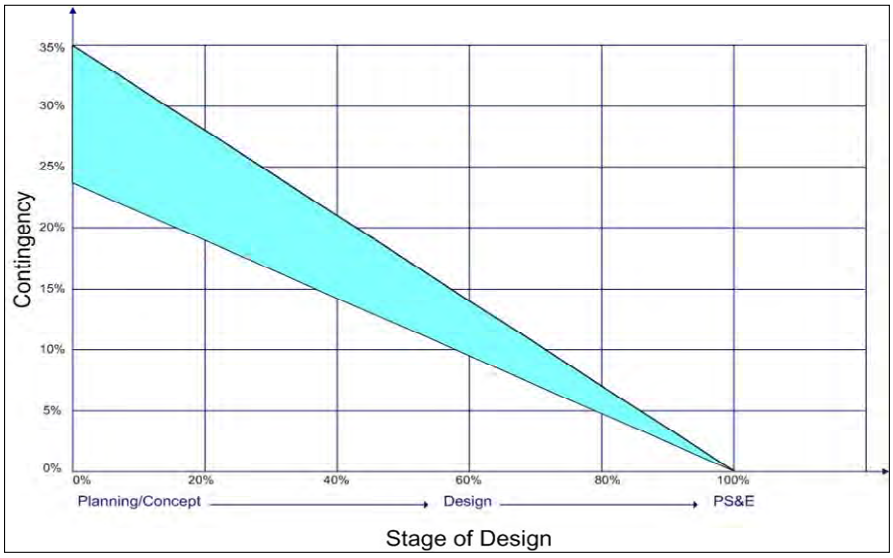


**Figure 2.5. Ohio DOT Design Completion Contingency Guidelines for Cost Estimating of Major Projects**

*Washington*[3]

WSDOT employs an extensive risk analysis program to set contingency. The WSDOT program will be discussed later in this report. They also have a simple method to define contingency as a percentage applied to account for substantial uncertainties in quantities, unit costs, and minor risk events related to quantities, work elements, or other project requirements. Washington uses

[2] This summary of the Ohio process was written primarily from the survey response. An in-depth case study of the Ohio risk management process is provided in Appendix J.

[3] This summary of the WSDOT process was written primarily from the survey response. An in-depth case study of the WSDOT risk management process is provided in Appendices E.

a combination of a standard predetermined contingency and a risk based analysis. Table 2.12 provides the standard predetermined contingencies from the survey response.

**Table 2.12. Washington State Sliding-Scale Contingency**

| Project Phase | Miscellaneous % |
|---|---|
| Planning | 30-50% |
| Programming and Preliminary Design | 20-30% |
| Detailed Design | 10-20% |

### 2.4.6.5 Range Estimating

As described in Table 2.5 from the AACEI, stochastic estimates are suggested for early estimates. Stochastic estimates use risk analysis technology that combines Monte Carlo sampling, a focus on the few key variables, and heuristics (rules-of-thumb) to rank critical risk elements. This approach is used to establish the range of the total project estimate and to define how contingency should be allocated among the critical elements.

Estimates are commonly communicated as a single number, or as a point estimate. Point estimates can include a stated contingency to help convey uncertainty. Another method of conveying estimate uncertainty is through the use of a range. Range estimates may include simple "best case" and "worst case" point estimates or they may be shown graphically with a probability curve (or probability mass function). Depending on the project phase, one method might be considered more appropriate.

Table 2.13 summarizes the use of ranges by agencies to communicate estimates. The results of the survey show that over one half of the states are in fact using ranges to communicate estimates. The results also show an as-expected decrease in the use of ranges as projects develop. Theoretically, the communication of estimates through ranges would be most appropriate at the earliest stages of project development when the project scope is most uncertain. As the level of information increases, estimate certainty increases and point estimates become more reliable.

**Table 2.13. Use of Ranges to Communicate Estimates**

| Project Development Phases | Never Use Ranges | Sometimes Use Ranges | Always Use Ranges |
|---|---|---|---|
| Planning | 36% | 55% | 9% |
| Programming and Preliminary Design | 53% | 38% | 9% |
| Final Design | 70% | 19% | 11% |

* 49 of 52 agencies reporting.

The results of this survey clearly show that range estimates are a viable method for communicating project cost estimates. The Guidebook presents tools to help agencies accurately and consistently estimate appropriate ranges.

## *2.5 Cost Estimating and Risk Management Definitions*

The approach to developing definitions relied heavily on adapting definitions from estimating and risk management standards to fit specifically into highway-risk management and cost control

processes. Over 500 definitions were reviewed to create the concise list of 40 definitions for the Guidebook. These referenced definitions have been integrated and modified to explicitly support highway project development processes, common transportation language, and current agency cultures. The following references were used to support the definition development:

Association for the Advancement of Cost Engineering International (2007). *Cost Engineering Terminology: AACE International Recommended Practice No. 10S-90*, AACE International, Morgantown, PA.

Association for the Advancement of Cost Engineering International Risk Committee (2000). "AACE International's Risk Management Dictionary," Cost Engineering Journal, Vol. 42, No. 4, pp. 28-31.

Caltrans (2003). Project Risk Management Handbook. *Report of the California Department of Transportation (Caltrans), Office of Project Management Process Improvement*. Sacramento, CA.

Department of Energy (2003). Project Management Practices, Risk Management, *U.S. Department of Energy, Office of Management, Budget and Evaluation, Office of Engineering and Construction Management*, Washington, D.C.

Molenaar, K.R., Diekmann, J.E. and Ashley, D.B. (2006). Guide to Risk Assessment and Allocation for Highway Construction Management, *Report No. FHWA-PL-06-032, Federal Highway Administration*, Washington, D.C.

Project Management Institute (2004). A Guide to Project Management Body of Knowledge (PMBOK® Guide), *The Project Management Institute*, Newton Square, PA.

Washington State Department of Transportation (2006). Cost Estimate Validation Process (CEVP®) and Cost Risk Assessment (CRA), Washington State Department of Transportation, Olympia, WA. <Viewed on August 1, 2007, http://www.wsdot.wa.gov/projects/projectmgmt/riskassessment>

Wideman, R.M. (1992). Project and Program Risk Management: A Guide to Managing Project Risks. Newton Square, Pennsylvania.

The Guidebook creates a common vocabulary and set of practices that promote learning and the exchange of new tools and innovations relating to risk management throughout the nation's state highway agencies. The definitions are presented in the categories of cost estimating terms, cost management terms, risk analysis terms, and project development phases. Appendix A contains these definitions.

## *2.6 The Risk Management Process*

### 2.6.1 Risk Management Process Overview

A cost estimate that directly addresses uncertainty and risk is at the core of a comprehensive risk management program. However, risk management must be viewed as a more comprehensive management process than simply a tool or set of tools for cost estimating. The output of a risk-based cost estimate helps to identify critical cost containment issues and helps to effectively inform the design team about the cost impacts of decisions as projects move through the development phases.

"Risk management" is the term used to describe a sequence of analysis and management activities focused on creating a project-specific response to the inherent risks of developing a new capital facility. Various organizations and mission agencies such as the Project Management Institute (PMI), the AACEI, or the US DOE use very similar steps, but each has slightly different terms, to describe their risk management approach (PMI 2004; AACEI 1998; DOE 2003). The research team has adapted a process from these organizations and agencies for use by the highway industry. The process includes risk: *identification, assessment, analysis, planning and mitigation, allocation, and monitoring and updating.* The research team believes that it is important to use these standard terms to promote consistency between the highway, infrastructure, and building construction sectors.

A recent FHWA research scan determined that the international highway community has an awareness of risk assessment and allocation techniques that is only now evolving in U.S. highway agencies (Molenaar, et. al 2005). The Highways Agency in England has developed Highways Agency Risk Management (HARM) to model the uncertainties of estimates for cost and time. HARM serves to ensure robust and realistic budgets for publicly financed projects (Highways Agency 2001). The Ministry of Transport, Public Works, and Water Management in the Netherlands has developed the Public Sector Comparator and the Public-Private Comparator (PSC/PPC) to assist with these same analyses (PPP 2002). Both agencies have dedicated staff that support project teams in identifying and quantifying project risk using probabilistic techniques, and then choosing delivery and contracting strategies that can best control and mitigate these risks. Some examples of integrated risk management in the highway sector internationally and in the U.S. In particular, WSDOT has developed the Cost Estimate Validation Process (CEVP®), Cost Risk Assessment (CRA), and an Online Project Management Guide that all address risk. Caltrans has also been developing and documenting their risk management program (WSDOT 2006; Caltrans 2003). There are also a number of excellent examples in the U.S. for project-based risk management plans.[4] WSDOT, Caltrans, and a number of other agencies are highlighted in the case study portion of this report (See Chapter 4).

The risk management process is shown in Figure 2.6 and forms the framework for this research. Contingency is integrally linked to risk management. Of particular note is that the overall risk management process is repetitive and cyclical. As the project evolves, some risks will be resolved or diminished, while others may surface and thus be added. The five fundamental risk management steps are repeatedly applied throughout the project life cycle, but the methods and tools to complete these steps are dependent on the project development phases and project complexity. The Guidebook consciously and directly addresses the interaction of these important elements.

[4] For example, see the Minnesota DOT's San Croix River Crossing Risk Assessment Workshop Report at: http://www.dot.state.mn.us/metro/projects/stcroix/documents.html. Also see ongoing workshops with the FHWA Program Management: http://www.fhwa.dot.gov/programadmin/mega/index.htm.


**Figure 2.6: Risk Management Process Framework**
*(varies by project development phase and complexity)*

Brief descriptions of the five steps are as follows:

- *Risk identification* is the process of determining which risks might affect the project and documenting their characteristics using such tools as brainstorming and checklists.
- *Risk assessment/analysis* is a component of risk management that bridges risk identification and risk analysis in support of risk allocation. Risk assessment involves the quantitative or qualitative analysis that assesses impact and probability of a risk. Risk assessment assists in contingency estimates.
- *Risk mitigation and planning* involves analyzing risk response options (acceptance, avoidance, mitigation, or transference) and deciding how to approach and plan risk management activities for a project.
- *Risk allocation* involves placing responsibility for a risk to a party through a contract. The fundamental tenants of risk allocation include allocating risks to the party that is best able manage them, allocating risks in alignment with project goals, and allocating risks to promote team alignment with customer-oriented performance goals.
- *Risk monitoring and control* is the capture, analysis, and reporting of project performance, usually as compared to the risk management plan. Risk monitoring and control assists in contingency tracking and resolution.

### 2.6.2 State Agency Risk Management Practice

While risk is indeed inherent in every capital transportation project, the survey found that only three of the 48 state agencies had formal, published project risk management policies or procedures (Figure 2.7). In these three states, it is clear how the risk analysis relates to controlling cost escalation. All three of these states have been interviewed and their case studies are presented later in this report. In other states, the manner in which the agencies set their project and program contingency implies that they are recognizing and incorporating risks into

project estimates; however this is not being accomplished using a formalized risk management procedure.

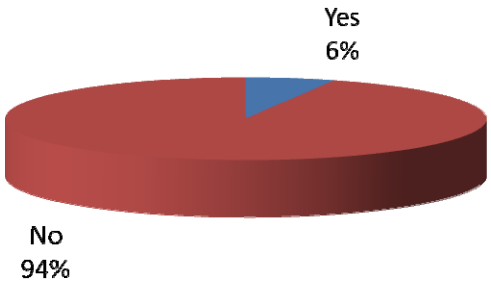


**Figure 2.7. Published Project Risk Management Policy or Procedures (48 of 52 State Agencies Responding)**

### 2.6.3 Conclusions on Risk Management

The need for formalized risk management procedures is clear. A systematic approach to risk management will assist in cost estimating and cost containment. Additionally, the value generated from the risk management process includes other benefits in addition to better cost control. Depending on the nature of the project, there are several possible outputs from the process. Among the most common are:

- Expected value analyses of cost and duration with probability values for other potential outcomes;
- Value of information and control;
- Contingency assessments for cost and duration;
- Sensitivity analysis for individual risks;
- Risk management mitigation plans and strategies;
- Risk-based analyses of preferred project contracting/procurement approach; and
- Risk allocation decisions that align team members with customer-oriented performance measures.

These outputs are explained in the Guidebook, including examples of best practices from throughout the transportation community and elsewhere. Effectiveness of the process as a management decision aid is most often linked to the clarity of communication. The simplest representations often work best. While the analysis may be supported by a complex, rigorous, and probabilistically-sophisticated model, it is of little value if its outputs are obscured in jargon or overly complicated in their representation. Similarly, simple qualitative analyses that are easily understood by the decision makers have a powerful influence on the selection of risk avoidance measures. Communication is very much a key in utilizing these outputs to their full potential.

## 2.7 Conclusions

This chapter presented the research methodology and results for the state-of-practice review and definition development. The salient findings of the review have been incorporated into the Guidebook. This chapter presented the methodology for the literature review and the state of practice summary. The results as they relate to the project development phases, agency estimating organizations, cost escalation, uncertainty and estimate development, highway cost estimating/management practice, and contingency estimates were also presented. The chapter concluded with a description of the risk management process and how it has been presented in the Guidebook.

# Chapter 3: Risk Identification, Categorization, Quantification, and Assessment Review

## *3.1 Introduction*

The goal of Task 2 was to review current practice in defining and categorizing risk, identifying and quantifying risk, and assessing the degree of uncertainty in transportation project-cost estimation. Transportation projects are long-term undertakings that are accomplished using a public processes that involve many different stakeholders. Because they involve multiple stakeholders, occur in the public domain, and especially due to their very long lifecycles, transportation projects rank as some of the riskiest infrastructure projects. The planning phase of a large transportation project may last 20 to 30 years. The programming phase may utilize another five or ten years before the project starts its final design phase. Clearly, a project's risk profile will change substantially during the intervening 30, or so, years from the start of planning to final design activities. Consequently, identifying and subsequent monitoring of transportation project risks is pivotal to the successful management of those risks throughout the project's lifecycle.

Project risk identification is a process of discovery. Risk identification requires the discipline to think hard and creatively about the diverse sources of risk that affect a project's outcomes. Risk identification requires asking the right questions at every point of the project's lifecycle and an understanding that the right questions are different at different stages of the project development. Early in the project's life, risk identification focuses on vital questions of the project's need and viability. Project managers must resolve fundamental questions about the necessity for the project, its financial feasibility, and the existence of insurmountable environmental impacts. Such large issues may take years to resolve, therefore, it is imperative that project risks are documented so they may be tracked throughout the early evolutionary activities of project development. As project scope becomes more focused, risks also become more focused. In the preliminary engineering stages of a project's lifecycle, the scope is more definitively defined and the right questions involve remaining scope uncertainty, corridor alternatives, technical problems, and regulatory ambiguity. Finally, during the final design phases of the project, risks revolve around elemental project considerations such as cost escalation, right-of-way costs, general price levels, schedule impacts, and the like. Conceptually, risk identification is an important activity that recurs periodically throughout the project lifecycle.

## *3.2 Risk Identification*

Objectives of risk identification are threefold:

- First, risk must be identified and documented so they can be monitored during the course of project development.
- Second, risks must be categorized to permit precise and specialized risk management actions.
- Third, risks must be qualitatively evaluated to gain an understanding of their relative likelihood of occurrence and the potential consequences.

In this document, the generic term "risk" should be interpreted to mean both threats and opportunities. Risks are events that carry potentially deleterious consequences for a project and

opportunities are events that have potentially beneficial consequences. Whether an event is classified as a risk or an opportunity is determined by the basic ground rules and enabling assumptions made of the project.

The most difficult part of the risk identification process is asking the right question. The risk identification process should promote creative thinking and leverage team experience and knowledge. Often the initial tendency of a team is to define risks too narrowly and to concentrate on specific, detailed technical and scope issues with which they are most familiar. Early in the identification process, it is necessary to step away from normal project management and engineering roles to view the project from the vantage point of the traveling public and other stakeholders. Questions such as "Are there risks that, should they occur, would defeat a key project purpose or goal?" should be considered. Likewise, are there risks that are associated with prerequisite stakeholder's needs or requirement? Only after these far-reaching, larger-scale issues are considered should the team focus on scope, quality, cost, and schedule risks. When the project reaches the final design phase, the risk identification process examines issues and concerns associated with the project description, work breakdown structure, cost estimate, design and construction schedule, and procurement plan.

As previously stated, the purpose of risk identification changes and evolves as the project itself matures. Throughout the project's lifecycle, one purpose of identifying risks is to allow the project leaders to manage the risk and mitigate the unfavorable consequences of a risk. During the planning phase of the project, risk identification should focus on "red flag" issues such as project funding concerns and significant environmental barriers. Significant risks might be attached to project stakeholders or the need for regulatory or legislative actions. At this early point in the project, it is essential to discover these red flag risks and allow the team to respond to them by modifying the project's scope or taking appropriate socio-political actions. Those that have a deep knowledge of the project and significant experience with similar projects can typically contribute to identifying red flag issues. This suggests that risk identification, at the planning stage, be conducted by a team of experienced persons from both inside and outside the SHA who rely on both personal experience and deep insights about the socio-political, economic, and environmental challenges to the project. Figure 3.1 is an excerpt from the Ohio DOT's Project Development Process (PDP) manual concerning Red Flag Item identification on right-of-way estimates for minor projects.

**301.6 Red Flags**
**Red Flags**, including environmental and engineering issues, are locations of concern within the study area. Red Flags do not necessarily identify locations that must be avoided, but rather, identify locations that will entail additional study, coordination, design, right-of-way, or construction cost. Locations that must be avoided are referred to as "fatal flaws." The project manager should ensure consultation with the appropriate specialists to determine the level of concern for each Red Flag item. Both environmental and design Red Flags are identified on the Red Flag Summary.

**Figure 3.1. Ohio DOT Red Flag Example**

As the project progresses to the Programming Phase, the focus of risk identification changes to large scale but project-specific issues like alternative design concepts, procurement issues, technical uncertainties and project phasing. It is crucial to recognize the risk impacts that these decision have on the project's risk profile. Risks identified during the Design Phase are often used as qualitative inputs to a historically based, top-down risk assessment for the project. For example, the historical record for cost growth on projects with large technical challenges, right-of-way uncertainties, and environmental issues may indicate the need for very large cost contingencies. On the other hand, performance history for well-defined projects that employ standard technology may indicate the need for much smaller cost and schedule contingency.

As the project enters into the final design and construction phases, the nature of risk identification again changes. Now the SHA can concentrate on detailed project scope and technical issues and their corresponding cost and schedule consequences. Now the team is concentrating on specific events that would cause changes to the project's scope or design bases or design solutions and risks associated with market conditions and contract or commercial terms. At this point, these detailed risks are used as inputs to quantitative risks analyses to help establish cost and schedule contingencies using bottom-up stochastic risk analysis approaches. To a greater or lesser extent, the occurrence of a risk event or the impact of the risk event may be influenced by project team mitigation actions. The team may adopt risk mitigation strategies that would decrease the likelihood that a risk event will happen or decrease the consequences of the event should it happen. The costs associated with risk mitigation actions and the change in a risk's probability of occurrence should be reflected in the bottom-up stochastic risk model.

The type of expertise necessary to support risk management, especially in regard to identification and assessment, varies over time. The earliest stages of project development may depend heavily on expertise in environmental planning, funding and operations. As engineering evolves and design nears completion, there will be more reliance on specialists in such areas as scheduling, cost estimating and budgeting/controls. Table 3.1 is adapted from the 2004 FTA report on *Risk Assessment Methodologies and Procedures* and provides an excellent summary of key expertise needed for risk identification and risk assessments by project phase.

**Table 3.1 – Key Expertise for Risk Analysis by Project Phase (Adapted from FTA 2004)**

| Discipline | Planning/ Programming | Preliminary Engineering | Final Design | Construction |
|---|---|---|---|---|
| Planning | ● | ● | ○ | |
| Environmental | ● | ● | ○ | ○ |
| Funding Approvals | ● | ● | ○ | |
| Project Management | ● | ● | ● | ● |
| Engineering | ● | ● | ● | ● |
| Civil, Structural, Systems | ○ | ○ | ● | ● |
| Cost Estimating | ○ | ● | ● | ● |
| Scheduling | ○ | ● | ● | ● |
| Budgeting Controls | ○ | ○ | ● | ○ |
| Real Estate/Right of Way | ○ | ● | ● | ○ |
| Construction Management / Oversight | ○ | ○ | ● | ● |
| Constructability / Contractor | ○ | ○ | ○ | ● |
| Other Technical (e.g. Legal, Permitting, Procurement) | ○ | ● | ● | ● |
| Risk Facilitation | ● | ● | ● | ○ |

* Includes FTA systems planning and alternatives analysis.

● Highly desirable
○ Desirable but optional depending upon circumstances

Even though the nature of risk identification changes throughout the life of a project, it is a persistent activity and a continuous process. Because early identification gives the SHA the most flexibility in response to the risk efforts should be made to identify risks as early in the process as possible. Risks that are identified early in project development allow the SHA to take actions such as changing the design or avoiding environmentally sensitive areas. These options might not be possible later in the project lifecycle when commitments have been made. To manage the continuity of the identification process many project teams establish a project risk register. Newly identified risks are added to the registered. Newly clarified risks are modified and risks that are resolved are removed. In this way, the SHA maintains continuous awareness of risks and their development throughout the project life. An example of a risk register from WSDOT is provided in Figure 3.2.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Project Title** | | | | | | | |
| | **Project PIN #** | | | | | | | |
| | **Date** | | | | | | | |
| | **Project Mngr** | | Name | **Telephone Number** | (xxx) xxx-xxxx | | | |
| | **PROJECT RISK M** | | | | | | | |
| | **Risk Identification** | | | | | | | |
| **Priority** | **Status** | **ID #** | **Date Identified Project Phase** | **Risk Event** (threat/opportunity) | **SMART Column** | **Risk Trigger** | **Impact Area** | **Affected MDL/WBS Level 2 process** |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Instructions | **Active**=actively monitored & controlled **Dormant**=risk is not currently a high priority, but may become active in the future. **Retired**=no longer a threat to project objectives. | E1 | For example: 6/30/99 Scoping | Risk is an uncertain event or condition that, if it occurs, has a positive (opportunity) or negative (threat) on a project. For example; Wetland Mitigation requires additional R/W. | Detailed description of the risk. Includes information on the risk that is **Specific, Measureable, Attributable, Relevant** and **Timebound**. Describe the consequences of the risk to scope, schedule, budget or quality. | Triggers are indications that a risk has occurred or is about to occur. Used to determine when to implement the Risk Response Strategy. For example: Wetland impact is greater than 1/2 acre. | Is the primary impact to the scope, schedule, or budget? | Which WBS element will be modified as part of the response strategy? For example: PC-19 Environmental Permits |
| | | | | | | | | WBS 165 Perform Environmental Studies and Prepare Draft Environmental Document (DED) |

| **PROJECT RISK MANAGEMENT PLAN** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Qualitative Analysis** | | | | **Risk-Response Strategy** | | **Monitoring and Control** | |
| **Impact Area** | **Affected MDL/WBS Level 2 process** | **Probability** | **Impact** | **Risk Matrix** | **Risk Owner** | **Strategy** | **ACTION TO BE TAKEN** (include advantages and disadvantages) | **Status Interval or Milestone Check** | **Date, Status and Review Comments** |
| (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| Is the primary impact to the scope, schedule, or budget? | Which WBS element will be modified as part of the response strategy? For example: PC-19 Environmental Permits | Assessment of the likelihood of occurrence. Valid entries are Low or High. | The severity of the risk's effect on the projects objectives. Valid entries are Low or High. | **High**: Substantial impact on cost, schedule, or technical. Substantial action required to alleviate issue. **Low**: Minimal impact on cost, schedule, or technical. Normal management oversight is sufficient. | Name of the person or office responsible for managing the risk event. | **A**voidance **T**ransferance **M**itigation **A**cceptance (See PM Online Guide for strategy definitions.) | Develop options and determine actions to be taken in response to the risk event. Immediate action may be required at the time of identification. Estimate value of risk and estimate cost to respond. | For example: Completion of wetland delineation expected: 2/28/00 | For example: Last status update 4/30/00. Wetland delineation completed 3/15/00. Over 1 acre of wetland was delineated, action is being taken to expedite meetings with regulatory agencies & expedite the effort to provide appropriate wetland mitigation & attain project permits. |
| | WBS 165 Perform Environmental Studies and Prepare Draft Environmental Document (DED) | | | Probability H L; Impact L H | | | | | |

**Figure 3.3. Example WSDOT Risk Management Plan Template (See Appendix E)**

## *3.3 Risk Categorization*

Categorization of risks helps the project team by providing a structured way of describing risks. Some agencies develop a *risk breakdown structure* that serves as a standard by which risks are categorized (see Figure 3.4). A structured risk identification scheme helps reduce redundancy, reduce ambiguity and provides for easier management of risks in later phases of the risk analysis process. The following paragraphs describe three dimensions of a risk categorization scheme.

### 3.3.1 Risk Ownership

Development and management of project risks requires exactness regarding the nature of the risks and their impacts. A key element in the precise understanding of risk is risk ownership,

that is, whose risk is it? Initially, all risks belong to the SHA. One of the objectives of a formal risk management program is to allocate all risks to the appropriate project party. For example, the SHA may use contract language to transfer a risk to a construction contractor or design consultant. Other risks may be transferred to insurance or bonding companies. Yet other risks may be retained by the SHA but management of the risk may be transferred to the project management team.

**Figure 3.4. Example Risk Breakdown Structure from Caltrans (see Appendix C)**

Some risks, those that are beyond the scope of an individual project, will be retained by the SHA. One type of risks retained by the SHA at the agency level are site-specific risks whose consequences are so significant that the recovery costs associated with the risk are so large that the risk cannot be reasonably borne by the project. Another type of risk that may be retained by a SHA are risks that will affect several different projects, such as market conditions or changes in statutory or regulatory conditions. Risk ownership incorporates the concept of risk control. Risks can reasonably be transferred from the SHA to the project or from the project to the contractor if the receiving party can control the likelihood of the occurrence of the risks or alternatively they can control its negative consequences.

### 3.3.2 Risk Foresee-ability

Another important characteristic of risks is foresee-ability. It is customary to categorize risks according to how easily it may be anticipated and identified. Traditional categories are known risks, unknown risks, and unknown unknowns.[5]

A known risk is an element that can easily be identify on the plans or otherwise in recognized as needed for the project. A very common type of known risks is estimate uncertainty that is a function of the quality of the project scope definition and the current estimate. In a mature project, one well into development, estimate uncertainty might manifest itself as relatively small

[5] Note that these are similar categories for estimating information were provided in section 2.4.4 of this report, but the following section is describing categories of risks rather than categories of estimating information. These sections are coordinated in the Guidebook to avoid any confusion.

(but pervasive) variations in the cost or productivity of individual work items. For example, it may be known that rock will be encountered in the excavation, it is shown on the plans and in the estimate, but we do not know the exact quantity.

On projects with a high degree of scope or technological uncertainty or projects early in their life cycle, there also will be individual risk events as well as estimate uncertainty. These risk events that can be identified and which may or may not happen in the future are known-unknowns. The project recognizes their potential but it is not yet clear whether the event will occur or the magnitude of its impact should the event take place. For example, there may be a risk event concerning whether an environmental document is approved as expected. Perhaps there is a large probability of success for the approval, a smaller probability that it will gain approval with minimal delay and a very small probability that it will be rejected altogether. If it is approved as expected, there will be no negative consequences to the project. If it is minimally delayed, there may be relatively minor cost and/or schedule consequences to the project. Finally, if it is rejected outright, there may be large cost and/or schedule consequences to the project. Risk events, therefore, may be relatively low probability events that may have large consequences if they occur.

Previously, this report noted that risk identification requires the discipline to think hard about the diverse sources of risk that affect a project's outcomes. However, even when a project team has the best discipline and procedures for identifying risks, some risks will not be recognized until they happen, for example, a hurricane Katrina-like weather event. These are unknown-unknown risk events, risks that are truly unforeseeable by the project team. Some agencies choose to ignore unknown-unknown risk events and deal with their consequences when (and if) they occur. Other agencies establish historically based cost and schedule allowances to cope with the effects of unknown-unknown risks.

### 3.3.3 Risk Type

A final dimension used to classify risks is to group them into like risks. The first aspect is whether the risk arises externally or internally to the project. External risks are items that are generally imposed on the project from beyond the limits of the project. Interactions with citizens' groups or regulator are typical external risks. External risks tend to refer to items that are inherently unpredictable but generally foreseeable. External risks (market forces, population demographics, ridership, and regulations) are subject to little control by the project team. Internal risks are those that arise within the scope and control of the project team. Most internal risks can be referenced to a specific project document such as a cost estimate or a schedule. Internal risks can be partitioned into technical risks (soil conditions, hydrology, or utilities) and non-technical (labor shortages, accidents, or contract default) risks. The Project Management Institute created a hierarchy of risks as shown in Figure 3.5.

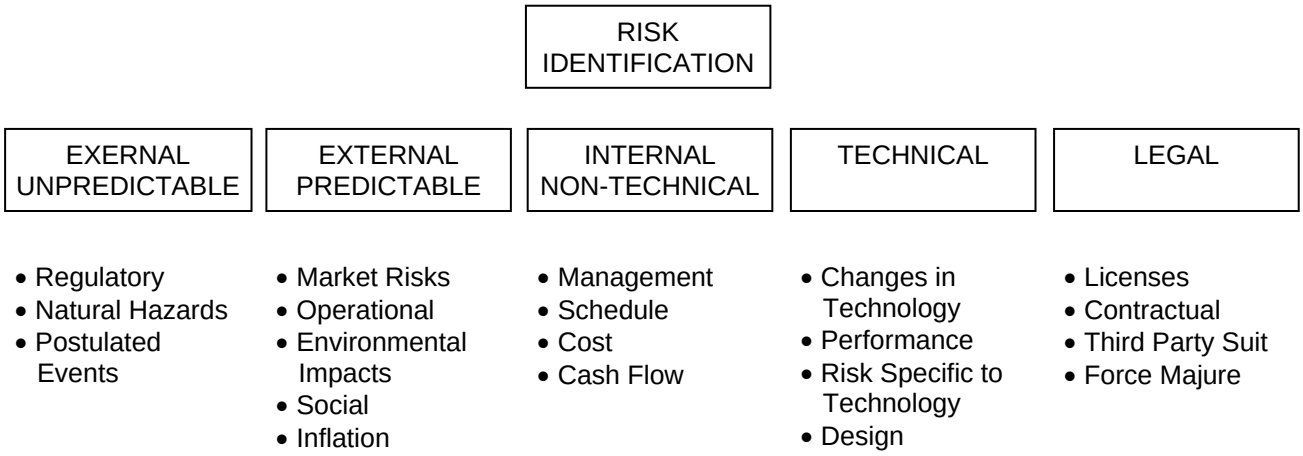


**Figure 3.5. Risk Identification Classification (Wideman 1992)**

## *3.4 Risk Quantification*

There are many kinds of risks and risk events on highway projects; few are pure cost or schedule risks. Most cost effects or schedule effects result from some other driving event or uncertainty. Therefore, the first step in risk quantification is to isolate the root cause of the risk and then to assess the scope, cost, schedule, and quality effects of the risk. The risk categorization system, previously described, aids the project team in identifying root causes of risk effects. Risk events are often interrelated; the occurrence of a technical risk usually gives rise to multiple consequences such as scope changes, direct cost and indirect cost increases, and schedule delays. Likewise, occurrence of a pure schedule risk will effect cost escalation and project overhead costs. One must carefully consider the likelihood of a risk's occurrence and its impact in the context of a specific set of project conditions, contract language, and regulatory circumstances. An adequate job of risk quantification requires that the project team understand the cascading and interrelated effects of each risks.

Once the multiple consequences of each risk are understood, risks can be qualitatively assessed to screen them for future management attention. The commonest way to screen risks is by qualitatively assessing both their likelihood of occurrence and their consequential impact on the project's cost and schedule. Typically, qualitative assessment of both likelihood of occurrence and impacts are guided by standard categories as shown in Figure 3.6 and Table 3.2. These standard categories of likelihood and impacts yield a five-by-five matrix resembling that shown in Figure 3.6. These two dimensions of risk are combined to classify risks into a "red", "yellow," or "green" category. Red risks are those whose combined likelihood of occurrence and consequences will produce a serious cost or schedule impact to the project. The project team must in some fashion mitigate red risks. Yellow risk events are either low-likelihood/high consequence events or high-likelihood/low consequence events. Project teams must monitor these risks and be prepared to initiate mitigation actions if they are needed. Green risk events should be monitored to assure they do not develop into more serious risk events.

| Level | Likelihood |
|---|---|
| A | Remote |
| B | Unlikely |
| C | Likely |
| D | Highly Likely |
| E | Near Certainty |

**ASSESSMENT GUIDE**

| Likelihood | a | b | c | d | e |
|---|---|---|---|---|---|
| E | M | M | H | H | H |
| D | L | M | M | H | H |
| C | L | L | M | M | H |
| B | L | L | L | M | M |
| A | L | L | L | L | M |

Consequence

| Level | Schedule | and/or | Cost |
|---|---|---|---|
| a | Minimal or no impact | | Minimal or no impact |
| b | Additional resources required; able to meet | | <5% |
| c | Minor slip in key milestones; not able to meet need date | | 5-7% |
| d | Major slip in key milestone or critical path impacted | | 7-10% |
| e | Can't achieve key team or major program milestone | | >10% |

**RISK ASSESSMENT**

High (Red)

Unacceptable. Major disruption likely. Different approach required. Priority management attention required

Moderate (Yellow)

Some disruption. Different approach may be required. Additional management attention may be need

Low (Green)

Minimum impact. Minimum oversight needed to ensure risk remains low

**Figure 3.6 Example Probability-Impact Matrix (Adapted from DOE 2003)**

**Table 3.2. Example Impact and Probability Levels (Caltrans – see Appendix C)**

| | Very Low | Low | Moderate | High | Very High |
|---|---|---|---|---|---|
| **Cost Impact** | Insignificant cost increase | <5% cost increase | 5-10% cost increase | 10-20% cost increase | >20% cost increase |
| **Schedule Impact** | Insignificant slippage | <5% project slippage | 5-10 % project slippage | 10-20% project slippage | >20% project slippage |
| **Scope Impact** | Change is barely noticeable | Minor areas are affected | Change requires TBPOC approval | Change not acceptable to TBPOC | Material termination of project |
| **Probability** | 1–19% | 20–39% | 40–59% | 60–79% | 80–99% |

In practice, risk identification and risk assessment are often completed in a single step. For example, if a risk is identified in the process of interviewing an expert, it is logical to pursue information on the probability that it will occur, its consequences/impacts, the time associated with the risk (i.e., when it might occur), and possible ways of dealing with it. The latter actions are part of risk assessment, but they often begin during risk identification.

## 3.5 Conclusions

Risk identification, categorization and assessment activities are crucial to all risk management programs. When risk identification and classification is rigorously and continuously pursued by the project team, it provides the foundation for subsequent risk analysis, risk mitigation and risk monitoring and control activities.

# Chapter 4: Case Studies

## *4.1 Introduction*

The objective of Task 4 was to prepare a series of case studies that demonstrate the effective application of risk-analysis tools and management practices in controlling project costs. The case studies involved a documentation of project facts and outcomes, interviews with project participants, and an assessment of the relative effectiveness of the risk analysis tools and techniques. The case studies proved to be an effective means of collecting valuable tool examples and applications for use in the Guidebook. Please note that the case studies (Task 4) are being presented prior to the tools (Task 3) because the case studies provided many of the final tools for the Guidebook.

Eight detailed case studies are provided in Appendices C-J. The case studies followed a semi-structured case study protocol that is provided in Section 4.2. The case study participants were also asked to complete the state of the practice survey on the web. The case study interview structure examined a wide range of risk management and contingency estimation for the agencies. Case studies were completed in person or via phone conference as noted in the descriptions in the appendices. In each case, multiple members of the agencies and the research team were present for discussions.

As illustrated in Table 4.1, the team attempted to select a set of case studies that covered the key risk management characteristics that are described in the final Guidebook. The attributes of the project development phase, risk management function, application of contingency, project complexity and tool complexity were used as criteria in selecting case studies. The team determined that it would be helpful to examine both project and program level risk management applications. Integrating risk analysis tools and management practices into SHA operations and culture will need to be accomplished at both the project and program levels, so the team chose to conduct case studies that would illustrate each level. The team believes that the eight case studies examined all of the risk management areas required for authoring the Guidebook.

**Table 4.1 Case Study Characteristics**

| Case Study Characteristic | Cal-trans | Bay Bridge | WS DOT | DOE-EM | FHWA | FTA | NY MTA | Ohio DOT |
|---|---|---|---|---|---|---|---|---|
| Number of projects in risk analysis | | | | | | | | |
| • Program-level analysis | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| • Project-level analysis | | ✓ | ✓ | ✓ | ✓ | | | |
| Phase in project development | | | | | | | | |
| • Planning | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| • Programming and Preliminary Design | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| • Final Design | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| • Construction | | ✓ | | ✓ | | | | |
| Function in the Risk Management Process | | | | | | | | |
| • Risk Identification | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| • Risk Assessment or Analysis | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| • Risk Mitigation and Planning | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| • Risk Allocation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| • Risk Monitoring and Control | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Application of Contingency | | | | | | | | |
| • Program Level | | ✓ | | ✓ | | ✓ | | |
| • Project Level | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Project Complexity | | | | | | | | |
| • Low-Medium | ✓ | | ✓ | | ✓ | | | ✓ |
| • Medium-High | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | |
| Analysis Complexity | | | | | | | | |
| • Simple, Non-Resource Intense | ✓ | | ✓ | | ✓ | | | ✓ |
| • Complex, Resource Intense | | ✓ | ✓ | ✓ | | ✓ | ✓ | |

## *4.2 Case Study Protocol*

This section provides the template for the case study protocol. This protocol was sent to each participant prior to the interview. It was then followed during the interview.

**MEMORANDUM**
***Insert Date***

**TO:** Insert Name

**FROM:** Keith Molenaar
Principal Investigator

**SUBJECT:** NCHRP 8-60 Interview Questionnaire

Thank you for agreeing to participate in the National Cooperative Highway Research Program (NCHRP) 8-60 Research Project on risk analysis and management. We have enclosed some background information about the project along with an outline of the questions that we plan to discuss with you during our phone interview. A research team member will call you on *<insert date and time>* to conduct the interview. The interview should take 60-90 minutes. Please review the enclosures prior to the interview and become acquainted with the nature of the questions that we will be discussing.

To help the research team prepare for the meeting, we would also ask that you complete a 15-minute on-line questionnaire. We have received responses from 49 state highway agencies on this questionnaire and your response will provide us with background information for our teleconference. The questionnaire can be completed on-line at:

http://www.zoomerang.com/survey.zgi?p=WEB226WBG46KA9

If you have any questions, please contact me by telephone at 303 735-4276 or by email at keith.molenaar@colorado.edu.

**Figure 4.1 Case Study Protocol**

**Background**
The National Cooperative Highway Research Program (NCHRP) is sponsoring a research project aimed at creating a guidebook on risk analysis tools and management practices (NCHRP Project 8-60). The University of Colorado is teaming with Texas A&M University, Arizona State University, and TDC Partners to develop the guidebook.

The research objective is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs. The guidebook will include a plain language toolbox for transportation agencies to use in selecting appropriate strategies, methods, and tools to apply in meeting their cost-estimation and cost-control goals and objectives.

**Interview Purpose**
The purpose of this interview is to prepare a series of case studies that demonstrate effective application of risk-analysis tools and management practices in controlling project costs during the planning, programming, and detailed design phases of both transportation and non-transportation projects. The interviews will explore how different agencies and organizations determine contingency and manage risk-related costs throughout the project development process. While the guidebook is being developed specifically for highway planning and construction, we are striving to collect data from all sectors of design and construction as a means of comparison and to collect new ideas from across the industry.

**Definitions**
Contingency and risk management practices vary throughout the project development process. For purposes of this questionnaire, we would like to ask questions about the following three distinct phases of the project development process.

*Planning* – The initial phase of project development in which the project purpose and need is determined. This phase can include benefit-cost analysis for ranking projects and including a project in the agency's 25-year planning horizon. Projects in this phase include a range of design that is approximately *less than 5% complete* as a general point of reference.

*Programming/Schematic Design* – This phase of project development involves project scoping. It often includes the development of environmental analyses, right-of-way impacts, design criteria and parameters, survey of utility locations and drainage, and alternative comparisons. Projects in this phase include a range of design that is approximately *5%-30% complete* as a general point of reference.

*Detailed Design* – The final design phase of project development in which detailed designs are completed for construction. This phase includes acquisition of right of way, and final development of plans, specifications, and estimates (PS&E). Projects in this phase include a range of design that is approximately *30%-100% complete* as a general point of reference.

**Figure 4.1 Case Study Protocol (continued)**

**Interview Scope**

The interview will be conducted via telephone following the outline provided below and the project development phases described in the previous section. Ideally, we would like to talk with a cross section of up to five (5) of your organization's project development personnel (e.g., planners, designers, project managers, estimators). During the interview, all persons representing your organization may be present for a group interview. We can also follow-up with other persons individually if that is more convenient. We expect the telephone interview will last approximately 60-90 minutes depending on the number of individuals involved in the discussion. Please note that not all the questions will apply to every individual. The research team would also appreciate receiving any supplemental information regarding your organization's risk management practices such as guidelines, manuals, or examples. If in electronic format please send to [Keith.Molenaar@Colorado.EDU]. If hard copy please mail to Prof. Keith R. Molenaar, Civil, Environmental and Architectural Engr., Univ. of Colorado at Boulder, Campus Box 428, ECOT 643 Boulder, Colorado 80309-0428

**Interview Outline**

We would like to discuss your organization's approach to the topics listed below. We are particularly interested in the following questions for each of the topics.

- Do you have any documented policies or procedures regarding the topic?
- How does your approach to the topic changes from planning to detailed design?
- What methods and tools do you use to address the topic?

1. *Contingency* – estimating the costs associated with identified uncertainties and risks.
2. *Risk Identification* – determining which risks might affect the project and documenting characteristics of the identified risk.
3. *Qualitative Risk Analysis* – performing a qualitative analysis of risks and conditions to prioritize their effects on project objectives. For example, assessing the probability and impact of project risks and classifying risks into categories of high, moderate, and low for prioritized risk response planning.
4. *Quantitative Risk Analysis* – measuring the probability and consequences of risks and estimating their implications for project objectives. For example, using quantitative techniques such as simulation and decision tree analysis.
5. *Risk Planning* – Analyzing risk response options (acceptance, avoidance, mitigation, or transference) and deciding how to approach and plan project risk management activities.
6. *Risk Monitoring and Control* – capturing, analyzing, and reporting of project performance (e.g., as compared to a risk management plan).
7. *Risk Documentation* – Recording, maintaining, and reporting assessments, handling analysis and plans, and monitoring results.

**Figure 4.1 Case Study Protocol (continued)**

## *4.3 Case Study Summary*

The following summaries provide a brief overview of the case studies. Also noted in the summaries are the top one or two unique findings from each case study. The complete case study documentation can be found in Appendices C to J.

### 4.2.1 Caltrans – Caltrans General Approach to Risk Management (Appendix C)

The California Department of Transportation (Caltrans) was selected as a leading state highway agency in risk management based on their formalized approach to risk management and documentation of the process through their Project Risk Management Handbook. Caltrans has a very successful risk management program that has increased dramatically over the past few years thanks to Caltrans integrating risk management into their internal project management certification training. Caltrans interviewees stated the more than 1,000 qualitative risk registers have been generated on projects across the state.

### 4.2.2 Bay Bridge – Caltrans San Francisco Oakland Bay Bridge Project (Appendix D)

The Caltrans San Francisco Oakland Bay Bridge (SFOBB) Project is part of the Toll Bridge Seismic Retrofit Program (TBSRP). The SFOBB was chosen as a case study owing to the project's unique characteristics, large size, complexity, and the comprehensive risk management plan mandated by the state legislature. The SFOBB staff is very actively managing risk and contingency on the project through a comprehensive risk management program. The team has created a versatile Risk Management Information System (RMIS). The RMIS is a web-based system linked to a database. It allows the widely distributed team members to continuously update the risk register and give management a real-time view of the project's status. The SFOBB team has also created a comprehensive communication and reporting structure.

### 4.2.3 WSDOT – Washington State Department of Transportation (Appendix E)

WSDOT has been a leader in risk management among SHAs. They have been conducting risk management activities since 2002 when they created their Cost Estimate Validation Process (CEVP) and conducted risk review workshops on 12 megaprojects. The CEVP was scaled down in 2003 to a less intense version known as Cost Risk Assessment (CRA) with procedures similar to the CEVP. As of 2006, over 70 risk assessment workshops had been conducted. WSDOT has now begun to explore the development of risk databases and portfolio risk modeling tools to further enhance the CEVP process. The case study of WSDOT was conducted with its CRA staff and reviewed the documents they use for risk workshops.

### 4.2.4 DOE-EM – Department of Energy Environmental Management (Appendix F)

The US Department of Energy Office of Environmental Management (DOE-EM) is responsible for the risk reduction and cleanup of the environmental legacy of the Nation's nuclear weapons program, one of the largest, most diverse, and technically complex environmental programs in the world. DOE-EM has a long history of applying rigorous risk management practices. The DOE-EM case study involved interviews with both the Headquarters in Washington, DC and the Battelle Pacific Northwest National Labs in Richland, WA. The case study highlights a dynamic risk management process with emphasis on effective communication of the risk management plan. The case study also includes a sample protocol and policy statement.

### 4.2.5 FHWA – FHWA CM ETG Risk Management Workshop (Appendix G)

The FHWA Construction Management Expert Task Group (CM ETG) is working to promote and implement risk assessment and allocation concepts in SHA organizational structures. The CM ETG is sponsoring workshops with volunteer DOTs. These workshops are designed to expose the SHA to risk management concepts and train staff to implement the concepts. The workshops are two-days in duration, with the first day being the training and the second day a practice risk workshop on a specific project. The workshops were conducted as a pilot effort in fall of 2007 and spring of 2008 to refine the course material and exercises. The SHAs of Texas, Florida and Colorado participated in these workshops. The emphasis of the workshops is to promote a formal and structured methodology to risk management. The workshops focused on qualitative assessment and management tools. From those workshops a variety of tools were captured for use in the Guidebook development.

### 4.2.6 FTA – Federal Transit Administration (Appendix H)

The Federal Transit Administration (FTA) administers federal funding to support a variety of locally planned, constructed, and operated public transportation systems throughout the U.S., including buses, subways, light rail, commuter rail, streetcars, monorail, passenger ferry boats, inclined railways, and people movers. The research team interviewed the FTA's team leader for risk management. The team reviewed extensive documentation on a very unique approach to risk management that seeks to emulate traditional engineering safety factors. The process was notably transitional, but demonstrates the evolution of risk management policies and procedures to more sophisticated approaches based on historical data.

### 4.2.7 NY MTA – New York Metropolitan Transit Authority (Appendix I)

The New York Metropolitan Transportation Authority (NY MTA) Capital Construction Company was formed in 2003 to manage the major transportation and infrastructure projects of Downtown Manhattan. The Company focuses all of its efforts on "mega projects." The NY MTA described their risk management procedures and how they operate under the guidelines of the FTA's risk management policies. The NY MTA interview confirmed the structured approach that is being promoted in this research study.

### 4.2.8 ODOT – Ohio Department of Transportation (Appendix J)

The Ohio Department of Transportation (ODOT) case study was selected because of the Department's well documented conceptual estimating practices and approach to the application of contingency. The estimating staff provided a number of documents describing their approach to contingency management. Most notable from this study was the use of a sliding scale contingency. ODOT also explained how they operate under the guidelines of the FHWA risk management policies.

## *4.3 Conclusions*

Eight separate case studies have been developed for this research. As demonstrated in Table 4.1, the research team believes that these case studies provided the breadth of information needed to complete the Guidebook on risk analysis tools and management practices for transportation projects. The research team is also satisfied that the depth of information is sufficient. As the research team conducted the final interviews, very little new information came to light that was not found in the early case studies.

# Chapter 5: Risk Tools

## *5.1 Introduction*

The goal of Task 3 was to document an array of established risk analysis tools and viable management practices. The research team used the literature review, state-of-practice survey and the case studies to collect and document a range of proven and emerging risk management tools. The result of this task was a listing of risk tools and practices that are organized by risk management steps and by project development phases.

The state-of-practice survey did not yield as many tools as the research team had hoped, but it did yield contacts for follow-up research. Respondents were asked if they had used any risk management tools from a predetermined list of common tools in the survey. Unfortunately the response was not overwhelming to this question in the survey. As seen in Figure 2.7, only three (3) of the 48 agencies responding to the questionnaire stated that they had published risk management guidelines or procedures. The team did find that all tools listed were in use by these three agencies or others, but detailed quantitative results relating to risk tools in use by the SHAs is not relevant to this report due to the low number of responses. The state-of-practice survey was useful in identifying those agencies with formal risk management procedures who were candidates for case study interviews.

The case studies conducted in Task 4 yielded a rich set of risk tools and management practices that are integrated into the final Guidebook. The case studies involved all three of the identified SHAs currently employing formal risk management procedures. The case studies also explored public sector agencies outside the highway sector. Risk tools were found in each of the eight case studies. The majority of these tools were also referenced in the literature. Finding the tools in use in the case studies gave the research team confidence to include them in the Guidebook and finding the tools in the literature assisted the research team in describing the tools and pointing users to further resources.

## *5.2 Risk Analysis and Contingency Tools*

When collecting these tools and practices, the research took special care in noting how they relate to the following three characteristics:

- Application by project development phase;
- Application to project complexity; and
- Function in the estimating and risk management process.

NCHRP Report 574 presented strategies and methods in a three-part structure of 1) Planning, 2) Programming and Preliminary Design, and 3) Final Design that follows a general project development process applicable to all state highway agencies. The documented tools in NCHRP Report 574 are contained in an appendix that cross-references them to each of these three project development phases. The research team utilized the same approach in the development of the NCHRP 8-60 Guidebook. However, the team realized that the 8-60 Guidebook needed to be written more concisely as it describes a much more focused topic. As the tools and practices were collected through the literature review, survey, structured interviews and case studies, care

was taken to collect information on the applicable project delivery phases for final collation into the guide.

Project complexity is a characteristic that was used to determine when each tool is applicable. Intuitively, one would expect that more complex projects require more complex risk analysis and risk management tools. In the experience of the project team, this statement is generally correct; nevertheless, even on the most complex projects, it is often the simplest representations that yield the best results. While the analysis may be supported by a complex, rigorous, and probabilistically-sophisticated model, it is of little value if its outputs are obscured in jargon or overly complicated in their representation. Therefore, the approach was to *suggest the simplest tool that is appropriate* given the project development phase and considering the estimating or cost management decision that is addressed.

The team collected data on the issue of tool complexity and requisite user knowledge. The tools require skills ranging from the use of "cookie cutter" methods (i.e. three point estimates) to being comfortable with multivariate statistics and stochastic modeling (i.e. Monte Carlo and Decision Tree methods). The topic of tool complexity and the resources needed to apply the tools was explored while gathering data during the structured interviews and case studies, and tested by professional practitioners at review sessions described later in this report.

Table 5.1 provides a summary listing of the tools discovered by the research team in the case studies and confirmed in the literature. The list is presented in the following format:

- **Tool Name** – A brief name as described in the case study or supporting literature.
- **Description** – A brief description of the tool with examples to enhance understanding.
- **Uses** – The step in the risk management process to which the tool applies. Note that some tools are used in more than one step or even throughout the process.
    - Identify – Tools used to *identify* risks that might impact the project and to *document* risk characteristics.
    - Assess/Analyze – Tools used to qualitatively or quantitatively evaluate the probability and impact of the identified risks.
    - Plan – Tools used to determine how to handle risks through acceptance, avoidance, mitigation, or transference.
    - Monitor and Controls – Tools used to capture, analyze and report the status of the risk management plan.
- **Phases** – The project development phase to which the tools most frequently apply.
    - Planning
    - Programming and Preliminary Design
    - Final Design
- **Case Studies** – The case studies in which the projects were observed. Details for these case studies can be found in Chapter 5 and the appendices.
    - California Dept of Transportation (Caltrans)– Appendix C
    - Bay Bridge – Appendix D
    - Washington State DOT (WSDOT) – Appendix E
    - Department of Energy (DOE) – Appendix F
    - Federal Highway Administration (FHWA) Workshops – Appendix G

- Federal Transit Administration (FTA) – Appendix H
- New York Metropolitan Transit Authority (NY MTA) – Appendix I
- Ohio Department of Transportation (ODOT) – Appendix J

**Table 5.1 – Summary of Risk Management Tools**

| Tool Name | Description | Uses | | | | | | Phases | | | Case Study Example |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Identify | Assess | Analyze | Allocate | Mitigate & Plan | Monitor & Control | Planning | Scoping | Final Design | |
| Assumption Analysis | The process of reviewing all assumptions for uncertainty that could generate risks. | ● | | | | | | ● | ● | ● | All |
| Expert Interviews | Speaking with experts in order to generate risks and/or assess risk probability/impact. | ● | ● | | | | | ● | ● | ● | Bay Bridge, FHWA, WSDOT |
| Crawford Slip | A group risk identification technique. Useful in generating a large number of risks in a short amount of time. | ● | | | | | | ● | ● | | FHWA |
| SWOT Analysis | Strengths, Weaknesses, Opportunities, & Threats. A risk identification technique used to help generate risks and place them into categories. | ● | | | | | | ● | ● | | FHWA |
| Checklists | The use of a historical list of project risks from experience or specific past projects that is used to aid in the risk identification process. | ● | | | | | | ● | ● | ● | Caltrans, FHWA, WSDOT |
| Risk Breakdown Structures | A formal coding of risks that can supplement the risk register and explore the relationships of different risks to each other. It can be helpful for an agency when organizing similar risks across multiple projects. | ● | | ● | | | | ● | ● | ● | CalTrans, DOE-EM, FHWA, WSDOT |
| Risk Workshops | Workshops that are conducted to identify and quantify the uncertainty involved in projects. Risk mitigation and planning are also often addressed. | ● | ● | ● | ● | | | ● | ● | ● | FHWA, WSDOT |
| Probability and Impact (PxI) Matrix | Qualitative analysis tool to provide a ranking of risks based on probability and impact. It is a powerful visual tool to convey risk ranking. | | ● | | | | | ● | ● | ● | Bay Bridge, CalTrans, DOE-EM, FHWA, WSDOT |

| Tool Name | Description | Uses | | | | | | Phases | | | Case Study Example |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Identify | Assess | Analyze | Allocate | Mitigate & Plan | Monitor & Control | Planning | Scoping | Final Design | |
| Three Point Estimate | A technique for generating range estimates by estimating an optimistic, most-likely, and pessimistic estimate. | | | ● | | | | ● | ● | ● | Caltrans |
| Monte Carlo Analysis | A risk analysis modeling method that uses repeated trials computing probabilistic outcomes of various risk events or uncertainties. The technique is used for both cost and schedule. | | | ● | ● | ● | | ● | ● | | CalTrans, DOE-EM |
| Probabilistic Cash Flow | The use of stochastic estimates and schedules to evaluate the construction project cash flow. This reveals more risks relating to the ability for a project to sustain itself during construction given its unique funding conditions. | | | ● | | | | ● | ● | | DOE-EM |
| Probability Mass Diagrams / Cumulative Mass Diagrams | Diagrams used to express the probability and some other project variable. Typically, these diagrams are used to show the probability of completing a project before, by or later than a certain target date; or the probability of completing below or above a certain cost. | | | ● | | | | ● | ● | | Bay Bridge, DOE-EM, FTA, WSDOT |
| Tornado Diagrams | Used to rank the risks on a project; they use levels of correlation of that risk to either project cost or project schedule. The risk with the largest correlation coefficient is the one that would have the highest impact to the project cost or schedule. | | | ● | | | | ● | ● | | Bay Bridge, WSDOT |
| Self Modeling Worksheet | A spreadsheet tool developed to model risk and uncertainty given basic project parameters. Based on Monte Carlo simulation. Allows for more customization than commercial software. | | | ● | | | | | ● | ● | WSDOT |
| Risk Priority Ranking | Using qualitative or quantitative analysis methods to rank risks. This often results in a dynamic “Top Ten” list to track risks with the highest potential impact at any given project development phase. | | ● | | | | | ● | ● | ● | All case studies in some form |

| Tool Name | Description | Uses | | | | | | Phases | | | Case Study Example |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Identify | Assess | Analyze | Allocate | Mitigate & Plan | Monitor & Control | Planning | Scoping | Final Design | |
| Risk Map | A tool that places all risks graphically on a probability and impact (P x I) matrix to show relative probability and impact of different costs. Can also show how mitigation changes the probability and impact of each risk. | | ● | ● | | | | ● | ● | ● | FHWA |
| Risk Comparison Table | Analysis tool to compare all risk to each other to determine prioritization and importance. | | ● | ● | | | | | ● | ● | FHWA |
| Risk Register | A risk management tool that lists risks in a given project and provides summary information that can include the risk description, probability, impact, ranking, ownership, and other important information. | ● | ● | ● | ● | ● | ● | ● | ● | ● | CalTrans, DOE-EM, FTA, WSDOT |
| Risk Management Information System | A data management system that tracks risks and risk related information throughout the project development process. | ● | ● | ● | ● | ● | ● | ● | ● | ● | CalTrans, DOE-EM |
| Red Flag Items | A technique to identify risks and focus attention on critical items with respect to cost and schedule impacts. Risks of greatest concern are “red flagged” for monitoring throughout the project. | | | | | ● | | | | ● | ODOT |
| Contingency – Identified | The process of estimating contingency on the basis of identified risks and the probability of their occurrence. | | ● | ● | | ● | | ● | ● | | ODOT, WSDOT, Caltrans |
| Contingency – Percentage | The process of estimating contingency based on a percent of the project. The percentage is typically based on policy, similar projects, or estimator judgment. | | ● | | | | | ● | ● | ● | ODOT, WSDOT, Caltrans |

The research created a Tool Appendix to describe all the tools referenced throughout the Guidebook. The common informational structure for describing each tool is the following:

- What is the tool?
- Why is the tool used?
- What does the tool do or create?
- When should the tool be used?
- How should the tool be used?
- What are examples or applications of the tool?
- What tips will lead to successful use of the tool?
- Where can the user find more information to support development of a specific tool?

This structure is similar to the cost estimation and cost estimation management tool appendix in NCHRP Report 574. However, the current Guidebook provides an additional section discussing how to use the tool in each case. This additional section provides users with an additional point of knowledge in applying the tools.

The final set of tools in the Guidebook has incorporated additional tools from the NCHRP 574 for consistency. These tools include: D1.1 Contract Packaging; D1.2 Delivery Decision Support; and R1.1 Complexity Definitions. The readers are also encouraged to refer to Report 574 for cost estimation and cost estimation management tools as needed.

## 5.3 Conclusions

A wide array of risk analysis and risk management tools to control project cost were found in the literature and through the case studies. The team has summarized the tools and included them in a Tool Appendix in the Guidebook. The Guidebook discusses how the tools can be used with varying levels of project complexity throughout all phases of project development.

# Chapter 6: Guidebook Development and Testing

## *6.1 Introduction*

This chapter presents how the Guidebook was developed and tested. The Guidebook development involved the development of a preliminary Guidebook outline (Task 5) that was reviewed in the interim report by the NCHRP Panel (Task 6) and then the preparation of a detailed annotated outline (Task 7) that was again reviewed by the NCHRP Panel. Various portions of the Guidebook were tested on site with three state highway agencies.

## *6.2 Preliminary Guidebook Outline*

Task 5 had as its main goal the development of a preliminary outline for the Guidebook including a proposed glossary of terms related to risk analysis tools and management practices for controlling transportation project costs. The research team worked to develop an outline that was closely aligned in format with the NCHRP 574 Guidebook and the subsequent NCHRP Procedures Guide for Right-of-Way Estimating and Cost Management. This Guidebook on risk analysis tools and management practices is however a standalone document, but the team desired to leverage the systematic process that has proven to be successful in the NCHRP Report 574. The team intentionally aligned the format of the Guidebooks to present a comprehensive process on cost estimating cost management and risk analysis. The outline produce for the Task provided examples of proposed Guidebook features and included text and figures.

The preliminary outline served as the basis for discussion with the NCHRP Panel and ultimately provided the framework for developing the content of the Guidebook. The NCHRP Panel approved the preliminary outline with the Interim Report. The major chapters of the preliminary outline are shown in Figure 6.1. While the majority of major chapters and subsections remained the same in the final Guidebook, there are minor changes. These changes are discussed in the following section.

**Executive Summary**
**Chapter 1 Introduction**
**Chapter 2 Integrated Estimating Process**
**Chapter 3 Agency Risk Management Overview**
**Chapter 4 Guidebook Framework**
**Chapter 5 Guide to the Planning Phase**
**Chapter 6 Guide to the Programming/Preliminary Design Phase**
**Chapter 7 Guide to the Final Design Phase**
**Chapter 8 Implementation**
**Chapter 9 Path Forward**
**References**
**Tools Appendix**

**Figure 6.1. Preliminary Guidebook Outline**

## 6.3 Annotated Guidebook Outline

The main objective of Task 7 was to create an annotated Guidebook outline for Panel review to approve. The research team took a proactive approach and provided much of the annotation and presentation materials in Task 5 with the Interim Report to enhance the feedback provided at the interim Panel meeting. The team then prepared sample sections of the Guidebook as well as develop appropriate presentation materials for practitioner review sessions in Task 8. All members of the research team worked on the detailed annotated Guidebook.

The main change from the preliminary outline to the final Guidebook outline involved the separation of Chapter 6 Guide to the Programming/Preliminary Design Phase and Chapter 7 Guide to the Final Design Phase into in Chapter 6 Guide to the Programming Phase and Chapter 7 Guide to the Design Phase. The change was spurred by discussion with the NCHRP Project Panel. The primary reason was the desire to show that the focus of the programming phase is to set a *baseline estimate* with an appropriate risk-based contingency, and the focus of the Design Phase should be risk monitoring and control with efforts to resolve the contingency. The final Guidebook outline is shown in Figure 6.2.

**Executive Summary**
**Chapter 1 Introduction**
**Chapter 2 Project Cost Estimation and Management**
**Chapter 3 Risk Management Overview**
**Chapter 4 Guidebook Framework**
**Chapter 5 Guide to the Planning Phase**
**Chapter 6 Guide to the Programming Phase**
**Chapter 7 Guide to the Design Phase**
**Chapter 8 Implementation**
**Chapter 9 Path Forward**
**References**
**Tools Appendix**

**Figure 6.2. Final Guidebook Outline**

## 6.4 Guidebook Structure and Layout

The guidebook is written the material in four major sections. Chapters 1, 2 and 3 provide the fundamental concepts of cost estimating and management and risk management. These chapters are specifically aimed at state highway agency upper management. Chapters 5, 6, and 7 focus on the application of the fundamental concepts presented in Chapters 1, 2 and 3. Chapters 5, 6, and 7 are written towards the needs of planners, project managers, designers, and estimators. These chapters provide guidance to risk management implementation during each phase. The goal of this structure is to help planners, designers, estimators, and project managers quickly locate the tools they need to implement a risk management approach. The structure follows a hierarchical

layout of project development phase, risk management step, and project complexity as shown in Figure 6.1.

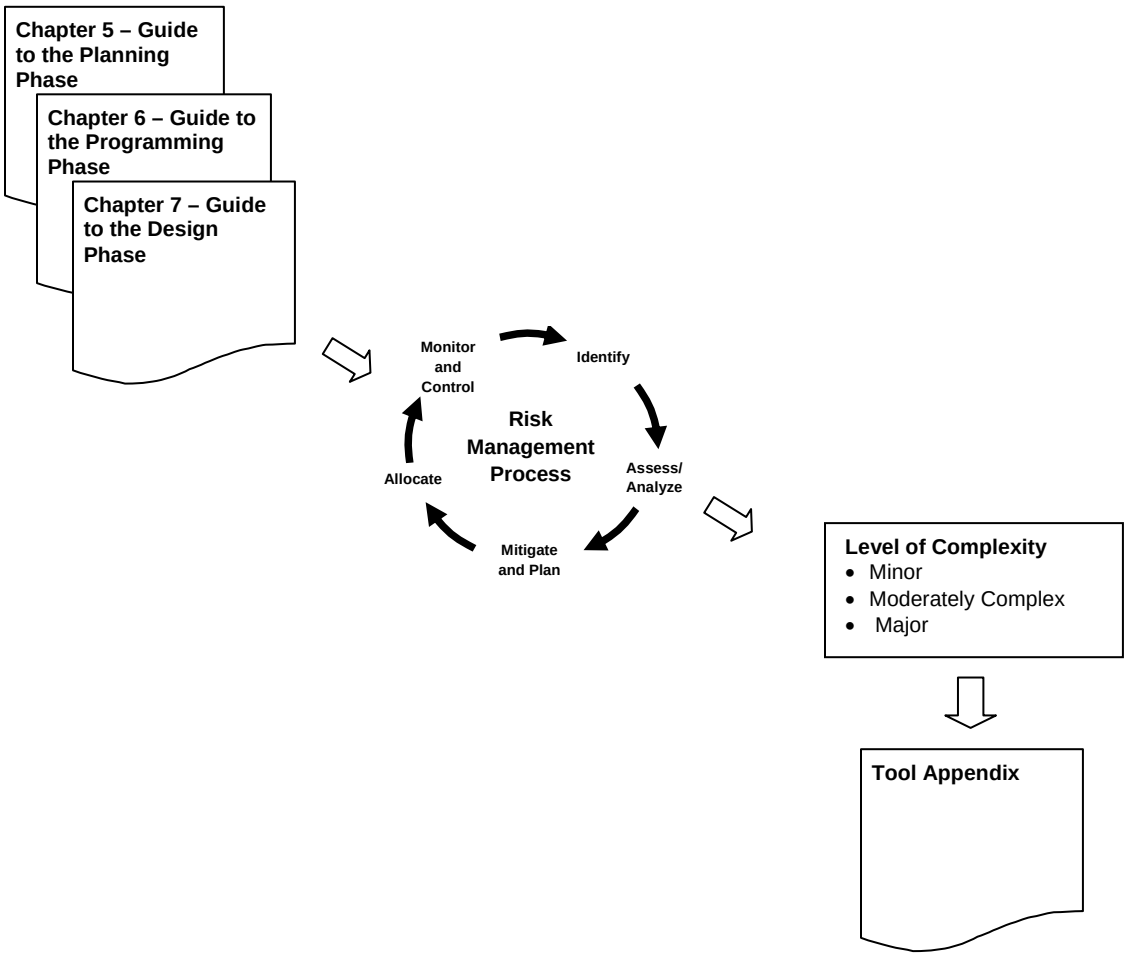


**Figure 6.3: Guidebook Structure**

Note that Chapter 7 – Guide to the Design Phase – combines the Preliminary Design and Final Design phases described in Chapter 2. These phases were combined to minimize redundancy and due to the fact that the risk management approach does not vary substantially from the Preliminary to Final Design Phases. Figure 7.2 illustrates how the risk management process focuses on changes throughout the phases. In the planning phase, the process focuses on risk identification with some initial assessment and planning activities. In the Programming phase, when the *baseline estimate* is often set, the process focuses on continued identification, analysis and detailed planning. The risk management process is completely implemented in the Design Phase. The subtle differences in the risk management process between the Preliminary and Final

Design Phases are explained in Chapter 7. These changes in the risk management process across the phases are discussed in Chapters 5, 6 and 7.

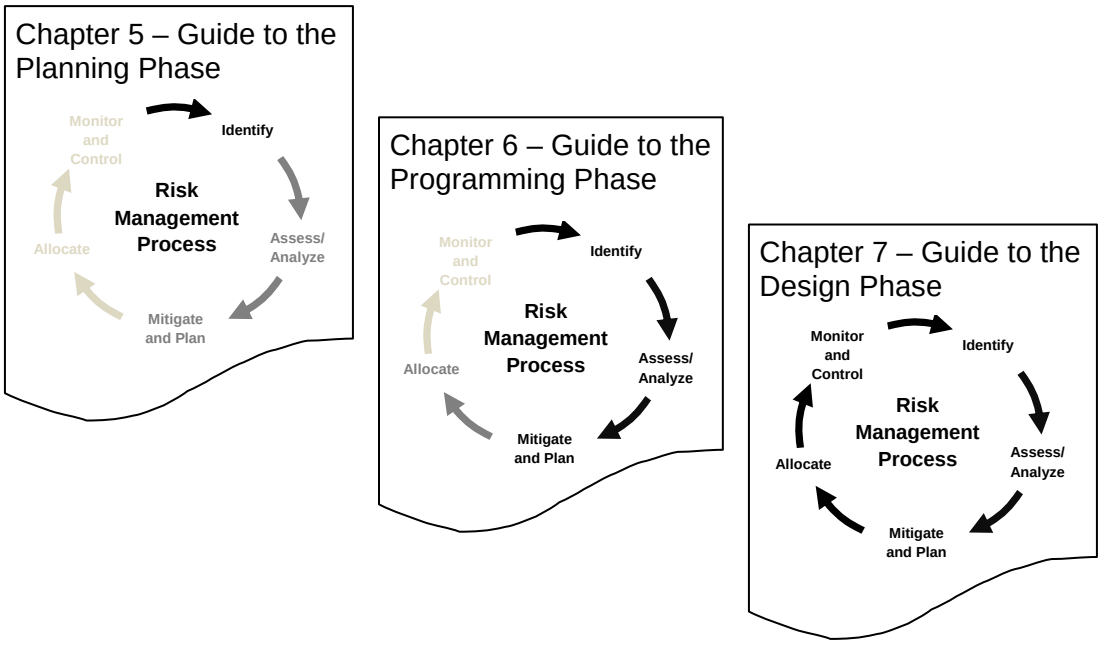


**Figure 6.4: Risk Management Focus within the Project Development Phases**

Within each Chapter, the application of each step of the risk management process is explained. It is the premise of this Guidebook that all projects, regardless of project size and project complexity, require some form of risk management planning. The framework of risk management remains the same, but the tools and level of effort vary with the project complexity. Each risk management step is described for each level of project complexity with the follow structure:

- Inputs – the information required for the risk management step;
- Tools – a mapping of appropriate tools that are included in the Tool Appendix;
- Tips – advice for implementing the risk management step and the use of risk management tools; and
- Outputs – the information that will be produced from the risk management step.

## *6.5 Guidebook Testing*

The team completed the Guidebook testing by conducting three one-day workshops with knowledgeable state highway agencies that were identified in the first phase of the research. These three workshops focused on the three project delivery phases defined in the Guidebook. WSDOT, Mn/DOT, and the Colorado DOT participated in the review workshops. The sections of the Guidebook that were reviewed in each workshop were:

- Planning Phase Workshop (WSDOT) – Chapters 1-5 and the Tools Appendix
- Programming Phase Workshop (Mn/DOT) – Chapters 1-4, 6 and the Tools Appendix
- Design Phase Workshop (CDOT) – Chapters 1-2, 7 and the Tools Appendix.

The research team developed a project summary and agenda for each workshop that was sent to the participants (Figure 7.4) beforehand. Each workshop involved multiple people from the agency in an attempt to represent a cross section of stakeholders who would be potential Guidebook users. The Guidebook sections were also sent to the participants to review prior to the workshop. In some cases, participants brought comments to the workshop and in other cases the participants provided verbal feedback and the participating research team members took notes.

Date

Name
Address
City, State Zip Code

Re: NCHRP 8-60 Risk Guidelines Presentation and Review

Dear XX:

Thank you for agreeing to participate in the National Cooperative Highway Research Program (NCHRP) 8-60 Research Project on risk analysis and management on <date>. We have enclosed some background information about the project along with a proposed agenda for our meeting. I will send the draft Guidebook material approximately one week prior to the meeting so that participants may review it before the meeting.

Please do not hesitate to call me with any question at all.

Sincerely,

Keith Molenaar

**Figure 6.4. Validation Interview Protocol**

## NCHRP 8-60 Risk Management Guidebook Testing Workshop

**Overview of Project**

Highway design and construction projects can be extremely complex and fraught with uncertainty. Engineers and construction managers must coordinate a multitude of human, organizational, technical, and natural resources. Quite often, the engineering and construction complexities are overshadowed by economic, societal, and political challenges. The outcome of these challenges has too often been significant cost escalation. Project cost escalation has a detrimental effect on a state highway agency's (SHA) ability to program and deliver projects.

Project cost escalation is a major problem for SHAs. In completing NCHRP Project 8-49, "Procedures for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction," members of this research team and the NCHRP research panel identified the need for more detailed tools in the area of risk analysis and risk management, particularly in the long-range transportation planning, priority programming, and preconstruction stages of the project development process. The following unique challenges, as identified in the research and included in the project statement, must be addressed to achieve a systematic integration of risk management into the cost estimating and cost management process:

- Developing consistent definitions for "cost escalation," "risk," and "uncertainty";
- Developing guidance for consistent application of contingency to risk management and cost estimation;
- Developing systematic and uniformed approach for documenting and tracking risk;
- Identifying appropriate timing of risk management procedures given various levels of project complexity during the different project development phases;
- Addressing policy, political, and communications issues;
- Determining appropriate organizational structures and required organizational commitment to achieve a risk management culture; and
- Developing performance measurements and accountability tools that can exist within transportation agency organizational structures.

<u>This research will provide a guidebook of risk analysis tools and management practices to aid in controlling project costs.</u> The guidebook will address risk identification, assessment, analysis, mitigation, allocation, and tracking and control in a manner that is systematically integrated into the organizational structure and culture of our nation's SHAs.

**Figure 6.4. Validation Interview Protocol (continued)**

**Workshop Goals**

The workshop goal is to obtain a critique of the Guidebook content including: the structure and layout; its user friendliness; and suggestions on areas of the Guidebook that need improvement. This workshop will last approximately one-half day and include up to ten participants. Please see the proposed agenda, Table 1.

**Table 1 Proposed Agenda**

| Time | Description |
|---|---|
| 1:00-3:00 pm | Overview of Guidebook Contents (Chapters 1-4)<br>❑ Guidebook Introduction<br>❑ Integrated Estimating Approach<br>❑ Risk Management Framework<br>❑ Guidebook Framework<br>❑ Discussion<br>❑ Critique |
| 3:00-4:30 pm | Programming (Chapter 6 and Tools Appendix)<br>❑ Risk Management Steps<br>❑ Tools Appendix<br>❑ Discussion<br>❑ Critique |
| 4:30-5:00 pm | Summary and Adjourn<br>❑ Review final comments and suggested changes |

**Figure 6.4. Validation Interview Protocol (continued)**

Based on the critiques obtained, the general concept of the Guidebook was acceptable and judged useful to DOTs as a mechanism to promote change in DOT risk analysis and cost management. The format and layout of the Guidebook evolved and was improved based on comments from the workshops. The content of Chapter's 1 through 4 became clear and concise through changes based on the critiques. The content of Chapter 5 and 7 was refined and terminologies for the individual project phases were refined. In Chapter 6, detail was removed because the participants believed that the tools were too detailed for the information available in the Planning Phase. In Chapter 6 and 7, additional detail about tool use was added. The tool appendix was generally perceived as reasonable and useful. Some tool descriptions required further information and a little more "how to" type discussions were added.

As an additional point of validation, Chapter 8 was sent to the lead cost estimating and risk management personnel in Mn/DOT and WSDOT for review. These states have experience with implementing risk management for the control of project costs and added valuable comments to the implementation chapter. Their comments were discussed among the project team and incorporated into the final version of the Guidebook.

The final point of validation was through the NCHRP Panel. The iterative testing process culminated in the final draft of the Guidebook being presented to the NCHRP Panel for review and approval. Members of the panel carefully reviewed and commented on the final draft of the Guidebook. While there was a general agreement that the Guidebook served its purpose, there were several specific comments. The researchers responded to the panel members comments clarifying the context and improving the Guidebook.

## 6.6 Conclusions

This chapter has described the different steps that were involved in the development of the Guidebook. It also provided the general layout for the Guidebook chapters and tools. The research team performed several iterations before an effective version of the Guidebook was crafted. The continual evaluation process of the Guidebook proved beneficial to refine the final product for the audience and to validate the contents. There was general consensus on the intent and content of the Guidebook during the testing period with continuous improvements as each test was conducted.

# Chapter 7: Conclusions

## *7.1 Introduction*

Project cost escalation is a serious problem facing SHAs. The failure to deliver individual projects and programs within established budgets has a detrimental effect on later programs and causes a loss of faith in the agency's ability to wisely use the public's money. A comprehensive risk management approach can help project teams identify, assess, mitigate, and control project risks. Among the benefits of a comprehensive risk management approach is the ability to generate range estimates early in the project development process and to establish justifiable contingencies that can be resolved throughout the design and construction process.

This Guidebook presents a systematic process to apply risk analysis tools and management practices to aid SHA management in controlling project cost growth. The Guidebook addresses risk identification, assessment, analysis, mitigation, allocation, and tracking and control in a manner that is systematically integrated into the organizational structure and culture of SHAs.

## *7.2 Guidebook Development*

The Guidebook developed in this research developed as an extension to NCHRP Report 574, *Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*. That research presented a strategic approach to cost estimating and cost estimate management. However, the research team and the NCHRP research panel members identified the need for more detailed tools and management practices in the area of risk analysis and risk management practices. These needs were recognized particularly crucial for the long-range transportation planning, priority programming, and preconstruction stages of the project development process.

As in initial effort of this Guidebook, the research team conducted a survey of current SHA risk management practices. The survey revealed that while risk is indeed inherent in every capital transportation project, only three of the 48 state agencies responding to the survey had formal, published project risk management policies or procedures. Additionally, the survey found that only eight of the 48 responding agencies have a formal published definition of *contingency*. Without a formal definition for contingency, agencies have a difficult time consistently calculating contingencies appropriate to project conditions. Therefore, this Guidebook is imperative to support SHA efforts to control project cost escalation.

Given the current state of practice, the research team's approach to developing the Guidebook included a critical review of the literature; in-depth case studies with leading agencies − both inside and outside of the transportation sector; and a thorough industry validation of the work. The research team gathered and annotated more than 80 papers and reports on risk and risk management. In reviewing these articles and reports, the team identified important research terms and sought risk management methods and tools to assist in cost estimating, estimating contingency, or risk management related to cost control. Following the literature review the team closely analyzed risk practices through eight in-depth case studies. The case studies were with Caltrans, the Caltrans San Francisco-Oakland Bay Bridge project, WSDOT, the US DOE, the FHWA, the Federal Transit Administration, the New Your Metropolitan Transit Agency, and

the Ohio DOT. The research team used the knowledge gained from industry surveys, the literature review, and the case studies to develop the initial Guidebook. The Guidebook was then tested with the WSDOT, Mn/DOT, and the Colorado DOT and reviewed by the NCHRP Panel. The resulting Guidebook is founded on industry practice and was validated through industry review.

## *7.3 The Risk Management Framework*

The risk management framework described in the Guidebook is based on best practices found across both SHAs and other agencies having extensive experience managing risk in design and construction. In the Guidebook, those practices are adapted to the unique needs of highway project development. The overall framework of the Guidebook includes three main elements:

1. **Risk Management Process**
   - Risk identification; assessment; analysis; planning and mitigation; allocation; and monitoring and control
2. **Project Development Phases**
   - Planning, programming, and design
3. **Project Complexity**
   - Project type, technical complexity, and management complexity

Of particular note is the fact that the overall risk management process is cyclical. As the project evolves, some risks will be resolved or diminished, while others may surface and thus be added to the analysis. The five fundamental risk management steps can be applied the throughout project life cycle. The extent of application of each step varies as the methods and tools used to support these steps are influenced by the project development phase and project complexity. The process is scalable from small and non-complex projects to large and complex projects. There are five imperative steps to managing project risk**.**

1. *Risk identification* is the process of determining which risks might affect the project and documenting their characteristics using such tools as brainstorming and checklists.
2. *Risk assessment/analysis* involves the quantitative or qualitative analysis that assesses impact and probability of a risk. Risk assessment assists in deriving contingency estimates. Quantitative and qualitative risk analysis procedures are applied to determine the probability and impact of risks.
3. *Risk mitigation and planning* involves analyzing risk response options (acceptance, avoidance, mitigation, or transference) and deciding how to approach and plan risk management activities for a project.
4. *Risk allocation* involves placing responsibility for a risk to a party – typically through a contract. The fundamental tenants of risk allocation include allocating risks to the party that is best able to manage them, allocating risks in alignment with project goals, and allocating risks to promote team alignment with customer-oriented performance goals.
5. *Risk monitoring and control* is the capture, analysis, and reporting of project performance, usually as compared to the risk management plan. Risk monitoring and control assists in contingency tracking and resolution.

## *7.4 Challenges and Keys to Success*

The challenges of implementing risk management processes to control project costs are similar to those identified by the research team for implementing new cost estimating and management practices in NCHRP Report 574. State highway agencies must consider several challenges when deploying this Guidebook:

- **Challenging the status quo and creating a cultural change** requires leadership and mentoring to ensure that all steps in the cost estimation management and cost estimation processes are performed.
- **Developing a systems perspective** requires organizational perspective and vision to integrate cost estimation management and cost estimation practice throughout the project development process.
- **Dedicating sufficient time** to changing agency attitudes toward estimation and incorporating the strategies, methods, and tools from this Guidebook into current state highway agency practices is difficult when resources are scarce.
- **Dedicating sufficient human resources** to cost estimation practice and cost estimation management beyond the resources that have previously been allocated to estimation processes.

Meeting these challenges will ultimately require a commitment by the agency's senior management to direct and support change. The benefit of this commitment will be manifested in projects that are consistently within budget and on schedule and that fulfill their purpose as defined by their scope. This benefit will also improve program management by allowing for better allocation of funds to projects to meet the needs of the ultimate customer, the public.

NCHRP Report 574 provided 10 key principals to successful cost estimation management and cost estimation practices. The 10 keys to success are repeated in this Guidebook on risk analysis tools to control project cost.

Cost estimation management:

1. *Make estimation a priority* by allocating time and staff resources.
2. *Set a project baseline cost estimate* during programming or early in preliminary design, and manage to this estimate throughout project development.
3. *Create cost containment mechanisms* for timely decision making that indicate when projects deviate from the baseline.
4. *Create estimate transparency* with disciplined communication of the uncertainty and importance of an estimate.
5. *Protect estimators* from internal and external pressures to provide low cost estimates.

Cost estimation practice:

1. *Complete every step in the estimation process* during all phases of project development.
2. *Document estimate basis,* assumptions, and back-up calculations thoroughly.
3. *Identify project risks and uncertainties* early, and use these explicitly identified risks to establish appropriate contingencies.
4. *Anticipate external cost influences* and incorporate them into the estimate.

5. *Perform estimate reviews* to confirm that the estimate is accurate and fully reflects project scope.

Of particular note is Cost Estimating Practice #3, which deals directly with identifying risks and uncertainties. Lessons learned from the development of this Guidebook can be summarized in 5 additional keys to success for risk analysis tools to control project cost.

1. Employ all steps in the risk management process.
2. Communicate cost uncertainty in project estimates through the use of ranges and/or explicit contingency amounts.
3. Tie risks to cost ranges and contingencies as a means of explaining cost uncertainty to all stakeholders.
4. Develop risk management plans and assign responsibility for resolving each risk.
5. Monitor project threats and opportunities as a means of resolving project contingency.

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# Appendix A: Definitions

A primary objective of Task 1 was to create a comprehensive set of definitions for the Guidebook. The Guidebook will help to create a common vocabulary and set of practices that will promote learning and the exchange of new tools and innovations relating to risk management throughout our nation's state highway agencies. The definitions are presented in the categories of cost estimating terms, cost management terms, risk analysis terms, and project development phases. These terms will be expanded as the Guidebook is completed, but the current list constitutes the core definitions for the Guidebook.

## Cost Estimating Terms

**Allowance:** An amount included in the Base Estimate for items that are known but the details of which have not yet been determined.

**Base Estimate:** The most likely project estimate, exclusive of Project Contingency, for known costs for all known design, engineering, cooperative agreements, right-of-way, environmental, utilities, preconstruction, and construction work.

**Contingency:** An estimate of costs associated with identified uncertainties and risks, the sum of which is added to the Base Estimate to complete the Project Cost Estimate. Contingency is expected to be expended during the project development and construction process.

**Cost Estimate:** A prediction of quantities, cost, and/or price of resources required by the Scope of a project. As a prediction, an estimate must address risks and uncertainties. The cost estimate consists of the Base Estimate for known costs associated with identified uncertainties and risks.

**Cost Estimating:** The predictive processes for approximating all project costs such as design, engineering, cooperative agreements, right-of-way, environmental, utilities, preconstruction, and construction work. As a predictive process, estimating must address risks and uncertainties. Project cost estimating generally involves the following general steps: determine Estimate Basis, prepare Base Estimate, determine Risk and set Contingency, and review Total Estimate.

**Estimate Basis:** A documentation of the project type and scope for each Cost Estimate, including items such as drawings that are available (defining percent engineering and design completion), project design parameters, project complexity, unique project location characteristics, and disciplines required to prepare the cost estimate.

**Range (or Stochastic) Estimating:** A risk analysis technology that combines Monte Carlo sampling, a focus on the few key variables, and heuristics (rules-of-thumb) to rank critical risk elements. This approach is used to establish the range of the total project estimate and to define how contingency should be allocated among the critical elements.

**Total Cost Estimate:** The sum of the Base Cost Estimate and Contingency.

## Cost Management Terms

**Baseline Cost Estimate:** The most likely Total Cost Estimate, which serves as the approved project budget and the basis for Cost Control. The approved budget must correspond to an approved scope of work, work plan and an approved project schedule.

**Cost Control:** The process of controlling deviations from the estimated project costs and monitoring the risks and contingencies associated with changes. Two principles apply: 1) there must be a basis for comparison (e.g. the Baseline Cost Estimate); and 2) only future costs can be controlled.

**Cost Escalation:** Increases in the cost of a project or item of work over a period of time.

**Cost Management:** The process for managing the cost estimate through reviews and approvals, communicating estimates, monitoring of scope and project conditions, evaluating the impact of changes, and making estimate adjustments as appropriate.

**Project Management:** The process of organizing, planning, scheduling, directing, controlling, monitoring, and evaluating activities to ensure that stated project objectives are achieved.

**Scope:** Encompasses the elements, characteristics, and parameters of a project and work that must be accomplished to deliver a product with the specified requirements, features and functions.

**Scope Changes:** Changes in the requirements, features or functions on which the project design and estimate is based. Examples would include changes to project

limits, work types, or changes to capacity factors such as traffic loads, vehicles per lane, or storm water factors.

**Scope Creep:** An accumulation of minor Scope Changes that incrementally change project scope, cost, and schedule.

## Risk Analysis Terms

**Biases:** A lack of objectivity based on the individual's position or perspective. There may be "system biases" as well as "individual biases."

**Confidence Level:** The probability that a range will contain the value under consideration. For example: "there is a 90% probability that the ultimate project cost will be less than $(number)."

**Probability:** A measure of how likely a condition or event is to occur. It ranges from 0 to 100 percent (or 0.00 to 1.00).

**Qualitative Risk Analysis:** Performing a qualitative analysis of risks and conditions to prioritize their effects on project objectives. It involves assessing the probability and impact of project risk(s) and using methods such as the probability and impact matrix to classify risks into categories of high, moderate, and low for prioritized risk response planning.

**Quantitative Risk Analysis:** Measuring the probability and consequences of risks and estimating their implications for project objectives. Risks are characterized by probability distributions of possible outcomes. This process uses quantitative techniques such as simulation and decision tree analysis.

**Risk:** An uncertain event or condition that, if it occurs, has a negative or positive effect on a project's objectives.

**Risk Acceptance:** This technique of the Risk Planning process indicates that the project team has decided not to change the project plan to deal with a risk, or is unable to identify any other suitable response strategy.

**Risk Allocation:** Placing responsibility for a risk to a party through a contract. The fundamental tenants of risk allocation include allocating risks to the party that is best

able manage them, allocating risks in alignment with project goals, and allocating risks to promote team alignment with customer-oriented performance goals.

**Risk Assessment:** A component of risk management that bridges risk identification and risk analysis in support of risk allocation. Risk assessment involves the quantitative or qualitative analysis that assesses impact and probability of a risk.

**Risk Avoidance:** This technique of the Risk Planning process involves changing the project plan to eliminate the risk or to protect the project objectives from its impact.

**Risk Documentation:** Recording, maintaining, and reporting assessments, handling analysis and plans, and monitoring results. It includes all plans, reports for the project manager and decision authorities, and reporting forms that may be internal to the project manager.

**Risk Event:** A discrete occurrence that may affect the project for better or worse.

**Risk Identification:** Determining which risks might affect the project and documenting their characteristics.

**Risk Management:** All of the steps associated with managing risks: Risk Identification, Risk Assessment, Risk Analysis (Qualitative or Quantitative), Risk Planning, Risk Allocation, and Risk Monitoring Control.

**Risk Management Plan:** A document detailing how risk response options and the overall risk processes will be carried out during the project. This is the output of Risk Planning.

**Risk Mitigation:** This technique of the Risk Planning process seeks to reduce the probability and/or impact of a risk to below an acceptable threshold.

**Risk Monitoring and Control:** The capture, analysis, and reporting of project performance, usually as compared to the risk management plan.

**Risk Planning:** Analyzing risk response options (Acceptance, Avoidance, Mitigation, or Transference) and deciding how to approach and plan risk management activities for a project.

**Risk Register:** A document detailing all identified risks, including description, cause, probability of occurring, impact(s) on objectives, proposed responses, owners, and current status.

**Risk Transference** This technique of the Risk Planning process seeks to shift the impact of a risk to a third party together with ownership of the response (see also, Risk Allocation).

**Sensitivity:** When the outcome is dependent on more than one risk source, the sensitivity to any specific one of those risks is the degree to which that specific risk (event or condition) affects the outcome or value.

**Simulation:** A simulation uses a project model that translates the uncertainties specified at a detailed level into their potential impact on objectives that are expressed at the level of the total project. Project simulations use computer models and estimates of risk at a detailed level, and are typically performed using the Monte Carlo technique.

## Project Development Phases

**Planning:** The project development phase that includes identifying and assessing transportation system needs, developing the initial design concept and scope of projects that would address those needs, crafting project purpose and need, considering environmental factors, facilitating public involvement/participation, and considering a proposed project in the larger context of the transportation system and the affected community.

**Programming and Preliminary Design:** The project development phase that includes conducting environmental analysis, conducting schematic development, holding public hearings, determining right-of-way impact, determining project economic feasibility, obtaining funding authorization, developing right-of-way needs, obtaining environmental clearance, determining design criteria and parameters, surveying utility locations and drainage, and making preliminary plans such as alternative selections, assign geometry, and create bridge layouts.

**Final Design:** The project development phase that includes acquiring right-of-way; developing plans, specifications, and estimates (PS&E); and finalizing pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, and cost estimates.

**Advertise and Bid:** The project development phase that includes preparing the contract documents, advertising for bids, holding a pre-bid conference, and receiving and analyzing bids.

**Construction:** The project development phase that includes determining the lowest responsive bidder; initiating the contract; mobilizing; conducting inspection and materials testing; administering contract; controlling traffic; and constructing bridge, pavement, and drainage.

# Appendix B: Annotated Bibliography

"AACE International's Risk Management Dictionary" (2000). *Cost Engineering Journal*, AACE's Risk Management Committee, Vol. 42, No. 4, April, pp. 28-31.

This article provides 50 definitions of terms related to the subject of risk management. It was originally published in an October 1995 issue of Cost Engineering and was the first article in AACE International's Professional Practice Guide to Risk. Many of the terms included are from probability and statistics or are peculiar to project risk management.

Abi-Karam, T., "Managing Risk in Design-Build" (2001). *AACE International Transactions*, CDR.07, Morgantown, pp. 7.1-7.5.

This article provides an overview of the design-build method of project delivery; where an owner contracts only with a design-builder rather than the traditional method of an owner contracting with an architect, engineer and contractor. The author proposes that there are inherent risks associated with design-build projects beyond those experienced on traditionally-delivered projects and discusses each one in detail.

Ahmad, I. (1992). "Contingency Allocation: A Computer-Aided Approach," *AACE International Transactions*, F.5, Morgantown, pp. 5.1-5.5.

This paper introduces a method for allocating contingency to individual work packages. For each package, ratios of actual cost to estimated cost are calculating for the highest, most likely and lowest values as determined by historical information. Using simulation software, one can then determine a most likely cost and allocate an associated contingency value to each individual package.

Ali, R. (2005). "The Application of Risk Management in Infrastructure Construction Projects," *Cost Engineering Journal*, AACE International, Vol. 47, No. 8, August, pp. 20-27.

According to this paper, risk management process (RMP) methodology provides a logically consistent framework for managing risk. An RMP methodology is used in this article to formulate a risk management model, incorporating infrastructure project costs for construction budgeting purposes, and applying it to the project in order to improve the evaluation and control of costs.

Amirkhalili, Reza (1997). "Risk and Capital Budgeting," *AACE International Professional Practice Guide to Risk*, pp. 4.0.1 – 4.0.4.

This paper presents a Monte Carlo simulation model using a spreadsheet and a personal computer (PC). The paper will demonstrate how managers can simulate the effect of changing the variables and examine the resultant range of the project NPV graphically.

Ashley, D. B., J. E. Diekmann, K. R. Molenaar (2006). *Guide to Risk Assessment and Allocation for Highway Construction Management*, FHWA Report No. FHWA-PL-06-032, October, pp. 72

In 2004, a team of representatives from the Federal Highway Administration, State highway agencies, industry, and academia visited Canada, Finland, Germany, the Netherlands, Scotland, and the United Kingdom. The purpose of this International Technology Scanning Program study was to identify practices that might be evaluated and applied in the United States to improve construction management.

Barrazza, G. A. and R. A. Bueno (2007). "Cost Contingency Management," *Journal of Management in Engineering*, ASCE, Vol. 23, No. 3, July, pp. 140-146.

In this article, the Monte Carlo simulation approach is recommended as part of a proposed methodology for cost contingency management, which also includes a heuristic for contingency assignment (allocation) among project activities, as long as the activities have some degree of uncertainty regarding their future costs.

Bent, J. A. (2001). "Evaluating and Calculating Contingency," *AACE International Transactions*, RISK.02, Morgantown, pp. 2.1-2.5.

A method of calculating contingency using an SFC rating and a contingency chart is discussed in this paper. The data demonstrated in contingency charts are obtained from historical data and the SFC rating (a percent) is developed by calculating the total assessment of 25 factors comprised of design, estimator performance, time, project conditions and team experience.

Bjornsson, Hans C. (1977). "Risk Analysis of Construction Cost Estimates," *AACE International Professional Practice Guide to Risk*, pp. 182 – 189.

This paper briefly discusses the basics of risk simulation, and presents a computerized model for cost estimating that is designed to cope with the problems of correlation and interpretation. It explains how an estimate approach using probability is more beneficial then a single value or point estimate approach.

Brand, D., Mehndiratta, S. R., and Parody, T. E. (2000). "Options Approach to Risk Analysis in Transportation Planning." *Transportation Research Board Record No. 1706*, pp. 54-63.

This paper describes the applicability of the real-options approach to risk management to the metropolitan transportation planning process. It also describes the new options approach; examples that illustrate the value of different kinds of options are given.

Buchan, David H. (1994). "Risk Analysis – Some Practical Suggestions," *Cost Engineering Journal*, AACE International, Vol 36, No. 1, January, pp. 29 – 34.

The purpose of this article is to suggest some practical methods and solutions in the field of risk management. This is done based on the authors experience in risk analysis work in the United Kingdom construction industry. He combines a logical approach and formal

methodology with readily available computer software, including Lotus P-2-3 version 2.4, with "add-ins" @risk 1.55, and What's Best 1.6.

Burger, R. (2003). "Contingency, Quantifying the Uncertainty," *Cost Engineering Journal*, AACE International, Vol. 45, No. 8, August, pp. 12-17.

In this paper, the author defines two methods for determining contingency. Zastrozny's method is used to calculate contingency, while SMART (Simple Multi-Attribute Rating Technique) is used to obtain an uncertainty rating that, when used together with the calculated contingency, provides an estimate for the contingency needed on a particular project.

Burroughs, S. E. and G. Juntima (2004). "Exploring Techniques for Contingency Setting," *AACE International Transactions*, EST.03, Morgantown, pp. 3.1-3.6.

This paper discusses the following commonly used techniques for determining contingency: predetermined percentage, expert's judgment, risk analysis and regression analysis. Based on the performance of each of these techniques; the author asserts that there are certain techniques that are more accurately and appropriately used depending on the project risks involved.

Caddell, C. P., S. R. Crepinsek, and G. P. Klanac (2004). "Risk Assessments: Value of the Process," *AACE International Transactions*, RISK.01, Morgantown, pp.1.1-1.6.

Conducting cost and schedule risk assessments on projects has proven to be a valuable exercise; however, this paper suggests that utilizing the right process can significantly increase the quality of the risk analysis and its results, and provide a number of other benefits to the project. If these assessments are conducted properly, management and the project team can capture the inherent value in this effort and improve their chances for success because key project risks are evaluated and mitigation steps are known.

*Project Risk Management Handbook* (2003). Caltrans Office of Project Management Process Improvement, Sacramento, June.

This is California Department of Transportation's guide to risk and risk management. It describes the basic concepts and processes that guide risk management planning and implementation during project development.

Carrier, Keith C. (1977). "A System for Managing Escalation and Contingencies," *AACE International Professional Practice Guide to Risk*, pp. 324-336.

This paper presents an approach to organizing, developing, maintaining, and reporting cost status situations on capital cost projects. The reporting and simulation techniques described result in predictions of the forecast of final project cost which is continually varying.

Clarke, R. F. (2003). "Early Planning and Decisions on the Southeast Corridor Project," *Leadership and Management in Engineering*, July, pp. 142-144.

This paper discusses decisions that affect the progress of a transportation project in the Denver region, with particular attention given to decisions concerning design/build elements, the allocation of risk, the levels of design incorporated into the request for proposals, and the organization of the project team. The importance of carefully developing the contract language and of determining the technical requirements that the design/builder must meet is stressed along with the reasons for separating certain parts of the project from the overall design/build contract.

Cochrane, Raymond E. (1994). "Using @Risk to Predict Project Costs," *AACE International Professional Practice Guide to Risk*, pp. F.3.1 – F.3.5.

This paper is an analysis of a search for a better way of estimating the cost of a project under current operating conditions. Information was used from several papers on risk analysis and from annual meetings including papers about developing a modified approach to estimating using the @Risk personal computer program.

Cohen, M. W. and G. R. Palmer (2004). "Project Risk Identification and Management," *AACE International Transactions*, INT.01, Morgantown, pp. 1.1-1.5.

This paper recommends the use of the Critical Path Method (CPM) Schedule as a mechanism to manage construction risk on a project. The project life cycle is defined and the author emphasizes the necessity to manage risks throughout the entire project life cycle using the CPM network to perform "what if" analyses in order to adjust a baseline schedule according to a set of risks brainstormed by the project team.

Coppo, R. J. (2003). "Risk Modeling with Influence Factors," *AACE International Transactions*, RISK.08, Morgantown, pp. 8.1-8.2.

The influence factor risk model is based on an interview process that asks a series of questions about the source of uncertainty in the estimate. This presentation will show how to model risk by assigning probability functions and associated costs to the influence factors. The model output will result in the total cost of uncertainty. Using this approach to risk modeling puts the focus on the work process and how it introduces uncertainty in the estimate.

Curran, K. M. (2006). "Value-Based Risk Management (VBRM)," *Cost Engineering Journal*, AACE International, Vol. 48, No. 2, February, pp. 15-22.

As practiced in today's varied applications, traditional risk management is typically defined as a process to identify, analyze, mitigate, and control risks and opportunities in decision-making. Although such actions move the ball, they do little to carry the decision-maker over the goal line. Two additional requirements of risk management are presented in this paper: benchmarking and grading. Incorporation of these two attributes

into traditional risk management practice produces a much-improved decision technology, value-based risk management (VBRM).

Curran, Michael W. (1976). "Range Estimating – Coping with Uncertainty," *AACE International Professional Practice Guide to Risk*, pp. 366 – 372.

This paper explains why conventional methods of estimating come up short, and explains why uncertainty needs to be considered and methods need to be changed. This paper proposes the idea of Range Estimating and goes in-depth about how they are used and they can be beneficial to coping with uncertainty.

Curran, Michael W. (1988). "Range Estimating: Reasoning with Risk," *AACE International Professional Practice Guide to Risk*, pp. N.3.1 – N.3.9.

This paper explains why our current methods of estimating come up short because of the methods we use, not the people who are performing these methods. It goes on to explain how we think about estimates and how we should think about estimates.

del Cano, A. D., and de la Cruz, M. P. (2002). "Integrated Methodology for Project Risk Management." *Journal of Construction Engineering and Management*, ASCE, pp. 128(6), 473-485.

First, the article explains a complete or generic project risk management process to be undertaken by organizations with the highest level of risk management maturity in the largest and most complex construction projects. After that, factors influencing possible simplifications of the generic process are identified, and simplifications are proposed for some cases. Then the application to a real project is summarized. As a final validation, a Delphi analysis has been developed to assess the project risk management methodology explained here, and the results are presented.

Dey, P. K. (2002). "Project Risk Management: A Combined Analytic Hierarchy Process and Decision Tree Approach," *Cost Engineering Journal*, AACE International, Vol. 44, No. 3, March 2002, pp. 13-26.

This article demonstrates a quantitative approach to construction risk management through an analytic hierarchy process (AHP) and decision tree analysis. The entire project is classified to form a few work packages. With the involvement of project stakeholders, risky work packages are identified. As all the risk factors are identified, their effects are quantified by determining probability (using AHP) and severity (guess estimate).Various alternative responses are generated, listing the cost implications of mitigating the quantified risks.

Douglas, E. E. (2001). "Contingency Management on DOE Projects," *AACE International Transactions*, RISK.03, Morgantown, pp. 3.1-3.6.

This paper defines contingency, outlines the elements of risk management, provides guidelines for the application of contingency to the project baseline, and proposes a standard process to establish, track, and control contingency on a DOE project. While the paper is specific to DOE projects, the definitions and basic guidelines can easily be used by other industries to supplement their methods of contingency management.

Eschenbach, Ted G. (1996). "Risk Management Through Sensitivity Analysis," *AACE International Professional Practice Guide to Risk*, pp. 4.1 – 4.6 .

This paper compares several approaches to identifying and describing the key risks and to defining cost/time/risk trade-offs. The paper goes in depth describing the advantages and disadvantage of using sensitivity analysis.

*Major Project Program Cost Estimating Guidance* (2007). Federal Highway Administration, January, pp. 1-12.

This paper explains key principals used when preparing a program cost estimate at any stage of a major project. It also explains the cost elements that should be included when preparing a program cost estimate for a major project and finally explains how program cost estimates should be used throughout the project.

*Risk Assessment Methodologies and Procedures* (2004). Unpublished, Federal Transit Authority, "Report for the Federal Transit Administration, Project Management Oversight under Contract No. DTFT60-98-D-41013.

This report describes procedures for performing risk analysis, which consists of two parts: Risk assessment, which includes identification and evaluation of risks in terms of their likelihood of occurrence and their probable consequences, and risk management, which involves taking cost-effective actions to reduce risks and to realize opportunities.

Gunham, S and D. Arditi (2007). "Budgeting Owner's Construction Contingency," *Journal of Construction Engineering and Management*, ASCE, Vol. 133, No. 7, June, pp. 492-497.

In this paper, it is suggested that the common practice of allocating a fixed owner contingency (e.g., 10% of the contract value) to all projects contracted out by an owner is not appropriate. Instead, a methodology is proposed whereby the owner (1) analyzes historical project data; (2) identifies the line items that are problematic; (3) takes the necessary measures at the preconstruction stage to streamline these line items with respect to site conditions, time constraints, constructability issues, and project scope; and (4) finally budgets contingency funds based on this information.

Hackney, John W. (1985). "Applied Contingency Analysis," *AACE International Professional Practice Guide to Risk*, pp. B.2.1 – B.2.4

This paper describes what contingency is and why it is so important to a projects performance. It then talks about the different ways in which it will help a project and how it can be used or analyzed at different points in the project.

Hartman, F., and Snelgrove, P. (1996). "Risk Allocation in Lump-sum Contracts - Concept of Latent Dispute," *Journal of Construction Engineering and Management*, ASCE, pp. 122(3), 291-296.

This paper presents findings of a study and investigation on evaluating the effectiveness of written contract language to communicate risk appointment between contracting parties.

Hastak, M., and Baim, E. J. (2001). "Risk Factors Affecting Management and Maintenance Cost of Urban Infrastructure," *Journal of Infrastructure Systems*, pp. 7(2), 67-76.

This paper identifies risk factors that influence the cost-effective management, operation, and maintenance of bridges, roads and highways, and subway stations as well as how and when in the project life cycle the identified risk factors impact the associated facility costs.

Hecht, H., and Niemeier, D. (2002). "Too Cautious? Avoiding Risk in Transportation Project Development," *Journal of Infrastructure Systems*, pp. 8(1), 20-28.

This research paper explores the relationship between risk adverse behavior (i.e., engineering judgment applied to certain types of situational problems) and transportation project development time/cost. It concludes that risk-averse behavior by project managers does not significantly affect project development time or cost and that the required project development process is simply too rigid and bureaucratic to allow an individual project manager to significantly reduce the time or cost of project development

*Highways Agency Framework for Business Risk Management, Report of the Highways Agency* (2001). Highways Agency London, England, pp. 1-9.

This document sets out the Highways Agency's framework for Risk Management. It outlines both the Agency's approach to Risk Management and the associated roles and responsibilities of Agency colleagues.

Hua, C., H. Guilin, S. W. Poon, F. F. Ng (2004). "Cost Risk Management in West Rail Project of Hong Kong," *AACE International Transactions*, INT.09, Morgantown, pp. 9.1-9.5.

In this paper, a case study was conducted to investigate risk management practice in a recently-finished railway construction project in Hong Kong. Research revealed critical risk factors concerning cost performance in this project such as price escalation of material cost, inaccurate cost budget and supplier of subcontractor's default. Research results also showed that no systematic risk management procedures have been applied in

this successful project. However, managers in the project adopted a flexible way of risk management. They hold the notion of risk management and apply the procedures in each decision and everyday activities.

Jarvis, J. A.. (1976). "Capital Estimates and Cost Control for a Long Term Construction Program," *AACE International Professional Practice Guide to Risk*, pp. 63-69.

The purpose of this paper is to examine, in context, the cost engineering problems associated with long-term strategies. These projects will include projects that have taken over ten years.

Jordan, Daniel W. (1989). "Managing Change: Making the Most of Contingency," *AACE International Professional Practice Guide to Risk*, pp. Q.1.1 – Q.1.9.

This paper describes a trend program that provides a means of identifying and evaluating the impact which changes have on the cost and schedule of a capital project. The program relies on the involvement and cooperation of all members of the project team and resulting effort provides management with an up-to-date report of the status of the project, a projection of the direction it is taking, and a means of documenting what changes have occurred to cause variations from the original plan.

Kageyama, Kazumi (1979). "Probabilistic Cost Estimate Tree Analysis – Computer Program," *AACE International Professional Practice Guide to Risk*, pp. C.3.1 – C.3.6.

This paper describes: (1) the probabilistic cost estimate tree and risk data preparation required to utilize PCET; (2) the PCET computer program flow diagram with algorithm; and (3) a sample of a typical operation.

Kaliprasad, M. (2006). "Proactive Risk Management," *Cost Engineering Journal*, AACE International, Vol. 48, No. 12, December, pp. 26-36.

This article serves to provide an overview of risk management, its concepts, components, and the associated terminology and methodology, together with different views on how risk management integrates into project management.

Karlson, J. T. and J. Lereim (2005). "Management of Project Contingency and Allowance," *Cost Engineering Journal*, Vol. 47, No. 9, September, pp. 24-29.

Cost overruns in engineering projects occur frequently because a certain margin of risk is inherent in all projects. As a result, risk management is continuously gaining the attention of the engineering industries. Reserves or contingencies represent the additional funding required to account for the cost of risk. However, many corporations have different practices for estimating and managing such reserves. This article also presents several techniques and methods for estimating such reserves.

Kraemer, George T. (1977). "Quick and Effective Risk Analysis," *AACE International Professional Practice Guide to Risk*, , pp. 177-181.

This paper describes a different kind of approach to risk analysis. It describes the "manual model" so that smaller companies can gain the knowledge needed for risk analysis without the use of a computer.

Kumaraswamy, M. M. (1997). "Appropriate Appraisal and Apportionment of Megaproject Risks," *Journal of Professional Issues in Engineering Education and Practice*, pp. 123(2), 51-56.

This paper develops and describes strategies for appraising the synergistic potential and risk carrying capacities of prospective project participants, and for identifying, analyzing, and responding to risks by an appropriate appointment to those best equipped and motivated to control them.

Lewis, Lou (1977). "Range Estimating – Managing Uncertainty," *AACE Bulletin*, November/December, pp. 205 – 207.

This paper describes Range Estimating. It also describes how and why it should be used. Range Estimating quantifies the uncertainty of an estimate by addressing itself to the uncertainties of the critical elements of the estimate.

Lorance, R.B. and R.V. Wendling (1999). "Techniques for Developing Cost Risk Analysis Models," *AACE International Transactions*, RISK.02, Morgantown, pp. 2.1-2.6.

This paper defines Monte Carlo simulation and discusses how the technique can be used to develop risk analysis models in order to manage risk and consequentially, predict cost overruns.

Lukas, Joseph A. (1995). "Managing Risk on Capital Projects," *AACE International Transactions*, AACE International Professional Practice Guide to Risk, pp. 7.1 – 7.4.

This paper will discuss risk management and cover the process phases that incorporate risk management, then focus on actual experiences of capital projects at Kodak in using risk management. Specific topics include the risk analysis process and how it is used to determine project contingency and the potential range of cost outcomes. Case histories comparing risk projections to actual project costs will be reviewed, along with key lessons from over 3 years use of risk management.

Mathur, Krishan S. (1989). "Risk Analysis in Capital Cost Estimating," *Cost Engineering Journal*, AACE International, Vol. 31, No. 8, August, pp. 9-16.

This article presents an approach to the analysis of historical cost data and the prediction of costs, which takes into account risk and contingency involved in budgeting and cost

control. The method is a computer model based on statistical and operation research (OR) techniques.

Marshall, H.E., R.E. Chapman, and C.J. Leng (2004). "Risk Mitigation Plan for Optimizing Protection of Constructed Facilities," *Cost Engineering Journal*, AACE International, Vol. 46, No. 8, August, pp. 26-33.

This article describes a three-step protocol for developing a risk-mitigation plan for optimizing protection of constructed facilities. Step 1 is to assess the risk of uncertain, costly, man-made and natural hazards, including terrorism, floods, earthquakes and fire. Step 2 is to identify alternative risk mitigation strategies, used singly or in combination, to reduce the expected value of damages from such events. Step 3 is to evaluate the life-cycle economic effectiveness of alternative mitigation strategies. A case study of a typical commercial building shows how to measure outcomes from alternative terrorist mitigation measures and choose the optimal protection package based on life-cycle cost analysis.

Mlaker, Paul F.and Bryant, Larry M. (1990). "Direct Range Cost Estimating," *AACE International Professional Practice Guide to Risk*, pp. k.4.1 – k.4.4.

This paper describes the Direct Range of cost estimating and how to fix the shortcomings of Range Estimating. It also goes into detail about how Range Estimating works and why it is popular despite its shortcomings.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management*, ASCE, pp. 131(3), 343-353.

This paper presents a methodology developed by the Washington State Department of Transportation (WSDOT) for its Cost Estimating Validation Process. Nine case studies, with a mean cumulative value of over $22 billion, are presented and analyzed. Programmatic risks are summarized as economic, environmental, third party, right-of-way, program management, geotechnical, design process, construction, and other minor risks.

Moselhi, O. (1997). "Risk Assessment and Contingency Estimating," *AACE International Transactions*, D&RM/A.06, Morgantown, pp. 6.1-6.6.

This paper describes the common sources of risk associated with the delivery of engineering, procurement, and construction (EPC) projects. It provides a basic anatomy for project risk. This paper focuses primarily on contingency as a vehicle for managing this risk. The paper presents a direct quantitative method for contingency estimation and avoiding time-consuming analyses. The method is simple and practical. It provides a robust statistical estimation of the variance of the total cost of a project; permitting the consideration of any correlation among the project's individual cost items.

Nabors, John K. and Owen, Patricia A. (1983). "Quantifying Risks in Capital Estimates," *AACE International Professional Practice Guide to Risk*, 1983, pp. B.5.1 – B.5.7.

This article explains why traditional cost estimating techniques cannot be used across all projects. It goes in depth on how to identify risk and uses an example of risk analysis and construction on a chemical plant.

Nassar, K. (2002). "Cost Contingency Analysis for Construction Projects Using Spreadsheets," *Cost Engineering Journal*, AACE International, Vol. 44, No. 9, September, pp. 26-31.

The purpose of this article is to present a quantitative approach for performing contingency analysis for a construction project using basic spreadsheet techniques. The approach is applied to a practical case study and a sensitivity analysis of the results is carried out. Practicing contractors can use the developed spreadsheet to analyze cost overrun risks.

Neil, James M. (1989). "Management of Project Risks," *AACE International Professional Practice Guide to Risk*.

This paper is an introduction to management of risks associated with a construction project, specifically those faced by the contractor. The principles involved generally apply to management of risk associated with any endeavor. This paper is a condensation of the report, "Management of Project Risk", prepared by the Construction Industry Institute.

Noor, I. and R.L. Tichacek (2004). "Contingency Misuse and Other Risk Management Pitfalls," *AACE International Transactions*, RISK.04, Morgantown, pp. 4.1-4.7.

In this article, the authors assert that the methodology that is to be used for the derivation of contingency funds should be based on the level of risks on a project. Contingency funds should be used to address specific risks as they occur along the project execution schedule. Any unspent funds should be returned for possible use on other projects or to fund other activities. Based on the results of the project risk assessments, contingency drawdown plots could be used to manage the contingency funds and to improve the project budgetary process.

Paek, Joon Hong (1994). "Contractor Risks in Conceptual Estimating," *Cost Estimating Journal*, AACE International, Vol. 36, No. 12, December, pp. 19-22.

This article describes the difficulties of bidding a job based on conceptual drawings. It explains the major problems with the estimate and goes in depth on how to bid successfully and be competitive.

Piekarski, Julian A. (1984). "Simplified Risk Analysis in Project Economics," *AACE International Professional Practice Guide to Risk*, pp. D.5.1 – D.5.3.

The purpose of this paper will be to demonstrate the use of a simplified method of incorporating risk analysis to project economics in order to bridge the technology gap and bring the decision maker in direct contact with the critical uncertainties of the project. This paper is meant to present another tool that can be used, not replace the computer model.

Ramgopal, M. (2003). "Project Uncertainty Management," *Cost Engineering Journal*, AACE International, Vol. 45, No. 12, December, pp. 12-24.

This article argues that all current project risk management processes induce a restricted focus on the management of project uncertainty because the term 'risk' encourages a threat perspective. The article discusses the reasons for this view, and argues that a focus on "uncertainty" rather than risk could enhance project risk management, in terms of designing desirable futures and planning how to achieve them.

Regan, S.T. (2003). "Risk Management Implementation and Analysis," *AACE International Transactions*, RISK.10, Morgantown, pp.10.1-10.5.

The author of this paper defines the term "risk" and provides a guideline for developing a risk management program capable of being implemented and analyzed on any type of project.

Ripley, P.W. (2004). "Contingency! Who Owns and Manages It?" *AACE International Transactions*, CSC.08, Morgantown, pp. 8.1-8.4.

This paper was used as a basis for discussion at the 2004 Annual Meeting of AACE International. The author defines contingency and discusses the various ways in which different project players utilize the reserve funds.

Robert J., S. (1987). "Allocating Construction Risks: What, Why, How & Who?" *Guidelines for Improving Practice - Architects and Engineers Professional Liability*, pp. 17(5), 1-5.

This paper describes how design professionals and owners could benefit from taking a more "global" view of risk. The author describes how this could benefit everyone involved and improve the current state of risk assessment.

Robert J., S., and Wichwire, G. (1992). *Owner's Guide to Saving Money by Risk Allocation*, The The American Consulting Engineers Council and Associated General Contractors of America, pp. 1-17.

This article examines the ability to divide up the risk of a project so as not affect any one party more then another. This can be done if the risk is properly handled and assigned to the appropriate member of the construction team.

Rothwell, G. (2005). "Cost Contingency as the Standard Deviation of the Cost Estimate," *Cost Engineering Journal*, AACE International, Vol. 47, No. 7, July, pp. 22-25.

This article compares project stages, accuracy ranges, and cost contingencies recommended by the Association for the Advancement of Cost Engineering International and the Electric Power Research Institute. It shows that current guidelines are consistent with contingencies equal to the standard deviation of the cost estimate. It suggests how this standard deviation can be derived from a confidence level (e.g., 80 percent) for a given accuracy (e.g., ±10 percent) for normal and lognormal probability distributions.

Rowe, J.F. (2006). "A Construction Cost Contingency Tracking System (CTS)," *Cost Engineering Journal*, AACE International, Vol. 48, No. 2, February, pp. 31-37.

The author of this article presents a forward-looking cost contingency tracking system (CTS) that uses readily available cost information and a simple spreadsheet format. Using CTS, project managers can assign contingency to construction contracts, track its consumption, and manage a reserve for upcoming work. This article discusses the development of rules, using the perceived risk of each construction contract, to assign an initial contingency value to each construction contract. The author then describes setting up the CTS using this initially assigned contingency value, basic cost information, and cost trends from field staff. The CTS has been successfully tested on a $1.4 billion rail and highway improvement program.

Shafer, Sam L. (1991). "Estimate and Project Risk Analysis Approaches," *AACE International Professional Practice Guide to Risk*, pp. k.5.1 – k.5.5.

This paper discusses the different methods that can be used to identify risk and with that set contingency. It tells you which method to use based on the individual characteristic of the project at hand.

Shafer, Sam L. (1974). "Risk Analysis for Capital Projects Using Risk Elements," *AACE International Professional Practice Guide to Risk*, pp. 218-223.

This paper introduces a definition of risk based on cost engineering standards and not the mathematical approach. The purpose of the paper is to present a simple mathematical aid, based on "risk assessments", for: 1) determining undefined costs, 2) evaluating Range of Accuracy, and 3) presenting the results of analysis to management.

Smith, G.L. (1966). "Monte-Carlo Simulation, A Tool For Combating Uncertainty In Economic Analysis," *AACE International Professional Practice Guide to Risk*, pp. 1 – 17.

This paper describes how a Monte-Carlo simulation can and should be used. It describes how the simulation will handle the uncertainty and produce the "best" estimate from the given data.

Smith, Kennith A.; Thoem, Robert, L. (1974). "Project Cost Evaluation Using Probability Concepts," *AACE International Professional Practice Guide to Risk*, pp. 275 – 279.

This paper outlines a stronger technique for preparing realistic cost estimates for major capital investments by utilizing probability techniques. These probability concepts for project evaluation are then compared with traditional approaches.

Stevenson, James J. Jr. (1984). "Determining Meaningful Estimate Contingency," *Cost Engineering Journal*, AACE International, Vol. 26, No. 1, February 1984, pp. 35-41.

This article describes the problems that a power plant company went through in order to set a program for setting contingency on the retrofitting operations of many of their power plants. It describes their goals for the project and how they went about attaining them.

Sonmez, R., A. Ergin, and M. T. Birgonul (2007), "Quantitative Methodology for Determination of Cost Contingency in International Projects," *Journal of Management in Engineering*, ASCE, Vol. 23, No. 1, pp. 35-39.

This paper presents a quantitative methodology to determine financial impacts of the risk factors during the bidding stages of international construction projects. Project and country data of 26 construction projects from 21 countries were collected for evaluation of the international risk factors. The factors impacting cost contingency were identified using correlation and regression analysis technique. The results indicated that four factors had major contributions for explaining the variations in the contingency levels. A regression model including the significant factors was developed to support bidding contingency decisions.

Stukhart, George (1982). "Sharing the Risks of the Cost of Inflation," *AACE International Professional Practice Guide to Risk*, pp. M.1.1 – M.1.7.

This paper discusses the risk of inflation over the period of a construction project. It discusses who and how the effect of inflation should be dispersed. It also talks about how the contract can help divide some of these costs for the contractor.

Touran, A. (2003). "Probabilistic Model for Cost Contingency," *Journal of Management in Engineering*, ASCE,Vol. 129, No. 3, June, pp. 280-284.

This paper proposes a probabilistic model for the calculation of project cost contingency by considering the expected number of changes and the average cost of change. The model assumes a Poisson arrival pattern for change orders and independent random variables. The probability of cost overrun for a given contingency level is calculated. Typical input values to the model are estimated by reviewing several U.S. Army Corps of Engineers project logs; numerical values of contingency are calculated and presented. The effect of various parameters on the contingency is discussed in detail.

*Program and Project Management for the Acquisition of Capital Assets* (2000). Guideline DOT O 413.3, U.S. Department of Energy, Washington DC, pp. 1-39.

This paper describes various definitions used by DOT. It then explains how these will be used in order to give the project management direction for the acquisition of capital assets that are delivered on schedule, within budget, and fully capable of meeting mission performance and environmental, safety, and health standards.

Project Management Practices: Risk Management (2003). U.S. Department of Energy, Washington DC, June, pp. 120.

This Practice is designed to provide acquisition professionals and program and project management offices with a reference for dealing with system acquisition risks. It is intended to be useful as an aid in classroom instruction and as a reference for practical applications.

*Risk Management* (2003). Government Report, Office of Management Budget and Evaluation & Office of Engineering and Construction Management, U.S. Department of Energy, pp. 1-120.

This Practice is designed to provide acquisition professionals and program and project management offices with a reference for dealing with system acquisition risks. It is intended to be useful as an aid in classroom instruction and as a reference for practical applications.

*Risk Assessment Methodologies and Procedures* (2004). FTA Contract No. DTFT30-98-D-41013, Project No. DC-03-5649, Work Order No. 6, U.S. Department of Transportation, May pp. 127.

The report explains in detail the rationale for risk analysis of public transit capital projects. The emphasis is on probabilistic methods for evaluating risks – as this approach provides an effective way for modeling uncertain events – and describes the procedures a project owner should follow to carry out the process.

<www.wsdot.wa.gov/> (viewed 7/1/2009). Washington State Department of Transportation, Olympia, WA.

This site was used to conduct research and contains many valuable links and useful information.

Wright, P.A. and Hill, T.V. (1986). "Cost Estimating – Dealing with Uncertainty," *AACE International Professional Practice Guide to Risk*, pp. E.5.1 – E.5.8.

This paper discusses the problem of cost estimating and how to deal with other types of markets. It goes into detail about how to use a probabilistic method for construction cost estimates when dealing with other economic markets uncertainties. It also describes how to forecast future competitive activity in other economic markets.

Yeung, D. K. L., S. Cheung, K.K.W. Cheung, and H.C.H. Seun (2003). "Web-Based Project Cost Monitoring System for Construction Management," *AACE International Transactions*, IT.09, Morgantown, pp. 9.1-9.11.

In this paper, the concepts of developing an automated online cost control/monitoring and assessment system for construction projects (PCMS) is discussed. One of the key functions of PCMS is as a detector of potential risks and hazards in cost management, or as a warning sign to the client and professionals, that the preset cost budget is overrun and requires immediate corrective action.

Zeanah, P. H. (1973). "Advanced Techniques for Contingency Evaluation," *AACE International Professional Practice Guide to Risk*, pp. 68-75.

This paper reviews the fundamentals of probability and then utilizes these techniques, along with Monte-Carlo simulation and decision trees analysis, to better understand an estimate when uncertainty is involved. It explains how to use these techniques when using objective data.

# Appendix C: Caltrans Case Study

## *Caltrans General Approach to Risk Management*

## *C.1 Introduction*

The main objective of the NCHRP 8-60 project is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs. Task 4 of the research involved preparing a series of case studies that demonstrate effective application of risk-analysis tools and management practices in controlling project costs during the planning, priority programming, and preconstruction phases of transportation project development. The California Department of Transportation (Caltrans) is a leading state highway agency in risk management based on their formalized approach to risk management and documentation of the risk process through their *Project Risk Management Handbook*.

### C.1.1 Caltrans Survey Response

The survey administered in Task 2 of the research gathered information on current practices in defining, categorizing, identifying and quantifying risks as a means of assessing uncertainty and controlling transportation costs.

The results of the survey provided background information on current practices in use by various transportation organizations. Specifically, the survey results were used to:

- Identify common response patterns across the various organizations.
- Identify departments of transportation (DOT) that provided the most useful risk related information.
- Check for consistency in responses within each organization.
- Select transportation agencies for further interviews.

A review of the responses to the questionnaires administered in Task 2 showed that out of a total of 48 state DOTs responding to the survey, only 8 had a formal published definition of contingency. Most of the other organizations use a unique project contingency determined by engineers, estimators and project managers using engineering judgment, statistical analysis of historic data and some level of specific risk identification. California State DOT (Caltrans), however, is one of four state highway agencies that use a combination of unique project contingency and a formal established risk analysis process (see Chapter 2). Caltrans was identified for further interviews primarily due to the comparatively large size of the organization and its use of two approaches to risk management: 1) the general approach; and 2) project specific applications. The organization's respondents provided information about the general risk management procedure based on the *Project Risk Management Handbook*, and a more comprehensive risk management process currently employed for the Toll Bridge Seismic Retrofit Program. This project has a baseline budget of almost $9 billion. Caltrans had been mandated by the state assembly to implement a highly comprehensive risk management program for the project. This unique project level application is presented as a case study in Appendix D of this report. This case study focuses on the general approach used by Caltrans and the processes described in the Caltrans *Project Risk Management Handbook*.

### C.1.2 Caltrans Interview

Based on the responses received in Task 2, two Caltrans persons, Nigel Blampied and Parviz Lashai, were interviewed at the Caltrans Headquarters in Sacramento by Dr. Stuart Anderson and Dr. Keith Molenaar. The purpose of this interview was to search for more information that would provide better insight as to how risk management is actually performed on a project by project basis within the Caltrans organization. Thus, the questions posed were related to the Caltrans risk management process covered in their handbook and the tools identified in the handbook. The interview was meant to identify some of the existing gaps in and challenges faced implementing the risk management process.

## *C.2 Risk Management Approach*

The Caltrans *Project Risk Management Handbook* defines risk management as "the systematic process for planning for, identifying, analyzing, responding to, and monitoring project risks. The main objective of the project risk management process is to help sponsors and project teams make informed decisions regarding alternative approaches to achieving their objectives and the relative risk involved in each, in order to increase the likelihood of success in meeting or exceeding the most important objectives (e.g. time) sometimes at the expense of other objectives (e.g. cost)." The handbook also describes the process, the various steps involved, the key responsibilities of project participants, success factors, and provides samples of the supporting tools.

The success of the project risk management is dependent on a culture that supports honest, realistic, and open recognition and discussion of project risks at meetings even if they indicate problems with a project. No resources are spared in the organization's effort to collect accurate project risk data and management remains involved in policy-making activities which clearly define the threshold of impact on the main project objectives of scope, cost, schedule, and quality.

The General Risk Management Process flow is illustrated as shown in Figure C-1:

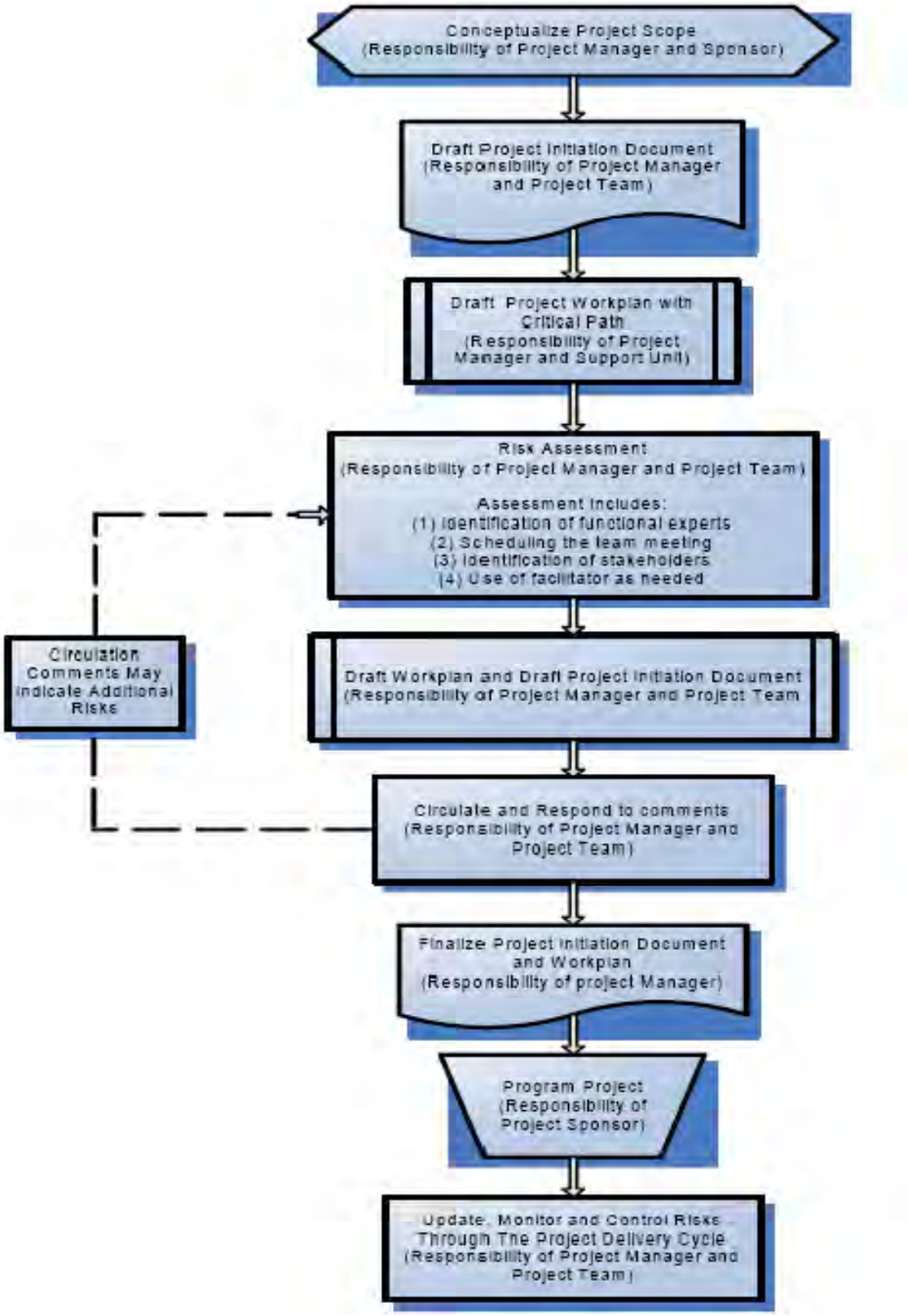


**Figure C-1. The Caltrans' Risk Management Process Flow Diagram**

There are six main stages involved in the risk management process; the matrix depicted in Figure C-2 shows the main process components and their respective deliverables.

| Process | Output(s) (deliverables) |
|---|---|
| Risk management planning | Risk Management Plan (RMP) |
| Risk identification | Risk Register (Register) |
| Qualitative risk analysis | Risk Register (updates)<br><br>Prioritized list of risks classified as high, moderate, or low. |
| Quantitative risk analysis | Quantitative Risk Analysis Reports<br><br>Numerical analysis of the project's likelihood of achieving its overall objectives<br><br>(Risk Register updates) |
| Risk response planning | 1- Risk Register (updates)<br><br>2- Project Management Plan (updates)<br><br>3- Project Risk Management Plan (updates)<br><br>4- Risk-related contractual agreements<br><br>The outcome may result in one or more of the following: residual risks, secondary risks, change control, contingency reserve (amounts of time or budget needed). |
| Risk monitoring and control | Risk Register (updates)<br><br>The outcome may result in workaround plans, corrective actions, programming change request (PCR), and updates to risk identification checklists for future projects |

**Figure C-2. Deliverables for the Risk Management Process**

**Risk Management Planning (RMP):** This is the process of deciding how to approach and conduct risk management activities of a project based on project importance to the organization. The RMP provides a basis for evaluating risks. Activities that comprise the process include assigning primary responsibilities and determining a systematic way of identifying, analyzing, monitoring, reporting and responding to risks on a project. RMP is performed to ensure that the organization maximizes the opportunities posed by positive risk events and minimize the threats posed by negative risk events. The major deliverable of this process is the **Risk Management Plan** (Sample RMP template shown in Section C.7). As part of the risk planning process, an estimate of the staff time is required. This estimate includes information on the number of meetings needed to support the risk management process.

**Risk Identification:** Potential project risks are identified primarily by using the organization's project **sample risk list** (Section C.8), and secondly by using individual knowledge of this or similar projects to determine other project-specific risks. Participants involved in this process generally would include the project manager, project team members, risk management team, and qualified risk management experts; in addition, all project personnel are encouraged to identify potential risks. These risks could be either positive (opportunities) or negative (threats), and are further categorized based on their sources by using a **risk breakdown structure** (Section C.9) suited to the project. All risks and risk related information (status, description, root causes, objective, probability, cost/time impact value, risk owner, strategy and response action) are documented in a **Project Risk Register** (see Figure C-3) which is constantly updated throughout the project life cycle by adding new risks and retiring anticipated risks that have been realized or mitigated. The risk management plan and the initial risk identification process must be completed before the end of the 'Project Initiation Document Phase' (shown in Figure C-1 – the risk management process flow).

**Qualitative Risk Analysis:** Risks identified in the previous stage are prioritized for further action by their probability of occurrence, corresponding impact on project objectives if they occur and other factors such as time frame of occurrence of such risks. This is split into 4 steps.

Step 1: Each risk is ranked using a risk probability ranking matrix with rank 5 for risks with the highest probability of occurrence (60-99%) and rank 1 for risks with the lowest probability of occurrence (1-9%) as shown in Figure C-4.

Step 2: The risks, depending on whether they are threats or opportunities are further assessed and categorized using the impact evaluation matrix (see Figure C-5 and Figure C-6 respectively) as very low, low, medium, high and very high impact on major project objectives-cost, time, scope and quality. This assessment is conducted by experts or functional units in their respective fields. The project sponsor defines for the team the levels of impact on time, cost, scope, and quality that would be considered as having a very low, low, moderate, high, very high impact on project objectives as well as various combinations of probability and impact that would qualify the risk as low, moderate or high priority for further action. Using these definitions, members of the risk team assess these risks and put them into low, moderate and high categories for each project objective – time, cost, scope, and quality.

**Project Risk Register**

**Project Name:**

**Dist./County/Rte./PM:**

**Project Manager:**

| Risk ID | Threat or Opportunity | Risk Category | Date Risk Identified | Risk Description | Root Causes | Primary Objective | Probability (P) | Impact (I) | Overall Risk Rating | Risk Owner | Risk Owner Contact Info | Risk Trigger | Strategy | Response Actions including advantages and | VBS (Affected) | Status | Status Date and Review Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-06321-01-A-RW-1 | Threat | Env | | Increase in cost of steel - market | Agency understaffed. | Time | 1 | 2 | Low | Arianne Glade | (877) 325-5609 | | Accept | | | Active, dormant, retired | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | |

Sample risk register

**Figure C-3. Sample Risk Register**

| Risk Probability Ranking | |
|---|---|
| **Ranking** | **Probability of Risk Event** |
| 5 | 60–99% |
| 4 | 40–59% |
| 3 | 20–39% |
| 2 | 10–19% |
| 1 | 1–9% |

**Figure C-4. Risk Ranking based on Probability of occurrence**

| Evaluating Impact of a Threat on Major Project Objectives | | | | | | |
|---|---|---|---|---|---|---|
| **Impact** | | **Very Low** | **Low** | **Moderate** | **High** | **Very High** |
| OBJECTIVE | **Time** | Insignificant Schedule Slippage | Delivery Plan milestone delay within quarter | Delivery Plan milestone delay of one quarter | Delivery Plan milestone delay of more than 1 quarter | Delivery Plan milestone delay outside fiscal year |
| | **Cost** | Insignificant Cost Increase | <5% Cost Increase | 5-10% Cost Increase | 10-20% Cost Increase | >20% Cost Increase |
| | **Scope** | Scope decrease is barely noticeable | Changes in project limits or features with <5% Cost Increase | Changes in project limits or features with 5-10% Cost Increase | Sponsor does not agree that Scope meets the purpose and need | Scope does not meet purpose and need |
| | **Quality** | Quality degradation barely noticeable | No safety issues, C, O, M deficiencies approved by project team | No safety issues, C, O, M deficiencies require District management approval | Quality may be made acceptable through mitigation or agreement (i.e. Fact Sheet) | Quality does not meet one or all of the following Safety, C, O, & M |

**Legend:** C – Constructability, O – Operability, M – Maintainability

**Figure C-5. Evaluating Impact of a Threat on Major Project Objectives**

| Evaluating Impact of an OPPORTUNITY on Major Project Objectives | | | | | | |
|---|---|---|---|---|---|---|
| Impact | | Very Low | Low | Moderate | High | Very High |
| OBJECTIVE | Time | Insignificant Schedule Improvement | Delivery Plan milestone does not improve but float is added | Delivery Plan milestone improves but still within the quarter | Delivery Plan milestone improves by 1 quarter. | Delivery Plan milestone improved by more than one quarter |
| | Cost | Insignificant Cost reduction | <1% Cost Decrease | 1% - 3% Cost Decrease | 3%-5% Cost Decrease | >5% Cost Decrease |
| | Scope | Scope effect is not noticeable | Improves chances to achieve project limits or features with cost increases of 10% or more | Improves chances to achieve project limits or features with cost increases of 5%-10% | Improves chances to achieve project limits or features with cost increases of 2%-5% | Improves chances to achieve project limits or features with cost increases of < 2% |
| | Quality | No quality improvement noticeable | C, O, M improvement noticeable by project team | C, O, M improvement can be seen and measured | Quality improvement can be claimed for the project | Quality improvement is "best in class" |

**Legend:** C – Constructability, O – Operability, M – Maintainability

**Figure C-6. Evaluating Impact of an Opportunity on Major Project Objectives**

Step 3: Each identified risk is assessed based on its probability of occurring (1 to 5) determined in step 1, and impact if it occurs (rated separately for each project objective in step 2). The assigned ranking remains the same for all four project objectives. The combined output from steps 1 and 2 shows for each risk a probability and up to four possible impacts corresponding to the affected project objectives.

Step 4: A probability and impact matrix is prepared by combining output from step 3 with the impact score to determine whether an activity is high risk, moderate risk or low risk. A larger emphasis is placed on high risk items by the organization and as such increasing non-linear weights are often assigned to the impact levels as the impact increases for each major project objectives from very low to very high impact. Different objectives could have different (linear/non-linear) scoring systems applied to them.

| Impact Scoring | | |
|---|---|---|
| | Degree of Focus on Risks with High and Very High Impacts | |
| | Significant (Non-linear) | Moderate (Linear) |
| Very High | 16 | 5 |
| High | 8 | 4 |
| Moderate | 4 | 3 |
| Low | 2 | 2 |
| Very Low | 1 | 1 |

**Figure C-7. Impact Scoring on Project Objectives**

The Probability and Impact (PxI) Matrix is formed using each risk's probability and impact. For each of the project objectives, the combinations could fall into one of these three categories:

RED: Indicating that the activity is high risk.
YELLOW: Indicating that the activity is moderate risk.
GREEN: Indicating that the activity is low risk.

Potentially, there could be four of such PxI matrices, one for each objective, although the color arrangement would remain the same. There could be 2 alternative matrices for threats and another 2 for opportunities using linear and non-linear scoring as delineated in Figure C-8.

Option 1: PxI Matrix for Significant Focus on High and Very High Impacts (Non-linear Impact Scoring)

| Probability | Threats | | | | |
|---|---|---|---|---|---|
| 5 | 5 | 10 | 20 | 40 | 80 |
| 4 | 4 | 8 | 16 | 32 | 64 |
| 3 | 3 | 6 | 12 | 24 | 48 |
| 2 | 2 | 4 | 8 | 16 | 32 |
| 1 | 1 | 2 | 4 | 8 | 16 |
| | 1 | 2 | 4 | 8 | 16 |
| | Impact on Selected Objective | | | | |

Option 2: PxI Matrix for Moderate Focus on High and Very High Impacts (Linear Impact Scoring)

| Probability | Threats | | | | |
|---|---|---|---|---|---|
| 5 | 5 | 10 | 15 | 20 | 25 |
| 4 | 4 | 8 | 12 | 16 | 20 |
| 3 | 3 | 6 | 9 | 12 | 15 |
| 2 | 2 | 4 | 6 | 8 | 10 |
| 1 | 1 | 2 | 3 | 4 | 5 |
| | 1 | 2 | 3 | 4 | 5 |
| | Impact on Selected Objective | | | | |

Option 1: PxI Matrix for Significant Focus on High and Very High Impacts (Non-linear Impact Scoring)

| Probability | Opportunities | | | | |
|---|---|---|---|---|---|
| 5 | 5 | 10 | 20 | 40 | 80 |
| 4 | 4 | 8 | 16 | 32 | 64 |
| 3 | 3 | 6 | 12 | 24 | 48 |
| 2 | 2 | 4 | 8 | 16 | 32 |
| 1 | 1 | 2 | 4 | 8 | 16 |
| | 1 | 2 | 4 | 8 | 16 |
| | Impact on Selected Objective | | | | |

Option 2: PxI Matrix for Moderate Focus on High and Very High Impacts (Linear Impact Scoring)

| Probability | Opportunities | | | | |
|---|---|---|---|---|---|
| 5 | 5 | 10 | 15 | 20 | 25 |
| 4 | 4 | 8 | 12 | 16 | 20 |
| 3 | 3 | 6 | 9 | 12 | 15 |
| 2 | 2 | 4 | 6 | 8 | 10 |
| 1 | 1 | 2 | 3 | 4 | 5 |
| | 1 | 2 | 3 | 4 | 5 |
| | Impact on Selected Objective | | | | |

Translate Score to Risk Rank

| Score | Risk |
|---|---|
| 1 – 6 | Low |
| 7 – 14 | Moderate |
| 15 – ++ | High |

**Figure C-8. Sample PxI Matrices**

The chosen scores for each objective are then added to the risk register for the impact on that particular objective. Generally, these PxI matrices are used by Caltrans departmental Project Managers; however, they can be altered and assigned different scores to better suit a given project if the need arises. Some project managers prefer to use PxI matrices based on narrative

probabilities (very low, low, moderate, high, very high) and not translated to numerical probabilities as previously shown in Figure C-8.

**Quantitative Risk Analysis:** This approach is used to numerically estimate the probability that a project would meet its cost and time objectives. Taking the model (cost or schedule) of a project, Monte Carlo simulation techniques are used to express the degree of uncertainty in a schedule or cost activity by a probability distribution showing three estimates – Optimistic, Most likely and Pessimistic, called a 3-point estimate. These 3 points are estimated during an interview with experts on the subject matter who focus on schedule and cost one after the other, at the same time recording the risks that had led to the estimates. Typical distributions usually are triangular, beta, normal and uniform as shown in Figure C-9.

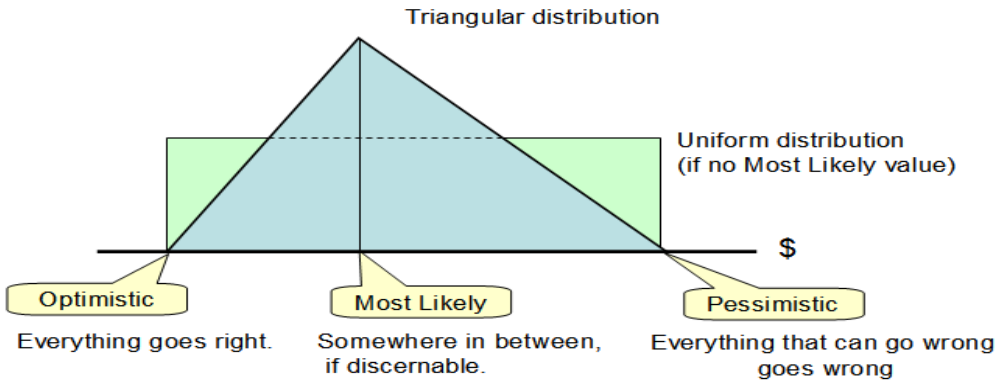



**Figure C-9. Typical Probability Distributions**

Simulation software is used to iterate the project schedule or cost estimate many times over, each time sampling values from the probability distribution. The results presented show several possible completion dates and project costs. These results can be used to estimate the likelihood of the project over-running or under-running schedule (see Figure C-10) or budget and the largest contributing factors (risks) to these possibilities can thereby be determined. The amount of contingency required to match the degree of uncertainty can be more accurately determined by the project team. The department generally does not require quantitative analysis for most projects, but project development teams within the districts could decide that a quantitative risk analysis is necessary on specific projects due to size or complexity.

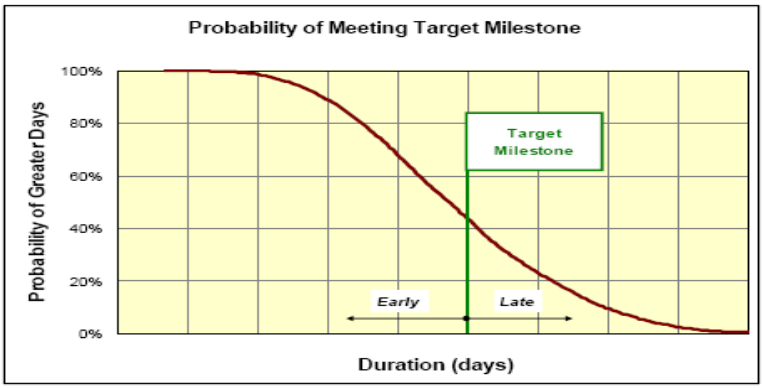



**Figure C-10. Probability of Meeting Target Milestone**

In Figure C-10, the curve represents the probability of the duration of all activities ending at a targeted milestone represented by the green line. The graph shows a 40 percent probability of finishing later and a 60 percent probability of finishing earlier.

**Risk Response Planning:** Alternative response actions are developed by the Project Manager and the project development team to adequately reduce risk threats or increase opportunities with a focus on high risk items. Responsibility is assigned for each risk response in case of occurrence.

Strategies for responding to threats could be to:

- Avoid by changing project plan (scope, time, and resources) to eliminate risk.
- Transfer by shifting the financial responsibility to another party on the project; for example, a competent contractor.
- Mitigate by taking early action to reduce the probability or the impact of a risk.

Strategies for responding to opportunities could be to:

- Exploit, by ensuring that the opportunity is realized (such as securing talented resources that may become available for the project).
- Share by allocating the ownership to a third party best able to capture the opportunity for the good of the project (such as risk sharing partnerships, joint ventures).
- Enhance by modifying the size of the opportunity by identifying and maximizing key drivers as a means of increasing its probability or positive impacts; deliberately targeting and reinforcing the opportunity.

When it is not possible to eliminate risk, the project manager and team do not need to change the project plan or scope; instead they decide to address the risk if it occurs; this strategy is called Risk Acceptance. They could either provide a contingency reserve (time or money), which is called active acceptance or simply establish a recovery plan to deal with the risks when they occur, known as passive acceptance.

**Risk Monitoring and Control:** This is the continuous process of keeping track of all risks and monitoring the effectiveness of planned strategies on these risks. This process continues throughout the life cycle of the project. The process involves the addition of new risks as they develop, reviewing planned responses, choosing alternative response strategies, implementing contingency plans, taking corrective actions or re-planning the project if applicable. Each risk owner is expected to give status reports to the project manager and team leader periodically, stating any unanticipated effects or recommendations necessary to effectively mitigate the risk.

**Contingency**

The Caltrans risk identification and the subsequent analysis is mainly based on a qualitative approach. Thus, a contingency amount is not provided as the end result of this risk analysis process. As a consequence, Caltrans relies on a tiered contingency structure. This structure is tied to project development phase as follows:

- Planning – 25%

- Programming/Schematic Design – 20%
- Final Design (PS&E) – 5%

Of the five Caltrans responses to the Task 2 survey, three of the respondents confirmed these percentages while a fourth respondent indicated that Caltrans uses standard percentages but did not specify the percentages. The fifth respondent did not know what contingency was used on projects. The Caltrans staff interviewed also confirmed these percentages. However, there was no recollection of how they were developed or how accurate these percentages seem to be for their projects.

### C.2.1 Project Applications

The general risk management procedures have been applied on over 1,000 Caltrans projects. However, for most of these applications, the risk analysis is only qualitative. The quantitative risk management analysis is applied more on large scale projects. One major project currently in the construction phase is the San Francisco Oakland Bay Bridge project. The level of risk management on this project includes the quantitative analysis and is expected to significantly reduce the overall project cost. The SFOBB risk management plan is discussed in further detail as a case study under Task 4, when a project-based application is more specifically considered.

The apparent wide use of the *Project Risk Management Handbook* is attributed to risk management training, at least to some extent. Caltrans encourages its employees to take the project management training course. An eight hour risk management module is covered as part of this course. According to those interviewed over 400 Caltrans staff members have taken the risk management module.

While the two persons interviewed were well informed about the risk management process, they stated that project applications of their process are best understand by directly interviewing district project managers. Three contacts were provided representing three different districts.

### C.2.2 Conclusions

Caltrans has a documented risk management process and approach. Their approach is documented in a *Project Risk Management Handbook*, 2nd Edition. This approach relies primarily on qualitative analysis of the risks that are identified. Thus, contingency is not determined based on the risk identification and analysis process for most projects. The use of the Caltrans risk tools appears to be wide spread across the districts. The manner in which these tools are used will be confirmed through follow-up interviews with selected district staff. Caltrans also develops a staff cost for the risk effort according to the Risk Management Plan.

## *C.3 Estimating*

Three of the five Caltrans respondents agreed that the organization uses both an estimating section and distributed project managers and engineers for estimating during the planning, programming and design phases of project development.

### C.3.1 Contingency and Risk Analysis

The respondents stated that a standard pre-determined contingency is applied across all projects, except for one who mentioned that a unique project contingency is set by engineers, estimators or project managers. According to one survey respondent, "Contingencies are a percentage of the subtotal of the cost of contract items, supplemental work, and state-furnished materials and expenses, and are included in the grand total of the final cost estimate to allow for unforeseen increases. Contingencies should be 5%. The Basic Engineering Estimating System automatically allows for a contingency of 5%, but any amount may be entered, either by percent or by specified dollar amount. However, justification is required when a contingency other than 5% is to be included in the final cost estimate." Contingency is generally applied in the planning, programming and final design phases of project development at both the project level and program level; while 4 of the respondents stated that contingency is never expressed as ranges vs. point estimates in any of these phases, one respondent indicated that sometimes it is. According to one respondent, formal risk analysis is carried out 100% on the project scope, schedule, cost and contracts; although qualitative risk assessment techniques identified by the various respondents differ, with each mentioning one or more of the following: engineering judgment, probability or decision tree, influence diagramming or probabilistic evaluation review techniques (PERT). Due to the qualitative nature of this process, it is not used solely to assign contingency; while 1 respondent did not know the percentages used, 3 of 5 respondents stated that contingency is applied to the project development phases as follows:

- Planning – 25%
- Programming/Schematic Design – 20%
- Final Design (PS&E) – 5%

## C.3.2 Caltrans Standard Risk Management Plan Format

District____EA_____

County_____Route:_____PM_____

**Purpose**

This document describes how Risk Management will be structured and performed on this project. The risk management plan includes methodology, roles and responsibilities, budgeting, timing, risk categories, definitions of risk probability and impact, probability and impact matrix, reporting formats, and tracking. The Caltrans Project Risk Management Handbook will be utilized as primary reference and guideline.

**Approved By:**

_____ _____

Project Manager Date

**Roles and Responsibilities**

Project Manager responsibilities include:

- Incorporate the resources and time required to execute the Risk Management Plan in the project budget and schedule
- Develop, distribute and implement this Risk Management Plan
- Develop and update the Risk Register with the support of the Project Team and incorporate it into the workplan
- Coordinate with the risk owners to monitor risks and implement risk response strategies

Project Manager Support or Risk Officer responsibilities include:

- Support the Project Manager in developing and updating the Risk Management Plan and the Risk Register
- Maintain updates to the Risk Management Plan and the Risk Register
- Maintain a list of risk and response strategies of all the projects in the district
- Update the Sample Risk List and the lessons learned database (http://pd.dot.ca.gov/pm/PMPI/LessonsLearned/index.asp).

Project Team responsibilities include:

- Identify the risk and describe it
- Assess the probability that a risk will occur and specify the criteria used to assess the probability
- Assess the impact of risks on project cost, time, scope, and quality objectives, and specify the criteria used to assess the impact
- Help identify the risk owners and assist in developing the risk response strategies (Project Team members may be assigned as “Risk Owner”)
- Perform the risk response steps assigned
- Assist the PM in activities associated with Risk Monitoring and Control

Risk Owner responsibilities include:

- Develop and/or update the assigned risk response strategy
- Monitor the risk assigned and inform PM of any threats or opportunities to the project. This includes monitoring the risk trigger and informing the PM, if the risk becomes a real event.

**Risk Register**

The Risk Register documents the identified risks, the assessment of their root causes, areas of the project affected (WBS elements), the analysis of their likelihood of occurring and impact if they occur and the criteria used to make those assessments and the overall risk rating of each identified risk by objective (e.g. cost, time, scope and quality).

Importantly, it includes the risk triggers, response strategies for high priority risks, and the assigned risk owner who will monitor the risk.

**Risk Identification Methods Used**

The risk breakdown structure (Section E.9) and Sample Risk List (Section E.8) is used as reference tools to help identify and categorize risks.

**Risk Analysis Methods Used**

**Qualitative Risk Analysis** attempts to rank the risks into high, medium and low risk categories based on their probability of occurring and impact on an objective. (The objective with the most impact, at a minimum).

This project will _____ will not _____ use qualitative risk analysis

This project will _____ will not _____ use District RM Web tool

**Quantitative Risk Analysis** attempts to estimate the risk that the project and its phases will finish within objectives taking into account all identified and quantified risks, estimates the contingency needed for cost and schedule and identifies the best decisions using decision tree analysis. (See *Project Risk Management Handbook* for additional information and when to use Quantitative Risk Analysis).

This project will _____ will not _____ use quantitative cost risk analysis

This project will _____ will not _____ use quantitative schedule risk analysis

This project will _____ will not _____ use decision tree analysis

This project will _____ will not _____ use other quantitative methods

_____

**Period of Risk Management Meetings and Full Review of Project Risk**

Meetings for the purpose of discussing and making decisions on Project risk will be held:

Weekly _____ Bi-Weekly _____ Monthly _____Other_____

The risk management identification, analysis and response planning process shall occur during project initiation document (PID). A full review and update of risk register will occur at the beginning of each subsequent phase of the project.

**Budget Allocated for Risk Management**

Staff allocated and assigned for risk management activities include:

| | | | |
|---|---|---|---|
| PMSU Chief | @ | _____ | Hrs |
| Risk Officer | @ | _____ | Hrs |
| PM | @ | _____ | Hrs |
| Environmental | @ | _____ | Hrs |
| Design | @ | _____ | Hrs |
| R/W | @ | _____ | Hrs |
| DES/Structure | @ | _____ | Hrs |
| Const. | @ | _____ | Hrs |
| Traffic Operations | @ | _____ | Hrs |
| Maintenance | @ | _____ | Hrs |
| | @ | _____ | Hrs |
| Total: | | _____ | Hrs |

___Hrs. × $ __ /Hr =

A total of $ is allocated for Risk Management on this project.

### C.3.3 Caltrans Sample Risk List

**Design Risks**

- Design incomplete
- Unexpected geotechnical or groundwater issues
- Inaccurate assumptions on technical issues in planning stage
- Surveys incomplete
- Changes to materials/geotechnical/foundation
- Bridge site data incomplete to DES
- Hazardous waste site analysis incomplete
- Unforeseen design exceptions required
- Consultant design not up to Department standards
- Unresolved constructability items
- Complex hydraulic features
- Unable to meet Americans with Disabilities Act requirements
- Project in a critical water shortage area and a water source agreement required
- Incomplete quantity estimates
- Unforeseen construction window and/or rainy season requirements
- New or revised design standard
- Construction staging more complex than anticipated

**External Risks**

- Landowners unwilling to sell
- Local communities pose objections
- Unreasonably high expectations from stakeholders
- Political factors or support for project changes
- Stakeholders request late changes
- New stakeholders emerge and request changes
- Threat of lawsuits
- Increase in material cost due to market forces
- Water quality regulations change
- New permits or additional information required
- Reviewing agency requires longer than expected review time
- Changes to storm-water requirements
- Permits or agency actions delayed or take longer than expected
- New information required for permits
- Environmental regulations change
- Controversy on environmental grounds expected
- Pressure to deliver project on an accelerated schedule
- Labor shortage or strike
- Construction or pile driving noise and vibration impacting adjacent businesses or residents

**Environmental Risks**

- Environmental analysis incomplete
- Availability of project data and mapping at the beginning of the environmental study is insufficient
- New information after Environmental Document is completed may require re-evaluation or a new document (i.e. utility relocation beyond document coverage)
- New alternatives required to avoid, mitigate or minimize impact
- Acquisition, creation or restoration of on or off-site mitigation
- Environmental clearance for staging or borrow sites required
- Historic site, endangered species, riparian areas, wetlands and/or public park present
- Design changes require additional Environmental analysis
- Unforeseen formal NEPA/404 consultation is required
- Unforeseen formal Section 7 consultation is required
- Unexpected Section 106 issues expected
- Unexpected Native American concerns
- Unforeseen Section 4(f) resources affected
- Project may encroach into the Coastal Zone
- Project may encroach onto a Scenic Highway
- Project may encroach to a Wild and Scenic River
- Unanticipated noise impacts
- Project causes an unanticipated barrier to wildlife
- Project may encroach into a floodplain or a regulatory floodway
- Project does not conform to the state implementation plan for air quality at the program and plan level
- Unanticipated cumulative impact issues

**Organizational Risks**

- Inexperienced staff assigned
- Losing critical staff at crucial point of the project
- Insufficient time to plan
- Unanticipated project manager workload
- Internal “red tape” causes delay getting approvals, decisions
- Functional units not available, overloaded
- Lack of understanding of complex internal funding procedures
- Priorities change on existing program
- Inconsistent cost, time, scope and quality objectives
- Overlapping of one or more project limits, scope of work or schedule
- Funding changes for fiscal year
- Lack of specialized staff (biology, anthropology, geotechnical, archeology, etc.)
- Capital funding unavailable for right of way or construction

**Project Management Risks**

- Project purpose and need is not well-defined
- Project scope definition is incomplete
- Project scope, schedule, objectives, cost, and deliverables are not clearly defined or understood
- No control over staff priorities
- Consultant or contractor delays
- Estimating and/or scheduling errors
- Unplanned work that must be accommodated
- Lack of coordination/communication
- Underestimated support resources or overly optimistic delivery schedule
- Scope creep
- Unresolved project conflicts not escalated in a timely manner
- Unanticipated escalation in right of way values or construction cost
- Delay in earlier project phases jeopardizes ability to meet programmed delivery commitment
- Added workload or time requirements because of new direction, policy, or statute
- Local agency support not attained
- Public awareness/campaign not planned
- Unforeseen agreements required
- Priorities change on existing program
- Inconsistent cost, time, scope, and quality objectives

**Right of Way Risks**

- Utility relocation requires more time than planned
- Unforeseen railroad involvement
- Resolving objections to Right of Way appraisal takes more time and/or money
- Right of Way datasheet incomplete or underestimated
- Need for “Permits to Enter” not considered in project schedule development
- Condemnation process takes longer than anticipated
- Acquisition of parcels controlled by a State or Federal Agency may take longer than anticipated
- Discovery of hazardous waste in the right of way phase
- Seasonal requirements during utility relocation
- Utility company workload, financial condition or timeline
- Expired temporary construction easements
- Inadequate pool of expert witnesses or qualified appraisers

**Construction Risks**

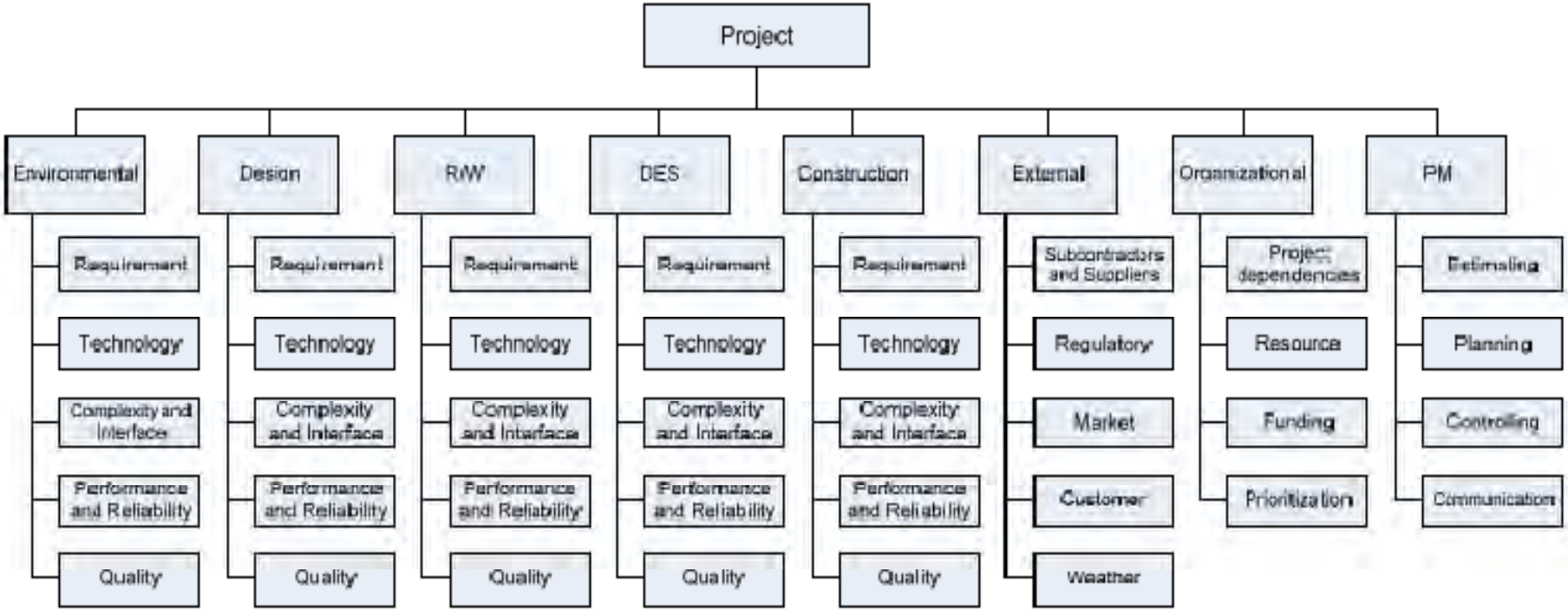
- Inaccurate contract time estimates
- Permit work window time is insufficient
- Change requests due to differing site conditions
- Temporary excavation and shoring system design is not adequate
- Falsework design is not adequate

- Unidentified utilities
- Buried man-made objects/unidentified hazardous waste
- Dewatering is required due to change in water table
- Temporary construction easements expire
- Electrical power lines not seen and in conflict with construction
- Street or ramp closures not coordinated with local community
- Insufficient or limited construction or staging areas
- Changes during construction require additional coordination with resource agencies
- Late discovery of aerially deposited lead
- Experimental or research features incorporated
- Unexpected paleontology findings
- Delay in demolition due to sensitive habitat requirements or other reasons
- Long lead time for utilities caused by design and manufacture of special components (steel towers or special pipe)

**Engineering Services Risks**

- Foundations utilizing Cast-In-Drilled-Hole or Cast-In-Steel-Shell pile 30” in diameter or greater may require tunneling and mining provisions within the contract documents and early notification of Cal-OSHA
- Bridges constructed at grade and then excavated underneath may require tunneling and mining provisions within the contract documents and early notification of Cal-OSHA
- Hazardous materials in existing structure or surrounding soil; lead paint, contaminated soil, asbestos pipe, asbestos bearings and shims
- Piles driven into fish habitat may require special noise attenuation to protect marine species
- Special railroad requirements are necessary including an extensive geotechnical report for temporary shoring system adjacent to tracks
- Access to adjacent properties is necessary to resolve constructability requirements
- Existing structures planned for modification not evaluated for seismic retrofit, scour potential and structural capacity
- Foundation and geotechnical tasks (foundation drilling and material testing) not identified and included in project workplan
- Bridge is a habitat to bats or other species requiring mitigation or seasonal construction
- Condition of the bridge deck unknown
- For projects involving bridge removal, bridge carries traffic during staging
- Verify that all seasonal constraints and permitting requirements are identified and incorporated in the project schedule
- Complex structures hydraulic design requiring investigation and planning
- Assumptions upon which the Advance Planning Study is based on are realistic and verification of these assumptions prior to completion of the Project Report
- Design changes to alignment, profile, typical cross section, stage construction between Advance Planning Study and the Bridge Site Submittal
- Unexpected environmental constraints that impact bridge construction

### C.3.4 Caltrans Sample Risk Breakdown Structure



# Appendix D: Bay Bridge Case Study

## *Caltrans San Francisco Oakland Bay Bridge (SFOBB) Project*

## *D.1 Introduction*

The main objective of the NCHRP 8-60 project was to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs. Task 4 of the research involved preparing a series of case studies that demonstrated the effective application of risk-analysis tools and management practices in controlling project costs during the planning, priority programming, and preconstruction phases of transportation projects. Case Study number 2 examined the San Francisco Oakland Bay Bridge (SFOBB) Project which is being executed by Caltrans. This project was mentioned briefly in the Case Study number 1 – Caltrans General Approach to Risk Management. The project is part of the Toll Bridge Seismic Retrofit Program (TBSRP). The SFOBB was chosen as a case study owing to its uniqueness, large size, complexity, and the comprehensive risk management plan mandated by the state legislature.

### D.1.1 The Toll Bridge Seismic Retrofit Program (TBSRP)

The TBSRP is a bridge rehabilitation program to strengthen or replace seven California State-owned bridges so that they can more effectively withstand high winds, earthquakes, and rough waters. The estimated baseline budget for this program is approximately $7.7 billion with an additional $900 million provided for contingency. Due to the large size of the program and the magnitude of risks involved, an assembly bill (AB 144) was signed into law by the California State Governor Schwarzenegger on July 18, 2005 authorizing Caltrans to develop and implement a comprehensive risk management plan for the TBSRP to augment the existing process. Of the seven bridges in the program, the SFOBB is the largest investment and accounts for over $5.5 billion of the allotted program funds. The bill created the Toll Bridge Program Oversight Committee (TBPOC) to perform oversight and project control functions for the TBSRP. This committee consists of the Caltrans Director, the Bay Area Toll Authority (BATA) Executive Director, and the California Transportation Commission (CTC) Executive Director.

### D.1.2 The San Francisco Oakland Bay Bridge Project (SFOBB)

The SFOBB, Figure D-1, is a bridge replacement over the San Francisco Bay between San Francisco and Oakland. Due to the complexity of the design and construction, a majority of the risks are foreseen (known risks) and have to be adequately provided for in order to control project cost growth. The bridge is currently under construction and is expected to be completed by 2013. Caltrans is currently utilizing a more comprehensive risk management program on this project in accordance with the state assembly bill AB 144. For the purpose of Task 4, more details about the risk management plan were required to be able to fully understand the process and effectively compare it with the Caltrans general approach discussed in Case Study number 1. Methods adopted to gather additional information involved Tasks 1, 2, and 3 results and interviews with the SFOBB project and risk management personnel.

### D.1.3 Research Methods

Information gathered from Task 1, 2 and 3 was used as a basis for comparison between Caltrans general risk management approach and that used on the SFOBB project. Interviews were conducted by Dr. Stuart Anderson and Dr. Keith Molenaar with Jon Tapping, the Risk

Management Coordinator on the San Francisco - Oakland Bay Bridge Project, Caltrans; Parviz Lashai, Senior Transportation Engineering, Caltrans; and Rein Lemberg, Project Risk Management, CALTROP Corporation. They provided information more specifically related to the risk management on the SFOBB project. The interviews were conducted to gain a better understanding of risk management on the SFOBB project and obtain first hand information about the challenges with a project of this size and complexity. Documentation received includes the TBSRP Risk Management Plan, a power point presentation explaining Project Risk Management for SFOBB, Volumes 1 and 2 of the 2nd Quarter 2007 Risk Management Report, and a *User's Guide to Risk Management Information System*.

**Figure D-1. Artist Rendition of the Self Anchored Suspension Superstructure (SFOBB Project)**

## *D.2 Risk Management Approach to SFOBB*

The TBSRP risk management plan was created by Caltrans as mandated by the AB 144 to serve several purposes. The plan clearly identifies roles and responsibilities for risk management on the TBSRP. The plan addresses the processes by which risk management is performed and how the effects of identified risks are quantified in financial and time terms. The plan describes the method of implementation of the risk management plan and lists the scheduled activities for review, updating, reporting and monitoring.

### D.2.1 The Process

The enhanced risk management program for the SFOBB project is a six-stage process as shown in Figure D-2 and is similar to the general approach as described in the Caltrans *Risk Management Handbook*. For this project, the state legislature through bill AB 144, mandated that thorough quantitative risk analysis be implemented to numerically quantify and more

effectively monitor the project risks. Since the project is under construction, new risks would evolve and previously identified risks would need to be monitored and risk registers updated regularly. For these reasons, the processes involved are repeated frequently through the life cycle of the project and not necessarily in the order in which they are stated. The six stages in the process are:

1. Risk management planning
2. Risk identification
3. Qualitative risk analysis
4. Quantitative risk analysis
5. Risk response planning
6. Risk monitoring and control

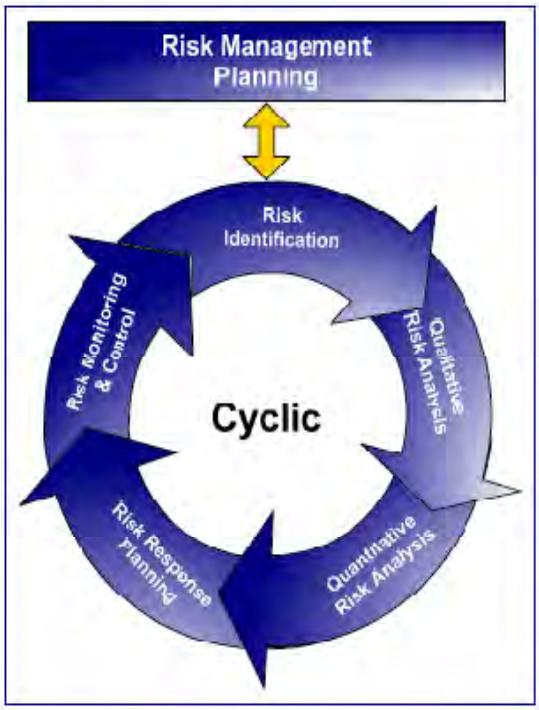



**Figure D-2. The Enhanced Risk Management Process**
*Source: TBSRP 3rd Quarter report 2005*

## D.2.2 Roles and Responsibilities

The Risk Response Team is central to the risk management process; the team comprises Caltrans Project Management Support personnel, Construction department staff and Functional Support personnel. Their responsibilities include performing, updating and reviewing risk management activities. The Project Manager participates in the team's activities when necessary. The Risk Manager and staff apart from performing the day-to-day risk management tasks, also document the activities of the risk response team (see Figure D-3).

The responsibilities of the Project Risk Response Team (RRT) are core to the risk management process and information herein must constantly be shared with Bay Area Toll Authority (BATA) and California Transportation Commission (CTC) representatives who operate in an oversight capacity. These representatives are given the opportunity to attend the meetings of the Risk Response Team and air their views and concerns. This openness helps ensure transparency in the team's activities.

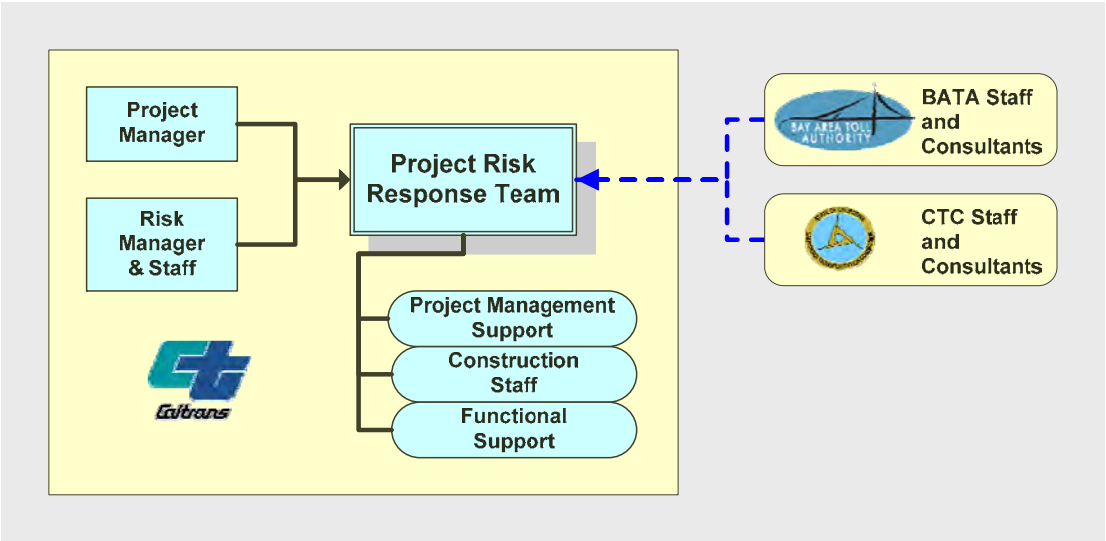



**Figure D-3: Risk Management Organization**

The roles and responsibilities of the various parties during the risk management process are highlighted in Table D-1.

**Table D-1: Risk Management Process Roles and Responsibilities**

| Risk Management Process | Program Manager | Project Manager & Risk Manager | Risk Manager | Risk Response Team |
|---|---|---|---|---|
| Risk Management Planning | Approve | Recommend approval | Responsible | Support |
| Risk Identification | | | Support | Responsible |
| Qualitative Risk Analysis | | | Support | Responsible |
| Quantitative Risk Analysis | | | Responsible | Support |
| Risk Response Planning | | | Support | Responsible |
| Risk Monitoring and Control | | | Responsible | Support |

**Risk management planning** is the process of determining the approach to risk management activities for the project to ensure that the methods used are suitable considering the risks involved and the project magnitude in terms of cost and economic importance. It is here that the basis for evaluating risks is determined. Risk identification processes, management roles and responsibilities, implementation procedures and frequencies of updates and reviews are determined at this stage.

**Risk identification** identifies project risks using the sample risk list and includes project specific additions. A tool called Risk Management Information System (RMIS) serves as a database of risks (risk register) for the project. During the project, the revised assessment of the risk register remains a baseline against which effective response actions can be measured by the risk response team. Periodically, new risks are identified, analyzed and added to the web based risk register, RMIS, as depicted in Figure D-4. Costs related to Notices of Potential Claims (NOPC) and

Contract Change Orders (CCO) are categorized as part of the risk management cost category. They are, therefore, identified along with project risks. NOPCs and CCOs are described as:

> *Notice of Potential Claims (NOPC)*: This is a request for additional monetary compensation by the contractor due to disputes between parties arising under and by virtue of the contract; NOPC must be prepared in accordance with Section 9-1.04, "Notice of Potential Claim," of the Standard Specifications.
>
> *Contract Change Order (CCO)*: When Caltrans determines that a change should be made to the contract scope, the additional work is included using a contract change order. If the proposed changes are outside the required work as contemplated at the time of plans and specifications approval, they would be included by a separate unit basis contract during the progress of the work.

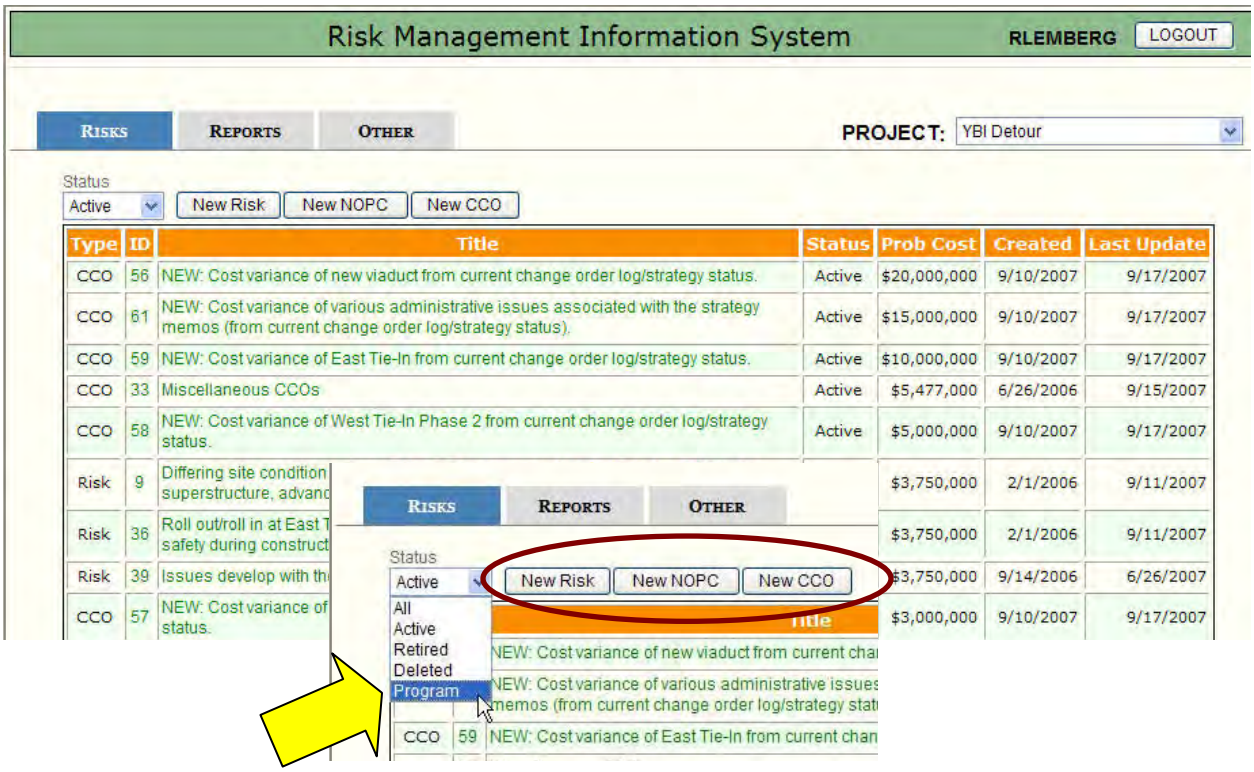



**Figure D-4: Risk Management Information System**

**Qualitative risk analysis** is the process that categorizes risks based on probability of occurrence using a matrix (see Table D-2) with rank 5 for the risk with the highest probability of occurrence (60-99%) and rank 1 for the risk with the lowest probability of occurrence (1-9%).

**Table F-2: Risk Probability Ranking**

| Risk Probability Ranking | |
|---|---|
| **Ranking** | **Probability of Risk Event** |
| 5 | 60–99% |
| 4 | 40–59% |
| 3 | 20–39% |
| 2 | 10–19% |
| 1 | 1–9% |

Each risk is assessed based on its impact (cost, schedule and scope) on the project objectives if such a risk occurs. The Project Sponsor defines the levels of impact on cost, schedule and quality that would be considered as very high, high, moderate, low, or very low impact on project objectives. The project risk lead and the team then assess and categorize the risks based on these definitions (see Table D-3).

**Table D-3: Definition of Impact and Probability Levels**

| | Very Low | Low | Moderate | High | Very High |
|---|---|---|---|---|---|
| **Cost Impact** | Insignificant cost increase | <5% cost increase | 5-10% cost increase | 10-20% cost increase | >20% cost increase |
| **Schedule Impact** | Insignificant slippage | <5% project slippage | 5-10 % project slippage | 10-20% project slippage | >20% project slippage |
| **Scope Impact** | Change is barely noticeable | Minor areas are affected | Change requires TBPOC approval | Change not acceptable to TBPOC | Material termination of project |
| **Probability** | 1–19% | 20–39% | 40–59% | 60–79% | 80–99% |

*Source: Caltrans Project Risk Management Handbook*

Greater emphasis is placed on high risk items by the organization and as such increasing non-linear weights are often assigned to the impact levels from very low to very high impact in support of major project objectives. Different objectives could have different (linear/non-linear) scoring systems applied to them (Table D-4). A probability and impact (PxI) matrix is prepared by combining output from Tables D-2 and D-3 with the impact score determined using Table D-4 to decide whether an activity is high risk, moderate risk or low risk.

**Table D-4: Impact Scoring on Project Objectives**

| Impact Scoring | | |
|---|---|---|
| | Degree of Focus on Risks with High and Very High Impacts | |
| | Significant (Non-linear) | Moderate (Linear) |
| Very High | 16 | 5 |
| High | 8 | 4 |
| Moderate | 4 | 3 |
| Low | 2 | 2 |
| Very Low | 1 | 1 |

For any particular impact, a combination of the probability level of the risk occurring and the impact level (using linear/non-linear impact scoring in Figure D-5), positions the risk in one of three colored zones in the PxI matrix; red, which signifies high importance, yellow, which signifies medium importance and green, which is of low importance (see Figure D-6).

| Option 1: PxI Matrix for Significant Focus on High and Very High Impacts (Non-linear Impact Scoring) | | | | | |
|---|---|---|---|---|---|
| Probability | Threats | | | | |
| 5 | 5 | 10 | 20 | 40 | 80 |
| 4 | 4 | 8 | 16 | 32 | 64 |
| 3 | 3 | 6 | 12 | 24 | 48 |
| 2 | 2 | 4 | 8 | 16 | 32 |
| 1 | 1 | 2 | 4 | 8 | 16 |
| | 1 | 2 | 4 | 8 | 16 |
| | Impact on Selected Objective | | | | |

| Option 2: PxI Matrix for Moderate Focus on High and Very High Impacts (Linear Impact Scoring) | | | | | |
|---|---|---|---|---|---|
| Probability | Threats | | | | |
| 5 | 5 | 10 | 15 | 20 | 25 |
| 4 | 4 | 8 | 12 | 16 | 20 |
| 3 | 3 | 6 | 9 | 12 | 15 |
| 2 | 2 | 4 | 6 | 8 | 10 |
| 1 | 1 | 2 | 3 | 4 | 5 |
| | 1 | 2 | 3 | 4 | 5 |
| | Impact on Selected Objective | | | | |

**Figure D-5: Linear and Non-linear Impact Scoring**

| Probability Level | | | | | | |
|---|---|---|---|---|---|---|
| | Very High | | | | | |
| | High | | | | | |
| | Moderate | | | X | | |
| | Low | | | | | |
| | Very Low | | | | | |
| | | Very Low | Low | Moderate | High | Very High |
| | | Impact Level | | | | |

**Figure D-6: PxI Matrix**

This stage of the risk management process generates a prioritized list of risks and a detailed understanding of their impacts upon the success of the project if they occur. This helps

determine where the greatest effort should be focused. The resulting prioritization of risks based on cost and schedule impact on project objectives and the probabilities of occurrence are recorded in the risk register- RMIS database as shown in Figure D-7.

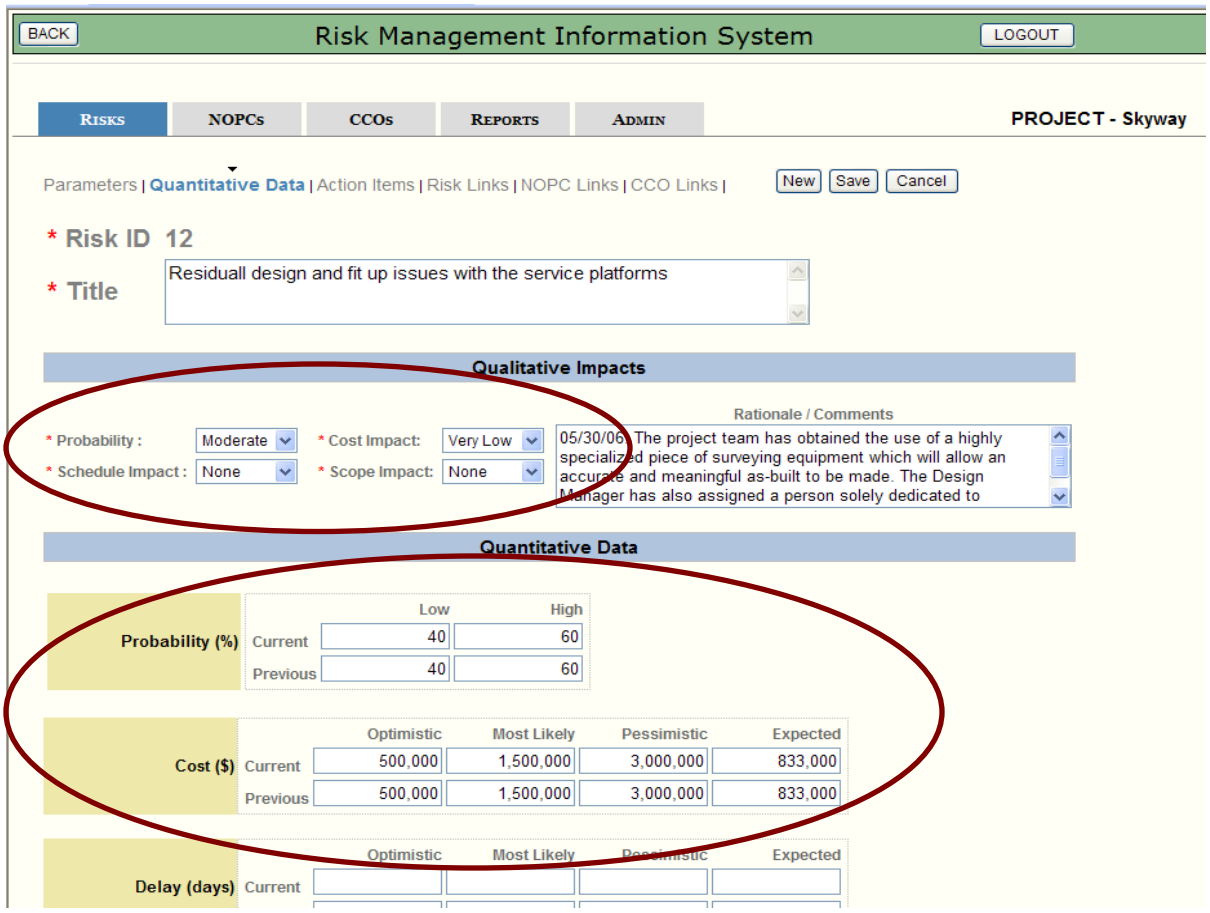



**Figure D-7: RMIS Captures Risk Analysis Data**

**Quantitative risk analysis** is the process of estimating the probability that a project would meet its cost and time objectives. High risk items are evaluated using Monte Carlo simulation techniques to derive the probability of over-running or under-running cost or schedule (shown in Figure D-8) using 3 point estimates (Optimistic, Most likely and Pessimistic) of the project cost or schedule. A similar quantitative analysis is also used to capture the probability of over-running the risk management cost (RMC), which is defined by Caltrans as the total cost of all project risks, notices of potential claim, outstanding disputes, and potential future contract change orders. It is a range of probable costs shown using a probability distribution - a 20 percent probability of overrun would suggest that there is need to increase the contingency. Schedule and Budget analysis is an ongoing process during project construction, to check that cost and schedule targets are not being exceeded. If the chances to budget or schedule are found to be high at any given instance, high priority risks which could cause such increases in cost or delays in schedule must be checked. RMIS can be used at any time to view the quantitative data, cost and probability, for the current quarter and compare with values for the previous quarter (as shown in Figure D-7).

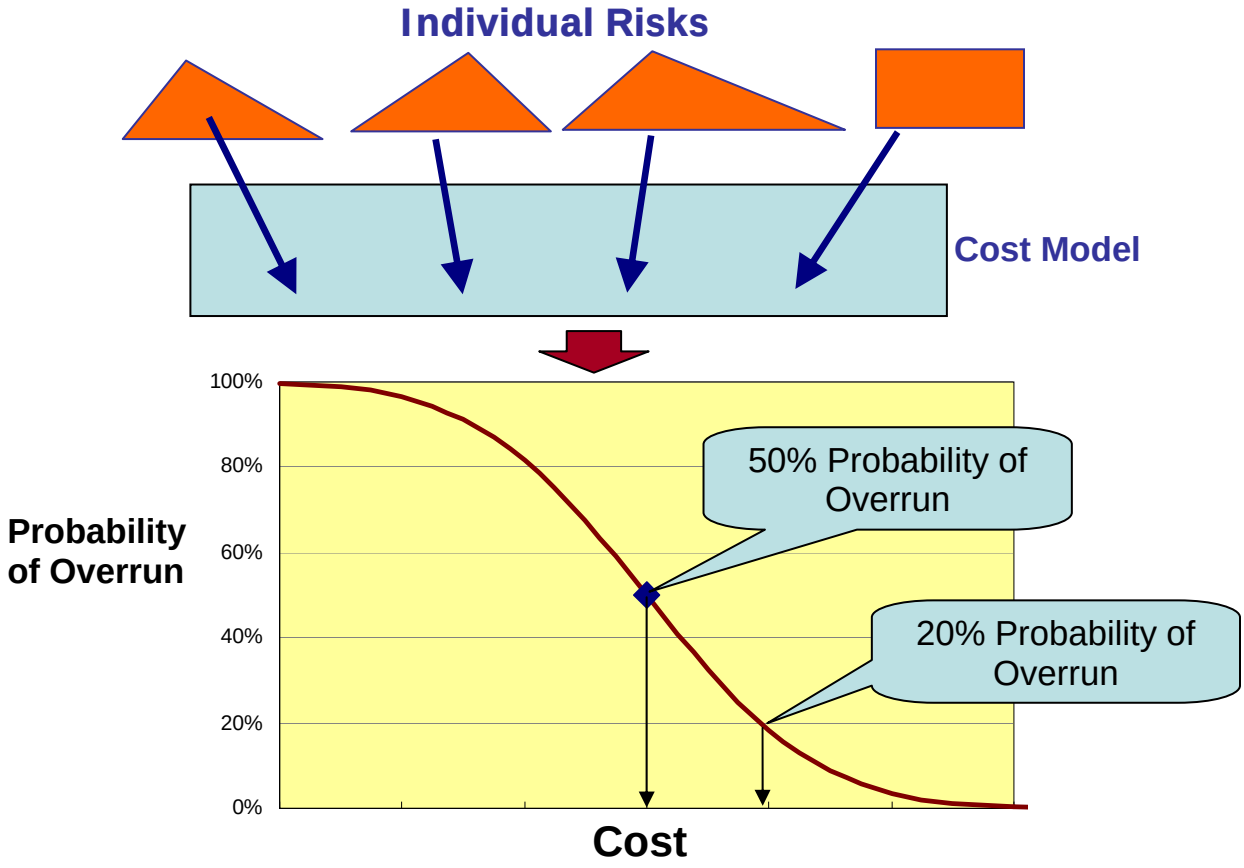



**Figure D-8: Probability of Overrunning Project Cost**

**Risk response planning** focuses on determining alternative response actions for the key perceived project risks and seeks to adequately mitigate the threats. Responsibility is assigned to risk owners for each risk response. Typical response strategies for negative risks include avoidance – by altering scope, schedule, or resources to protect the objectives, transfer – by shifting the impact to a third party, that is, the contractor, or mitigation – by taking early measures to reduce the threat, impact, or probability of occurrence of the risk. In the event that a risk can neither be prevented nor avoided, the risk response team must accept the risk and make recovery plans to be used in the event that the risk occurs.

**Risk monitoring and control** by each assigned a risk owner seeks to ensure that causal factors do not cause the impact of the risk to escalate. In the event that an unforeseen risk surface, previously planned responses are reviewed for adequacy and further response planning is carried out if found to be insufficient.

***Some Program Highlights***
Risks are separated into cost and schedule risks
Risk Management Cost = Risk cost + NOPC + CCO
Risk register is a web based database system
Risk reporting is a systematic process

The stages of the process described above are not necessarily carried out in the described order during the life of the project. However, there is still a sense of order which must be maintained when all or some of the activities are performed. When some of the main activities are required, one or more of the stages of the process have to be performed concurrently or subsequently as shown in Table D-5.

**Table F-5: Risk Management Processes in Each Activity**

| Main Activity | Contains Risk Management Processes |
|---|---|
| Monitoring & Control | Risk Monitoring and Control |
| Initial Risk Identification and Assessment | Risk Identification<br>Qualitative Risk Analysis<br>Quantitative Risk Analysis<br>Risk Response Planning |
| Risk Review and Updating | Risk Identification<br>Qualitative Risk Analysis<br>Quantitative Risk Analysis<br>Risk Response Planning |
| Risk Response Actions | Risk Response Planning (actions) |
| Risk Analysis | Quantitative Risk Analysis |

## D.2.3 Tools

Some of the tools used in the risk management process include:

<u>Risk Management Information System (RMIS)</u>
RMIS is a web-based interactive data management system that tracks risks and risk related information at the various stages of the process. It serves as a database of all the project risks and is used especially during risk identification and documentation of risks. It is also used to generate standard reports such as the top 20 risks by cost, top 20 risks by delay, top five risks by project, qualitative analysis and quantitative analysis; and custom reports such as new or retired risk entities.

<u>Pertmaster</u>
Pertmaster is a software tool that allows the tracking of project costs and schedule; it is used to manage contingency and set more realistic project expectations using bar charts and precedence diagrams; a key feature is its Monte Carlo simulation method. Pertmaster is used by Caltrans for the schedule risk analysis; it helps to quantify risks that impact project duration and determines the likelihood of overrunning the schedule.

<u>@ Risk</u>
This 'Monte Carlo' based software is a simulation tool used to generate 3 point estimates for the project cost, schedule and risk cost, to determine the probability of meeting cost and completion targets and checking the adequacy of contingency allowance at various stages of the project.

<u>Influence Diagrams</u>
The influence diagram is used to graphically show the interdependencies among contracts on the SFOBB project.

## D.2.4 Reporting

The Risk Response teams are responsible for the preparation of project risk management reports encompassing all the risk management activities carried out through a specified period. These reports are then submitted to the Risk Manager who along with the project manager reviews the submission and recommends approval by the program manager. The Program Manager approves and informs the Toll Bridge Program Oversight Committee. The Risk Manager provides copies of the approved submissions to Caltrans Senior Management as delineated in Figure D-9.

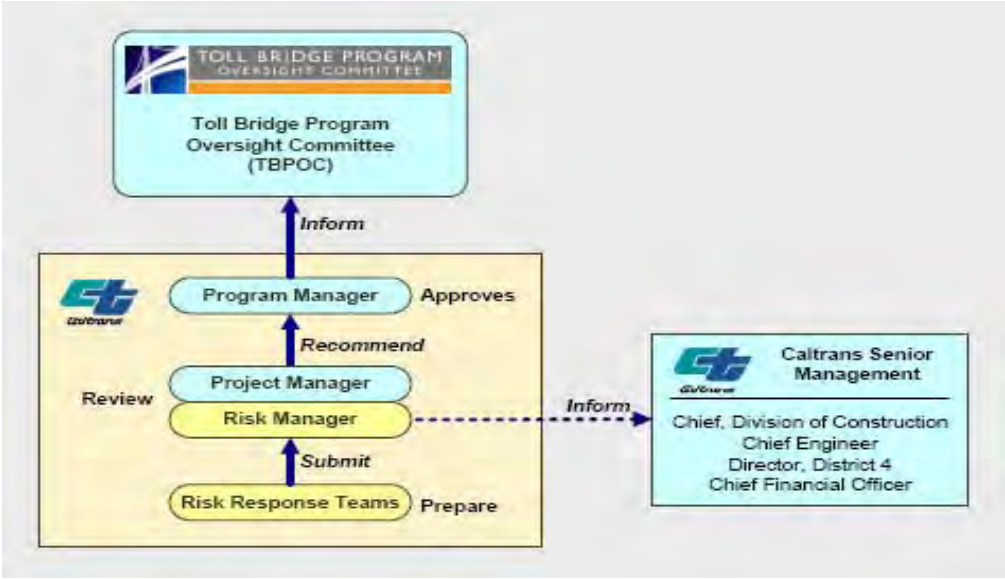



**Figure D-9: Reporting Sequence for the TBSRP**

**Illustrations from the 2nd Quarter 2007 Report**

<u>Schedule Risks</u>
Risks are included in the program as 'special activities'; showing the overall effect that such risks have on the schedule. This report shows which activities are on the critical path and prioritizes the risks for alternative response actions. The result of this effort is the TOP 15 CORRIDOR SCHEDULE RISKS (see Figure D-10) for the project as covered in the 2nd Quarter

2007. Topmost on the list is the 'tower lift 1 fabrication' and lowest is the "conflicts over welding deck 1E-6E erection." These 15 risks were determined from the schedule risk analysis process to be high priority due to their ability to significantly delay the project schedule if they occur. They have owners assigned to them and must be constantly monitored and controlled throughout the project. In most cases, there are interactions between activities of several contracts and such risks must be managed and balanced without affecting the overall schedule duration or budget. For example, their top identified schedule risk, 'the tower lift 1 fabrication' has the highest likelihood of increasing the project duration. To effectively check this possibility, Caltrans has a project team in China that deals with all fabrication issues to ensure that they do not significantly affect the project schedule.

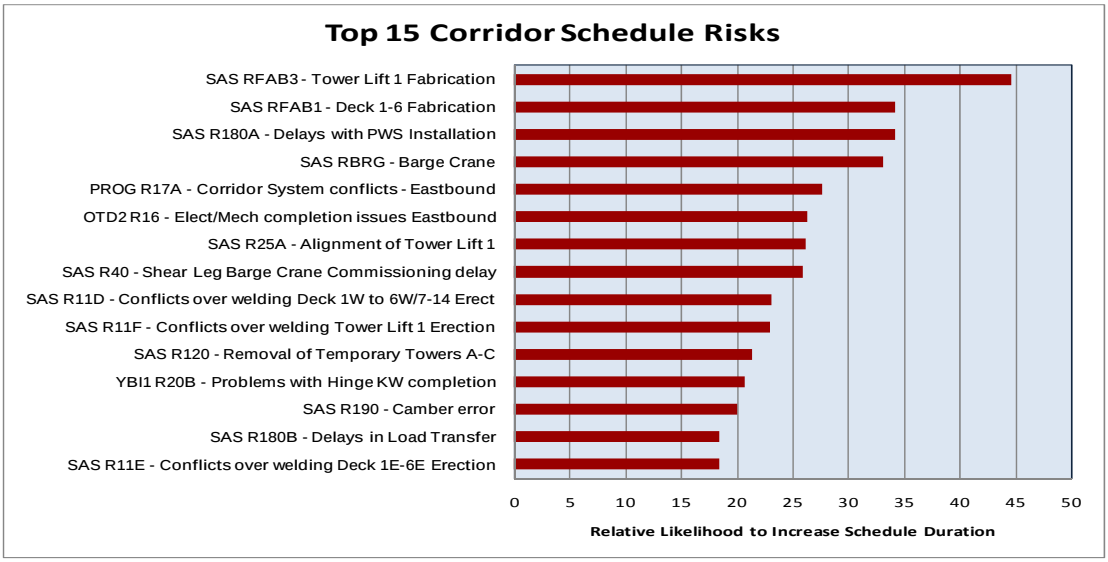



**Figure D-10: Top 15 Schedule Risks**

For illustrative purposes, Figure D-11 shows the result of a Pertmaster analysis on the project schedule. It shows an 80 percent probability of completing the project before 21st December 2014 and a 50 percent probability of completing the project before 9th October 2014.

<u>Budget Analysis during Construction</u>

As an example in the skyway contract, the bid items, CCO, State Furnished Materials (SFM) and Supplemental Work (SW) were taken out of the contract budget. NOPC was excluded, possibly since there were none on that contract. The amount left was the remaining contingency for that contract as of that date. Thus, Contract Contingency is determined as follows:

*Contract Contingency = Approved Contract budget – (Bid items + SFM + SW + CCO)*

SFM refers to quantities and costs of State Furnished Materials to be included in the Contract quantities. Supplemental work (SW) is work of an uncertain nature or amount and therefore it is not performed on a contract item basis.

The probability curve shown (see Figure D-12) indicates a 20 percent chance of overrunning the budget for that contract. Where the remaining contract contingency is significantly less than the needed contingency, the budget for that contract may have to be revised. Draw downs on contingency are constantly monitored during each phase of construction and should fall within the expected ranges allocated to adequately mitigate the contract risks.

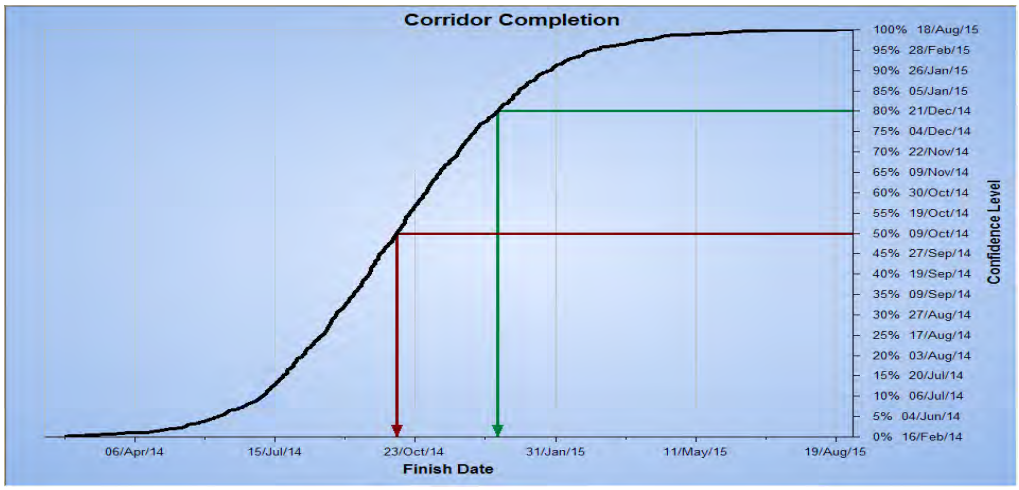



**Figure D-11: Probability of under running Schedule**

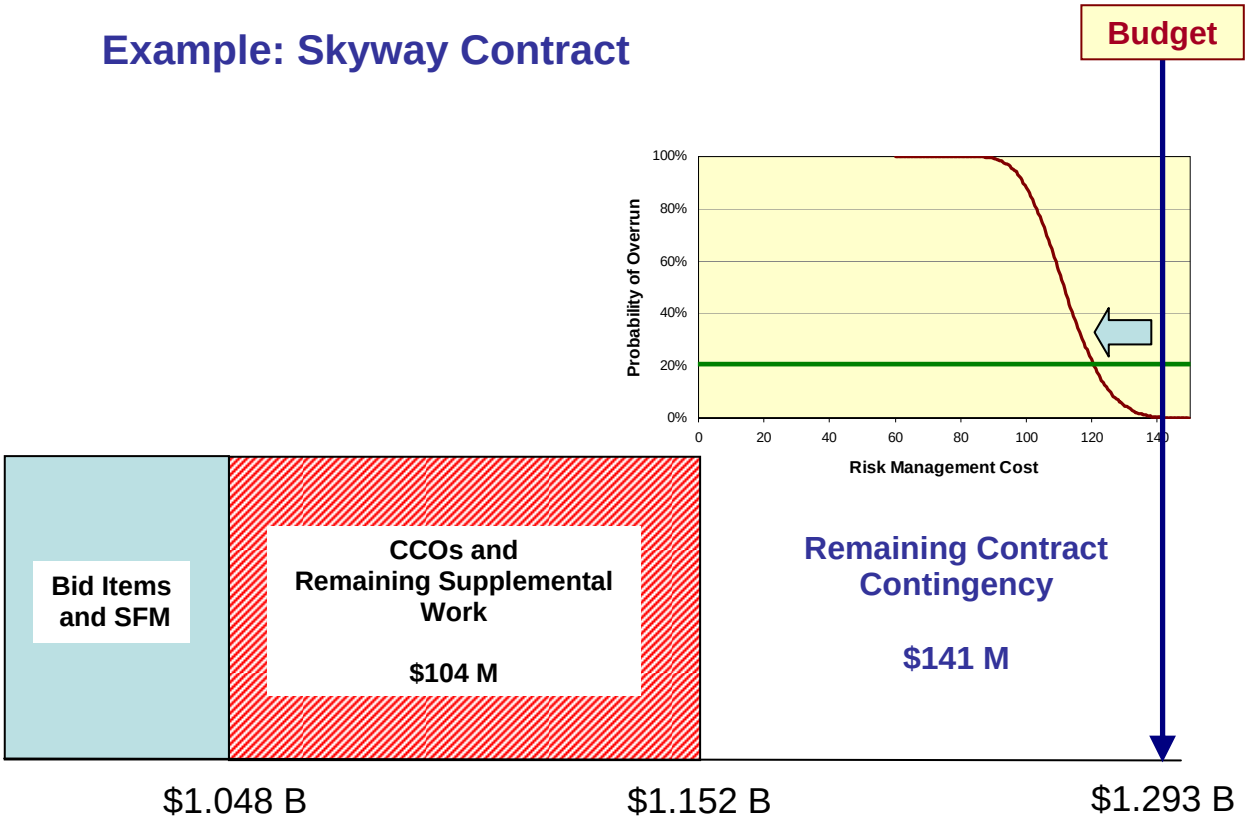



**Figure D-12: Contract Contingency (Skyway)**

**Capital Outlay Risks**

The result of the cost risk analysis is the Top 15 Capital Outlay Risks. These risks are shown graphically (Figure D-13) with Table D-6 showing their current rankings as covered in the 2nd quarter 2007 report compared with corresponding ranks in the previous quarter.

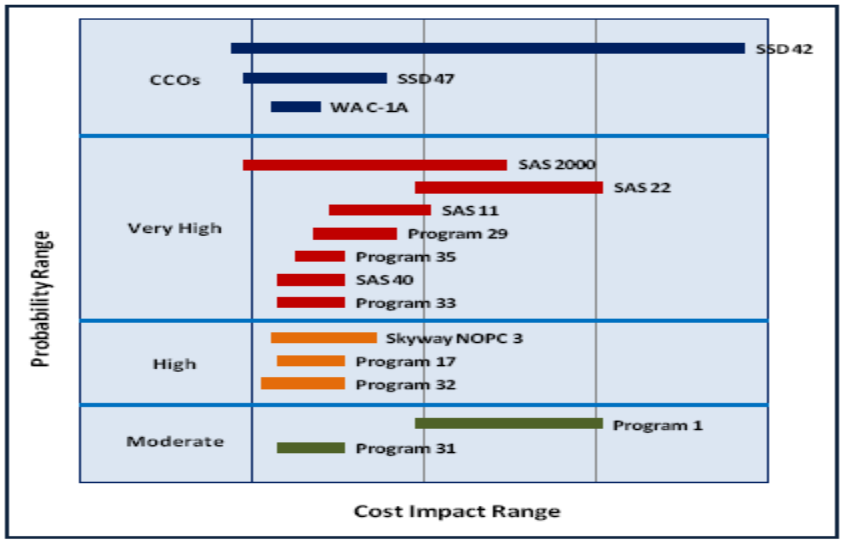



**Figure D-13: Top 15 Capital Outlay Risks**

**Table D-6: Top 15 Capital Outlay Risks**

| Rank | | Contract | Type | ID | Title |
|---|---|---|---|---|---|
| Q2 | Q1 | | | | |
| 1 | 1 | SSD | CCO | 42 | Cost uncertainties in the elements of work outlined in the Anziano/Land strategy memorandum. |
| 2 | 3 | SAS | Risk | 22 | Steel plate conflicts or other constructibility issues during construction. |
| 3 | | Program | Risk | 1 | Cross-impact of delays among contracts |
| 4 | 4 | SAS | Risk | 11 | Conflicts or differing opinions over welding |
| 5 | 5 | SAS | Risk | 2000 | Schedule delay during construction |
| 6 | | Program | Risk | 29 | Tugboat prevailing wage differential decision |
| 7 | | Program | Risk | 35 | Additional cost to incorporate light pipe into the bridge |
| 8 | | SAS | Risk | 40 | Overseas fabrication causes a delay or increased cost to the project. |
| 9 | 14 | Program | Risk | 33 | Additional cost to incorporate BASE system into new bridge. |
| 10 | 6 | SKY | NOPC | 3 | Tub Girder Production NOPCs #14-25, #27-#29 |
| 11 | 2 | SSD | CCO | 47 | Cost to incorporate Advanced YBI Work per Anziano/Land strategy memorandum |
| 12 | 8 | WA | CCO | C-1A | Extra costs (TRO & TRO+) due to project delays. |
| 13 | | Program | Risk | 17 | Cost of MEP Systems increases due to scope changes and problems during systems testing |
| 14 | | Program | Risk | 32 | Extend design liability insurance for the East Span project |
| 15 | | Program | Risk | 31 | Additions or changes beyond the scope contemplated by AB144. |

The cost-risk analysis results, as shown in Figure D-14, provides the partial TBPOC approved budget versus costs at 80 percent, 50 percent, and 20 percent probabilities of greater costs and the probability of exceeding the approved budget.

| Contract | AB144 Budget ($M) | TBPOC Q1 Approved Budget ($M) (Start of Q2) | Cost ($M) at 80%, 50% and 20% Probability of Greater Cost | | | Probability of Exceeding Approved Budget |
|---|---|---|---|---|---|---|
| | | | 80% | 50% | 20% | |
| Skyway | 1,293.0 | 1,293.0 | 1,241 | 1,245 | 1,250 | 0% |
| E2/T1 Foundations | 313.5 | 313.5 | 282 | 282 | 283 | 0% |
| YBI South/South Detour | 131.9 | 334.4 | 385 | 415 | 444 | 99% |
| SAS Superstructure | 1,753.7 | 1,753.7 | 1,724 | 1,747 | 1,770 | 40% |

**Figure D-14: Partial Cost Risk Analysis Results**

Program risks include the cost of risks that are outside the scope of the project and not provided for in the budget (e.g. light pipe, base systems); they are included in the capital outlay. It is assumed that these costs will be paid from the program contingency. They will be included in the risk register as potential scope changes and removed if they are found to be unnecessary.

"Capital outlay support cost includes support cost risks that affect all contracts and risks from contracts that have an impact on capital outlay support." They may include risk of high consultant costs on specific contracts, schedule delays from complexity of work and increase in overseas travel expenses for state personnel during fabrication operations. The corridor total cost is the addition of capital outlay, program risks and capital outlay support.

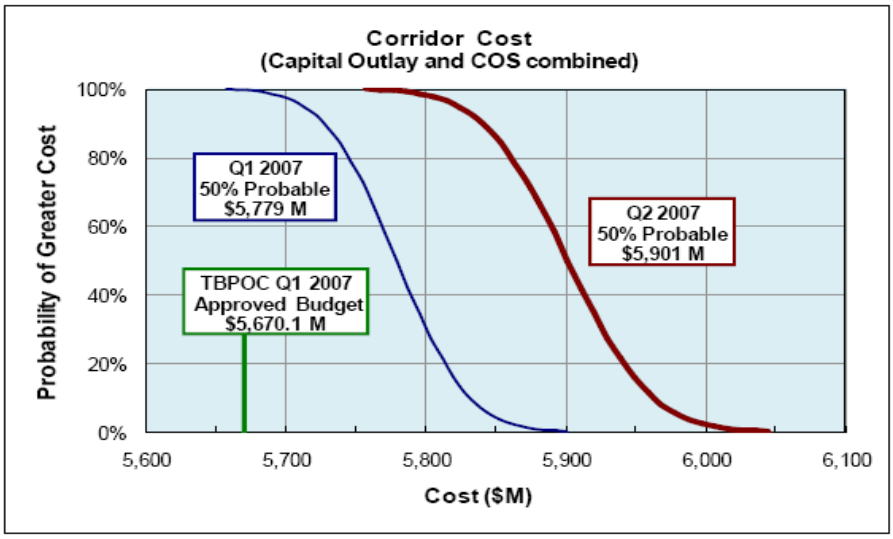



**Figure D-15: Corridor Total Cost**

From Figure F-15, the Quarter 2, 2007 cost (ranging between $5,800 million and $6,050 million) has increased over the Quarter 1, 2007 cost due to changes in scope of one construction contract (YBI detour) and increased risks on another contract (Self Anchored Suspension Bridge). The

Q2, 2007 50 percent probable cost of $5,901 million also exceeded the then current budget of $5,670.1 million by $231 million. This excess of $231 million represents the potential draw on the program contingency at the current date (illustrated in Figure D-16).

Program Contingency

Caltrans regularly checks the adequacy of program reserve (contingency) in accordance with the requirements of the bill AB144. For the said quarter shown in Figure D-16, at a 50 percent probability level, the draw on contingency is $231million out of a total TBPOC approved budget program contingency of $809.8 million.

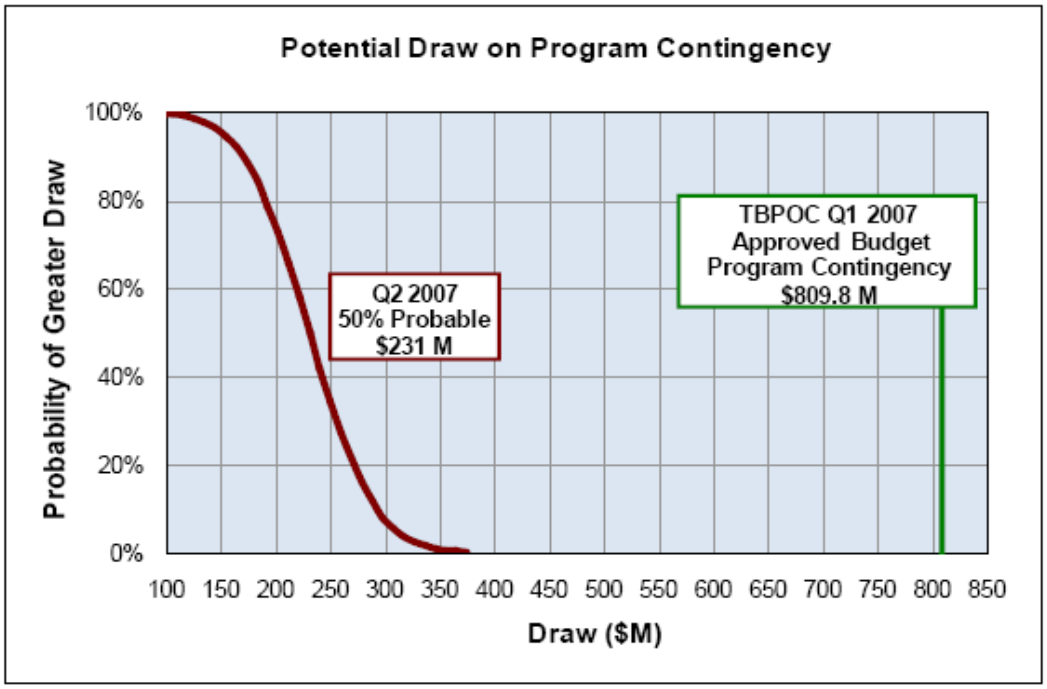



**Figure D-16: Potential draw on Contingency**

The SFOBB quarterly report further summarizes the results of the quantitative analysis for each of the corridor program contracts and the capital outlay support. The report shows a 3-point cost range such as low/most likely/high, the probability of occurrence-low/high, and a 50 percent probable risk management cost for all the various contracts within the project.

All the above results are used by the risk response teams and risk monitoring team to evaluate the process and assess the effectiveness of methods utilized. Management relies on key information provided by this process to make vital project based decisions that could include modifying project scope, schedule, cost and contingency provisions.

## *D.3 Conclusions*

The major driver for this level of risk management on the SFOBB project is the state assembly bill AB 144 which mandates a formalized project specific risk management plan due to the

complexity and size of the project. The risk management approach adopted is an enhancement of the general Caltrans *Project Risk Management Handbook* approach. The main differences between the general approach discussed in Case Study 1 and this case study approach are:

- The risk register for the SFOBB is web based using the Risk Management Information System.
- Extensive quantitative analysis is carried out on all project risks to derive reliable numerical estimates of impacts on major project objectives, cost and schedule.
- Project risks are split into cost and schedule risks and assessed accordingly to determine the likelihoods of overrunning the budget or the schedule.
- The risk management cost is the total cost of risks, notices of potential claims and contract change orders.
- The influence of the Toll Bridge Program Oversight Committee ensures greater overall commitment of all involved in the risk management process.

These differences in several ways improve the accuracy of budget or time estimates derived. The use of technology especially enhances the risk tracking, updating, monitoring and reporting processes.

# Appendix E: WSDOT Case Study

## *Washington State Department of Transportation Approach to Risk Management*

## *E.1 Introduction*

This case study of the risk management process of the Washington State Department of Transportation (WSDOT) is part of the Task 4 of this study. Task 2 of the project involved interviews with organizations to obtain information about their risk management and related practices, and the tools they used while Task 3 covered a review and documentation of the risk process procedures. WSDOT was identified as one of the organizations whose risk management approach was to be further investigated as part of Task 4.

The Washington State Department of Transportation addresses risk issues in its project cost estimation process by conducting risk workshops. This workshop approach to risk management was first implemented in 2002 as the "Cost Estimate Validation Process" (CEVP). The CEVP workshop is a collaborative effort where project teams, engineers, risk managers, and subject matter experts from private firms come together with WSDOT engineers to scrutinize transportation projects and relevant project information that would help in evaluating the cost and schedule estimates. They brainstorm and contribute to the effort of identifying and assessing the risks on a project. The first series of CEVP workshops were conducted on 12 mega projects in 2003.

CEVP was scaled down in 2003 to a less intense version known as the "Cost Risk Assessment" (CRA) with procedures similar to the CEVP. According to 'the WSDOT Policy for Cost Risk Assessment' the CEVP was designed for use on larger projects with values exceeding $100 million, while the CRA was designed for use on smaller projects with values between $25 million and $100 million. As of 2006, by which time over 70 risk assessment workshops had been conducted, WSDOT began to explore the development of risk databases and portfolio risk modeling tools to further enhance the CEVP process. This report focuses on describing the CEVP and CRA process. The discussion covers the methods of risk management currently in use by WSDOT.

### E.1.1 Research Methods

This case study details the risk management approach currently adopted by WSDOT. It was compiled by combining information gathered from the WSDOT website (www.wsdot.wa.gov) and from interviews conducted by the project team. Documents obtained for this purpose included:

- "The WSDOT Guidelines for CRA-CEVP Workshops" (January 11, 2008)
- "The Development of CEVP – WSDOT's Cost-Risk Estimating Process" by John Reilly et al (February 2004)
- "WSDOT policy for cost risk assessment" (August 2005)
- "WSDOT Cost Estimate Validation Process (CEVP) 2006 Update"
- "Cost Risk and Estimating Management" by Mark Gabel

These documents were used to better understand the CRA process. Members of the NCHRP 8-60 project research team conducted interviews with a team of personnel at the WSDOT office in Olympia, Washington on the subject of risk assessment as implemented on their various projects.

This meeting served a dual purpose of clarifying the use of the WSDOT Cost Risk Assessment process and providing updates on enhancements proposed for the current process.

The risk application to WSDOT projects is illustrated using extracts from a CRA report on the "I-5 Grand Mound to Maytown widening Project" for which construction began in Spring 2008 and is expected to end in summer 2010. The project CRA report was provided by a member of the NCHRP 8-60 research team who was involved with risk related activities on that project at the earlier stages while working with WSDOT.

Information received at the interview and the project case study will be described in more detail further on in this report.

### E.1.2 Factors Considered when Establishing the CRA

The development of the CRA process incorporated the following considerations and established them as guiding principles:

Expressed estimates as a likely range of possible values: The organization needed to adopt a method of expressing estimates as a likely range of possible values NOT as a single number because at the early stages of project development it is often difficult or almost impossible to accurately express an estimate as a single number. This is simply due to the fact that there are still very many unknown factors or unquantifiable known factors that might affect the outcome of the project. As such all these factors need to be treated as uncertainties in the estimates and expressed accordingly as illustrated in Figure G-1. For example, instead of reporting to the public that a project would cost $450 million, the information would be that the final cost of the project would be between $425 and $475 million, or there would be a 20 percent chance of completing the project at a cost below $430million or an 80 percent chance of finishing under $475 million.

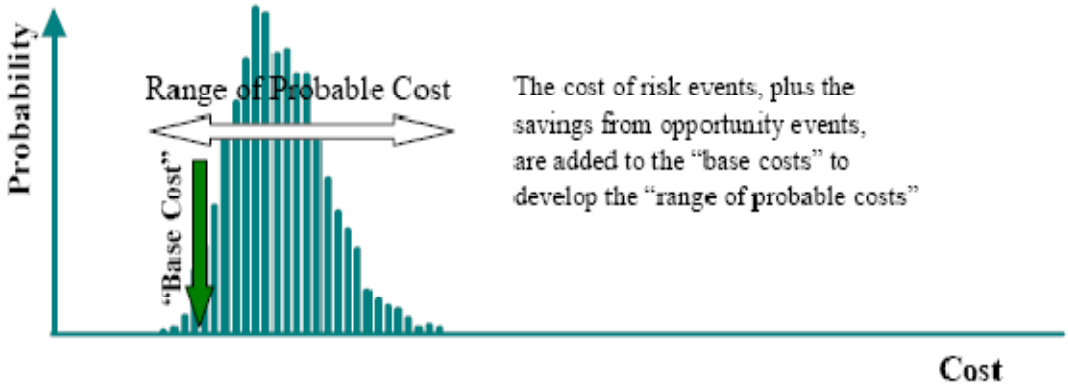



**Figure E-1: Range of Probable Costs**

Collaborative assessment: Collaborative assessment of projects is necessitated to be able to incorporate a diversity of opinions and expertise in the estimate review and risk assessment for better accuracy. Naturally there might be a tendency for participants directly involved in the project (Owners/Managers) to be biased in their decision making and be in favor of project

success. To overcome this, professionals and subject matter experts from private firms are involved to discuss with peers, WSDOT engineers, and others involved in the project, this brings varied experience from other projects to the table in addressing WSDOT cost estimation issues.

Cost and Schedule Uncertainty: It was very important to recognize the fact that both cost and schedule are contributing factors to the outcome of project estimates. The CEVP/CRA methodology, therefore, integrates both into the estimating process using schedule based analytical methods.

Risk description and Quantification: When assessing the uncertainty in a project, the identification of risks and subsequent quantification has to be guided by practicality and the use of common sense in making judgments. The level of experience of participants plays an important role in this identification.

Ease of understanding of Project results by the public: There is the need to communicate project results by means which can be easily understood and interpretable by the public, hence cost estimates are to be expressed as ranges to account for the uncertainty in the estimate, and probabilities are used to show the likelihood of meeting these estimates.

## *E.2 The WSDOT Risk Management Approach*

### E.2.1 Introduction

The WSDOT found that in the past the problem of inadequate cost estimates haunted most of the high profile infrastructure projects in the state. Risks and opportunities were not thoroughly considered when preparing estimates and a lack of objective validation of the estimates made them, most of the time, inaccurate and far below the final cost of the project. The Cost Estimate Validation Process (CEVP) and the Cost Risk Assessment (CRA) were therefore established in 2002/2003 to solve these issues related to uncertainty and risk in project cost estimation for larger projects. A Risk Management Plan is established early in the project development process to determine the approach to risk activities on that project. Hence the following steps to WSDOT risk management:

- The Risk Management Plan
- The Cost Estimate Validation Process (CEVP) / Cost Risk Assessment (CRA)

The risk management plan is a part of the project management plan; it is a standardized way of planning the risk management effort on a project. According to the WSDOT Online Project Management Guide “it is the systematic process of deciding how to approach, plan, and execute risk management activities throughout the life of a project. It is intended to maximize the beneficial outcome of the opportunities and minimize or eliminate the consequences of adverse risk events”. The primary functions of this risk management plan are shown in Figure E-2:

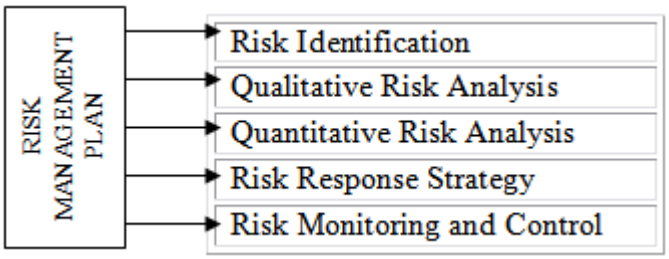



**Figure E-2: Functions of the Risk Management Plan**

The risk management plan is used to determine the level of risk assessment on any project. The project team reviews the project details in terms of size, location, requirements, type of work, risks involved and their consequences. Cost Risk Assessment policies are also reviewed to determine the appropriate level of detailed risk analysis to be performed. Risk factors to be considered, the risk tolerance levels to be used, and risk reporting and visibility requirements are determined by organization's management. The Risk Management Plan Template (Figure E-3) is used for projects that are determined not to require a CRA.

Risk Identification is the process of identifying risks that have the potential to affect the outcome of the project. Risks are documented in the risk register (Section E.8) for reference purposes, easy tracking and monitoring throughout the project. Risks are determined, depending on the size of the project, either by the project team or by the participants during CRA workshops.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Project Title** | | | | | | | |
| | **Project PIN #** | | | | | | | |
| | **Date** | | | | | | | |
| | **Project Mngr** | | Name | **Telephone Number** | (xxx) xxx-xxxx | | | |
| | | | | | | | | **PROJECT RISK M** |
| | | | | **Risk Identification** | | | | |
| **Priority** | **Status** | **ID #** | **Date Identified Project Phase** | **Risk Event** (threat/opportunity) | **SMART Column** | **Risk Trigger** | **Impact Area** | **Affected MDL/WBS Level 2 process** |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Instructions | **Active**=actively monitored & controlled **Dormant**=risk is not currently a high priority, but may become active in the future. **Retired**=no longer a threat to project objectives. | E1 | For example: 6/30/99 Scoping | Risk is an uncertain event or condition that, if it occurs, has a positive (opportunity) or negative (threat) on a project. For example; Wetland Mitigation requires additional R/W. | Detailed description of the risk. Includes information on the risk that is **Specific, Measureable, Attributable, Relevant** and **Timebound**. Describe the consequences of the risk to scope, schedule, budget or quality. | Triggers are indications that a risk has occurred or is about to occur. Used to determine when to implement the Risk Response Strategy. For example: Wetland impact is greater than 1/2 acre. | Is the primary impact to the scope, schedule, or budget? | Which WBS element will be modified as part of the response strategy? For example: PC-19 Environmental Permits |
| | | | | | | | | WBS 165 Perform Environmental Studies and Prepare Draft Environmental Document (DED) |

**PROJECT RISK MANAGEMENT PLAN**

| | | Qualitative Analysis | | | | Risk-Response Strategy | | Monitoring and Control | |
|---|---|---|---|---|---|---|---|---|---|
| **Impact Area** | **Affected MDL/WBS Level 2 process** | **Probability** | **Impact** | **Risk Matrix** | **Risk Owner** | **Strategy** | **ACTION TO BE TAKEN** (include advantages and disadvantages) | **Status Interval or Milestone Check** | **Date, Status and Review Comments** |
| (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| Is the primary impact to the scope, schedule, or budget? | Which WBS element will be modified as part of the response strategy? For example: PC-19 Environmental Permits | Assessment of the likelihood of occurrence. Valid entries are Low or High. | The severity of the risk's effect on the projects objectives. Valid entries are Low or High. | **High**: Substantial impact on cost, schedule, or technical. Substantial action required to alleviate issue. **Low**: Minimal impact on cost, schedule, or technical. Normal management oversight is sufficient. | Name of the person or office responsible for managing the risk event. | **A**voidance **T**ransferance **M**itigation **A**cceptance (See PM Online Guide for strategy definitions.) | Develop options and determine actions to be taken in response to the risk event. Immediate action may be required at the time of identification. Estimate value of risk and estimate cost to respond. | For example: Completion of wetland delineation expected: 2/28/00 | For example: Last status update 4/30/00. Wetland delineation completed 3/15/00. Over 1 acre of wetland was delineated, action is being taken to expedite meetings with regulatory agencies & expedite the effort to provide appropriate wetland mitigation & attain project permits. |
| | WBS 165 Perform Environmental Studies and Prepare Draft Environmental Document (DED) | | | Probability H L L H Impact | | | | | |

**Figure E-3: Risk Management Plan Template**

Qualitative Risk Analysis is the process of assessing the likelihood of occurrence (Low/High) of each identified risk and its impact (Low/High) on project objectives if it does occur. These project objectives relate to the cost, schedule and scope of the project. This is done primarily by the project team or in consultation with subject matter experts from WSDOT or private firms. A Risk matrix (Figure E-4) is formed for each risk placing the risk in one of four categories:

- Low Probability of occurrence/Low Impact on project objectives (cost, schedule, scope)
- Low Probability of occurrence/High Impact on project objectives (cost, schedule, scope)
- High Probability of occurrence/Low Impact on project objectives (cost, schedule, scope)
- High Probability of occurrence/High Impact on project objectives (cost, schedule, scope)

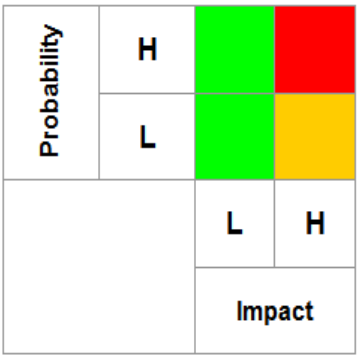



**Figure** E-4**: Risk Matrix**

The risks with high probabilities of occurrence and high impact on project objectives are in the red zone and considered most critical because if such a risk occurs it would either have a considerable impact on the project cost and schedule or require a substantial effort for the project team to rectify the issue. These risks need to be constantly monitored to prevent escalation of any factors that could lead to their occurrence. On the other hand, the ones with low probabilities of occurrence and low impact on project objectives are in the green zone and are

less of a threat to the success of the project. Even if these risks do occur, the impact may not be significant in terms of cost or schedule. Nevertheless, all risks are monitored regardless of classification. This classification is determined by the project team for smaller projects, or in conjunction with the experts for other projects during the CRA workshops.

Quantitative Risk Analysis is a process used to numerically estimate the probability of a project meeting its defined objectives; the probabilities of completing the project before a given date or below a given cost. This numerical estimation is only carried on projects whose values exceed $25 million or projects with preliminary estimates above $5 million that meet certain criteria as listed out in the WSDOT Policy for Cost Risk Assessment. The criteria are as follows:

- Projects that are unique or unusual
- Projects with a high degree of political interest
- Projects that have been through an abbreviated scoping process
- Projects with alternative solutions that vary the scope and cost
- New alignment or bypass sections
- Capacity improvements that widen an existing highway
- Major structures
- Interchanges on multilane facilities
- Projects with extensive or expensive environmental or geotechnical requirements
- Materials that are difficult to acquire or require special efforts
- Major reconstruction or difficult construction
- Projects requiring major traffic control
- Projects with multiple stages
- Major right-of-way and/or utility issues

The quantitative assessment of risks is performed only on projects that require a CRA and would be discusses further in Section III, which describes the workshop process.

Risk Response Planning: The project team plans possible response actions to reduce risk threats or actions to enhance identified opportunities on a project. Team members are identified and assigned responsibility for each risk response strategy. The response strategies could be:

1. Avoidance – the scope, duration or cost is/are altered or other resources varied to shield the project from its impact.
2. Transference – the consequence of a risk is transferred to a third party. That third party is made fully responsible for the impact of that risk on project objectives.
3. Mitigation – early action is taken to reduce the probability of a risk occurring or to reduce the impact on project objectives, if it does occur.
4. Acceptance – when a suitable response action cannot be identified nor the project plan changed, the project team may have to accept the possibility of the risk occurring and either provide a contingency to accommodate for the impact, or just accept the fact that if it occurs they will have to address it.

Risk Monitoring and Control is the ongoing process of tracking or retiring previously identified risks, monitoring residual risks and identifying new risks as they emerge within the life of a project.

### E.2.2 Cost Risk Assessment

CRA is the broad term used by WSDOT to describe the risk process whether the CEVP for larger projects (> $100 million) or the CRA for smaller ones (> $25 million). The primary aim of the CRA is to define the probable cost and schedule required to project completion. This process provides a probabilistic-based evaluation of the estimates. The workshop provides an analysis of the project cost and schedule estimates; information which can be used by the project team to improve the success rate on a project. The workshop is conducted anytime between the planning and PS&E phases of project development (Section E.9). A CRA begins with an examination of the initial cost estimate of the project to give a rough idea of the total cost, evaluate the quality, and check for consistency in the estimates. Results of this process are expressed using probability distributions as illustrated in Figure E-1.

Typically, participants at the CRA workshops include members of the project team, Subject Matter Experts (SME) and members of the cost risk team. The Table E-1 highlights their major roles and responsibilities.

**Table E-1. Typical Workshop Participants**

| **Project Team Members** | **Role & Responsibility** |
|---|---|
| *Project Manager | Project resource and decision maker. |
| *Estimator | Prepare and document project estimate. |
| *Scheduler | Prepare and document project schedule. |
| *Lead Designer | Primary resource for design questions. |
| Key Technical Experts | Specialty groups as needed. |
| **Subject Matter Experts (SME)** | **Role & Responsibility** |
| SMEs | SMEs provide external review and validation of the project cost and schedule estimates. Provide objective review and comment regarding project issues, risks and uncertainty. At the end of the workshop the SMEs should provide a brief (i.e. one page summary of their thoughts about the workshop). |
| **Cost-Risk Team Members** | **Role & Responsibility** |
| *Risk Lead | Leads risk elicitation and manages meeting during risk elicitation. |
| Risk Lead Assistant | Assists with risk elicitation and meeting management during risk elicitation. |
| *Cost Lead | Leads Base Cost Review and validation; manages meeting during cost review. |
| Cost Lead Assistant | Assist cost lead as appropriate. |
| CREM Workshop Coordinator | Coordinates agenda and participants, works with project manager to insure well-being of the workshop. |

Pre-Workshop Activities include the following:

- Prep Sessions: These are usually held a couple of weeks prior to the workshop and are attended by the risk and cost leads along with the project team. The Consultants are selected by the Cost Risk Estimating Management (CREM) Office (recently changed to the Strategic Analysis and Estimating Office). From the interviews carried out with WSDOT personnel in March 2008, it appears that there are usually about six participants at these prep sessions, significantly less than at the main workshop. This is performed to save time at the workshop. Those in attendance are charged with the responsibilities of developing the project schedule in the form of a project flow chart and an initial list of risks that might impact the project cost or schedule. This risk list would serve as a convenient starting point for further risk identification at the workshop. Points of concern are identified where major input would be required from the subject matter experts.

- Estimate and Schedule Reviews: The draft cost estimate, flow chart and schedule should be reviewed by the cost lead, the SMEs, and other disciplines involved before the workshop (i.e. between the prep session and the workshop) for any corrections and/or recommendations.

- Advanced Risk Elicitation Interviews: Risk elicitation interviews are often conducted with specific individuals or small groups in advance of the workshops to identify risks in their particular area of expertise. Some of the elicitation sub-groups used by WSDOT include Right of Way (ROW), Utilities and Railroad; Environmental, Cultural resources and Stormwater; Structures and Geotech; and Design. Identified risks are included in the risk register.

The Workshop flow chart in Figure E-5 shows the Pre workshop, Workshop and Post Workshop Activities.

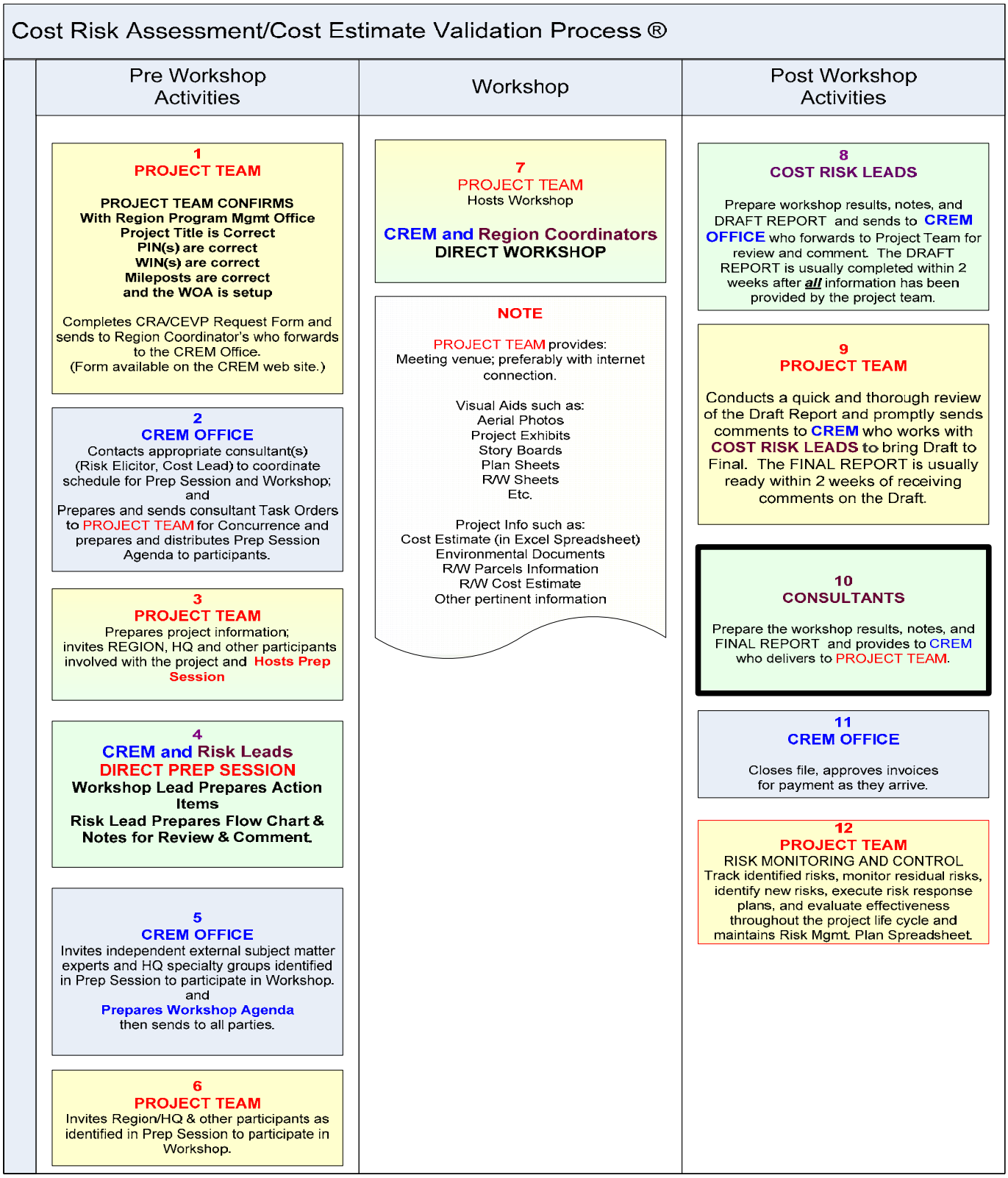



**Figure E-5: Workshop Activities**

### E.2.3 Workshop

According to the WSDOT guidelines for CRA-CEVP workshops (2008), there are seven steps involved in these workshops. A workshop is conducted in two phases; the first 3 steps taken together make up the first phase (Cost Validation Workshop) and the next 4 steps make up the second phase (Risk Elicitation Workshop).

*The Cost Validation Workshop*

During this phase, the Base Cost, which is the most likely cost of the project excluding contingency is determined by the project team and the CEVP/CRA team. This workshop is described in steps 1 to 3 below.

1. Project and Method Selection

   Once a project has been identified as requiring a CRA based upon the guidelines laid out in the Policy for CRA, the scale of effort required for the workshop must be determined by the project team based on the complexity of the project, the knowledge of the project and the planned use of the workshop results.

2. Structuring the Project Team Effort

   The project team prepares detailed expected project plans and other documents that describe the scope, limits and target dates for the project or makes use of documents provided from the prep session. Initial cost estimates are then reviewed by the CRA/CEVP team to be able to determine the basis and assumptions for the preparation of that cost estimate and for the CRA/CEVP evaluation. The project team and the CRA/CEVP team review the estimates to ensure that items such as right of way, seasonal constraints, permitting, cuts and fills, mobilization and de-mobilization, storage, and archaeological issues have been taken into consideration in the cost estimate. The project schedule is also reviewed to ensure that time allotted to each of the above mentioned activities is reasonable. The information provided in the plan is used by the CRA/CEVP team to develop flow charts (Figure E-6) showing the sequence of major activities to be performed on the project and highlighting important milestones and base costs at various stages of the project.

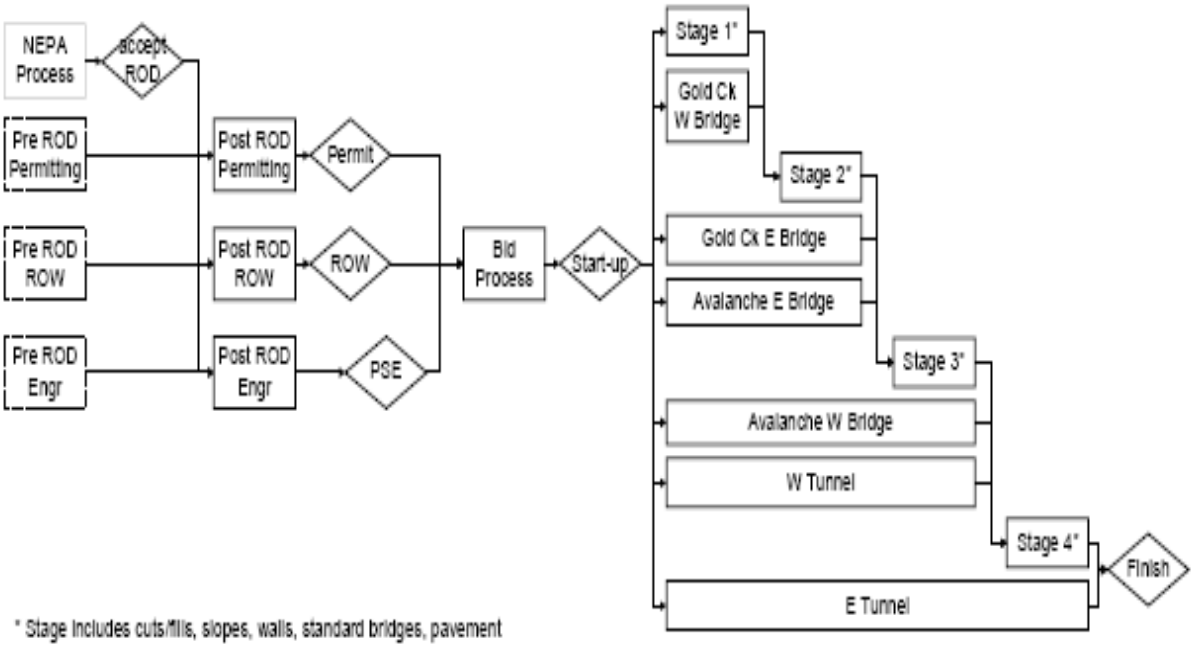



**Figure E-6: Sample Project flow chart**

3. Define and Evaluate the Base Cost Estimate and Schedule

   The project team's initial estimate is separated into two components; a base component representing the basic cost estimate of the project without any contingencies and a second component comprising other costs representing the project uncertainties either in the form of risks or opportunities.

   The base cost estimate is thoroughly scrutinized by subject matter experts to determine its precision and discard any previously added contingency which would later be replaced by the individual assessments and quantification of the uncertainties in the project.

   The evaluation using the CEVP could involve a comprehensive assessment of all the initial cost items, while for a CRA it could be a review of the base components to verify the accuracy of the major cost items that make up the base cost estimate for the project. Unit prices and production rates for each of the cost items are examined to check their accuracy and see if there are any other risks not taken into account that could affect those prices. Items not accounted for in the estimate as revieled by the review are noted for inclusion so that necessary adjustments can be made to the estimate. The contingency previously added by the project team to items in the estimate or the entire cost estimate is removed to be replaced later by the probable risk cost. This estimate stripped of contingency becomes the agreed project base cost.

*The Risk Elicitation Workshop*

The Risk Elicitation Workshops are conducted to determine the risks or opportunities that affect the project cost, schedule or scope; determine their likelihood of occurrence cost impact and schedule impact. The potential cost of such risks and opportunities is determined and added to the base cost developed during the cost validation workshop.

1. Assess Uncertainty and Risk

   Risks are identified by brainstorming using a prior list of potential risks developed at the pre-sessions. They are further characterized as either risk events or opportunities. A risk event is a possible occurrence on a project that could adversely affect the outcome of the project, while an opportunity tends to be beneficial in some way to the project. This identification of risks and opportunities is performed by SMEs and members of the CEVP team during the CRA workshop. Risk elicitation can also be achieved through the advanced elicitation interviews conducted prior to the workshop, by administering questionnaires prior to the workshop, by teleconferencing or by elicitation at the workshop. All possible risks that could affect the project are captured and included in the risk register. They are assessed according to their likelihood of occurrence, impact to major project objectives, cost, schedule and scope if they occur, and relationship with other events. The basis for this assessment is determined by collective opinions of those present at the workshop (project team, professionals, and independent subject matter experts). Risks are also classified as technical risks such as structural or environmental issues, non-technical such as right of way or regulatory concerns, political such as funding or legal issues. The risks identified at the workshop are evaluated individually. The risk elicitor leads the group to come to a consensus about the range of consequences of a perceived risk. The cost/schedule impacts determined are noted in the risk register. They should be defined as independent where possible; otherwise dependencies among events must be clearly defined. When risks have multiple occurrences in major project activities, such activities must be noted and the correlations among the occurrences must be determined.

2. Quantify uncertainty in the Project Cost and Schedule

   Probabilistic models are developed to quantify the uncertainty in the cost and schedule to project completion. Analysis is typically performed using Monte Carlo simulation techniques to generate a range of possible values for cost or schedule estimates. The individual probabilities are obtained after an iterative process of calculating multiple scenarios by taking samples randomly from a range of possible values for the project cost. The results of the simulation are expressed as a probability distribution showing the likelihood of completing a project at/below certain cost or on/ahead of certain target dates. Figure E-7 shows a sample cost range from a CEVP workshop on a WSDOT project. The bars in the histogram represent the individual probabilities of completing the project at those costs; the 3$^{rd}$ bar for example represents approximately a 23 percent

probability of completing the project around $475 million. The curve, however, shows the cumulative probabilities of completing the project below or above certain cost. The range shown includes a 10 percent chance of completion below $475 million, a 50 percent chance of completion below $525 million and a 90 percent chance of completion below $590 million.

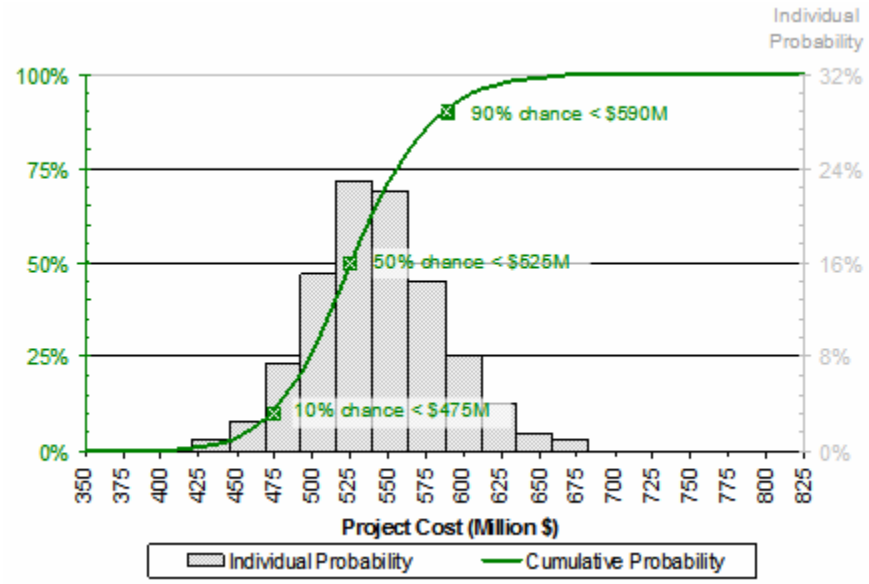



**Figure E-7: Cost Range**

3. Probabilistic Analysis and Documentation

The results of the CRA are expressed using probability distributions showing graphically (Figures E-8 and E-9) the likelihood of meeting or exceeding given cost and schedule projections (i.e. the degree of uncertainty in meeting cost or schedule targets). These distributions provide information including:

- Probabilities using current dollar (at the time of assessment)
- Probabilities using future dollar (at the year of expenditure)
- Expected completion dates for the projects and likelihood of meeting milestones
- Comparative design options
- Various funding alternatives (full or part funding)

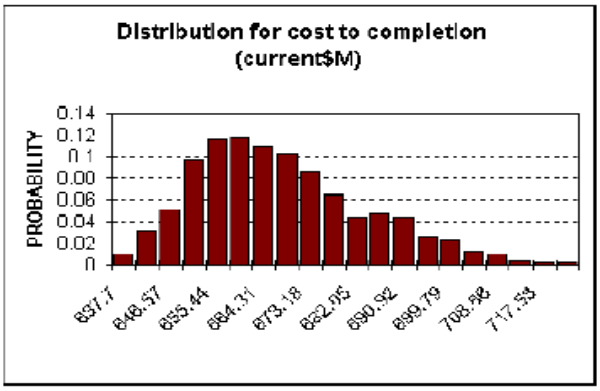



**Figure E-8: Probabilities using current dollar (at the time of assessment)**

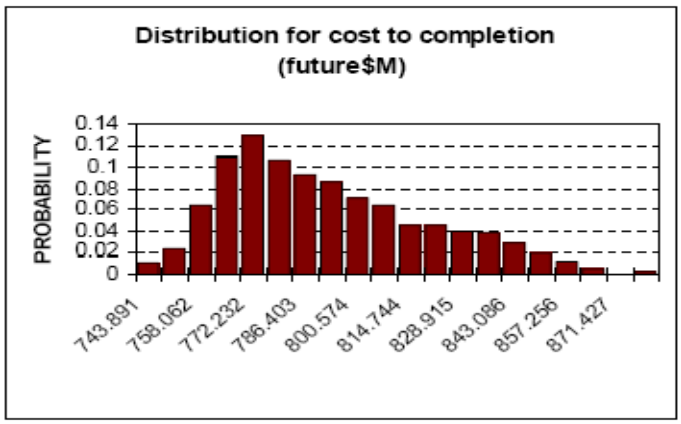



**Figure E-9: Probabilities using future dollar (at the year of expenditure)**

Results obtained from the CRA workshops are documented and can be interpreted in various ways depending on its use at that time. According to the 'WSDOT Policy for CRA' these primary results of the assessment can be used for the following:

- Project Assessment and Management: Due to the high level of involvement of professionals and subject matter experts in the cost risk analysis, the results are thorough and can be used during project delivery as some assessment of the success of that project with respect to some agreed performance measures such as cost, schedule and scope.

- Risk Management and Value Engineering: The CRA results provide a list of risks which can serve as input for value engineering studies.

- Integrated management of Projects and Programs: The results of the CRA form a useful reference for the review of the project or program management effort. The CRA provides information on the sort of risks that could be related to individual projects or projects in a larger program. Decision makers may use this information to determine if any improvements are necessary at the program/project level.

- Design/Build and Other Construction Applications: Results give an idea of the risks involved with the project and are used to assign responsibility for each risk area to WSDOT or a design-build contractor.

- Communications: In the CRA report, risks are included as uncertainties in the project estimates and give the recipients of the reports a higher appreciation of the kinds of cost and schedule risks involved in the project.

- Financial Management: Decision makers are guided as to the timing and funding of a project based on the project risks and the level of uncertainty in the project cost and schedule estimates.

4. Implementation and Performance Measurement by the Project Team

   Due to the cyclic nature of the process, risks are constantly monitored, registers constantly updated and all actions documented to enable easy tracking of progress during the project. Risks identified are planned for and monitored to ensure that they are effectively mitigated and the cost of such mitigation measures does not exceed the assessed value of the impact to cost or schedule if the risk occurs. In order to check the success of the project and the risk assessment activities, project costs determined after such activities are compared to the final cost of the project at completion.

Post Workshop Activities: The project team, risk lead, and cost lead must continue to monitor the risks on the project and where possible develop improved mitigation strategies for each risk or a general one for overall management of the risks and the project as a whole, with an emphasis on quality control. All documentation from the workshop – preliminary draft results, charts, estimates, must be checked to ensure that the correct information is contained in the post workshop reports which are eventually presented to the Project Team and CREM.

Risk management performance on any WSDOT project can be measured by comparing the "pre-mitigated" to "post-mitigated" results. This could help to identify gaps in the process or points of concern which might require additional risk mitigation planning.

Typically, for some projects, the results of the CRA workshop are presented in a one page format. This summary, called a 'one-pager' summarizes the project important facts and the main output of the workshop including project risks, schedule, cost ranges, key assumptions made in evaluating the project, and the level of design at the time the workshop was performed. A typical 'one-pager' is shown in Figure E-21.

The Cost Risk Assessment process described above is summarized in Figure E-10 using a flow chart.

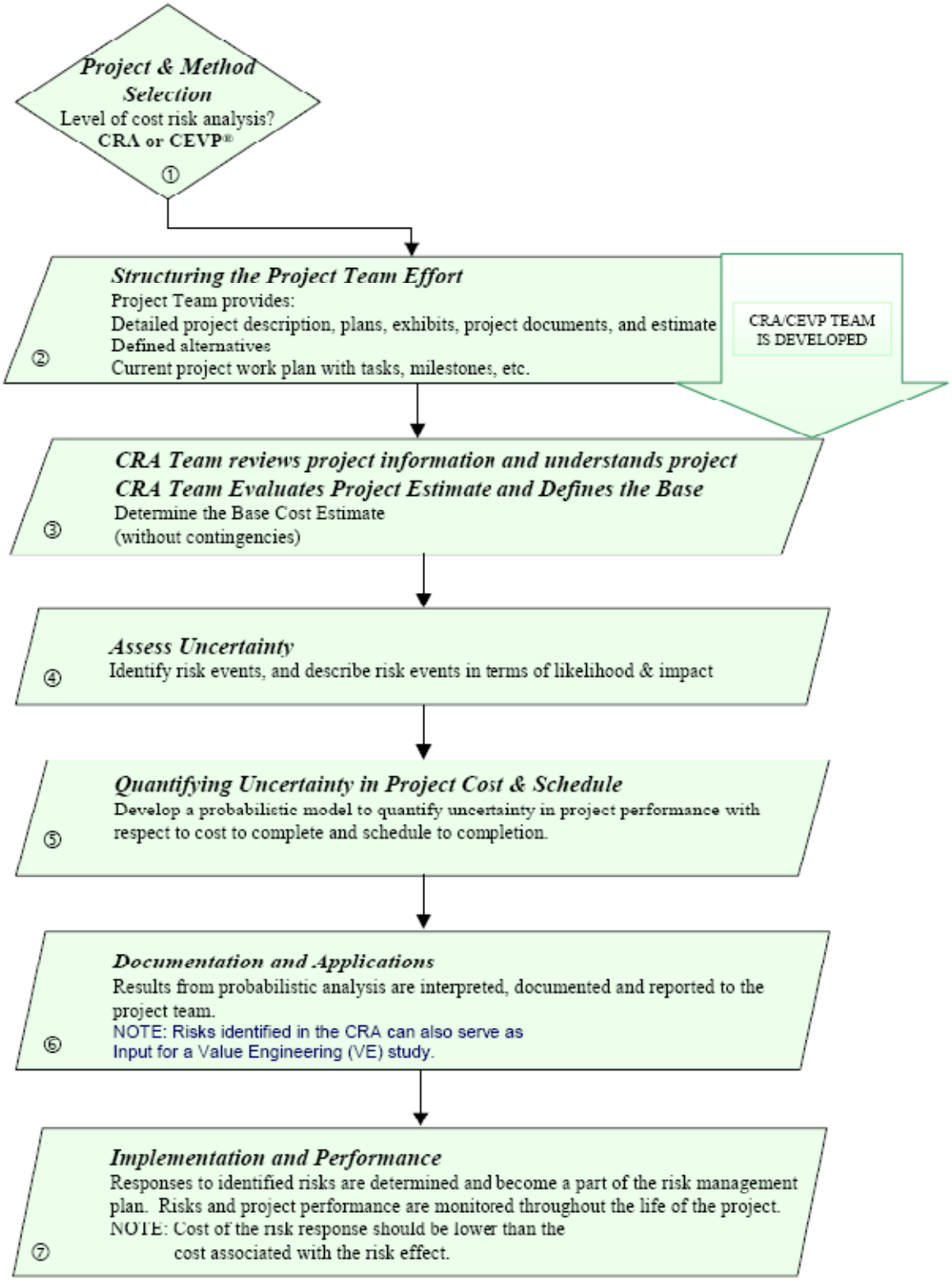



**Figure E-10: The CRA Process**
**Source: WSDOT Policy for CRA**

### E.2.4 Risk Management Tools

Risk Management Planning Template: This template is used for projects that do not require a CRA or CEVP; as such there is no provision made on the worksheet for a quantitative analysis. It is mainly qualitative. The template is an excel spreadsheet used to capture all the information related to risks on a project, the risk description, likelihood of occurrence, impact to project objectives, and mitigation strategies.

Probability Mass Diagrams: These diagrams are used to express the probability of completing a project before, by or later than a certain target date; or the probability of completing below or above a certain cost.

Tornado Diagrams: These are used to rank the risks on a project; they are express using levels of correlation of that risk to either project cost or project schedule. The risk with the largest correlation coefficient is the one that would have the highest impact to the project cost or schedule.

CEVP/CRA Workshops: These workshops are conducted to quantify the uncertainty involved in WSDOT projects and represent identified risk as ranges of probable costs or target dates. They can be conducted at any stage of the project development to express the level of uncertainty as perceived at that point. As the project draws close to completion, the uncertainty decreases; therefore, a CRA performed at the Planning Stage would have a higher estimate due to the large amount of uncertainty present, unlike a CRA performed at the preparation/submission of Plans Specifications & Estimates with less uncertainty.

Detailed Risk Management Plan Worksheet: This tool is used by the project team to monitor project risks following a CRA workshop. It is similar to the Risk Management Plan template earlier described though slightly more comprehensive and includes provisions on the spreadsheet for quantitative analysis (Section E.12).

Self Modeling Worksheet: This tool is for project teams wishing to perform some quantitative risk analysis and go beyond the qualitative analysis spreadsheet provided in the Project Management Online Guide. The use of this tool is discussed further in the subsequent section of this report based on the outcome of the interviews held with WSDOT on 11 March 2008.

@Risk for Microsoft Project: This software has been used by WSDOT for cost and schedule analysis of projects. It uses Monte Carlo simulation methods typically with about 5,000 iterations to model project uncertainty.

### E.2.5 Workshop Process Output

This section highlights some of the most important outputs from the CEVP/CRA workshops. Some of these will be illustrated using extracts from the CRA report on the "I-5 Grand Mound to Maytown widening Project." This report was prepared based on a CRA Workshop held in March 2006 (this project would be referred to as "I-5 Project" for the purpose of this Study).

The scope of this project includes widening the I-5 from Grand Mound to the Maytown interchange in Thurston County by providing one additional lane for traffic in either direction making a minimum of 3 lanes in both directions. The additional lanes are being provided to relieve congestion and improve safety on the highway. In addition the existing freeway on-ramps and off-ramps will be upgraded to meet current WSDOT and Federal Highway Administration (FHWA) design standards while the I-5 mainline curve section of the road will be realigned and flattened to improve sighting distance, driving conditions, visibility and overall safety of the road users. The Prairie Creek bridges will be replaced to accommodate the curve realignment and road widening and the bridges over Scatter Creek replaced with wider structures to effectively span the Creek. The scope of work also involves addition of bicycle lanes, ramp removal/replacement, signalization at some sections, and general renovation of the existing section of the road. Figure E-11 shows an aerial view of the project. Appendices D and E illustrate the risk assessment methods used on the project and the impact estimation process.

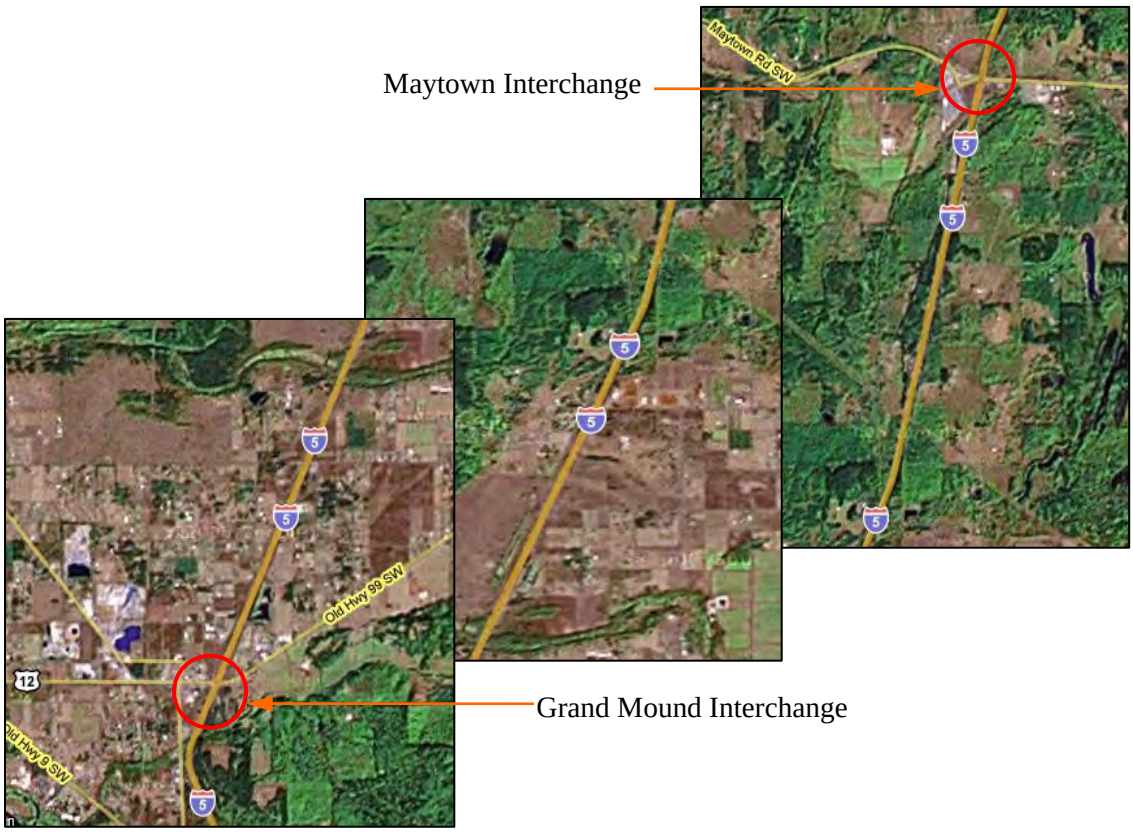



**Figure E-11: I-5 Project**

Base Cost Validation and Base Schedule Duration: The results of the Cost Estimate Validation show the activity, base cost, base duration and escalation. According to the WSDOT Cost Risk Estimating Management, "Escalation is the total annual rate of increase in cost of the work or its sub-elements. The escalation rate includes the effects of inflation plus market conditions and other similar factors." The escalation for most of the base activities varies between 0.1% and 10 percent (Figure E-12).

| ID | Activity | Base Costs | Base Duration | Escalation |
|---|---|---|---|---|
| **PROJECT DEVELOPMENT** | | | | |
| 1 | Design Documentation / PFA | $375,511 | 6 | 0.6% |
| 2 | Access Evaluation | $187,755 | 3 | 0.3% |
| 3 | Environmental Documentation | $375,511 | 6 | 0.6% |
| 4 | ROD / Design Approval | | | |
| 5 | Environmental Permits | $751,021 | 12 | 2.5% |
| 7 | Wetland Mitigation | $500,681 | 8 | 0.8% |
| 8 | Hydraulics Report | $312,926 | 5 | 0.5% |
| 9 | Geotechnical | $1,126,532 | 18 | 1.8% |
| 11 | PS & E | $938,777 | 15 | 2.1% |
| 12 | RR Agreement | $375,511 | 6 | 1.8% |
| 13 | Agency Agreement | $563,266 | 9 | 2.1% |
| 14 | Other Agreement | $375,511 | 6 | 1.8% |
| **RIGHT OF WAY ACQUISITION** | | | | |
| 6 | R/W Acquisition | $3,000,000 | 12 | 4.1% |
| 10 | R/W Certification | | | |
| **CONSTRUCTION** | | | | |
| 15 | AD | | | |
| 16 | North End (Maytown) Bridge Stage 1 | $8,120,451 | 10 | 3.9% |

**Figure E-12: Activity Base Cost, durations and escalation factors**

There is also some uncertainty in the project base cost and duration and these are determined by consensus of the CRA team during the workshop. They are shown in Figure E-13 as variations in percentages from the expected base costs.

| Cost Category | Range | | |
|---|---|---|---|
| | Minimum | Most Likely | Maximum |
| Preparation & Existing Item Removal | 0.0% | 0.0% | 0.0% |
| Grading | -10.0% | 0.0% | +10.0% |
| Drainage / Storm Water Treatment | -10.0% | 0.0% | +10.0% |
| Structures | -10.0% | 0.0% | +10.0% |
| Surfacing | 0.0% | 0.0% | +15.0% |

**Figure E-13: Uncertainties in Base Cost Assumptions**

Cost and Schedule Distributions: The results for the I-5 Project CRA show a cumulative probability distribution for total project cost with a 10 percent probability of the total project costs being less than $94.0 million and a 90% probability of being less than $101.8 million while the most likely cost estimate after risks have been factored-in is $97.3 million (Figure E-14). Figure E-15 shows a 70% chance of completing the project by 23rd July, 2010. The results also shows a less than 30 percent chance that the project team will exceed the baseline 10 July end date as a result of missing the first fish window in Summer 2008, resulting in a project

completion date beyond July 2011. There is a less than 5 percent chance that the project would not be completed until 2012, if a second fish window is missed. According to the King County Road Services Division' a fish window is 'A period of time designated by the Washington Department of Fish and Wildlife when construction work is allowed to occur, or otherwise create impact, below the ordinary high water mark of a regulated water body.' It is the time when construction work around a fish habitat can be conducted with little risk to the fish habitat. The population of fish in the water at that time is relatively small. If construction work occurs outside the fish window, it could lead to the loss of some aquatic life or cause harmful changes to their breeding environment and/or disruptions in their natural activities. The bridge removal in the I-5 Project can only be accomplished during this period in the year which happens to fall in summer. Once missed, the next opportunity to carry out the work is 12 months later. 'Fish window constraints' was identified as one of the major schedule risks on the project because of the huge impact it would have on the schedule if it occurs (see Figure E-15).

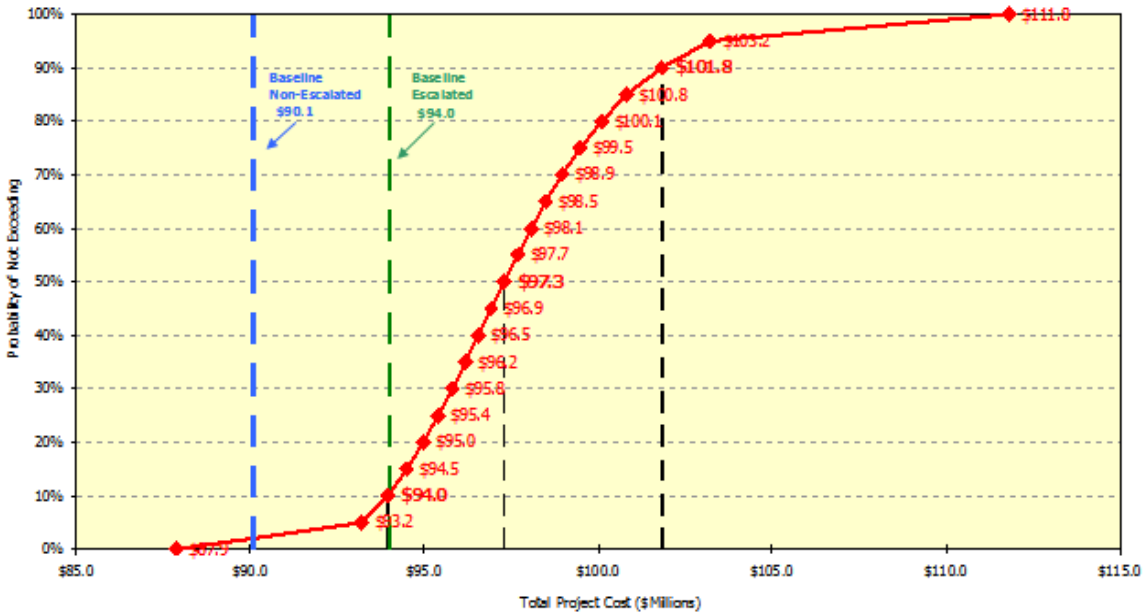



**Figure E-14: Risk Analysis of Total Project Cost (I-5 Project)**

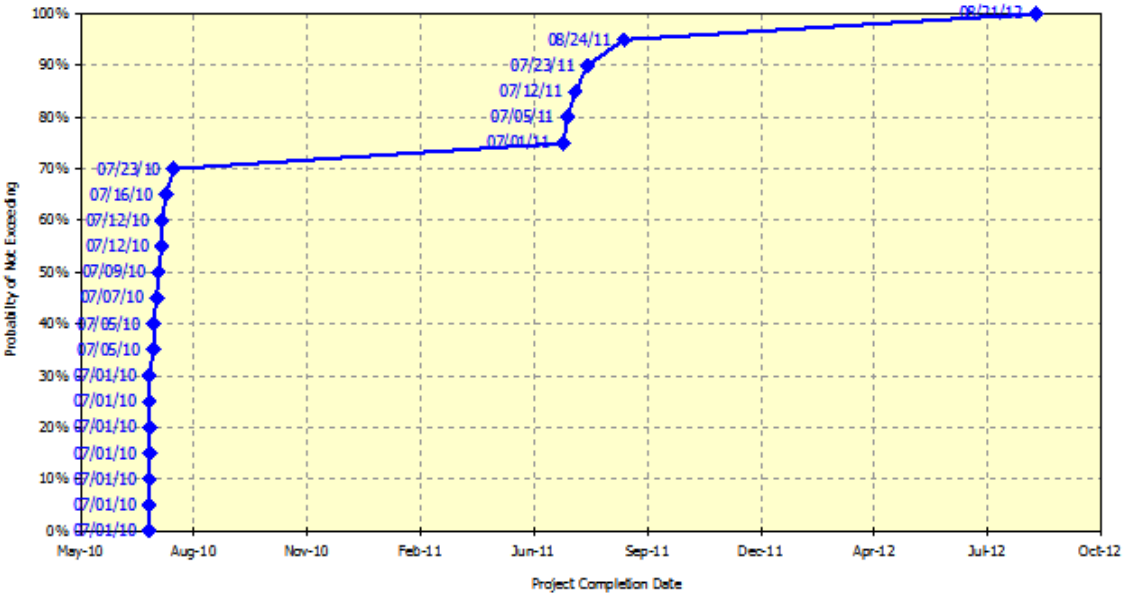



**Figure E-15: Risk Analysis of Project Completion date (I-5 Project)**

Risk Rankings: The top risks contributing either positively or negatively to the project cost or schedule estimates are ranked and listed based on their levels of contribution (impact). They are the most important risks. The one with the largest contribution to the cost estimate is the highest on the ranked list. These risks could include technical or non-technical risks, policy, environmental, or other risks. CRA result of the I-5 Project shows a ranking of the projects risks based on their expected impact on project costs using a tornado chart (Figure E-16). The risk item with the 2nd highest correlation of 0.410 "Uncertainty in the Environmental Permitting Process" is expected to have the 2nd largest impact on the project cost. On the other hand, the risk item with the lowest correlation of -0.122 "reduction in storm water pond size" would have the least impact on the project cost.

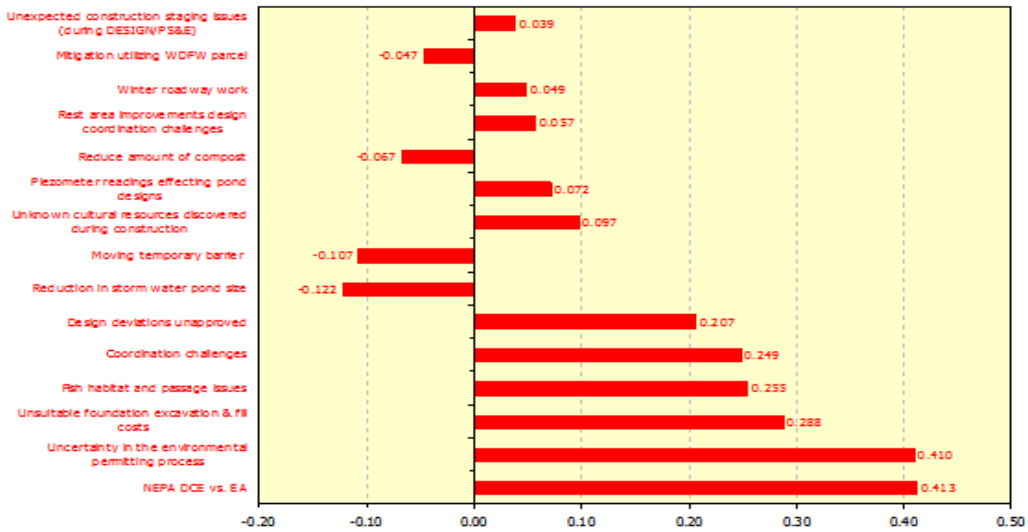



**Figure E-16: Cost Risk Factors (I-5)**

Risk items that could create the longest delays to the overall schedule are also shown using a tornado diagram (Figure E-17). The "uncertainty in the environmental permitting process" with a correlation of 0.711 is expected to have the largest impact on the schedule and "unanticipated geotechnical hazards" the least impact (correlation 0.028).

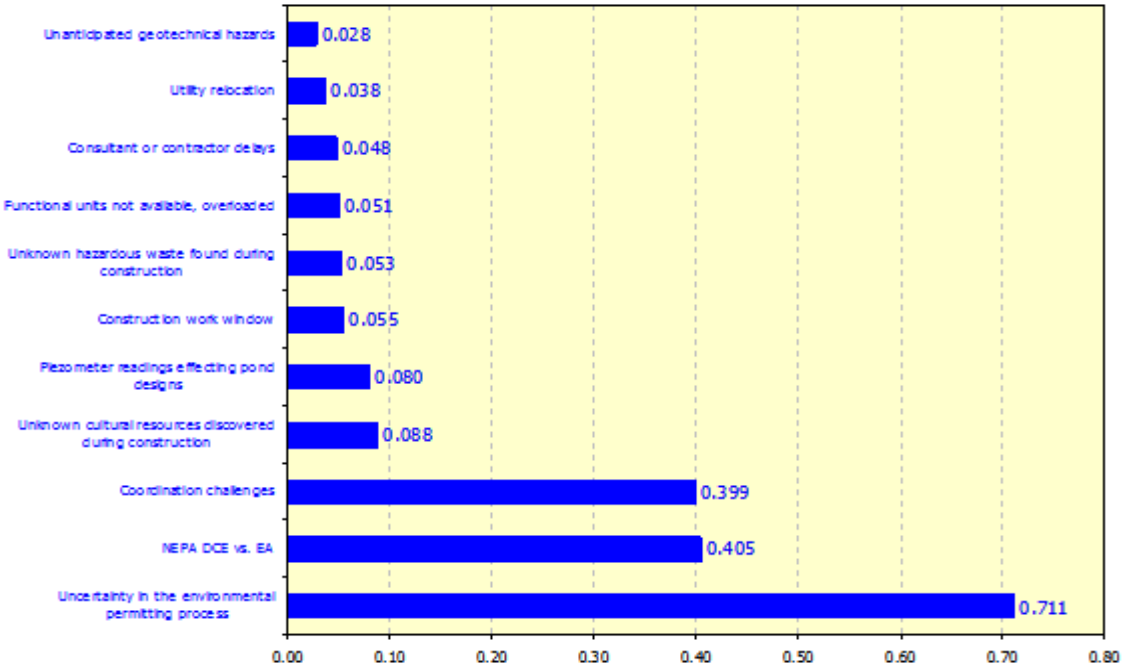



**Figure E-17: Schedule Risk Factors (I-5)**

Figure E-18 shows the expected cash flow for I-5, through some major project phases – project development, right-of-way acquisition, and construction. The total cash flow for the project is $97.3M, which was derived at the CRA workshop as the most likely estimate.

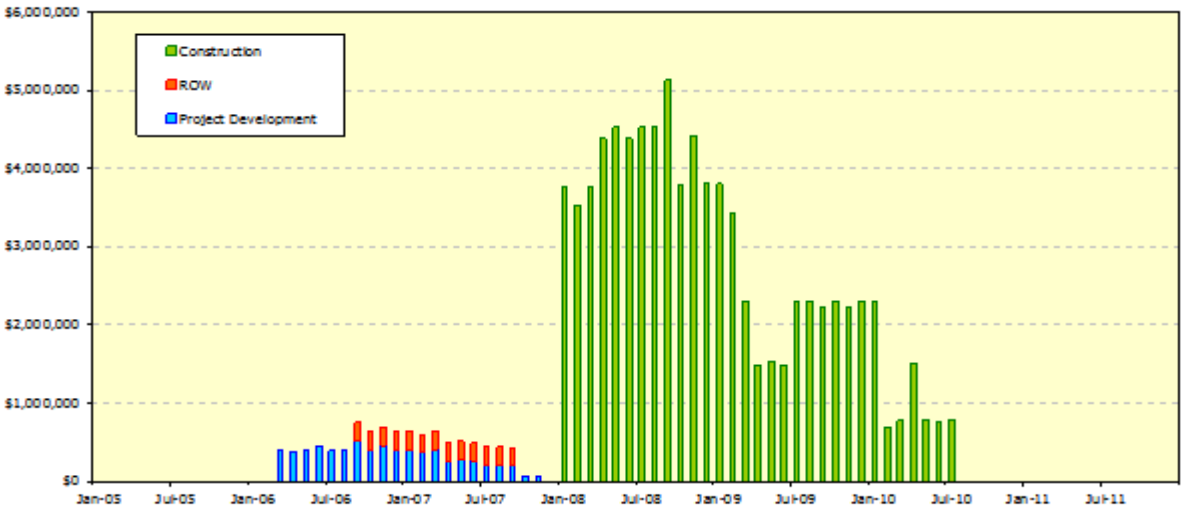



**Figure E-18: Project Cash flow (I-5)**

Based on the results of the CRA performed at this stage in the I-5 Project development, it is expected that by March/April 2009, a total of $70,000,000 would have been spent on the project including Project development, ROW expenses, and some Construction work. This is illustrated in the cumulative cash flow for the project (Figure E-19). The amount spent would continue to increase with time and gradually start to level off from above $95 million in July 2010 till the total gets to $97.3 million around December 2011.

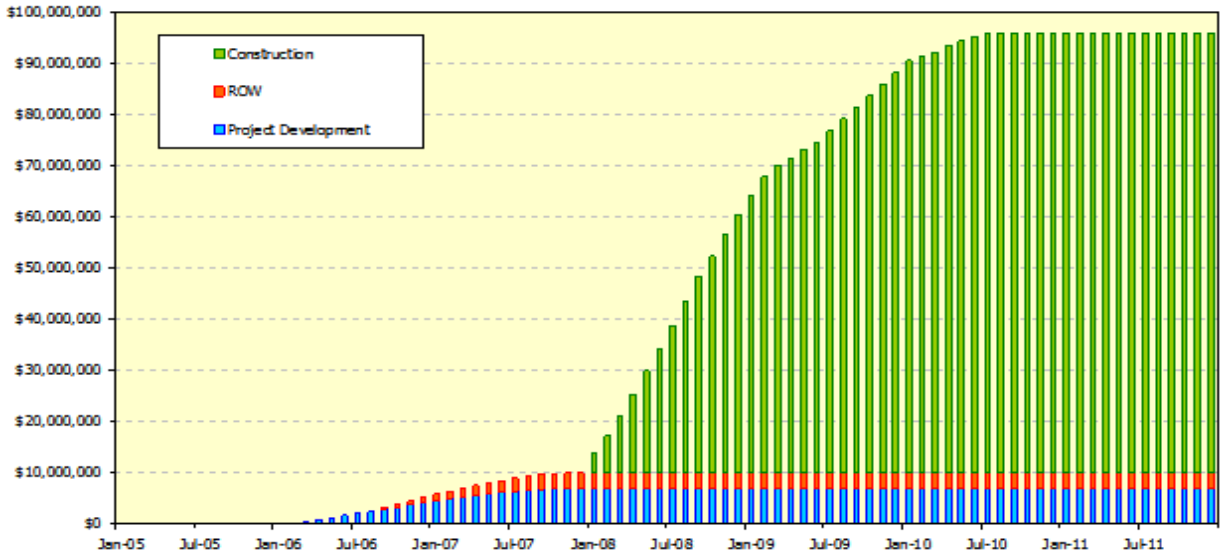



**Figure E-19: Project Cumulative Cash flow**

During the workshop, mitigation strategies were identified for some of the major project risks (Figure E-20). Some of them are:

D1: Design deviations unapproved
The mitigation strategy assigned for this risk is to coordinate design activities early and more efficiently to ensure that the process is started quickly so that even if there is delay in the approval, it would not significantly affect the project cost or schedule.

C2: Fish Work Window
The strategy used here is to accelerate construction work to meet the fish window which comes up once every year in summer. Specific construction activities such as underwater bridge work have to be performed within the fish window to prevent disruptions to the fish habitat and marine life. If there are any significant delays in construction activities that should be completed before the activities scheduled during the fish window, the fish window would be missed and those activities would have to be delayed for another 12 months and may have cost implications as well. Extra work shifts would be used if necessary to ensure that construction work is to schedule.

| ID | Threat / Opportunity Event | Risk Management / Response Actions |
|---|---|---|
| E6 | Uncertainty in the environmental permitting process | Agency coordination. |
| D8 | Fish habitat and passage issues | Thorough communication with WDFW. |
| C11 | Coordination challenges | Request extension of fish window. |
| C2 | Fish work window | Project acceleration to meet window (double shifts). Request extension of fish window. |
| C3 | Construction work window | Extra shifts. |
| D1 | Design deviations unapproved | Early coordination. |
| D10 | Unknown hazardous waste found during construction | Disposal or treatment of contaminated soil. Potential hazmat investigation. |
| D14 | Dewatering challenges for structure construction | PS&E to include adequate resources to eliminate issues, as they are identified. Also early geotechnical investigations are very important. |
| D16 | Unexpected construction staging issues - including issues encountered during DESIGN/PS&E | PS&E to include adequate resources to eliminate issues, as they are identified. |
| D9 NEW | Disposal of surplus material | Better coordination with the health department. |
| P4 | Agreements | Continuous coordination. |
| P5 | Functional units not available, overloaded | Advance notice and coordination. |
| P6 | Consultant or contractor delays | Coordination. |
| R5 | Objections to Right of Way appraisal takes more time and/or money | Early disclosure of appraisal to property owners. Trust building. |

**Figure E-20: I-5 Project Risk Mitigation Strategies**

Figure E-21 shows the 'One pager' for the I-5 Project. It provides a brief description of the project and some of the benefits, and summarizes the main results of the CRA workshop in terms of cost, schedule, scope, and major identified risks.

# I-5 Grand Mound to Maytown Widening Project

*March-April 2006*

**Scenario**

N/A

## Project Description:

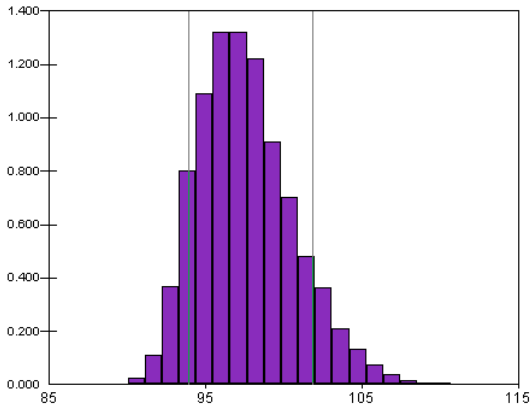
- Adds two lanes to I-5 between the Maytown and Grand Mound interchanges.
- Realigns and flattens I-5 mainline.
- Improves Grand Mound interchanges to accommodate I-5 widening and enhance safety.
- Adds two lanes, bike lanes and sidewalks to US-12.
- Improves various access and exit ramps/points.
- Replaces Prairie Creek bridges.
- Replaces bridges over Scatter Creek.
- Provides storm water treatment ponds.
- Connects rest areas to the Thurston County Sanitary sewer system.

## Schedule:

Begin Construction
80% Range:
Jan-08 to Apr-08

End Construction
80% Range:
Jul-10 to Jul-11

## CRA Results:




## Project Benefits:

- Improves traffic flows and LOS along I-5.
- Enhance safety along I-5 mainline.
- Enhances safety and improves traffic flows at I-5 access and exit points.
- Improves operation and safety of Grand Mound interchange.
- Improves traffic flows and safety, and promotes alternative mode use on US-12.

## Project Risks:

- Fish window constrains bridge removal work schedule.
- NEPA decision made three years ago.
- Uncertainty in the environmental permitting process (e.g., wetland mitigation).
- Unsuitable foundation excavation and fill costs (additional costs due to wet-season work or unsuitable areas).
- Fish habitat and passage issues (numerous culverts requiring replacement or lengthening).
- Coordination challenges.
- Design deviations unapproved.

## Project Cost Range:

10% chance the cost < **$94.0** million

50% chance the cost < **$97.3** million

90% chance the cost < **$101.8** million

## What's Changed Since 2002 SCoRE Workshop:

- Storm water treatment and erosion control BMP's
- Bridges now replaced rather than widened

## Financial Fine Print (Key Assumptions):

- Inflation escalation for project construction ranges from 1.30% to 3.10%; costs are escalated to mid-point of construction.
- Project costs include about $6 million of (non-quantified) other miscellaneous items.
- Rest area improvement costs are not included in total project costs.

| Level of Project Design: | Low | Medium | High |
|---|---|---|---|
| | ■ | | |

April 20, 2006

Washington State Department of Transportation

**Figure E-21: 'One Pager' for I-5 Project**

### E.2.6 Improvements to the Current CRA Process

As informed at the Interviews, the organization is in the process of improving the efficiency of the current CRA-CEVP process by considering the use of some additional tools such as Pertmaster Software and an Enhanced Self Modeling worksheet. Practical use of these tools was demonstrated by WSDOT personnel at the meeting.

Pertmaster Software: This is a risk management tool which uses advanced Monte Carlo simulation methods to analyze the cost and schedule risks on a project. Pertmaster integrates the cost estimate and project schedule in modeling the project uncertainty. WSDOT is contemplating the introduction of this software for modeling project uncertainty with the aim of developing higher confidence levels in the final project cost estimates. Some features of the Pertmaster software are schedule checking where points of danger such as constraints, open-ended tasks, and milestones that have great potential to affect the project completion dates. The in-built risk register allows for easy and automatic addition of new risks directly using a risk event plan, planning of risk mitigation strategies, and quantitative assessment of risks with the schedule. Pertmaster is also capable of risk reporting using histograms and distribution charts.

Self-Modelling Worksheet: The self-modeling worksheet is used for quantitative analysis of risks on projects. However, this does not contain some of the proposed enhancements to the process as demonstrated by WSDOT at the interview. Some of the enhancements that are not found incorporate the levels of dependence or independence of one risk to another and the use of correlation between risks to better estimate the overall impact to the project estimates. The basic self-modeling worksheet on the website can be used when the number of risks for evaluation is a minimum of 12 or maximum of 24. It serves as a risk management plan. It is excel based and utilizes simulation techniques and generates quantitative results. Columns 1 to 8 are used for risk identification (Figure E-22). Information entered into these columns include the priority number assigned to the risk, the current status of the risk (active/dormant/retired), date and project phase when the risk was first identified, functional assignment of the risk (threat/opportunity), a detailed description of each risk, and triggers that indicate that the risk is likely to occur.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Project Title | 0 | | | | | | | | |
| 2 | Estimate Date | February 12, 2007 | | | | | | | | |
| 3 | Project PIN # | 0 | The yellow highlighted cells have to be filled if risks are assigned. | | | | | Target AD date | | |
| 4 | Last Review Date | March 21, 2008 | | | | | | | | |
| 5 | Project Manager | | | | | | | Estimated Current Cost | | |
| 6 | | | | | | | | Base Construction Duration | | |
| 7 | | | | | | | | | | |
| 8 | Risk Identification | | | | | | | | | |
| 9 | Priority | Status | ID # | Date Ident. ---------- - Project Phase | Project Phase | Summary Description Threat and/or Opportunity | Detailed Description of Risk Event (Specific, Measurable, Attributable, Relevant, Timebound) [SMART] | Risk Trigger | Type | Probability (%) |
| 15 | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 16 | EXAMPLE | Active | | Mar-06 | Geotech | Opportunity | The mitigation ratio has not been finalized and also there could be additional impacts to wetlands which would increase the amount of R/W needed for the mitigation area. | If Wetland impact is larger than 1/2 acre and ratio exceeds 4:1. | Cost | 25% |
| 17 | | | | | | | | | | |
| 18 | | | | Design/PS&E | | Wetland mitigation may require additional R/W | | | | |
| 19 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 21 | | | | | | | | | Schedule | |
| 22 | | | | | | Threat | | | | |
| 24 | 13 | Retired | | Mar-07 | Construction | Opportunity | | | Cost | |
| 25 | | | | | | | | | | |
| 26 | | | | | | | | | | |
| 27 | | | | n/PS&E | | | | | | |

**Figure E-22: Example Self Modeling Worksheet (Risk Identification section)**

Columns 9 to 12 are used for the quantitative analysis of risks, to numerically analyze the probability and consequences of a risk occurring. Inputs for this section include the probability of occurrence, the cost and schedule impacts, and the expected impact on the project with results reflecting minimum, maximum and best guess values. Columns 13-15 are the qualitative analysis of the best guess impact providing information such as the probability, impact and position in the risk matrix. Information in these cells is automatically updated based on the quantitative analysis (Figure E-23).

The info captured on this shaded area is updated automatically

| | Date | Variability | Markups | | |
|---|---|---|---|---|---|
| Target AD date | Feb-10 | 10% | Mob+PE | 25% | |
| | | 10% | Tax | 8% | |
| Estimated Current Cost | 10.00 $M | 10% | CE | 15% | |
| Base Construction Duration | 24.0 Month | 36 Month | Total | 1.55 | |

This Spreadsheet is us

PROJECT RISK MANAGEMENT PLAN

| | Quantitative Analysis | | | | | Qualitative Display of the Best Guess Impact | | |
|---|---|---|---|---|---|---|---|---|
| Risk Trigger | Type | Probability (%) | | Risk Impact ($M) and (Month) | Expected Impact ($M) | Probability (%) | Impact | Risk Matrix (Probability of Occurrence by Best Guess Impact) |
| (8) | (9) | (10) | [10a] | (11) | (12) | (13) | (14) | (15) |
| If Wetland impact is larger than 1/2 acre and ratio exceeds 4:1. | Cost | 25% | MIN | 1.00$M | 0.50 | Low | Very High | |
| | | | MAX | 5.00$M | | | | |
| | | | BEST GUESS | 2.00$M | | | | |
| | Schedule | | MIN | 2.0Mo | | | | |
| | | | MAX | 7.0Mo | | | | |
| | | | BEST GUESS | 5.0Mo | | | | |
| | Cost | | MIN | | 0.00 | NO RISK | NO RISK | |
| | | | MAX | | | | | |
| | | | BEST GUESS | | | | | |

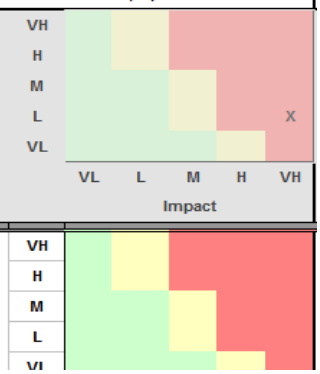



**Figure E-23: Example Self Modeling Worksheet (Quantitative/Qualitative analysis Section)**

Columns 16 to 21 are used for risk response planning, monitoring and control (Figure E-24). Risks that are not on the critical path are not used to define the project duration.

| Risk Response Plan | | Monitoring and Control | | | Critical Issue |
|---|---|---|---|---|---|
| Strategy | ACTION TO BE TAKEN Response Actions including advantages and disadvantages include date | Risk Owner | Risk Review Dates | Date, Status and Review Comments (Do not delete prior comments, therefore providing a history) | Is Risk on Critical Path? |
| (16) | (17) | (18) | (19) | (20) | (21) |
| Mitigation | Finalize design to identify all wetlands that are impacted. Early coordination with the outside agencies to determine mitigation ratio. | Design Leader/Enviro. mgr | 2007-Jan-2<br>2006-Dec-2 | As of Nov. 15, 2005 there are only two potential areas where there could be additional wetland impacts. As of Dec. 2, 2005 agency has initially determined that mitigation ration would be 4:1. | YES |

**Figure E-24: Example Self Modeling Worksheet (Risk Response Planning Section)**

Using an iterative simulation process, results are generated as displayed in the example Table 2.

**Table E.2: Self Modeling Worksheet (Output Ranges)**

| | | Bin | Input | Output Range | | | |
|---|---|---|---|---|---|---|---|
| | YOE [$M] | Range | Range | *Bin* | *Frequency* | Probablity | Cumulative |
| **Min** | **9.56 $M** | 9.60 | 10.60897 | 9.60 | 11 | 0.11% | 0% |
| **Max** | **11.71 $M** | 9.70 | 10.15586 | 9.70 | 52 | 0.52% | 1% |
| **Median** | **10.63 $M** | 9.80 | 10.28343 | 9.80 | 117 | 1.17% | 2% |
| **10%** | **10.06 $M** | 9.90 | 10.93436 | 9.90 | 229 | 2.29% | 4% |
| **20%** | **10.23 $M** | 10.00 | 10.74616 | 10.00 | 321 | 3.21% | 7% |
| **30%** | **10.36 $M** | 10.10 | 10.00743 | 10.10 | 515 | 5.15% | 12% |
| **40%** | **10.51 $M** | 10.20 | 10.23339 | 10.20 | 594 | 5.94% | 18% |
| **50%** | **10.63 $M** | 10.30 | 10.80357 | 10.30 | 683 | 6.83% | 25% |
| **60%** | **10.75 $M** | 10.40 | 10.89743 | 10.40 | 658 | 6.58% | 32% |
| **70%** | **10.87 $M** | 10.50 | 10.69613 | 10.50 | 717 | 7.17% | 39% |
| **80%** | **11.00 $M** | 10.60 | 10.86574 | 10.60 | 848 | 8.48% | 47% |
| **90%** | **11.21 $M** | 10.70 | 10.65904 | 10.70 | 882 | 8.82% | 56% |
| | | 10.80 | 10.54823 | 10.80 | 800 | 8.00% | 64% |

Probabilities of completion of a project by certain dates and within certain cost ranges, based on the input data for this worksheet, are shown graphically using histograms (normal distributions) and cumulative probability diagrams (Figures G-25 and G-26).

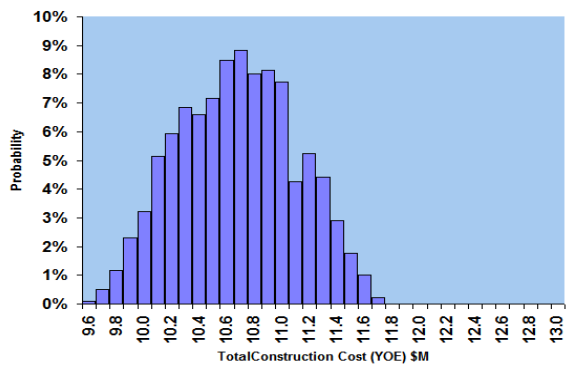



**Figure E-25: Probabilities of Completion (at Year of Expenditure)**

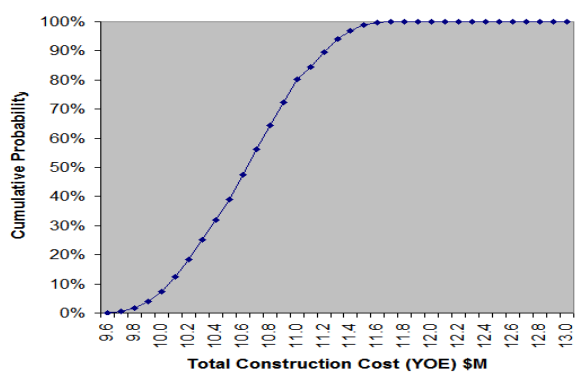



**Figure E-26: Cumulative Probabilities of Completion (at year of Expenditure)**

Policy Documents: A few important WSDOT policy documents which influence the project management and risk management proceedings were also described at the meeting. They include:

> Project Management Executive Order E1032 (July 1, 2005): which directs WSDOT employees (Executives, Senior Managers, Project Managers, Project Team Members, Specialty groups and Design and Construction) to deliver capital transportation projects consistent with the principles, and practices of the departments project management process as laid out in the online guide. They must ensure that all managers have good management skills, provide appropriate resources for project management implementation, and adhere to roles and responsibilities as defined in the specific project management plan.
>
> Instruction Letter IL4071 (July 13, 2007): which guides management and project teams in applying inflation rates and determining market conditions on all WSDOT construction projects, including guidelines for use and reporting of CRA/CEVP. This letter supports principles outlined in the Executive Order E1032 above. Project teams are currently directed to use the 90$^{th}$ percentile figure as the default for reporting CEVP/CRA results to account for inflation and market conditions, except when express approval is granted to do otherwise.
>
> Enterprise Risk Management Secretary's Executive Order E1038.00 (September 4, 2007): This policy is a statement of WSDOT's commitment to risk management to be implemented through the department's Enterprise Risk Management Program.

Early Risk Elicitation: For some of the CRA workshops previously performed, it was observed that there was the need to focus more on the pre-workshop risk elicitation activities to reduce the amount of time spent identifying these risks at the workshop. The WSDOT is working on ways to increase the efficiency of the current risk elicitation process by involving the various relevant functional groups early, well before the formal CRA workshop. It is believed that this would significantly increase the efficiency of participants before and during the workshop, as well as improve the reliability of the workshop results. An additional tool which WSDOT is currently developing for use in the risk elicitation is a work breakdown structure (WBS). The WBS would define some basic risks which may be expected on a project categorized according to the project group responsible for that risk. Some of these groups might include Right-of-Way, Design, PS&E, Structures, Railroad and Construction. This WBS would serve as a risk database, a checklist for the various functional groups at the beginning of the risk elicitation activities, and a common way to organize and categorize risks on a project.

WSDOT is currently exploring methods to better assess the accuracy of the CEVP/CRA results against bid data for the project. *'Is the actual (final) cost of the project within the expected range as determined at the CRA workshop?'* If the answer to this question is NO, *'by how much did it differ and why?'* The methods developed are expected to provide ways to answer this question and others that might explain the variation between the actual cost and workshop results, and provide insight to the stages of the process where additional attention may be required.

## *E.3 Summary*

The Washington State Department of Transportation uses a process of risk identification, qualitative analysis, risk response planning and monitoring on small projects. For larger projects with values exceeding $25 million and projects that meet other criteria listed out in the 'WSDOT Policy for Cost Risk Assessment', a CRA/CEVP workshop is performed. The aim of the workshop is to numerically estimate the probabilities of meeting project cost and schedule by a validation of the project base cost and evaluating of project risks to determine a suitable contingency for each risk.

The workshop process has been used on over 90 of the organization's projects and has yielded successful results on most of them. The process is reviewed continually. The review looks at tools and methods that would improve the efficiency of the process and the accuracy of risk cost estimates. Among the tools considered for use from 2008 is the PertMaster which may be used to perform an integrated cost and schedule analysis on projects. This integration of cost and schedule is expected to decrease the variation in the CRA results and increase the level of confidence in the project estimates.

The Organization emphasizes that regardless of the sophistication of the risk management procedures, an exact figure cannot be determined for the project cost until the project is actually completed. This is due to the fact that at the earlier stages of the project, there are some unknown or unquantifiable known factors present that could affect the cost or schedule, impacts of which cannot be determined at that time. As the project progresses, more risks become known, some previously identified risks are retired or become dormant and cost estimate ranges become more definite.

### E.3.1 References

*WSDOT Guidelines for CRA-CEVP Workshops* (2008). Washington State Department of Transportation.

*Cost Risk Assessment Report SR 520 West Lake Sammamish Parkway to SR 202 Project* (2006). Washington State Department of Transportation.

*Cost Risk Assessment Report I-5 Grand Mound to Maytown Widening* (2006). Washington State Department of Transportation.

*Policy for Cost Risk Assessment* (2005). Washington State Department of Transportation.

### E.3.2 Extracts from the WSDOT Sample Risk List by Category

Technical Risks

- Design incomplete
- Right of Way analysis in error
- Environmental analysis incomplete or in error
- Unexpected geotechnical issues

External Risks

- Landowners unwilling to sell
- Priorities change on existing program
- Inconsistent cost, time, scope, and quality objectives
- Local communities pose objections

Environmental Risks

- Permits or agency actions delayed or take longer than expected
- New information required for permits
- Environmental regulations change

Organizational Risks

- Inexperienced staff assigned
- Losing critical staff at crucial point of the project
- Insufficient time to plan

Project Management Risks

- Project purpose and need is poorly defined
- Project scope definition is poor or incomplete
- Project scope, schedule, objectives, cost, and deliverables are not

Right of Way Risks

- Utility relocation may not happen in time
- Freeway agreements
- Railroad involvement

Construction Risks

- Inaccurate contract time estimates
- Permit work windows

Regulatory Risks

- Water quality regulations change
- New permits or new information required

## E.3.3 Sample Risk Register

| Activity Impacted | Risk ID | Functional Assignment | Threat / Opportunity Events | SMART Column | Type of Risk | Probability | Cost Impact ($) | | | | | | | Schedule Impact (months) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Distribution | V1 | V2 (Low) | V3 (High) | P1 | P2 | P3 | Distribution | V1 | V2 (Low) | V3 (High) | P1 | P2 | P3 |
| All construction tasks | D18 | Design / WZTC | Unexpected construction staging issues - including issues encountered during DESIGN/PS&E | Although conceptual staging strategies have been identified, Work Zone Traffic Control (WZTC) design not yet complete. Chance that - during staging/WZTC design- additional costs are identified that were not accounted for in the original estimate. Also, chance that additional impacts to traveling public are identified. So, risk to budget and quality. | Cost and Quality | 75% | Pert | $200,000 | $100,000 | $300,000 | | | | | | | | | | |
| 3 | E1 | Environmental | NEPA DCE vs. EA | NEPA DCE decision made three years ago. New person is responsible now. Possible mitigation. | Cost and Schedule | 5% | Pert | $1,000,000 | $500,000 | $1,500,000 | | | | Pert | 18.0 | 12.0 | 24.0 | | | |
| All construction tasks | E2 | Environmental | Reduction in storm water pond size | Pond sizes may be reduced due to several factors, including policy changes regarding forested conditions for retrofitting. Early assumptions regarding storm water design will likely prove conservative. | Cost | 50% | Pert | -$800,000 | -$800,000 | -$400,000 | | | | | | | | | | |
| 5 | E8 | Environmental | Uncertainty in the environmental permitting process | Examples: wetland mitigation, critical area ordinances in Thurston County being modified now. $5,000 an acre for mitigation. | Cost and Schedule | 20% | Pert | $100,000 | $50,000 | $1,000,000 | | | | Pert | 2.0 | 0.0 | 8.0 | | | |
| All construction tasks | E10 | Environmental | Unknown cultural resources discovered during construction | Unanticipated archeological finding at the Creeks. Would delay excavation work and construction. | Cost and Schedule | 10% | Discrete | $400,000 | $0 | $0 | 10% | 80% | 0% | Discrete | 3.0 | 0.0 | 0.0 | 10% | 80% | 0% |
| n/a | X1 | External | Landowners unwilling to sell | Very low probability. Unlikely to delay the project. Already accounted for in the baseline estimates. | n/a | | | | | | | | | | | | | | | |
| 23 | P1 | Project | Rest area improvements design | Coexistence of sewer and water lines with other highway facilities on the east | Cost | 5% | Pert | $800,000 | $300,000 | $1,000,000 | | | | | | | | | | |

### E.3.4 Illustration of the WSDOT Estimation Process from Start to Finish

The CEVP/CRA workshops are conducted at any time during the project development phase. The results at the various levels of project development, Planning, Scoping and Design, are different; as the project progresses some earlier identified risks get resolved thereby decreasing the uncertainty in the estimates and narrowing the range of possible costs and durations for the project. Results are still constantly reviewed and updated throughout the project till the end of the Construction Phase. Figure below shows the typical timeframe within which the risk assessment workshops are held. The lengths of these workshops usually range between 1-2 days for the CRA and 3-5 days for the CEVP which is more intense.

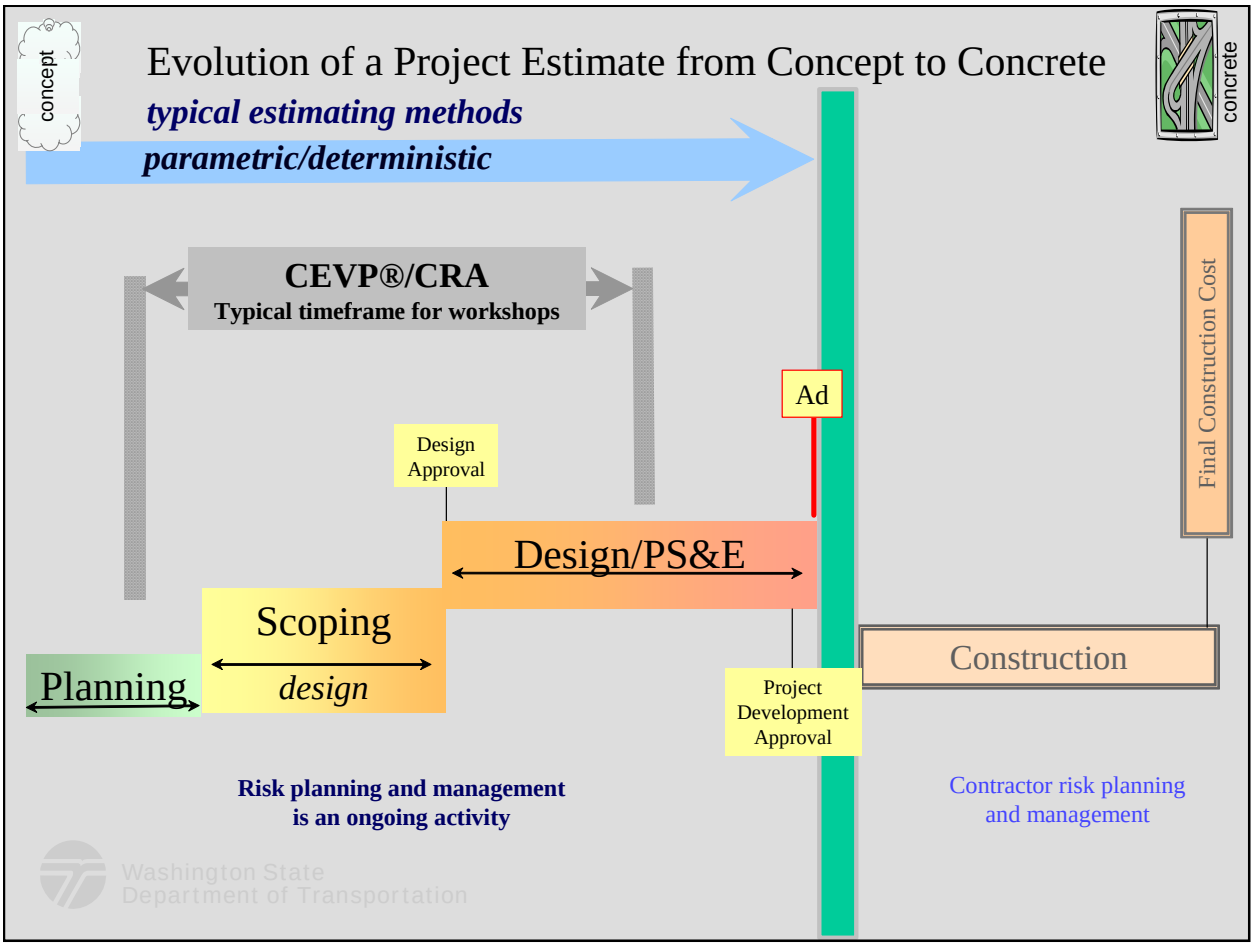
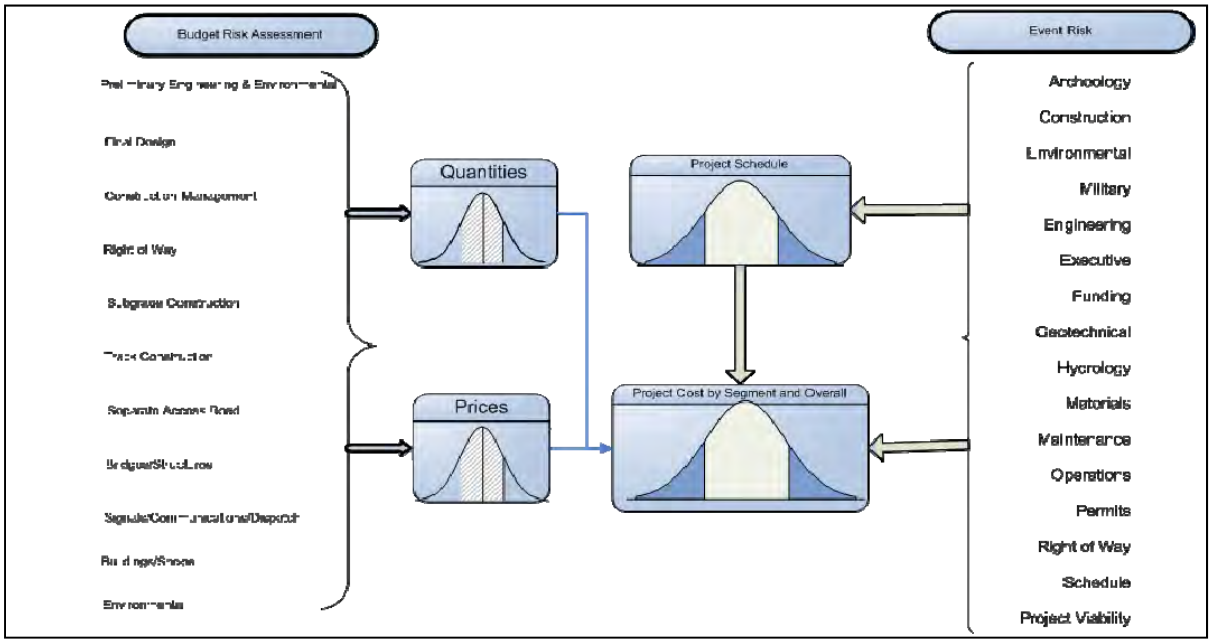
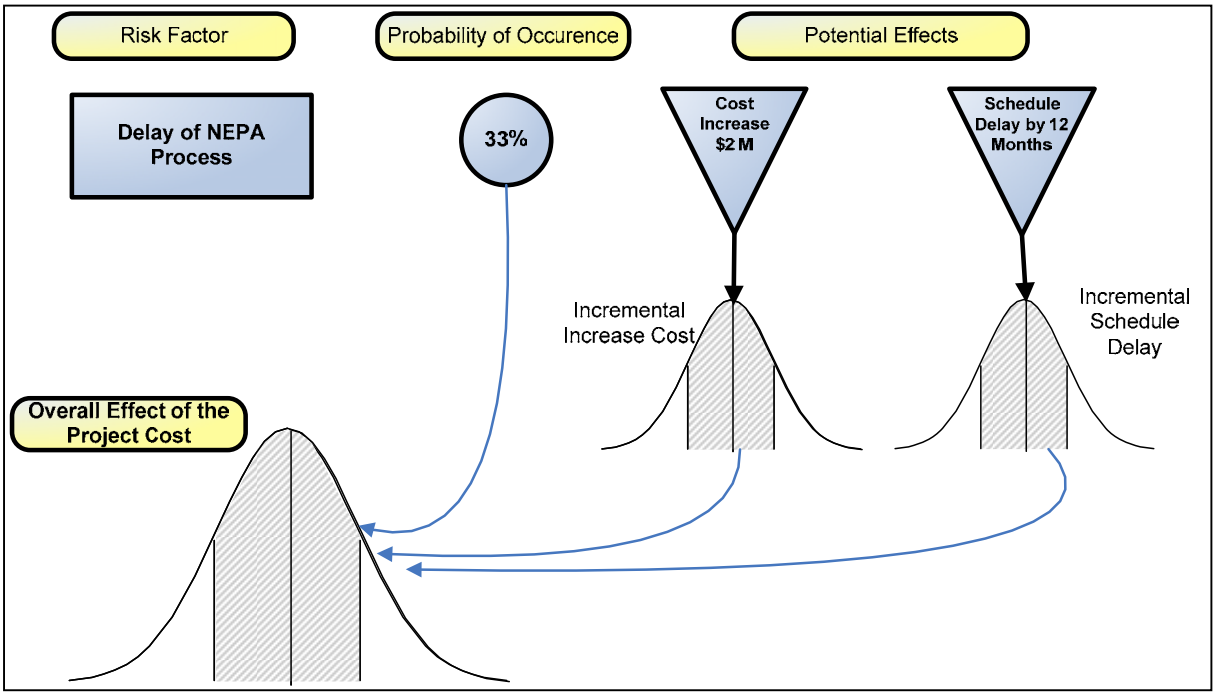



**Figure E-27: Timeframe for the WSDOT Risk Assessment Workshops**
***Source: WSDOT Guidelines for CRA-CEVP Workshops***

## E.3.5 Illustration of the Risk Assessment Process for the I-5 Project

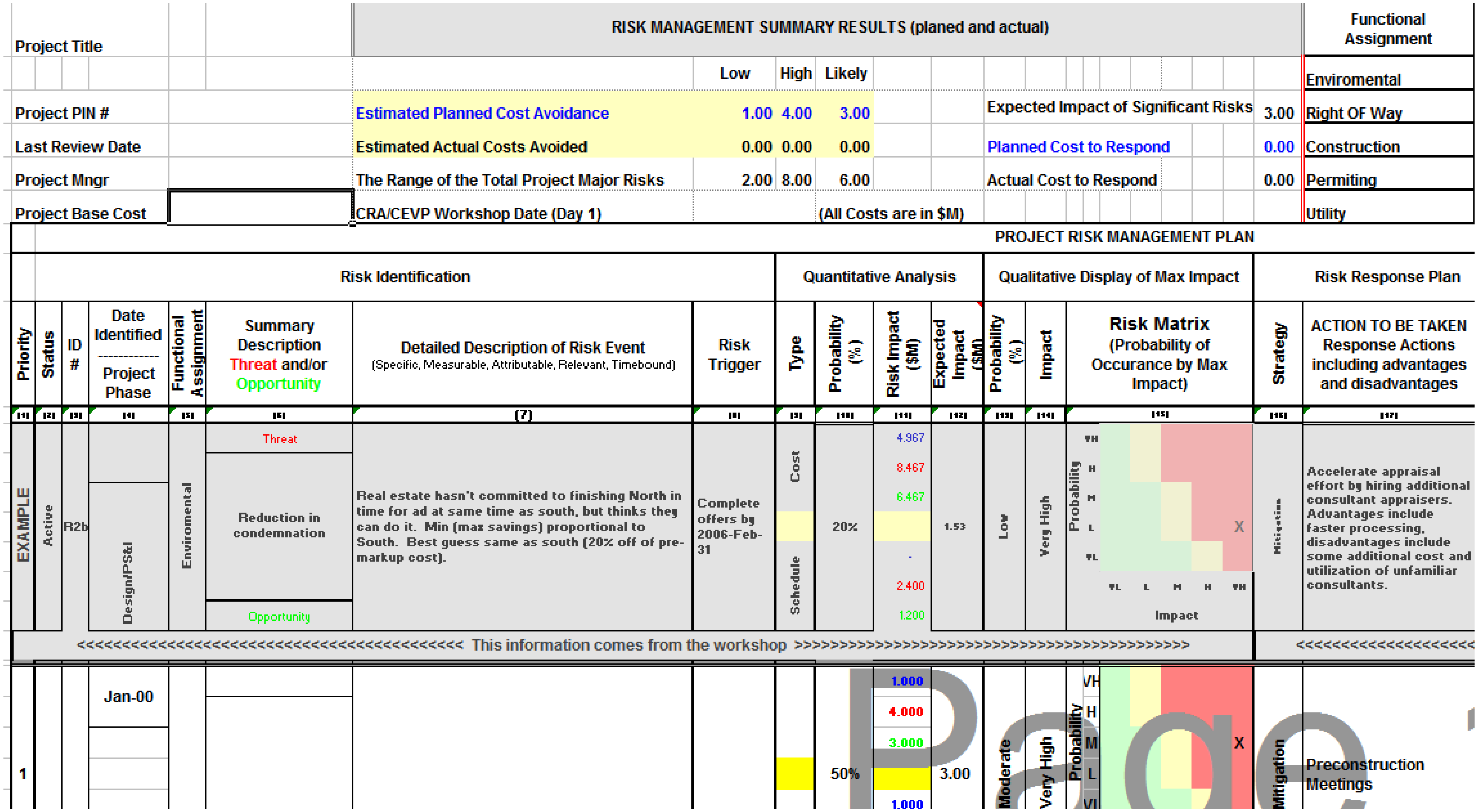


## E.3.6 Illustration of the Impact Estimation for the I-5 Project



## E.3.7 Detailed Risk Management Planning Worksheet for Quantitative Analysis (CRA)

**1st page**



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Project Title | RISK MANAGEMENT SUMMARY RESULTS (planed and actual) | | | | | | Functional Assignment |
| | | Low | High | Likely | | | Enviromental |
| Project PIN # | Estimated Planned Cost Avoidance | 1.00 | 4.00 | 3.00 | Expected Impact of Significant Risks | 3.00 | Right OF Way |
| Last Review Date | Estimated Actual Costs Avoided | 0.00 | 0.00 | 0.00 | Planned Cost to Respond | 0.00 | Construction |
| Project Mngr | The Range of the Total Project Major Risks | 2.00 | 8.00 | 6.00 | Actual Cost to Respond | 0.00 | Permiting |
| Project Base Cost | CRA/CEVP Workshop Date (Day 1) | | (All Costs are in $M) | | | | Utility |

PROJECT RISK MANAGEMENT PLAN

| Risk Identification | | | | | | | | Quantitative Analysis | | | | Qualitative Display of Max Impact | | | Risk Response Plan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority | Status | ID # | Date Identified<br>------------<br>Project Phase | Functional Assignment | Summary Description Threat and/or Opportunity | Detailed Description of Risk Event (Specific, Measurable, Attributable, Relevant, Timebound) | Risk Trigger | Type | Probability (%) | Risk Impact ($M) | Expected Impact ($M) | Probability (%) | Impact | Risk Matrix (Probability of Occurance by Max Impact) | Strategy | ACTION TO BE TAKEN Response Actions including advantages and disadvantages |
| [1] | [2] | [3] | [4] | [5] | [6] | (7) | [8] | [9] | [10] | [11] | [12] | [13] | [14] | [15] | [16] | [17] |
| EXAMPLE | Active | R2b | Design/PS&I | Enviromental | Threat<br>Reduction in condemnation<br>Opportunity | Real estate hasn't committed to finishing North in time for ad at same time as south, but thinks they can do it. Min (max savings) proportional to South. Best guess same as south (20% off of pre-markup cost). | Complete offers by 2006-Feb-31 | Cost<br>Schedule | 20% | 4.967<br>8.467<br>6.467<br>-<br>2.400<br>1.200 | 1.53 | Low | Very High | Probability VH H M L VL<br>X<br>VL L M H VH<br>Impact | Mitigation | Accelerate appraisal effort by hiring additional consultant appraisers. Advantages include faster processing, disadvantages include some additional cost and utilization of unfamiliar consultants. |
| <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< This information comes from the workshop >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> | | | | | | | | | | | | | | | <<<<<<<<<<<<<<<<<<<< | |
| 1 | | | Jan-00 | | | | | | 50% | 1.000<br>4.000<br>3.000<br>1.000 | 3.00 | Moderate | Very High | Probability VH H M L VL<br>X | Mitigation | Preconstruction Meetings |

**(Continued)**

| Functional Assignment | Response Cost | Likely Cost Avoidance | Functional Assignment | Response Cost | Likely Cost Avoidance |
|---|---|---|---|---|---|
| romental | 0.00 | 0.00 | Design | 0.00 | 0.00 |
| t OF Way | 0.00 | 0.00 | Place Holder | 0.00 | 0.00 |
| struction | 0.00 | 0.00 | Place Holder | 0.00 | 0.00 |
| niting | 0.00 | 0.00 | Place Holder | 0.00 | 0.00 |
| y | 0.00 | 0.00 | Place Holder | 0.00 | 0.00 |

| k Response Plan | | Monitoring and Control | | | Response Cost and Cost Avoidance | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TION TO BE TAKEN esponse Actions luding advantages d disadvantages | Activity | Risk Owner | Risk Review Dates | Date, Status and Review Comments | Planned Cost to Respond [$M] | Est. Value of Risk Avoided [$M] | Actual Cost to Respond [$M] | Est. Actual Costs Avoided [$M] | |
| [17] | [18] | [19] | [20] | [21] | [22] | [23] | [24] | [25] | |
| elerate appraisal rt by hiring additional sultant appraisers. antages include er processing, dvantages include e additional cost and ation of unfamiliar sultants. | ROW Acquisition/Relocation - North section | Ms. Land Expert | 2005-Dec-32<br>2006-Jan-32 | As of the date 2005-Nov-31 appraisers had been hired and additional E-3 has been assigned to manage consultant work. | 0.5 | 0.493<br>1.673<br>1.033 | | - | 1.53 |
| <<<<<<<<<<<<<<<<<<<<<<<< This information is entered by the project manager to act, monitor, and control. >>>>>>>>>>>>>>>>>>>>>>>> | | | | | | | | | |
| construction tings | ay Construction | | | | | ***<br>***<br>*** | | -<br>-<br>- | 3.00 |

# Appendix F: DOE Case Study

## *The Department of Energy Office of Environmental Management Approach to Risk Management*

## *F.1 Introduction*

This case study reviewed the risk management efforts within the United States Department of Energy (DOE). Specifically, this case study focused on the Office of Environmental Management (EM) and one of its project offices, the DOE Richland Operations Office.

The EM DOE website describes the agency's operations and the transition that is taking place at the DOE, specifically in their changing attitude towards risk management policies. The DOE EM office is responsible for the risk reduction and cleanup of the environmental legacy of the Nation's nuclear weapons program, one of the largest, most diverse, and technically complex environmental programs in the world. EM will successfully achieve this strategic goal by ensuring the safety of DOE employees and U.S. citizens, acquiring the best resources to complete the complex tasks, and by managing projects throughout the United States in the most efficient and effective manner. EM has made significant progress in the last four years in shifting away from risk management to embrace a mission completion philosophy based on cleanup and reducing risk. EM continues to demonstrate the importance of remaining steadfast to operating principles while staying focused on the mission. EM has made progress in recent years in the cleanup and/or closure of sites. In addition to its emphasis on site cleanup and closures, EM is also focusing on longer-term activities required for the completion of the cleanup program.[6]

Since 1989, the DOE Richland Operations Office has been working to remediate the effects of production of plutonium that began in 1943. The Hanford site (located outside of Richland, WA) is currently the largest clean-up site in the world. The office is working on ten separate projects to aide in the clean-up of the former plutonium production site. Descriptions of each of the projects are included in Section F.4.

In the state of the practice survey, the respondent indicated that the annual program size was $1 billion. They use designers and managers for estimating during planning and programmatic design. They transition to using both an estimating section and the designers and managers during detailed design. A definition for contingency exists, but is currently being revised. They use a formal risk analysis process for setting contingency. It was indicated that engineering judgment and specific identification processes are used for setting contingency. The DOE sometimes uses ranged estimates to represent costs during planning, and always uses ranged estimates during programming and detailed design. Contingency is set only at the project level, not at the program level. Approximately 95% of the projects use formal risk analysis for project scope, project schedule, and project cost. During the risk identification step, the DOE uses brainstorming, expert interviews, and Delphi methods. The DOE uses qualitative risk assessment techniques alongside Monte Carlo analysis. Approximately 95% of the projects use a risk register, a risk management plan, and risk mitigation plans. The DOE uses formalized risk tracking and monitoring as well as formal risk allocation techniques to draft contract provisions.

### F.1.1 Research Methods

This case study details the risk management approach currently adopted by the DOE EM office. It was compiled by combining information gathered from the a state-of-practice survey

[6] From www.em.doe.gov

completed by one of the case study participants, information from the DOE EM website www.em.doe.gov and from interviews conducted by the project team with DOE EM. Two separate interviews were conducted; one with the Department of Energy Office of Environmental Management in Washington, D.C.; and another with the Battelle Pacific Northwest National Labs in Richland, WA.

## *F.2 Risk Management Approach*

### F.2.1 Risk Management Policy

The Office of Environmental Management states their support for risk management practices in one of their policy statements (See Section F.6 for full policy statement):

"The Policy captures the essential elements of safety and cost in analyzing risks as well as the benefits of a rigorous, systematic analysis. Finally, the Policy acknowledges that risk management is part of sound project management and is designed to enable and enhance the procedures stated in DOE Order 413.3A."

### F.2.2 Effect of Project Complexity / Size on Risk Management

Within the EM's risk management process, almost all steps are consistent regardless of project complexity and size. The risk analysis steps do differ from large to small projects. Smaller projects are not required to undergo quantitative risk analysis, while it is strongly suggested that larger projects undergo quantitative analysis.

### F.2.3 Contingency

The EM guide defines schedule contingency, management reserve, funded contingency, and unfunded contingency.

> **Schedule Contingency** – Extra time in the project that is added to cover the loss of time in the event a risk is realized.
> **Management Reserve** – Extra cost added to the project to cover the use of additional funds to cover realized risks. Management reserve also includes the assessment of opportunities. The management reserve covers "known unknowns." As such, the use of management reserve is tracked closely throughout the construction process.
> **Funded Contingency** – This is extra money held at the site office to cover events that will have an adverse impact on the cost or schedule of a project. This amount should not exceed the 80% confidence interval of the Monte Carlo simulation estimate.
> **Unfunded Contingency** – This cost is to address risks retained by the DOE. These risks cannot be carried by either the EM or by the contractor. A specific request must be made to the DOE to access these funds for a given project.

## F.2.4 Risk Management

The DOE – EM utilizes a fairly linear progression of risk management (as opposed to a cyclical risk management strategy). The EM guide summarizes the process as shown in Figure F-1.

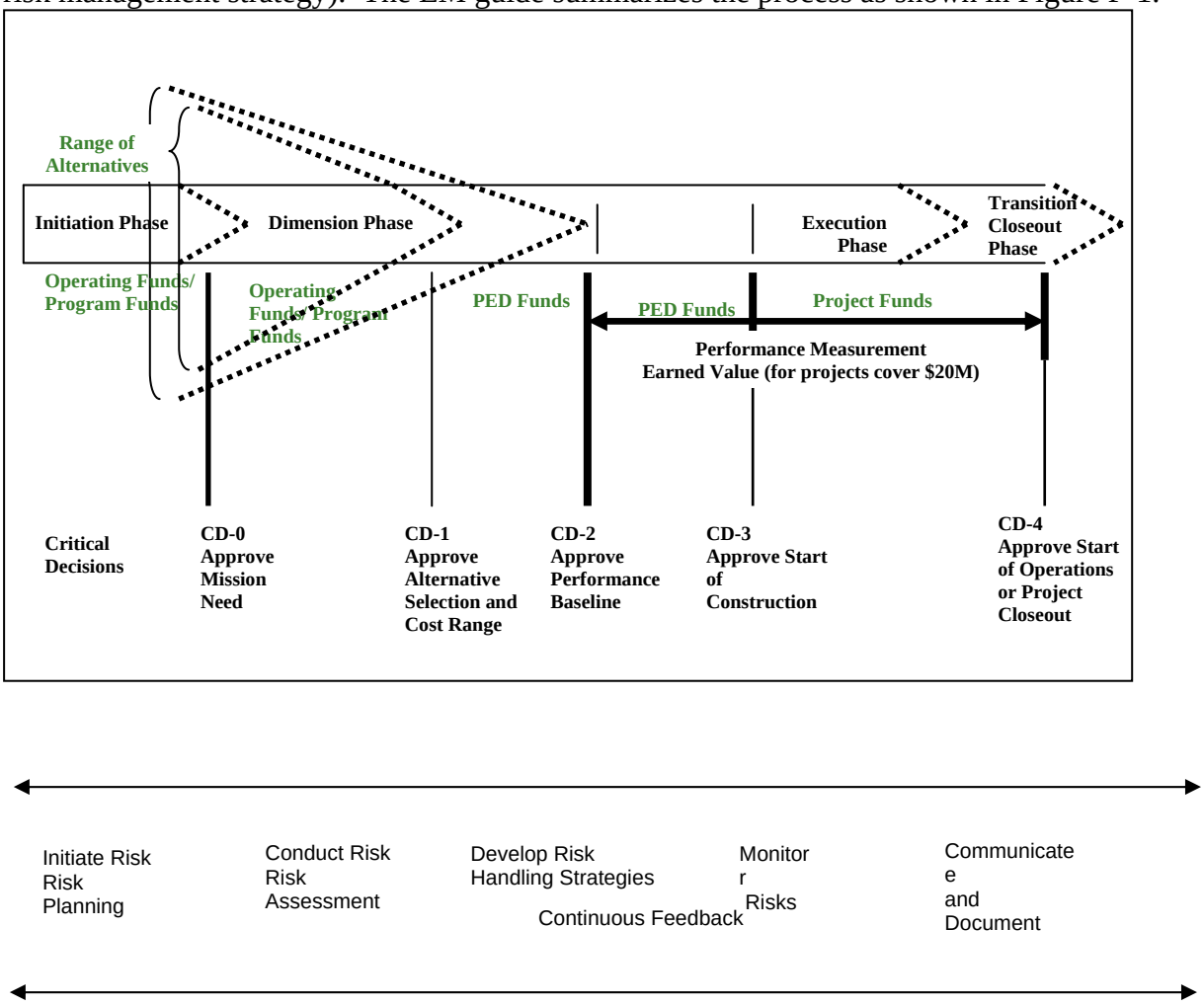



**Figure F-1. DOE EM Risk Management Process**

Figure F-2 depicts the steps used in the risk analysis process.

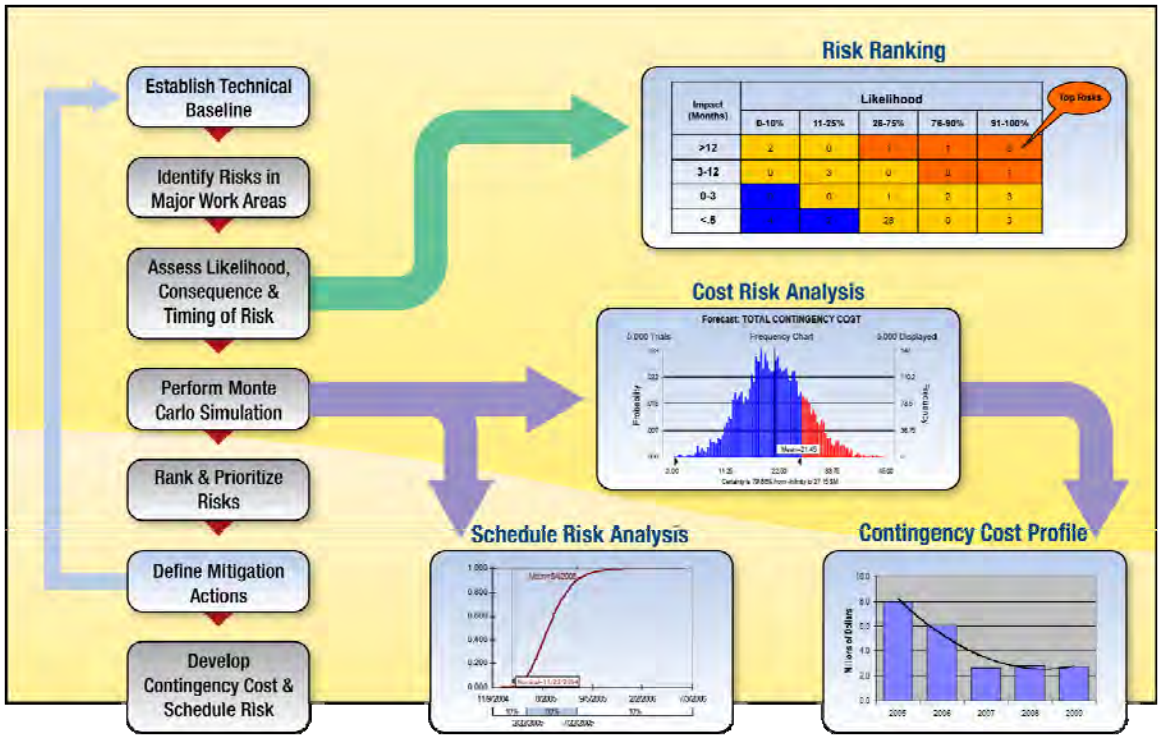



**Figure F-2. DOE EM Risk Analysis Process Steps**

1. *Risk Identification*
   Risk identification is a continuous step throughout the project lifecycle. Risks are identified by brainstorming, interviews, and diagramming techniques. The goal is to involve as many project personnel as possible to identify risks. Once identified, a risk should be categorized within a "Risk Breakdown Structure" or "RBS." An example RBS is shown in Figure F-3. The goal is to take the risk register beyond a simple list of risks and explore the relationships of different risks. Below is an example of the hierarchy of an RBS:

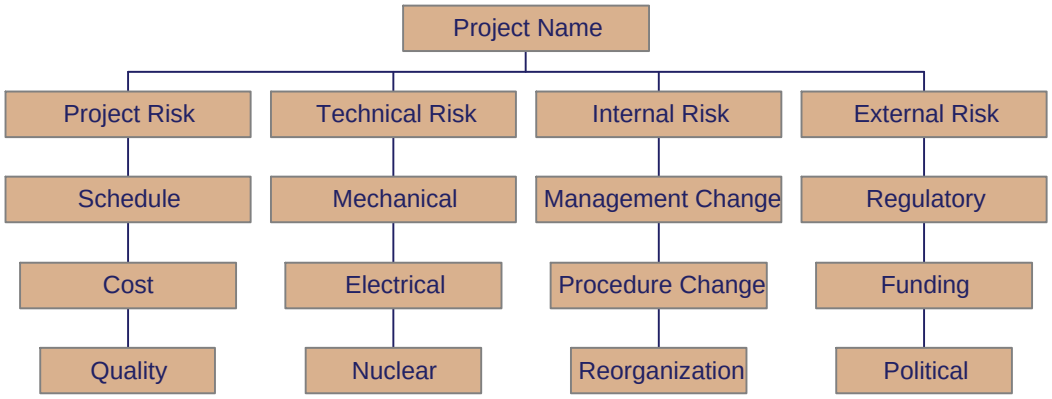



**Figure F-3. DOE EM Example Risk Breakdown Structure**

As a foundation for the risk breakdown structure, and possibly as a starting point for brainstorming risks, the DOE – EM defines five categories to apply to risks: project (including scope, cost, and schedule), technical, internal, external, and opportunity.

2. *Qualitative Risk Analysis*
   All projects are required to undergo qualitative risk analysis. Standard methods are used to identify risks with the greatest potential impact and likelihood of occurrence. Table F-1 is an example of a matrix used to classify risks.

**Table F-1. Risk Matrix Classification**

| | Consequence | | | | | |
|---|---|---|---|---|---|---|
| Probability | Federal Matrix | Negligible | Marginal | Significant | Critical | Crises |
| | | Minimal or no consequence. Costs within allocated funding. | Small reduction in meeting strategic objectives. Marginally exceeds allocated funding or schedule. | Significant degradation in meeting strategic objectives, allocated funding, or schedule. | Strategic goals and objectives not achievable. Serious threat to mission need. | Program cannot be completed. Catastrophic threat to mission need. |
| | Very Likely >80% | Low | Moderate | High | High | High |
| | Likely 40% to 80% | Low | Moderate | High | High | High |
| | Unlikely 10% to 40% | Low | Low | Moderate | Moderate | High |
| | Very Unlikely <10% | Low | Low | Low | Low | High |

The Office at Richland uses the guides found in Section F.5 to convert the quantitative risk analysis to the qualitative risk analysis.

3. *Quantitative Risk Analysis*
   DOE – EM uses Monte Carlo simulations for their quantitative analysis. Sources of judgment used to identify risks are "subject matter expert judgment, actual cost and time impact, historical records, Delphi Techniques, interviewing staff, crafts, retirees, and others familiar with similar work efforts." DOE – EM also attaches a text to their analysis listing all assumptions of their Monte Carlo simulation.

4. *Risk Planning*

DOE - EM only applies risk planning or "risk handling" to risks with medium or high classification. DOE has several different risk handling strategies that include: acceptance, avoidance/exploit, mitigation/enhance, and transfer/share. As tools for this risk planning, DOE – EM suggests the use of pictorial modeling, fish-bone diagramming, string diagramming, "what-if" analysis systems modeling, and time-specific sequencing simulation modeling.

5. *Risk Monitoring and Control*
   Each project or program should have a risk monitoring process specifically designed to give decision makers the proper information at appropriate intervals. Each risk is assigned a risk owner who is responsible for monitoring and controlling that risk. However, in order to make a change to the risk register or to access management reserve or unfunded contingency, the risk owner must bring the changes to the attention of the integrated project team.

6. *Risk Documentation*
   Documents included in the risk plan are the Risk Management Plan, Risk Register, and the Risk Management Communication Plan. DOE – EM requires that a risk report be filed at a minimum of once every month. The integrated project team conducts a quarterly review of the risks listed in the register. Figure F-4 shows the complex relationships between the various risk analyses tools used within the organization. Figure F-5 on the following page depicts an integrated program and project risk management process flow gap analysis. Both of these figures are examples demonstrate that DOE has a very structured process.

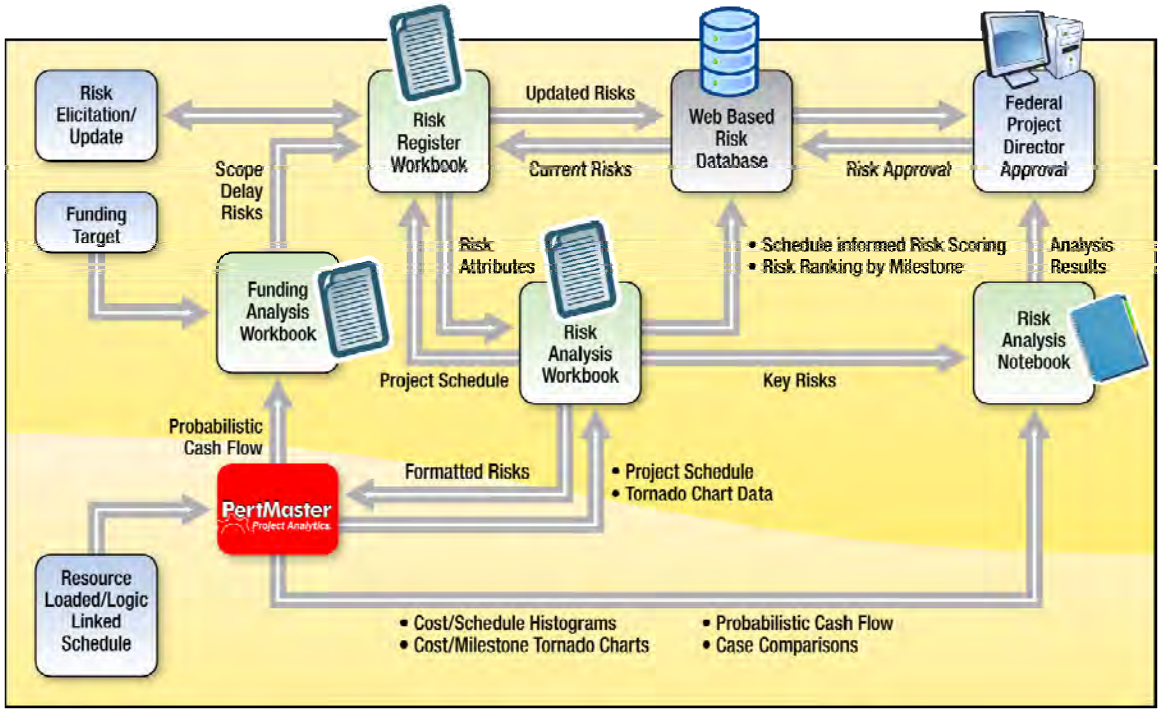



**Figure F-4. Integration of Risk Analysis Tools in Project Management Structure**

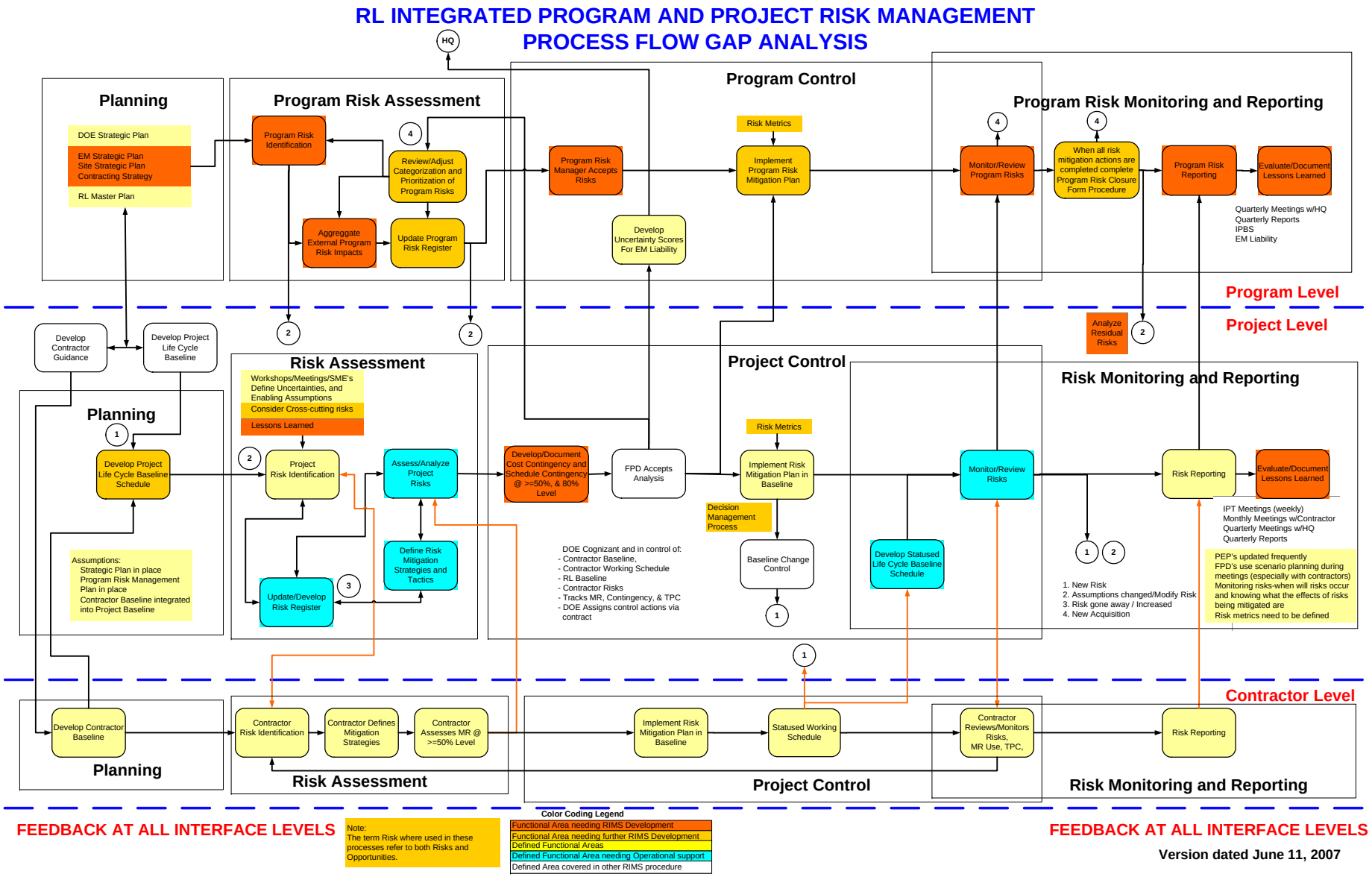



**Figure F-5. Integrated Program and Project Risk Management Process Flow Gap Analysis**

### F.2.5 Communication of Risk Management Plan

hough the communication plan is optional for a DOE project, the guidelines for it are extensive. Table F-2 is an outline for the DOE risk communication guide.

**Table F-2. Risk Management Plan**

- I. Background and Purpose
  - a. Responsible Office and Key Individuals
  - b. Necessary Oversight and Signatory Responsibilities
- II. Project Review
- III. Target Objectives
  - a. Development of Standard and As Needed Communication Formats and Messages for Identified Risk Stakeholders
  - b. Development of Communication Flow Diagrams
- IV. Strategy
  - a. Statement of Overall Strategy Elements
  - b. Assumptions and Uncertainties
  - c. Process for Validating and Verifying Assumptions and Uncertainties
- V. Key Target Stakeholders
  - a. Identification Process
  - b. Known Stakeholders
- VI. Identified Communication Channels for Each Target Stakeholder Grouping
  - a. Process for Identifying Key Points of Contact
    - i. Primary Point-of-Contact
    - ii. Back-up Point-of-Contact
  - b. Process for Identifying Key Points of Contact for Emergency Communications
- VII. Key Messages
  - a. Site Communication Requirements
    - i. Goals and Objectives
    - ii. Processes
  - b. When Certain Communications may be Issued
  - c. Definition of Various Modes of Communication
  - d. Situational Requirements
  - e. Definition of Special Circumstances
  - f. Definition of Special Approval Channels
  - g. Communication Development
    - ii. Who Should be Involved in Construction of Communications
    - iii. Who Should Review
  - h. Standard Messages
  - i. Key Interfaces
  - j. Communication Distribution and Feedback
- VIII. Roles and Responsibilities
  - a. Identify All Parties
  - b. Responsibility Assignment Matrix
- IX. Overview Metrics for Responsible Persons
  - a. Message Approval Process
- X. Revisions and Updates

## *F.3 Conclusions*

While the DOE EM's risk management approach is fairly straight forward, the steps themselves are rather complex and regimented. The process varies little from project to project, given the similar magnitude of scope. The use of risk management in the agency is of paramount importance given that there is more at risk than just money.

The remainder of this case study presents examples of DOE EM risk assessment tools and risk assessment policies and protocols.

### F.3.2 DOE EM Risk Assessment Tools

Figures F-6 through F-8 are examples of various risk assessment tools used by the DOE EM.

**Likelihood Criteria**

| | |
|---|---|
| Very Very Low (VVL) | 0-1% |
| Very Low (VL) | 1-10% |
| Low (L) | 11-25% |
| Moderate (M) | 26-75% |
| High (H) | 76-90% |
| Very High (VH) | 91-100% |

**Schedule Consequence Criteria**

| | |
|---|---|
| Very Low (VL) | 0-0.5 months |
| Low (L) | 0-3 months |
| Moderate Low (ML) | 3-6 months |
| Moderate Moderate (MM) | 6-9 months |
| Moderate (M) | 3-12 months |
| Moderate High (MH) | 9-12 months |
| High (H) | 12-18 months |
| Very High (VH) | 12-24 months |

**Figure F-6. Probability and Impact Assessment Criteria Example**

**PID**

Likelihood vs. Schedule

| Likelihood Scale | VL 2 | L 3 | ML 4 | MM 5 | M 6 | MH 7 | H 8 | VH 9 |
|---|---|---|---|---|---|---|---|---|
| VH 1 | M | MH | H | H | H | VH | VH | VH |
| H | M | M | MH | H | H | H | VH | VH |
| M | L | L | M | M | M | MH | H | H |
| L | VL | L | L | L | L | M | M | MH |
| VL | VL | VL | L | L | L | L | M | M |
| VVL | VL | VL | VL | L | L | L | M | M |

Impact Scale (Schedule)

**Priority Ranking**

Using qualitative risk score

| Risk Score | L 2 | M 3 | H 4 |
|---|---|---|---|
| VH 1 | H | H | H |
| H | M | H | H |
| MH | M | M | H |
| M | M | M | M |
| L | L | L | M |
| VL | L | L | M |

Urgency

**Priority Ranking**

Using schedule-informed risk score

| Risk Score | L 2 | M 3 | H 4 |
|---|---|---|---|
| CRITICAL 1 | M | H | H |
| SIGNIFICANT | M | M | H |
| WATCH | L | M | M |
| DEMINIMIS | L | L | M |

Urgency

| Urgency | Desc |
|---|---|
| H | Critical-path activity starts this fiscal year |
| M | Activity starts within next 3 fiscal years |
| L | Activity starts after next 3 fiscal years |

**PID**

Likelihood vs. Cost

| Likelihood Scale | VL 2 | L 3 | M 4 | H 5 | VH 6 |
|---|---|---|---|---|---|
| VH 1 | L | M | H | VH | VH |
| H | L | M | H | H | VH |
| M | L | M | M | H | H |
| L | L | L | M | M | H |
| VL | VL | L | L | M | M |
| VVL | VL | VL | L | L | L |

Impact Scale (Cost)

**Figure F-7. Probability and Impact Assessment Matrix Example**

| Likelihood Lookup Table | | | |
|---|---|---|---|
| | range Min % | range Max % | midpoint |
| VH | 91.0 | 100.0 | 95.0 |
| H | 76.0 | 90.0 | 83.0 |
| M | 26.0 | 75.0 | 50.0 |
| L | 11.0 | 25.0 | 18.0 |
| VL | 1.0 | 10.0 | 5.0 |
| VVL | 0.0 | 1.0 | 0.5 |
| N | 0.0 | 0.0 | 0.0 |
| Linked | | | |

| Impact Lookup Table (Schedule, Cost, Performance) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Years = (months / 12) | | | Months | | | Days = (Months * 20) | | |
| | Min | ML | Max | Min | ML | Max | Min | ML | Max |
| VH | 1.00 | 1.50 | 2.00 | 12.0 | 18.0 | 24.0 | 240 | 360 | 480 |
| H | 1.00 | 1.25 | 1.50 | 12.0 | 15.0 | 18.0 | 240 | 300 | 360 |
| MH | 0.75 | 0.86 | 1.00 | 9.0 | 10.5 | 12.0 | 180 | 210 | 240 |
| M | 0.25 | 0.63 | 1.00 | 3.0 | 7.5 | 12.0 | 60 | 150 | 240 |
| MM | 0.50 | 0.63 | 0.75 | 6.0 | 7.5 | 9.0 | 120 | 150 | 180 |
| ML | 0.25 | 0.38 | 0.50 | 3.0 | 4.5 | 6.0 | 60 | 90 | 120 |
| L | 0.00 | 0.13 | 0.25 | 0.0 | 1.5 | 3.0 | 0 | 30 | 60 |
| VL | 0.00 | 0.02 | 0.04 | 0.0 | 0.3 | 0.5 | 0 | 5 | 10 |
| N | 0.00 | 0.00 | 0.00 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 |
| Linked | | | | | | | | | |

| Cost Lookup Table | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Millions of Dollars | | | Thousands of Dollars | | | Real Dollars | | |
| | Min $ | ML $ | Max $ | Min $ | ML $ | Max $ | Min $ | ML $ | Max $ |
| VH | 100.00 | 350.00 | 500.00 | 100,000.00 | 350,000.00 | 500,000.00 | 100,000,000.00 | 350,000,000.00 | 500,000,000.00 |
| H | 10.00 | 60.00 | 100.00 | 10,000.00 | 60,000.00 | 100,000.00 | 10,000,000.00 | 60,000,000.00 | 100,000,000.00 |
| M | 1.00 | 6.00 | 10.00 | 1,000.00 | 6,000.00 | 10,000.00 | 1,000,000.00 | 6,000,000.00 | 10,000,000.00 |
| L | 0.10 | 0.60 | 1.00 | 100.00 | 600.00 | 1,000.00 | 100,000.00 | 600,000.00 | 1,000,000.00 |
| VL | 0.00 | 0.05 | 0.10 | 0.00 | 50.00 | 100.00 | 0.00 | 50,000.00 | 100,000.00 |
| N | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Linked | | | | | | | | | |

**Figure F-8. Probability and Impact Assessment Results Example**

## F.3.3 DOE EM Example Risk Management Policy and Protocol

The following is an example of risk management policy that captures the essential elements of safety and cost in analyzing risks as well as the benefits of a rigorous, systematic analysis. The policy acknowledges that risk management is part of sound project management and is designed to enable and enhance the procedures stated in DOE Order 413.3A.

RISK MANAGEMENT POLICY STATEMENT

1. PURPOSE AND SCOPE. The EM Risk management Policy strengthens accountability in project management decision-making processes and is designed to enhance and build upon DOE Order 413.3A by providing the platform to establish a formal, organized process to plan, perform, assess, and continually enhance risk management performance.

2. POLICY. It is the policy and practice of EM to conduct its operations in a manner that promotes overall risk planning including the assessment (identification and analysis of), implementation (or mitigation actions), monitoring, and documentation of risk. The objective of this policy is to safeguard the interests of the public, the environment, the worker, and the government during the conduct of operations in meeting the EM mission objectives. It is also the objective of this policy to provide an accurate reflection of the bounding cost and schedule contingency requirements of the EM field operations.

   To accomplish this objective EM has established there implementing policy goals:

   a. Risk management policy, procedure, and processes apply to all work done by EM, its field offices, contractors, and subcontractors.
   b. The risk planning process is to be applied and documented in a step-wise process. All documentation is to be incorporated into the appropriate project management documentation for the specific work to be done at the specific work site and is to be updated semi-annually and reviewed at least monthly depending upon specific regulatory or other site specific changes or risk factor changes.
   c. The first strategy to be taken in the handling of any identified risk is to take actions to prevent or mitigate risk factors if it can be accomplished within reasonable cost/benefit analysis within the approved funding profile.
   d. All risks identified by the field office or contractors must be monitored for change by the designated risk owner to protect the worker, the public, and the environment.

**PROTOCOL FOR EM CLEANUP PROJECT PERFORMANCE BASELINES AND CONDUCTING THE EXTERNAL INDEPENDENT REVIEW OR THE EM INDEPENDENT PROJECT REVIEW**

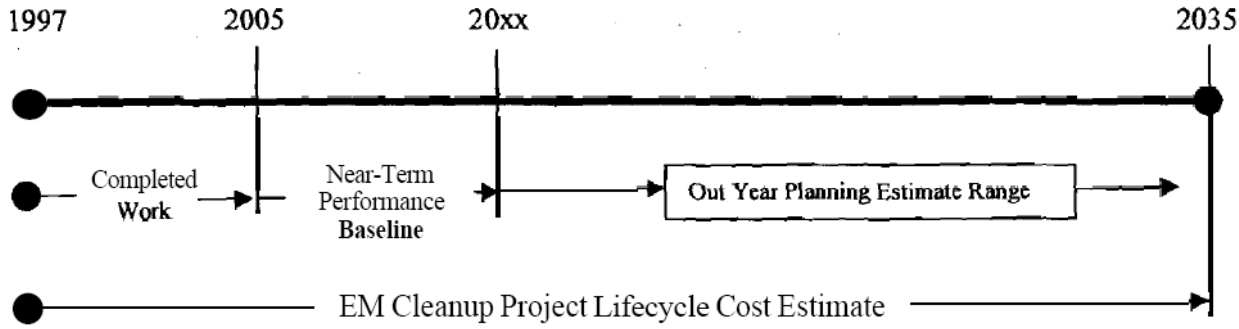
This Protocol for EM Cleanup Project will cancel the June 30, 2005 Protocol for EM Cleanup Projects in its entirety with the one exception of open EIR s. In FY 2003 EM decided to "projectize" the Project Baseline Summary (PBS) activities required to complete the EM mission at each DOE site. In most cases EM defines a Cleanup Project as the entire PBS; however, in some cases the project maybe a portion of one PBS or portions of multiple PBSs. It is EM'S responsibility to clearly define the composition of each project prior to the on site review. EM cleanup projects will apply the project management principles and policies described in DOE Order 41 3.3A in a tailored manner. Unlike the line-item capital asset projects that require an OECM validated performance baseline prior to requesting construction funds, EM'S cleanup projects were already in the CD-3 execution phase when EM decided to "projectize" them and are funded under operations budget accounts. Critical Decision (CD)-0 and CD-1 for these on going projects were waived because they were already in the execution phase. As new Cleanup Projects are created, a CD-0 and CD-1 approval by EM-1 as the designated Acquisition Executive (AE) utilizing the Environmental Management Acquisition Advisory Board (EMAAB) process will be required; however, for designated projects, the Deputy Secretary or Under Secretary for Energy may be the AE. These projects range from small projects with few risks and well defined scopes of work that can be completed in a short period of time with reasonable costs; to complex first-of-a- I kind projects that have many unknowns, a longer schedule, and substantial costs; to I projects that have undefined scopes of work with many risks and are scheduled for many years in the future at significant costs; to straight forward operating projects. Because of the diversity of projects in the EM portfolio it is impossible to apply a single approach to I validating baselines.

The Office of Engineering and Construction Management and the Office of Environmental Management developed &e initial protocol for conducting external independent reviews where the near-term baseline (scope that was under contract) would be validated and the remaining portion of the lifecycle cost would be considered reasonable. The results of those reviews were mixed, with fairly good success in validating the near-term baseline and less than expected in declaring the remaining portion of the lifecycle cost reasonable.

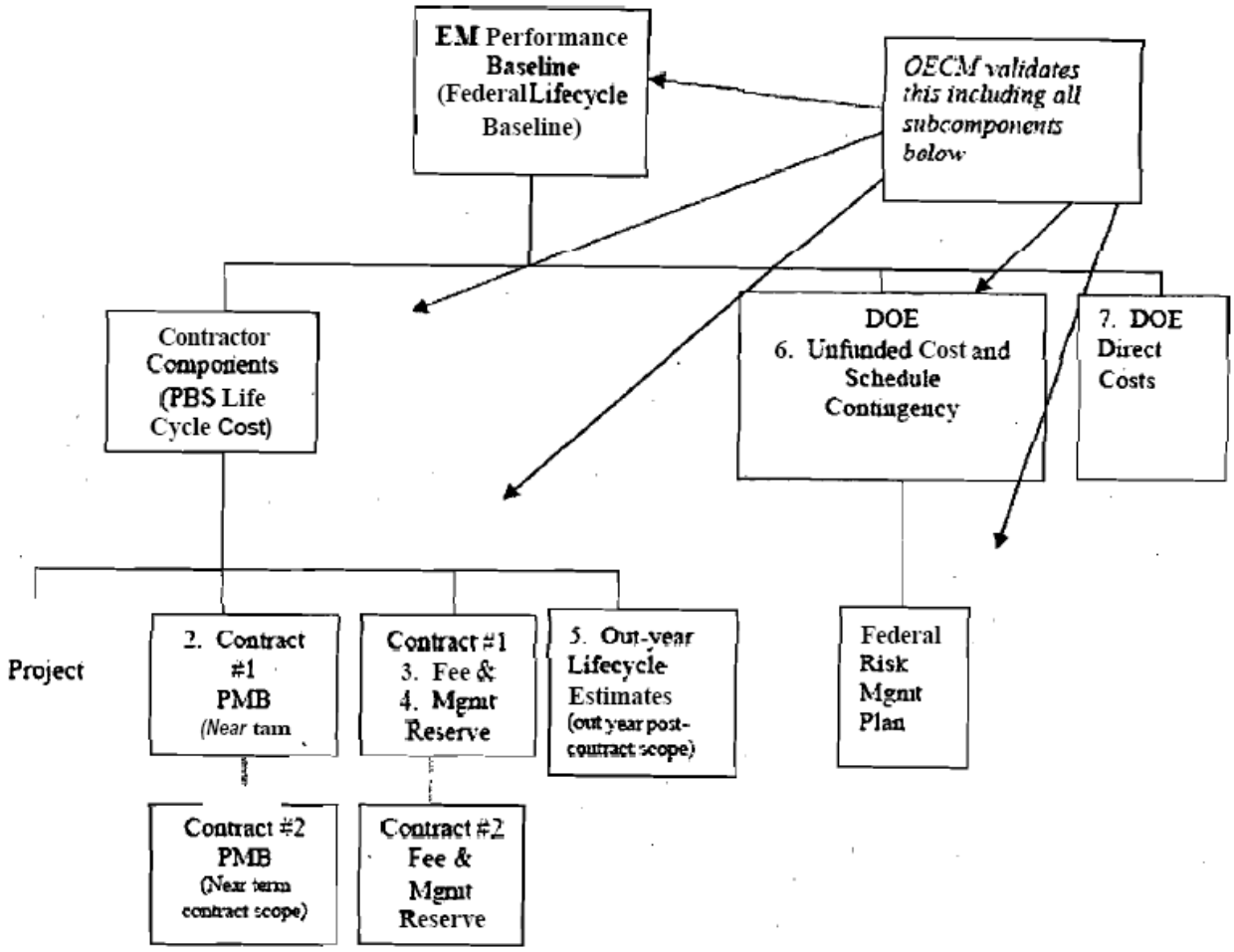
Discussions with the Deputy Secretary on EM Cleanup Projects prompted a change in the protocol for the execution of Cleanup Projects under DOE Order 413.3A. The protocol for EM having a near-term baseline that is reviewed for validation and a lifecycle estimate that is reviewed for reasonableness will continue; however, the approvals and the content for them will be modified. For CD-2, CD-3, and CD-4, the Acquisition Executive thresholds are as follows: the Deputy Secretary utilizing the Energy Systems Acquisition Advisory Board process serves as Secretarial Acquisition Executive (SAE) for Major System Cleanup Projects with a near-term baseline of $lB or more or other EM Cleanup Projects designated as Major System Cleanup Projects, and the Assistant Secretary for Environmental Management using the EMAAB process serves h AE for Cleanup Projects with a near-term baseline below $1B. A new CD-0 and CD-I approval will not be required when the next phase of the lifecycle estimate is advanced into a new near-term baseline; rather, a new CD-213 approval will be required after the EIR or IPR is

completed and the near-term performance baseline is validated. As part of each new CD-213, key documentation such as the Project Execution Plan and Acquisition Strategy must be updated, reviewed, and approved. A CD-4 approval will be required when each near term baseline is completed. The CD-4 documentation identified in DOE 0 413.3A may be required for each CD-4.

**Lifecycle of an EM.Cleanup Project**




**Components of the EM Performance Baseline which are validated by OECM**



Lifecycle Cost (LCC) Estimates for EM Cleanup Projects will be comprised of three components:

**a.) <u>Completed Work (The Prior Year Actual Costs).</u>** EM has established 1997 as the starting point for all Cleanup Projects. No costs before 1997 should be included in this number. The ending year will be the year before the near-term baseline begins. The timeframe of the completed work will increase each time the next near-term baseline or phase (5 or more years) of the cleanup project lifecycle is established and validated. In order to focus on the performance of the current near-term baseline, the performance measurement data including the cost and schedule variances and the variance at completion at the end of the near-term baseline will be archived in a historical file and not included as part of the near term baseline variance reporting in either the EM Integrated Planning, Accounting, and Budgeting System (IPABS) or the OECM Project Assessment Reporting System (PARS). Each near-term baseline will have a new baseline to report performance against. Adjustments will not be allowed annually. The prior year actual costs are not a factor in determining who will serve as the AE or in determining if an EIR or IPR will be performed.

**b.) <u>The Near-Term Performance Baseline (e.g., Near-Term Baseline).</u>** The near-term performance baseline for Cleanup Projects will be for a minimum of five years or for the period of performance for the current contract if it exceeds five years. For projects which are scheduled to be completed within a few years (UP to 3 years) after the five year period, the project validation will include the entire remaining out years. In the case where less than 5 years remain on the current contract, the near-term baseline should include the current contract plus the expected period of performance for the next contract. For Cleanup Projects with durations of five years or less, the entire project will be reviewed. In all cases except possibly the tail end of the project lifecycle, the near-term baseline will start at the beginning of a fiscal year and complete at the end of a fiscal year. When the proposed near-term period is not completely covered by a contract, EM will be responsible for developing summary level planning packages for those years not covered by the contract, and the entire near-term period will be included in the EIR or IPR. Once the contract is awarded and a detailed near-term performance baseline is developed, a follow-up limited EIR or IPR will be required if it exceeds the previously validated federal near-term performance baseline costs by 15 percent or more, increases schedule by a year, or modifies scope significantly. The near-term performance baseline includes fee and all costs associated with executing the project within the applicable (e.g., 5 year) window, even if the funding for the fee is in the next fiscal year budget which may be outside the near-term baseline. The fee is reported outside the performance measurement baseline but included in the near-term performance baseline. Because the number of years included in the near-term baseline can vary for each project, the final decision on the scope of the EIR including the length of the near-term baseline will be based on a negotiated agreement between OECM and EM. Near-term baselines will be based on target funding levels which are part of the current approved strategic funding plan (e.g., Five-Year Plan) issued by EM-30. An EIR will be conducted on the near-term baseline if its cost is equal to or greater than $250M, otherwise an IPR will be conducted. Data will be reported in PARS through IPABS and will be used in developing the

Monthly Project Status Report for the Deputy Secretary. The AE must approve CD-213 for the near-term baseline within 6 months after OECM issues a memorandum validating the near-term performance baseline or the validation will be considered void. The goal will be to provide a draft EIR report within 30 days after the on-site visit is completed. Corrective actions plans and closure of the actions will be the joint responsibility of EM and OECM. Directed changes will be addressed thru the baseline change process with EM being responsible for approving those baseline changes, ensuring they are appropriately documented, and incorporating them into the near-term performance baseline in a timely manner. A directed change is a change imposed on a specific EM cleanup project by a source external to DOE (e.g., Congress, OMB, Regulator, etc.) that affects the near-term baseline. Examples include changes in funding, DOE policies or directives, and regulatory or statutory requirements. A directed change will require a limited EIR or IPR if it affects the near-term performance baseline cost by 15 percent or more or delays scope by more than one year. For EM Major System Cleanup Projects an Independent Cost Estimate should be developed or an Independent Cost Review should be performed as part of the OECM near-term performance baseline validation EIR. An Independent Cost Estimate should be performed where complexity, risk, cost, or other factors create a significant cost exposure for the Department.

**c.) <u>The Out-Year Planning Estimate Range (OPER).</u>** The OPER is defined as the first fiscal year following the last fiscal year of the current near-term baseline through project completion. If the completion date remains constant, the timeframe of the OPER will decrease each time a new near-term baseline is validated. Verifying the reasonableness of the OPER will be part of either the near-term baseline EIR or IPR. EM-1 will approve the reasonableness of the OPER, and will be responsible for managing, changing and controlling the cost and schedule ranges. The cost and schedule ranges may be adjusted annually based upon changing project or program conditions including directed changes. The OPER is audited annually by an external auditor as part of the external Environmental Liability Audit Review. The OPER will only be reviewed by the EIR or IPR team, when a new near-term baseline review is being performed. The OPER will not be a factor in determining who will serve as the AE. EM will tailor the requirements of DOE 0 413.3A to the OPER but at a minimum include a summary scope of work, a cost and schedule range, a funding profile provided by EM-30, and a robust project and program risk management plan. The amount of details required will be less than the near-term baseline, and may vary from project to project based upon the complexity of the work, ability to define the remaining scope, regulatory drivers, disposition paths, existing or new technology requirements, etc. The scope of the OPER EIR and required documents will be part of the OECM and EM negotiations. The OPER will be reported in IPABS and in the planning section of PARS.

This protocol has been revised to address the concerns raised by the Deputy Secretary; concentrate the EIR review effort on validating the near-term performance baseline; provide for tailoring the DOE 0 413.3A requirements, review plans and criteria for the various types of cleanup projects (soil and groundwater, deactivation and decommissioning, environmental remediation, spent nuclear fuel, solid or liquid waste, operating projects, etc.); and for developing a standard set of expectations for each type of EM Cleanup project.

**Summary Process for Review and Validation of the Near-Term Performance Baseline and Verification of Reasonableness of the OPER**

1. The near-term baseline and OPER for EM Cleanup Projects will have a tailored approach applied for complying with the DOE 0 413.3A requirements.

2. Tailored lines of inquiry and the required documentation will be negotiated between EM and OECM prior to the on-site review.

3. In approving the near-term performance baseline at CD-2, the AE will use the results of either OECM's EIR validation review or the EM IPR of the near-term baseline.

4. An EIR or IPR will be conducted for each near-term baseline and OPER. For efficiency and where sensible, a single EIR or IPR, or possibly a joint EIRIIPR, may be conducted at a site where multiple cleanup projects are presented for validation. This determination will be part of the OECM and EM negotiations. OECM will conduct EIRs of all Cleanup Project near-term baselines that are $250M million or greater. The EIR team will also verify the reasonableness of the OPER.

5. An OECM representative will accompany the EIR team to foster communication between the EIR and project teams, to facilitate the EIR process, ensure the focus remains on the scope of work and timeline, and help resolve issues.
    - In advance of each EIR, OECM and EM will come to an agreement on the scope of the EIR and documentation that will be required.
    - The FPD will be responsible for providing all required supporting program/project documentation to OECM and the. EIR team 5 weeks in advance of the on-site review. No significant changes to the documentation should be made after it is submitted, nor should updated documentation be presented to the EIR team at the onsite review.
    - The EIR team will recommend if the project as planned is executable to the scope, cost, and schedule baselines and OECM will make the final determination if the project's near-term baseline can be validated.

6. Each site will develop an integrated project and funds management plan based on a detailed scope of work, cost, schedule, and target funding (budget) profile for the near-term baseline for each PBS and a summary level plan for the OPER.
    - Project near-term baselines must include, but are not limited to, establishing scope, cost and schedule, a resource loaded schedule or equivalent, work breakdown structure, a project execution plan or equivalent, updated Acquisition Strategy, risk management plan, and contingency analysis. Key documents should identify any further tailoring of the requirements contained in DOE 0 413.3A and this protocol. The near-term baseline must be supported with documented basis for cost and schedule. For example EM project baselines must address:

        - Regulatory requirements in addition to technical and safety requirements.

- Risk management through risk identification, analysis, and mitigation. It is the policy and practice of EM to conduct its operations in a manner that promotes overall risk planning including the assessment (identification and analysis of), implementation (or mitigation actions), monitoring, and documentation of risk. The objective of this policy is to safeguard the interests of the public, the environment, the worker, and the government during the conduct of operations in meeting the EM mission objectives. It is also the objective of this policy to provide an accurate reflection of the bounding cost and schedule contingency requirements of the EM field operations.

- Project OPERs must include, but are not limited to, a summary level work breakdown structure, a cost range, a schedule range, a risk management plan, and contingency analysis. Other summary level documents may be available and required based upon the project scope and how well the OPER is defined.

- Both federal and contractor elements of the risk assessment/management plans and contingency analyses (e.g., management reserve, unfunded contingency) will be part of the EIR or IPR.

7. The FPD and the contractor shall use an Earned Value Management System (EVMS) to manage, control, and measure progress and performance. Each contractor's EVMS must be reviewed and certified as compliant with the American National Standards Institute (ANSI) EVMS standard (ANSIIEIA-748- 1998). OECM is responsible for the EVMS certification program. The EIR will perform a limited review of the contactor's EVMS system. If the contractor's EVM system has been certified by OECM, the EIR Team should inform OECM as to whether EVM is being executed per the certified system.

8. The FPD and the contractor shall identify measurable performance outcomes. Performance will be measured and performance metrics provided monthly to the I appropriate executive official. Executive-level management reviews will be conducted for all projects quarterly to facilitate early identification of problems and to focus attention on solutions.

9. The FPD shall report cost and schedule performance data into PARS against the validated near-term baseline within 30 days after the near-term baseline has been validated. In the case where a near-term baseline has not been validated, the FPD shall report cost and schedule performance data into PARS against the EM controlled near-term baseline.

10. In the monthly assessment of project performance OECM will utilize all available information to make its assessment including but not limited to:
    - PARS data
    - Data Validity (including timeliness of entry)
    - Quarterly Reports
    - Project Reviews (EIRs & IPRs)
    - Discussions with Program and Project Managers
    - Other Information (e.g.DNFSB)

Projects will be assessed as:

- **Green** if the project is expected to meet its near-term cost/schedule performance baseline.
- **Yellow** if the project is at risk of breaching its cost/schedule performance baseline; and
- **Red** if the project is expected to breach its cost/schedule performance baseline.

## Attachment

### EIR Scope for EM Cleanup Projects (in support of CD-213) and Required Documentation

The OECM EIR conducted on EM'S cleanup project near-term baselines will cover five broad topical areas-Technical Scope, Schedule, Cost, Risk Management, and Project Management. Both the scope and required documentation may vary for specific operating projects depending on the types of activities that compose the project. This is in close conformance with the structure of the EM Project Definition Rating Index (PDRI). The verification of the reasonableness of the OPER will be based on similar summary level documents and information. The OPER will not be expected to meet the details required by the PDRI. Listed under each of the five topical areas are primary lines of inquiry. The review plan developed by the EIR Team, coordinated with EM and the project team, and approved by OECM for each EIR will clarify and expand upon the particular lines of inquiry in each topical area based on the scope of each project being reviewed.

**Technical Scope**

- Completeness of work scope definition; enables identification and quantification of risks
- Appropriateness of major methods utilized to achieve results
- High-level and regulatory requirements, key assumptions, end state vision, program and strategic initiatives, key agreements/decisions, Mission Need; key performance objectives
- Security, safety and hazards; DNFSBNRC issues
- Facility - operations, D&D, construction; Remediation - soil, burial grounds, groundwater

**Schedule**

- Integrated project schedule consistent with the scope and cost estimate
- Detailed basis for the schedule duration
- Reasonableness of key schedule assumptions; relationship between PBSs
- Consistency of resource loaded schedule with the near-term baseline
- Reasonableness of schedule relative to the critical path and activity logic relationships
- Schedule contingency appropriate for the risks recognized

**Cost**

- Independent Cost Review of the near-term cost and assessment of the remaining lifecycle
- Basis for the cost estimates; comparison to parametric estimates and benchmark analyses
- Reasonableness of key cost assumptions
- Cost contingency appropriate for the risks recognized
- Consistency of project funding profile with resource-loaded schedule
- Inappropriate classification of discrete work as level-of-effort work

**Risk Management**

- Project risks identified, defined, prioritized, and analyzed
- Risk classification (high, medium, low) and quantification (probability and consequence)
- Avoidance and mitigation efforts incorporated in the baseline
- Risks analyzed and accounted for as MR/contingency in near-term and lifecycle baselines
- MR/Contingency based on quantitative risk analysis provides appropriate level of confidence

**Project Management**

- Management plans are valid, credible, and appropriate for type of project/operation
- Execution planning and staffing adequate and consistent with DOE requirements/guidance
- Organization and staffing plans/levels; appropriate disciplines included in IPT
- Identify any deficiencies in the IPT that could hinder successful execution of the project.
- Management controls, processes, procedures, responsibilities, authorities and reporting
- If EVMS not appropriate, assess the adequacy of an alternate project control system.
- Acquisition strategies and plans
- Performance management (e.g., performance metrics)

**Required Documentation**

In general, the following documents or equivalents are provided as a guide to determine which ones will be required for the EIR or IPR team to perform its review. Starting with the meeting between OECM, EM and the project team to define the scope of the EIR and continuing through the development of the review plan, OECM and EM will identify the appropriate documents that must be provided to the EIR team. The team may request other associated material to ensure a complete and accurate review is performed.

- Detailed Schedule with Resources for that portion of the near-term baseline that is under contract (resource-loaded schedule or equivalent documentation which links technical scope to cost resources to schedule),
- Summary Schedule with Resources for that portion of the near-term baseline that is not under contract but developed by EM.
- Detailed Cost Estimate of "near-term" activities for each project with supporting documentation for cost basis e.g. Vendor1subcontractor quotations for selected work items (normally provided at the on-site meeting); Escalation rates and Escalation Analysis;
- Critical Path Schedule for each cleanup project;
- Target Funding Profile provided by EM-30
- Baseline Change Control Process description;
- System Functions and Requirements Document (e.g., "Design-to" requirements, Design Criteria - if applicable)
- Preliminary Design Drawings and performance specifications (if applicable)
- Results of and Responses to Preliminary Design Reviews (if applicable)
- Start-up Test Plan (if applicable)
- Hazards Analysis (if applicable)
- Risk Management Plan/Assessment (both federal and contractor)
- Management Reserve/Contingency analysis
- Acquisition Strategy
- Final Design Drawings and Specifications (if applicable)
- Results of and Responses to Site Final Design Review (if applicable)
- Construction Planning Document (if applicable)
- Current Contract (Scope of Work)
- Key Performance Objectives and other Performance Metrics (e.g., EM Gold Chart)

- Regulatory Compliance Plan (or equivalent) including Requirements, Processes and Status
- EM Liability Audit and Unfunded Contingency for Site
- Safety Documentation including Safety Validation Report (if applicable)
- Project Execution Plan, Performance Management Plan, Annual Work Plan, and/or equivalent documentation
- Results of previous reviews and Corrective Action Plan matrix showing resolution of all recommendations from previous reviews (i.e., EIRs, IPRs including PDRI results, Independent Cost Estimates/Reviews ,other independent reviews)
- IPT Charter, FPD appointment document, program/project management structure
- Most recent monthly reports (Three Months)
- Value Management/Engineering Report
- QA Plan and ISMP
- NEPA documentation
- Regulatory Consent Orders and Agreements
- Recent correspondence with DNFSB and/or USNRC identifying any issues or concerns and corrective actions taken or planned, if applicable.
- Complete WBS and WBS Dictionary
- Critical Decision approval documentation
- Sustainable environmental stewardship plan

Note: In advance of each EIR, the FPD shall provide, through EM headquarters all required documents in support of the EIR.

# Appendix G: FHWA Case Study

***FHWA Construction Management Expert Task Group***
***Risk Management Workshop***
***Approach to Risk Management***

## *G.1 Introduction*

In May 2004, a delegation of U.S. officials from the Federal Highway Administration (FHWA), State departments of transportation (DOTs), industry, and academia visited Canada, Finland, Germany, the Netherlands, Scotland, and the United Kingdom as part of International Technology Scanning Program study was to identify practices that might be evaluated and applied in the United States to improve construction management. One significant finding from the scan was that all of the countries visited had an advanced awareness of risk assessment and allocation techniques that are just now evolving in U.S. highway agencies.

The Highways Agency in England has developed Highways Agency Risk Management (HARM) to model the uncertainties of estimates for cost and time to ensure robust and realistic budgets for publicly financed projects. The Ministry of Transport, Public Works, and Water Management in the Netherlands has developed the Public Sector Comparator and the Public-Private Comparator (PSC/PPC) to assist with these same analyses. Both agencies have dedicated staff that support project teams in identifying and quantifying project risk using probabilistic techniques, and then choosing delivery and contracting strategies that can best control and mitigate these risks. Few U.S. State highway agencies use formalized risk assessment and management programs like HARM and PSC/PPC.

The FHWA formed a Construction Management Expert Task Group (CM ETG) to implement concepts found on the scan. To aid in implementing risk assessment and risk allocation, the CM ETG developed a *Guide to Risk Assessment and Allocation for Highway Construction Management*. The guide raises awareness within the highway construction management community that risk can be understood and managed. The more strategic goal is that DOTs and contractors, as appropriate, will actually identify, access, analyze, mitigate, allocate, and monitor risk in a structured and cooperative way of doing business.

Scan Website: http://www.fhwa.dot.gov/programadmin/contracts/cmetg.cfm
Risk Report: http://international.fhwa.dot.gov/riskassess/

### G.1.1 Research Methods

This case study details the risk management approach currently being promoted in a series of FHWA risk assessment and allocation workshops. It was compiled by combining information gathered from *The Guide to Risk Assessment and Allocation for Highway Construction Management* and the risk workshop training materials. Two of the research team members, Drs. Molenaar and Anderson, are members of the CM ETG and have access to all of the workshop information and training material. Additionally, Dr. Molenaar has been on-site for all of the workshops conducted to date. The case study provides a summary of this information.

### G.1.2 FHWA Risk Assessment and Allocation Workshops Overview

The CM ETG is working to implement the risk assessment and allocation concepts and promote them in the United States. The group is distributing the guide in print and on the Web as part of the initial awareness effort. In addition, the CM ETG is involved in workshops with volunteer DOTs that are evaluating risk management in their project development and construction management organizations. If these efforts prove successful, it is hoped that other DOTs will use these implementation tools as catalysts to examine and adopt risk management in their own organizations. The workshops are designed as a two-day course to train DOTs in risk assessment

and risk management. There workshops were conducted as a pilot effort in fall of 2007 and spring of 2008 to refine the course material and exercises. The following states participated in the pilot projects.

- Texas
- Florida
- Colorado

The high-level workshop goals are:

- To assist DOTs in understanding and applying the principles and processes included in the Risk Guidelines
- To prepare and present workshops based on the Risk Guidelines
- To provide technical assistance to DOTs before, during, and after the workshop
- To prepare other educational documents to meet the needs of Expert Task Group

The first day of the workshop is intended to be instruction, comprised of lectures and simple exercises to provide the participants a fundamental understanding of risk assessment and management methods; and the second day is intended to be a practical application of the methods learned on Day 1 to a specific project, resulting in a preliminary Risk Register and Risk Management Plan for the project. It is expected that the DOT will subsequently use the risk register and risk management plan from the course in a formal monitoring and updating process on that project, and might choose to use this in a subsequent quantitative risk analysis (e.g., to determine appropriate budgets and contingencies). Additionally, the goal is to develop the DOT staff in the first workshop such that they would be able to conduct their own separate workshop (based on the skills they learned in the first workshop). The workshop organizers are also incorporating the results in an FHWA report that will include data from other workshops around the country.

## G.2 FHWA Risk Assessment and Allocation Process

The workshops describe risk management as the formal and structured process of anticipating and planning for potential problems ("risks"), as well as opportunities ("negative risks"), before they occur, to better understand and control project outcomes (e.g., cost and schedule). Understanding the need for adequately anticipating and planning for potential problems, as well as opportunities, is key. Project risk management allows better control of possible project outcomes (e.g., establish realistic budgets and milestones), better control of project outcomes (e.g., minimize cost and schedule), and better allocation of risks to the party that can best control them throughout the project development and construction processes. In order to properly perform this task, establishing a formal and structured, but flexible and efficient, process for project risk management will aid the entire process. A systematic approach to risk management is required, but various methods are available for each step. Different methods might be more appropriate at various stages of project development and each has advantages and disadvantages, but the methods must be compatible with each other.

The risk management process promoted in the workshops is shown in Figure G-1.


**Figure G-1. Risk Management Process**

The workshops teach qualitative risk analysis methods. They also introduce and discuss quantitative risk analysis methods, but due to time constraints they do not teach these quantitative methods. Qualitative analysis allows for influence of the project performance estimate (e.g., contingency) and the rating of each risk (e.g., to guide subsequent risk management). Quantitative analysis quantifies uncertainty in project performance (e.g., total escalated cost) and also quantifies the significance of each risk (e.g., for subsequent risk management cost-benefit analysis).

## G.2.1 Structuring the Project for Risk Management

Structuring a project is − adequately defining the "baseline" project scenario, against which risk and opportunity can be identified and assessed, and eventually managed. Establishing the baseline requires the project to be planned under assumed conditions. The baseline should exclude contingency, conservatism, risk, opportunity, float, etc. Structuring the project for risk management includes seven key objectives. These objectives include:

- defining the "baseline",
- documenting key conditions and assumptions,
- clarifying project scope and strategy,
- developing a common understanding of the project,
- confirming consistency of scope, strategy, and cost and schedule estimates,
- facilitating risk identification and assessment, and
- forming basis for quantitative risk analysis.

It should be noted that the level of detail of project description (including project cost and schedule estimate, as well as design documents) varies with phase of project development, ranging from very simple descriptions (e.g., several item cost and schedule estimates, and simple design sketches) at conceptual planning to very complex (e.g., several thousand item cost and schedule estimates, and extensive design documents) at bid time. The Summary Project Description/Baseline Form that is used during the process of structuring and baseline definition can be seen Figure G-2.

**Summary Project Description**

**Brief Project Description:**
<>

**Scope, Strategy, and Key Conditions and Assumptions:**

- Detailed scope (including alternatives): <>
- Funding: <>
- Design:
  - Design level: <>
  - Structural: <>
  - Geotechnical: <>
  - Drainage: <>
  - Pavement: <>
  - Design deviations: <>
- Environmental:
  - Environmental documentation: <>
  - Wetlands: <>
  - Streams: <>
  - ESA: <>
  - Floodplain: <>
  - Stormwater: <>
  - Contaminated/hazardous waste: <>
  - Section 106: <>
  - 4(f): <>
  - Permitting (incl 404): <>
- Right of way and other agreements
  - Right-of-Way: <>
  - Utilities: <>
  - Railroad: <>
  - Other stakeholders: <>
- Procurement:
  - Delivery method: <>
  - Contract packaging: <>
  - Market: <>
- Construction:
  - Construction access/restrictions (including shifts): <>
  - Maintenance of traffic: <>
  - Construction phasing: <>

**Project Schedule:**
<>

**Cost Estimate:**
<>

**Project Schematics (Scope and Flowchart):**
<>

**Figure G-2. Summary Project Description/Baseline Form**

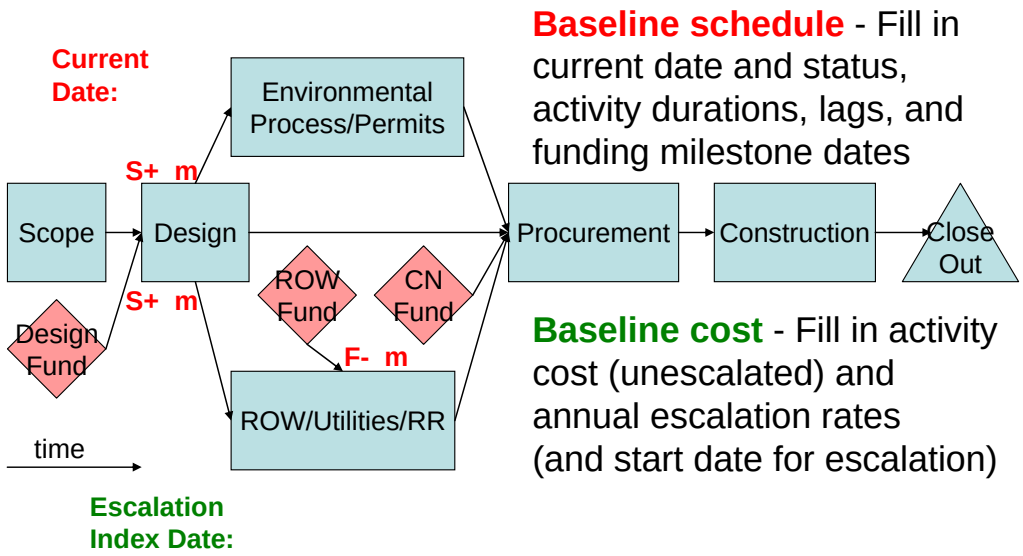



**Figure G-3. FHWA "Standard" Baseline Flowchart**

The FHWA workshop is promoting the use of a "standard" flowchart (see Figure G-3). This flowchart is applicable to traditional single phase/contract design-bid-build procurement, although different project delivery approaches could be approximately described in this format. A more detailed, custom flowchart would be needed for better schedule analysis (especially for other project delivery approaches) and for quantitative risk analysis.

## G.2.2 Risk Identification

Risk identification is the process of identifying, categorizing, and documenting a comprehensive, non-overlapping set of "risks" (potential problems) and "opportunities" (potential improvements). These events that might occur could change "baseline" project cost or schedule. After structuring, this is the critical first step in the risk management process. It should be noted that identification does not involve screening, assessment, or prioritization.

The objective of risk identification is simple:

- Identify, categorize, and document all risks (and opportunities) that could affect the project
- Start "risk register" – comprehensive and non-overlapping list of risks
- Set stage for subsequent steps
    - Risk-factor assessment and risk rating
    - Quantitative risk analysis (if needed)
    - Risk management

To perform the risk identification process, the project team, perhaps facilitated by and including reviewers, should compile a list of all issues of concern. This should start with consolidating

each individual's list of identified issues into one list. One way of performing such action would be with a group brainstorming session. The alternative to the brainstorming session would be to conduct expert interviews and combine the results in a fitting manner. Expert interviews do not provide interaction among experts (which is valuable), and is, therefore, not preferred unless the experts are unavailable for a group workshop. Other more formal techniques are generally used for special applications, e.g., where defensibility is critical and resources are available.

In order to reduce bias during these sessions, it is recommended that the following six steps be followed for a facilitated workshop that includes the project team and the reviewers. The issues should be brought up in the following order:

- Existing concerns of project team
  - "What keeps me up at night is…"
- Existing concerns of project reviewers
  - "What concerns me about the project is…"
- Issues identified while defining "baseline" project
- Judgment and experience from other projects
- Evaluation of project scope, assumptions, conditions, delivery strategy
- Risk checklists and databases

At the end of the project, everything significant that actually happened during the project (changes from baseline) should have been identified during risk identification as possibilities (although not necessarily predicted). Risks should be organized into a list to be sure they are non-overlapping (as well as comprehensive) to avoid double-counting; this does not mean that risks should be mutually exclusive because many risks could occur together.

In order to perform this step correctly, the proper methods and tools should be used. A very detailed, but generic risk check list is shown on the following pages in Figure G-4. The list is also presented in a graphic hierarchical risk breakdown structure in Figure G-5. It should be stressed again that this checklist should be used only at the end of the risk identification process to ensure that no major risks have been overlooked. This risk checklist should not be used in place of a comprehensive risk identification process.

**Generic List of Uncertainties, Risks and Opportunities**

As shown, the items on this list do not form a formal risk register (i.e., this is not a comprehensive list of items for any particular project, and the listed items are not non-overlapping). The list is only intended to serve as a supplemental "checklist" to identify items missed during brainstorming. Identified items then need to be redefined/recast to ensure a comprehensive, non-overlapping set of events in the risk register (adequately considering relationships among items in the list, if any).

Some items shown are really "base uncertainty" (i.e., uncertainty within the base project/estimate assumptions), while the remainder are truly risk and opportunity events (i.e., uncertain conditions and events outside the base assumptions).

**Uncertainty in "Soft" Costs and / or Schedule** (other than identified through other items, and excluding additional costs that result from project delays, which are accumulated directly and additionally through simulation). Fundamental question: Is the base estimate for each in terms of a percentage of construction cost? or a detailed line-item estimate?

- Design completion
- PS&E completion
- Administration costs (owner)
- Oversight costs (regulator)
- Construction management and construction inspection (CEI)
- Project management
- Design support during construction / construction engineering
- Mobilization
- Sales tax
- Financing
- Insurance
- Surety capacity and bonding
- Annual inflation rates (construction, right-of-way, engineering, other)
- Stipends

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities**

**Construction and Constructability**

- ❒ Additional pavement resurfacing
- ❒ Additional geometry re-alignment
- ❒ Uncertainty in construction unit costs (e.g., earthwork)
- ❒ Uncertainty in construction quantities (e.g., bridges, walls)
- ❒ Inadequate staging areas identified for construction
- ❒ Dewatering issues during construction
- ❒ Issues related to tunnel construction procedures (see also tunneling under Geotech)
- ❒ Issues related to other construction procedures
- ❒ Problems with or uncertainty in construction sequencing / staging / phasing / construction duration
- ❒ Maintenance of Traffic (MOT) / Work Zone Traffic Control (WZTC) Issues
    - o Labor for assumed plan if plan is adequate
    - o Proposed plan is not adequate
    - o Issues related to detours
- ❒ Difficult or multiple contractor interfaces
- ❒ Uncertainty in structure demolition sequence and method
- ❒ Force Majeure during construction (earthquake, tornado, etc.)
- ❒ Safety issues (personnel, adjoining structures)
- ❒ Material reuse, removal, restoration
- ❒ Material, labor, and/or equipment procurement delays
- ❒ Condition of existing structures (repair required?)
- ❒ Accidents/incidents during construction (traffic/collapse/slope failure/vandalism)
- ❒ Critical equipment failure
- ❒ Excessive scour or flooding
- ❒ New or unproven systems, processes, or materials
- ❒ Marine-construction issues
- ❒ Other difficult or specialized construction issues
- ❒ Tie-ins with existing facilities/roadways/structures/local access
- ❒ Failure prior to replacement (e.g., bridges)
- ❒ Additional temporary erosion and sediment control (TESC) costs
- ❒ Railroad conflicts (anticipated or unanticipated)
- ❒ Utility conflicts (anticipated or unanticipated)
- ❒ Work-window restrictions (e.g., fish windows, weather shut-down windows)
- ❒ Other third-party delays during construction

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities (continued)**

**Design**

- ❒ Uncertainty in, or risk or opportunity related to, the "base" design elements (e.g., due to early design, project definition, or development), including type, size, and location (TS&L) and unit prices and quantities. Consider related impacts to design, ROW, environmental documentation, permitting, utilities, and construction. Consider relationships to other issues in this list (conditionality/correlation). Example items include:
    - horizontal alignment (e.g., geometry / grade)
    - vertical alignment (e.g., underground vs. surface vs. aerial)
    - bridges
    - other structures
    - retaining walls
    - earthwork
    - noise walls
    - stormwater collection and treatment
    - paving
    - right-of-way (e.g., full vs. partial takes; uncertain parcels/quantities)
    - maintenance of traffic / traffic control
    - Traffic Demand Management (TDM) / Intelligent Traffic Systems (ITS)
    - construction staging/phasing
    - electrical (systems, signals, illumination)
    - mechanical
- ❒ Design errors and omissions or errors in plans/specs/estimates (discovered during construction)
- ❒ Urban design and construction issues
- ❒ Changes in design standards (e.g., increased seismic criteria for structures)
- ❒ Design deviations (e.g., design speeds, vertical clearances, turn radii)
- ❒ Access deviations (e.g., FHWA)
- ❒ Additional aesthetics / context-sensitive solutions (CSS)
- ❒ Allowances for miscellaneous items (known pay items not yet itemized in the estimate)
- ❒ Floodplain issues

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities (continued)**

**Environmental**

- ❒ Uncertainty in appropriate environmental documentation (e.g., DCE vs. EA vs. EIS), and all the related consequential events (e.g., change in design, ROW, scope, and construction costs)
- ❒ Challenge to environmental documentation (e.g., resulting in delay in ROD)
- ❒ Delay in review and/or approval of environmental documentation
- ❒ Supplemental environmental documentation or Re-evaluation required
- ❒ Challenge to Early-Action Mitigation Plan (Wetlands, Floodplain/Habitat)
- ❒ Additional habitat mitigation required, on- or off-site (e.g., wetlands, etc.)
- ❒ Uncertain wetland mitigation (e.g., uncertain impacts, uncertain type of mitigation (replacement, enhancement, banking); different replacement ratio than assumed)
- ❒ Biological Assessment consultation issues / delay
- ❒ Uncertain stormwater treatment standards or quantities
- ❒ Uncertain stormwater discharge criteria (e.g., Receiving body exemptions)
- ❒ Uncertain groundwater treatment standards or quantities
- ❒ Encounter unanticipated contaminated or hazardous materials
- ❒ Additional noise mitigation required
- ❒ Additional view mitigation required
- ❒ Unanticipated Section 106 issues (archaeological, cultural, or historical finds)
- ❒ Known Section 106 issues different than anticipated
- ❒ Unanticipated 4(f) issues
- ❒ Known 4(f) issues different than anticipated
- ❒ Other Regulatory Issues (EIS, NEPA, etc.)

**External Influences (e.g., Political, Regulatory, Municipalities, Economic)**

- ❒ Difficulty obtaining other agency approvals/agreements (WSDOT, Municipalities)
- ❒ Conflicts with other projects (Municipalities, Counties, WSDOT)
- ❒ Coordination with other entities (e.g., Railroads)
- ❒ Coordination between multiple contractors on this project
- ❒ Public opposition
- ❒ Political opposition
- ❒ Funding shortfall (and related delay or increased financing cost)
- ❒ Funding delay
- ❒ Legal challenges (other than environmental)
- ❒ Intergovernmental agreements and jurisdiction
- ❒ Labor issues (contract negotiations/strike)
- ❒ Tribal issues (e.g., fishing rights, TERO employment, etc.)
- ❒ Failure of contractor to comply with permits
- ❒ Claims related to clarity of bid and contract documents (other than captured elsewhere)
- ❒ Program Management / executive oversight issues
- ❒ Project management issues / workload management
- ❒ Revenue issues
- ❒ Cash flow constraints

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities (continued)**

**Geotechnical and Structural**

- ❒ Uncertainty in bridges or culverts (including type/size/location (TS&L) – foundations and superstructure)
- ❒ Uncertainty in retaining walls (including type, length, height – foundations and superstructure)
- ❒ Poor ground/subsurface conditions
- ❒ Adverse groundwater conditions
- ❒ Slope stability issues
- ❒ Liquefaction design issues
- ❒ Tunneling-specific issues
    - o Uncertain or early design
    - o TBM problems (e.g., TBM operator issues / inexperience; machine procurement; machine maintenance; drive rate; other problems)
    - o Other construction problems
- ❒ Compatibility of new structures when placed adjacent to existing structures
- ❒ Other general geotechnical risk

**Operations and Maintenance**

- ❒ Uncertain annual costs for typical maintenance
- ❒ Additional resurfacing or re-decking cycle(s) required
- ❒ Additional significant (unplanned) maintenance required
- ❒ Uncertain O&M period (e.g., for P3 concessions)

**Permitting**

- ❒ Difficulty obtaining permit approval (by permit type; e.g., 401, 404, NPDES, USCG, shoreline)
- ❒ Uncertain permit requirements (current and in the future)
- ❒ Challenges to permits once issued (e.g., shoreline, 401, 404)
- ❒ Air quality permitting issues
- ❒ Non-compliance with permits

**Project Delivery and Procurement**

- ❒ Project delivery method (D/B, D/B/B, PPP), including new or unique method to owner
- ❒ Single vs. multiple contracts (if not captured under market conditions)
- ❒ Construction market conditions (cyclic market, and location within cycle at time of bid; number of viable bidders), including the potential for delay to the procurement process and/or re-bidding
- ❒ Bid protests
- ❒ Unclear contract documents (identified during either procurement or later during construction)
- ❒ Other delays to procurement process
- ❒ Owner approach to specifications (e.g., prescriptive versus performance-based)

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities (continued)**

**Right-of-Way / Real Estate**

- ❒ Global Right of Way (ROW) problems (for widening, drainage, pipelines, detention, staging, etc.)
- ❒ Difficult or additional condemnation (either globally or for particular parcels)
- ❒ Additional relocation required (either globally or for particular parcels – business vs. residential)
- ❒ Additional demolition required (including unanticipated remediation) (either globally or for particular parcels)
- ❒ Accelerating pace of development in project corridor
- ❒ Changes in land use / demographics in project corridor
- ❒ Manpower shortages
- ❒ Process delays (e.g., ROW plan development by team; plan approval process)
- ❒ Planned ROW donations do not occur, or opportunity for additional donations
- ❒ Railroad ROW Problems
- ❒ Other ROW issues

**Scope Issues** (other than identified through other items elsewhere in this list, such as design)

- ❒ Additional capacity required (e.g., lanes)
- ❒ Additional interchanges required (system-to-system or service)
- ❒ Additional local improvements required (e.g., additional paving or signals on local connections)
- ❒ Additional transit facility, park-and-ride, etc. required
- ❒ Other additional structures required (e.g., wildlife crossings)
- ❒ Scope reduction opportunity / Value Engineering
- ❒ Replace structures instead of retrofit existing (or vice-versa)
- ❒ Tolling facilities
- ❒ Managed lanes
- ❒ Note on scope changes: scope changes can occur during design and/or construction, and can be due to:
    - o Incomplete design
    - o Stakeholder influences leading to additional scope (e.g., aesthetics; political pressure)
    - o Errors in design
    - o Construction problems
    - o Regulatory changes

**Systems**

- ❒ Software problems (technical, labor)
- ❒ Electrical-system problems (technical, labor)
- ❒ Mechanical-system problems (technical, labor)
- ❒ Problems with station finishes (technical, labor)
- ❒ Track-installation problems (technical, labor)
- ❒ Problems related to systems integration and testing

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities (continued)**

**Traffic and Access Issues**

- ❒ Uncertainty in Traffic Management Costs (ITS, TDM)
- ❒ Access to site during construction
- ❒ Business or economic disruption mitigation

**Utilities Issues**

- ❒ Utility relocations to be completed by others (Utility companies, municipalities) are not completed on time
- ❒ Encounter unexpected utilities during construction
- ❒ Utility integration with project and/or utility betterments not as planned
- ❒ Cost sharing with utilities not as planned

**Vehicles**

- ❒ Uncertainty in required number and/or type of vehicles
- ❒ Uncertainty in contracted price for vehicles (may include uncertainty in number/type of vehicles)
- ❒ Delay in vehicle delivery
- ❒ Cost increase due to change orders (for various reasons, perhaps detailed separately; separate from uncertainty in contract price)

**Figure G-4. Generic List of Uncertainties, Risks and Opportunities (continued)**

| Environmental | Design / PS&E | Scope | Right-of-Way | Partnerships and Stakeholders | Financial / Economic | Management / Policy | Contracting and Procurement | Construction |
|---|---|---|---|---|---|---|---|---|
| NEPA/SEPA Documentation / Challenges (incl. Section 4f, Section 106, etc.) | Potential Changes to Horizontal/Vertical Alignment | Discretionary Scope Changes | Issues Associated with Development of ROW Plan | Utility Design, Agreements, and Relocations | Availability of Funding / Cash Flow Restrictions | Change in Leadership | Change in Project Delivery Method | Traffic Control and Staging Issues |
| ESA Issues (incl. Fish Passage) | Potential Changes to Structures Design (Bridge Superstructure, Retaining Walls) | Additional Mitigation (e.g., artwork, shared-use path) Driven by Third Party Concerns | ROW Acquisition Issues (incl. condemnation, full vs. partial takes, relocations, demolitions) | Railroad Coordination and Agreements | Labor Disruptions | Political/Policy Changes | Issues Related to Contract Language (Warranties, Liquidated Damages, DBE, Insurance/Bonding, etc.) | Construction Permitting Issues (incl. work restrictions) |
| Environmental Permitting (incl. Appeals) | Potential Changes to Geotechnical Design (Foundations, Liquefaction Mitigation, etc.) | Additional Scope Driven by Internal Considerations (e.g., Maintenance, Traffic Projections) | Access Management (incl. APDR, Access Hearing, etc.) | Tribal Issues (if not addressed elsewhere) | Uncertainty in Future Escalation Rate for Labor, Materials, and Equipment (general) | Delayed Decision Making | Delays in Ad/Bid/Award Process (Addenda, Protests, etc.) | Work Windows (Weather, Fish, etc.) |
| Archaeological, Cultural, Historical Discoveries | Potential Changes to Design of Permanent Traffic Items (ITS, Illumination, etc.) | Other Scope Issues | Uncertainty in Future ROW Escalation Rate (Project-Specific, includng change in land use, urbanization, etc.) | Public Involvement Issues (if not addressed elsewhere) | Market Conditions - Project-Specific Premium for Raw Materials, Labor, or Equipment | Other Management / Policy Issues | Market Conditions (Lack of Competition for Contracts) | Unanticipated / Difficult Subsurface Conditions |
| Hazardous Materials | Potential Changes to Pavement Design | | Construction / Subterranean Easements | Other Interagency Agreements | Financing Costs | | Delays in Procurement of Specialty Materials or Equipment | Marine/ Over Water Construction Issues |
| Permanent Noise Mitigation | Potential Changes to Architectural, CSS, Landscape Design | | Other ROW Issues | Other Partnership/Stake holder Issues | Other Financial / Economic Issues' | | Constractor Non-Performance | Misc. Change Orders / Claims |
| Wetlands / Stream / Habitat Mitigation | Changes to Design Criteria (e.g., seismic, security) | | | | | | Other Contracting & Procurement Issues | Earthwork Issues (re-use, haul,disposal, TESC etc.) |
| Water Quality / Detention Requirements | Design / PS&E Reviews (incl. approval of deviations) | | | | | | | Coordination with Adjacent Projects During Construction |
| Other Environmental Issues | Other Design Issues | | | | | | | Contractor Access / Staging Issues |
| | | | | | | | | Force Majeure |
| | | | | | | | | Construction Accidents |
| | | | | | | | | Construction QA/QC Issues |
| | | | | | | | | Other Construction Issues |

**Figure G-5. Generic Risk Breakdown Structure**

Although these are good tools, it should be noted that risk checklists are generic "shopping lists" to be used at the end of the identification process to help ensure no major issues were missed. They are not proper risk registers! Also, they are neither non-overlapping nor necessarily comprehensive (otherwise there would never be new risks), and are not necessarily at the appropriate level of detail or project-specific.

An example of how to perform the above process is the best way to show what is and needs to be done during these steps. In the following figures, screen shots of the actual forms to be used will be shown and explained.

| Category | Risk or Opportunity | Description |
|---|---|---|
| *EXAMPLE* | | |
| Scope<br>Design<br>Environ. Proc.<br>ROW/Util.<br>Procurement<br>Construction<br>Closeout | *Landowner(s) unwilling to sell at US555-SH111 junction* | *Additional right-of-way needed for US555-SH111 junction, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.* |
| **Scope (S)** | | |
| S1 | | |

**Figure G-6. Risk Identification Form Example**

The next step is to sort all the risks by category. After the risks have been sorted by category, then edit identified risks or add risks that were not included. The goal in the end is for the list to be comprehensive and non-overlapping ("Risk Register").

In summary, the overall goal of risk identification is to prepare a risk register which is a comprehensive, non-overlapping set of risks and opportunities that is relative to the pre-defined "baseline" project and to specific stakeholders ("risk to whom"), and still at the appropriate level of detail, and independent of other risks (if possible).

## G.2.3 Risk-Factor Assessment and Rating

The objective of risk-factor assessment and rating is to determine the significance of each identified risk (or opportunity). The result will be a ranked list of project risks for prioritization in the risk management steps that follow. The risks need to be prioritized in order to focus limited resources on their assessment and management. To adequately prioritize risks, as well as to predict project performance, their severity must be assessed. Typically, both risk ranking and risk value assessment are done by assessing risk "factors" (e.g., likelihood of occurrence and cost and schedule impacts of occurrence), and then appropriately combining those factors. If the value can be determined, then the risks can be ranked on the basis of these values. The risks can be evaluated either qualitatively (e.g., "small" risk) or quantitatively (e.g., $1M value). If done qualitatively, "ratings" are used, which are typically easier to assess but much more approximate than quantitative assessments. Care must be taken in combining qualitative assessments.

As previously discussed, "severity" of a risk considers both its likelihood of occurrence and its consequences if it does occur. Even though risk factors (impacts and probability of occurrence)

might be subjectively assessed, it is generally more accurate to assess the factors (as accurately as possible) and then appropriately combine them to determine risk severity, as opposed to assessing risk severity directly. The reason for this is people's perceptions of risk severity are often inaccurate, i.e., for various reasons, they incorrectly perceive some risks to be much larger or much smaller than they really are. Assessing the more detailed factors first and then combining them can generally mitigate such incorrect perceptions.

Many risk assessment methods exist. The FHWA workshops are promoting the *mean-value method*. For the mean-value method, either rating scales are defined on a mean-value basis, or mean consequences are assessed directly (no rating scales are used). Both mean-value approaches build on the "rating scale" method. The first mean-value method is mean rating. The mean ratings approach characterizes risks in terms of mean ratings, which are categories that are easier to assess than absolute values. The mean rating method uses category mean ratings (e.g., L, M, H) defined on mean values to characterize individual risk factors (i.e., likelihood and impacts). By doing this, the mean rating method mathematically defines the risk factors and risk factor ratings (value ranges), assesses ratings for each risk factor, and determines rating for each risk.

The second method, mean values, simply skips the ratings and characterizes risks in terms of mean consequences, which are more refined but also more difficult to assess than categories/ratings. The approach also characterizes individual risk factors directly in terms of mean values in the corresponding units/dimensions (e.g., $). By using this approach, the mean value method assesses mean value of each risk factor (e.g., $) and mathematically determines mean value, in those units (e.g., $), for each risk.

The first step of the mean-value methods – ratings method is quantitatively defining factor ratings (value ranges) for each risk factor. The rating is a qualitative (rather than quantitative) descriptor, so this particular approach uses category ratings (e.g., L, M, H) for each risk factor. The category rating for each risk factor is defined by (based on) specific ranges of values for that category and factor, which in turn defines a category mean value for the probability of occurrence (e.g., in % or 0 to 1 or odds) and also mean value for each consequence type (e.g., $, months). Costs are expressed as a percentage of the project un-escalated base cost, whereas schedule impacts are expressed in terms of months of delay. The cost and schedule impacts are subsequently assigned to specific project activities, so that schedule delay is not necessarily to the project's critical path.

| | Impacts if Event Occurs | | | | Probability of Event Occurring | |
|---|---|---|---|---|---|---|
| | Cost (unesc base cost) | | Schedule (months) | | | |
| Rating | For Risk Factor Rating | Mean Value | For Risk Factor Rating | Mean Value | For Risk Factor Rating | Mean Value |
| VH | > 25% | 35% | > 12 | 18 | > 70% (2:3) | 85% |
| H | 10 to 25% | 15% | 4 to 12 | 8 | 40% to 70% (~2:3) | 55% |
| M | 3 to 10% | 6% | 1 to 4 | 2.5 | 20% to 40% (2:5) | 30% |
| L | 1 to 3% | 2% | 0.25 to 1 | 0.6 | 5% to 20% (1:5) | 12% |
| VL | 0 to 1% | 0.5% | 0 to 0.25 | 0.1 | < 5% (1:20) | 2% |
| -VL | -1 to 0% | -0.5% | -0.25 to 0 | -0.1 | | |
| -L | -3 to -1% | -2% | -1 to -0.25 | -0.6 | | |
| -M | -10 to -3% | -6% | -4 to -1 | -2.5 | | |
| -H | -25 to -10% | -15% | -12 to -4 | -8 | | |
| -VH | < -25% | -35% | < -12 | -18 | | |

**Figure G-7. Mean Value Ratings (Step 1)**

It should be noted that the ranges and mean values shown in Figure G-7 are the default values for each rating in the course template, although the ranges and mean values can be revised. The un-escalated cost and schedule impacts by activity are translated to an equivalent escalated project cost (considering critical path impacts and associated extended OHs, as well as escalation), which (as subsequently discussed) is done automatically in the course template. For example, in the table above:

- "-L" cost rating is defined by the range in cost of savings of -3% to -1% of the base un-escalated project cost, with a mean value of -2%. If the base un-escalated project cost was $30M, then the range of additional un-escalated costs for "–L" would be -$0.9M to -$0.3M, with a mean value (which would be used for mean-value risk-ranking purposes) of -$0.6M (which would be escalated and combined with schedule impacts).
- "H" probability rating is defined by the range in probabilities of 0.4 to 0.7, with a mean value of 0.55.

Once the factor rating scales have been quantitatively defined, the following steps are performed on each risk:

- Rate each risk factor (i.e., conditional cost impact, conditional schedule impact and probability of occurrence) using the corresponding category ratings (e.g., L, M, H).
- Translate each risk factor rating into a mean value (using the factor rating definitions)
- Combine (using a cost/schedule model) the mean values across risk factors to get very approximate mean value of risk (can combine consequence types into equivalent cost).
- Translate back into a mathematically correct mean risk rating (e.g., L, M, H) for each risk; the mean risk rating considers all consequence types.
- Finally, the risk factors should be prioritized by their mean risk ratings.

| Risk # | Risk | Impact Rating | | Probability Rating |
|---|---|---|---|---|
| | | Cost | Schedule | |
| C1 | D/B Design & Construction Risk Contingency, Escalation & Profit | H | L | VH |
| C2 | Bidding Climate for NATM Tunnel | M | VL | H |
| C3 | Construction Materials Escalation | M | VL | L |
| R1 | ROW Acquisition | M | M | M |

| Mean Risk Rating (equivalent cost in inflated $M) |
|---|
| VH |
| H |
| L |
| M |

**Figure G-8. Mean Value Ratings (Step 2)**

The first step of the mean-value method is defining the values of each risk factor. Each risk factor is defined and assessed directly in terms of the units of interest by probability of the risk's occurrence (e.g., in %), or mean value for each consequence type if the risk occurs; such as, direct cost ($) and delay to overall schedule (months). Next, the group should combine the risk factor values and the mean risk values. They can now combine the consequence types into a single equivalent consequence and calculate the mean value of the risk. Finally, the risks should be prioritized by their mean risk values.

| Risk # | Risk | Mean Consequences If Risk Occurs | | Probability of Occurrence |
|---|---|---|---|---|
| | | Mean Cost (uninflated $M) | Mean Delay to Overall Schedule (months) | |
| C1 | D/B Design & Construction Risk Contingency, Escalation & Profit | 75 | 1 | 80% |
| C2 | Bidding Climate for NATM Tunnel | 20 | 0.5 | 50% |
| C3 | Construction Materials Escalation | 12 | 0.5 | 10% |
| R1 | ROW Acquisition | 15 | 3 | 25% |

| Mean Risk (in Equivalent cost, Inflated $M) (escalation=10%, 1mo delay=$6M) |
|---|
| 70.8 |
| 12.5 |
| 1.6 |
| 9.6 |

**Figure G-9. Mean Value Ratings (Step 3)**

## G.2.4 Risk Mitigation and Planning

Risk mitigation and planning involves proactively assigning responsibility/ownership for each significant risk and developing plans (and a program to implement those plans) for appropriately addressing those risks early on. Allocation of risks will be done later, as part of the contract. Risk management also includes consideration of contingency, both funds (which must be controlled) and recovery plans (in case contingency funds are not adequate).

The objectives of risk mitigation and planning can be summarized as planning specific actions, providing adequate resources/procedures (i.e., "program") to successfully implement those actions, and answering questions of who/what/when/how. This must all be done in the most cost-effective manner, while still understanding/accepting the "residual risk" and ensuring the meeting of budget and milestone goals. When planning for the process, the following questions should be considered:

- Who is responsible?
- What can be done and what options are available?
- When can they be done?
- How can they be done and what is needed?
- What are the tradeoffs in terms of all costs, benefits, and risks among the available options?
- What are the impacts of current decisions on future options?

The process of risk mitigation and planning often involves an analysis of tradeoffs to maximize the cost effectiveness of mitigation options. Even with the best mitigation and planning, some risks will remain. The process will allow for a better understanding of these risks but the risks still must be accepted by the owner with the development of appropriate contingency plans.

Risk planning includes documentation in a number of different methods. The methods include using a red flag item lists, a risk register, and also a formal risk management plan. Red flag items lists are simple and straightforward to create and use; however, they do not allow for active contingency management or mitigation decision making. Risk registers provide more detail than simple red flag item lists; however, without maintenance and updating, their usefulness is limited. A formal risk management plan is typically used on only the largest projects. They should be part of the project management plan that FHWA requires on large projects. They help to clearly assign risk management responsibilities on the project team; however, without adequate implementation (including monitoring/maintenance and updating), they have limited usefulness.

The risk mitigation identification and evaluation form is provided and can be seen in the example shown in Figure G-10. For each highly ranked risk, the identification of possible actions, the assessment of factors and the determination of cost-effectiveness of each action are determined.

| **Risk Rank** | **Risk (see Risk Register/Factors)** | **Response Strategy** (Circle One) | **Management Action** | **Implementation** | | | | **Effectiveness (% reduction)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Cost** (unesc $M) | **Affected $ Activity** (Circle One) | **Delay** (months) | **Affected T Activity** (Circle One) | **Proba-bility** | **Impacts (if occurs)** | |
| | | | | | | | | | **Cost** | **Schedule** |
| *EXAMPLE* | | | | | | | | | | |
| *1* | *Ri. Landowners unwilling to sell US 555-SH111 junction* | Avoid<br>Mitigate<br>Transfer<br>Accept | *The team will design around areas where right of way may be an issue.* | *$0.5* | Scope<br>Design<br>Environ. Proc.<br>ROW/Util.<br>Procurement<br>Construction<br>Closeout | *2.0* | Scope<br>Design<br>Environ. Proc.<br>ROW/Util.<br>Procurement<br>Construction<br>Closeout | *100%* | *NA* | *NA* |
| | | Avoid<br>Mitigate<br>Transfer<br>Accept | | | Scope<br>Design<br>Environ. Proc.<br>ROW/Util.<br>Procurement<br>Construction<br>Closeout | | Scope<br>Design<br>Environ. Proc.<br>ROW/Util.<br>Procurement<br>Construction<br>Closeout | | | |

**Figure G-10. Risk Mitigation Identification and Evaluation Form Example**

Once the cost-effectiveness of each possible action has been determined (based on the assessments in the previous form), select the most cost-effective risk management action for each significant risk. These are then translated to the risk management plan form, which also requires

input of who is responsible for action, the schedule for implementing the action, and the current status / progress of that action (update). This set of selected actions constitutes the risk management plan, the form can be seen in the example shown in Figure G-11.

**Risk Management Plan**
**(expand if necessary)**

| Rank | Management Actions | Implementation | Risk Reduction | Responsibility | Schedule or Milestone Check |
|---|---|---|---|---|---|
| *1* | *The team will design around areas where right of way may be an issue, specifically at US555-SH111 junction.* | *2 month delay in design and $0.5M increase in construction cost* | *100% decrease in Risk R1* | *Design lead, in conjunction with right-of-way lead* | *By end of preliminary design* |

**Figure G-11. Risk Management Plan Form Example**

## G.2.5 Risk Allocation

Risk Allocation is the process of contractually assigning the residual risks to a specific party. Although part of risk management, such contractual assignment is done later than the proactive risk management previously discussed. This assignment (and the associated price) is negotiated between the owner and the contractor. The objectives for risk allocation include allocating the risks before they occur to the party that is best able manage them, aligning the risk with project goals, and allocating the risks clearly and unambiguously to reduce disagreements. There is an option to share risks when appropriate to accomplish the project goals, but ultimately the goal is allocating risks to promote team alignment with customer-oriented performance goals.

The methods of risk allocation depends on the choice of project delivery method (i.e., design-build, design-bid-build, etc.), choice of procurement method (i.e., low bid, best-value, etc.), choice of payment method (i.e., lump sum, unit price, escalation clause, etc.), and the language of general and technical specifications (i.e., who is allocated the risk for undiscovered conditions). Figure G-12 provides some examples of project delivery, procurement and contract payment approaches for risk allocation. Industry review of proposed project delivery methods (and associated risk allocation) is often useful to identify potential risks allocation problems.

**Project Delivery Approaches**

- Indefinite Quantity/Indefinite Delivery
- Construction Manager at Risk
- Design-Build
- Design-Build-Warranty
- Design-Build-Operate-Maintain (DBOM)
- Design-Build-Operate-Maintain-Finance (DBOM-F)
- Performance-Based Total Asset Management Contracts

**Procurement Approaches**

- Bid Averaging Method (BAM)
- Alternative Bids/Designs
- Request for Proposals
- Cost Plus Time (A+B)
- Multi-Parameter Bidding (A+B+Q)
- Best-Value

**Contract Payment Approaches**

- Disincentive or Penalty Contracts
- Incentive Contracts
- Incentive/Disincentive Contracts
- Lane Rental Contracts
- Active Management Payment Mechanism
- No Excuse Bonus Contracts
- Lump Sum Contracts

**Figure G-12: Risk Allocation Methods**

## G.2.6 Risk Monitoring and Updating

Risk monitoring and updating is the process of tracking risks and opportunities over time and reassessing them as conditions change and/or new information becomes available (e.g., implementation of risk management plan). Eventually, all risk and opportunity events will either happen, with particular impacts, or not happen. Risk monitoring and updating is also used to track actual contingency resolution or drawdown, and make decisions on recovery (if needed).

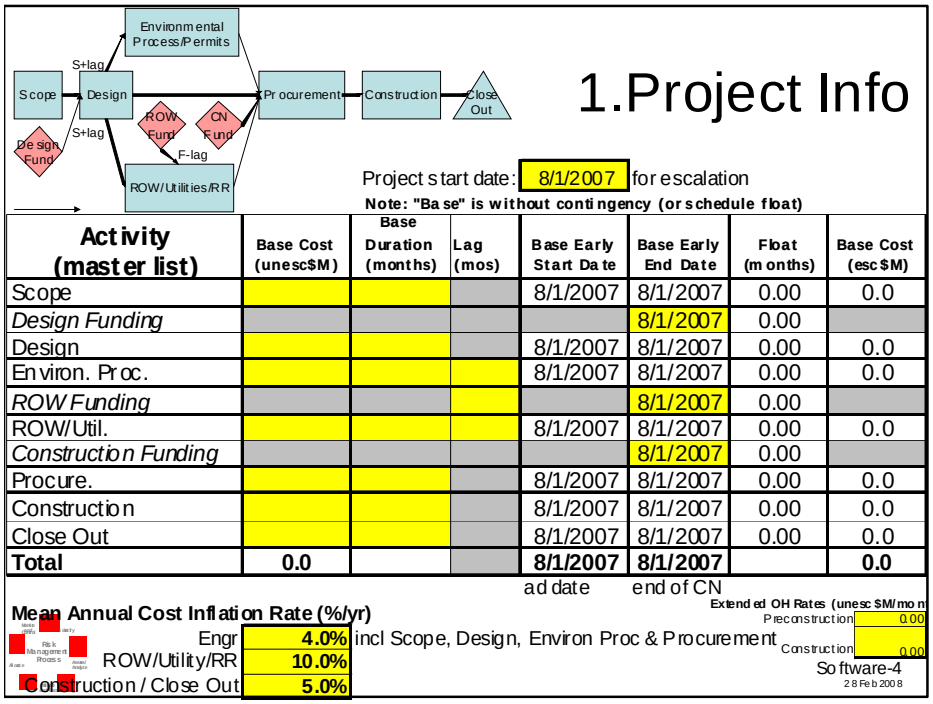
The objectives of risk monitoring and updating are monitoring implementation and results (i.e., risk and opportunity resolution) of the risk management plan, implementing contingency plans, revising risk management plan, updating risk assessment (e.g., cost and schedule projections), and updating/drawdown contingency through planned contingency resolution processes. This process needs to be both adequate and efficient. The process should be a clear, consistent and comprehensive monitoring, updating and reporting process that is relatively simple and appropriately periodic.

## G.2.7 Software Template

The FHWA workshops have developed an MS Excel-base software to facilitate the risk management process that has been presented above. The software is a template, consisting of linked Excel worksheets, in which assessed inputs are entered (either directly as they are assessed or from forms) and appropriate calculations are performed “behind the scenes”, inputs are highlighted and the rest of the spreadsheets are protected /hidden to prevent inadvertent changes. The results are approximate due to low level of detail and simplifications in the models and in the inputs. The results are adequate for risk management purposes, but generally not adequate for project budgeting/scheduling.

The worksheets that comprise the template are presented in the following text and figures in the order in which they are intended to be used.

**<1.Project Info> -** The project information sheet provides for significant project baseline cost and schedule information. The baseline schedule and total cost (unescalated and escalated) are automatically determined from the form inputs.




| Activity (master list) | Base Cost (unesc$M) | Base Duration (months) | Lag (mos) | Base Early Start Date | Base Early End Date | Float (months) | Base Cost (esc $M) |
|---|---|---|---|---|---|---|---|
| Scope | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| *Design Funding* | | | | | 8/1/2007 | 0.00 | |
| Design | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| Environ. Proc. | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| *ROW Funding* | | | | | 8/1/2007 | 0.00 | |
| ROW/Util. | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| *Construction Funding* | | | | | 8/1/2007 | 0.00 | |
| Procure. | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| Construction | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| Close Out | | | | 8/1/2007 | 8/1/2007 | 0.00 | 0.0 |
| **Total** | **0.0** | | | **8/1/2007** | **8/1/2007** | | **0.0** |
| | | | | ad date | end of CN | | |

**Figure G-13. Software Template – Project Information**

**<2a.Initial Risks> -** The initial risk sheet provides a template for all risks and opportunities identified through brainstorming, and which project activity each would happen during, and a more detailed description of each (as needed)

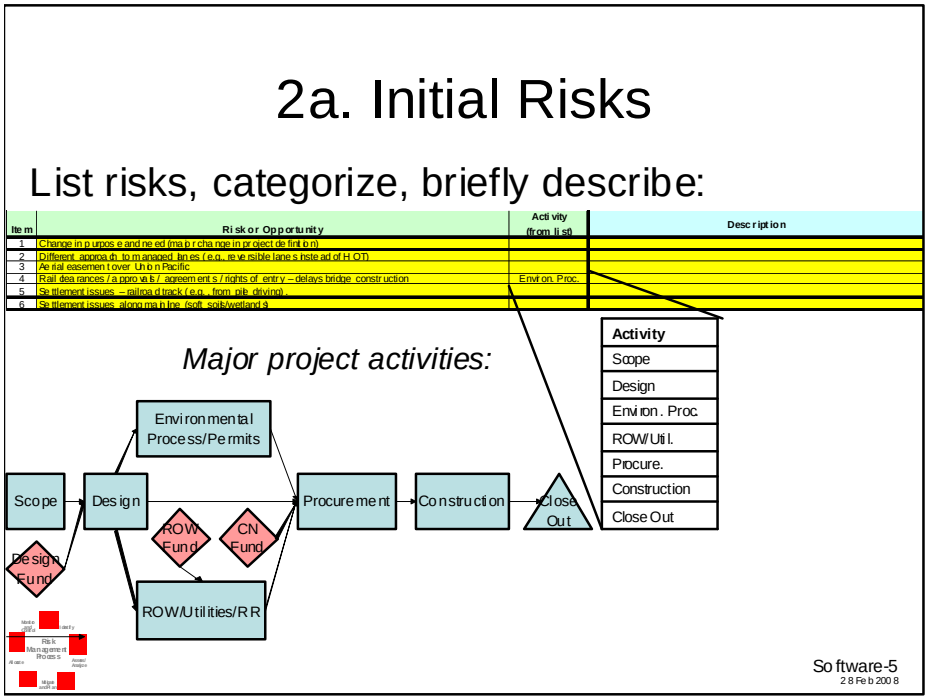


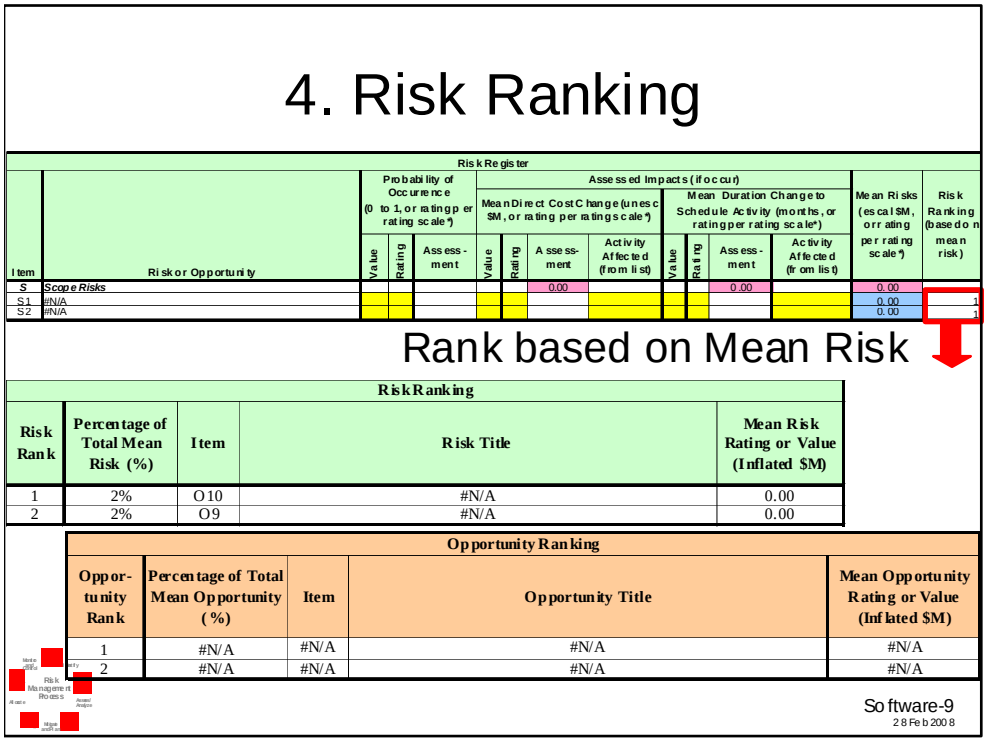

**Figure I-14. Software Template – Initial Risks**

**<2b.Risks by Category> -** The risks from <2a.Initial Risks> are carried over and listed in appropriate category (activity). This sheet provides a sorting and categorization function for the initial risks.

**<3a.Rating Scales> -** This sheet provides for the use of both mean values and mean ratings as explained earlier in this chapter.

**<3b.Risk Assess> -** The risks from <2b.Risks by Category> are carried over into this sheet. The user enters the mean rating (per rating scale) or mean value for each risk factor. The mean risks are determined automatically. If the set of risks is comprehensive and non-overlapping, approximate mean values for collective risk and total cost and schedule are also determined automatically.

**<4.Risk Ranking> -** The ranking of the identified risks (based on their mean risk) is automatically determined.



# 4. Risk Ranking

Risk Register

| Item | Risk or Opportunity | Probability of Occurrence (0 to 1, or rating per rating scale*) | | | Assessed Impacts (if occur) | | | | | | | | Mean Risks (escal $M, or rating per rating scale*) | Risk Ranking (based on mean risk) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean Direct Cost Change (unesc $M, or rating per rating scale*) | | | | Mean Duration Change to Schedule Activity (months, or rating per rating scale*) | | | | | |
| | | Value | Rating | Assess-ment | Value | Rating | Assess-ment | Activity Affected (from list) | Value | Rating | Assess-ment | Activity Affected (from list) | | |
| *S* | *Scope Risks* | | | | | | 0.00 | | | | 0.00 | | 0.00 | |
| S1 | #N/A | | | | | | | | | | | | 0.00 | 1 |
| S2 | #N/A | | | | | | | | | | | | 0.00 | 1 |

Rank based on Mean Risk

Risk Ranking

| Risk Rank | Percentage of Total Mean Risk (%) | Item | Risk Title | Mean Risk Rating or Value (Inflated $M) |
|---|---|---|---|---|
| 1 | 2% | O10 | #N/A | 0.00 |
| 2 | 2% | O9 | #N/A | 0.00 |

Opportunity Ranking

| Oppor-tunity Rank | Percentage of Total Mean Opportunity (%) | Item | Opportunity Title | Mean Opportunity Rating or Value (Inflated $M) |
|---|---|---|---|---|
| 1 | #N/A | #N/A | #N/A | #N/A |
| 2 | #N/A | #N/A | #N/A | #N/A |

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**Figure G-15. Software Template – Risk Ranking**

**<5.Risk Management Alternatives> -** The ranked risks from <4.Risk Ranking> are carried over. The user enters the candidate actions for each critical risk (both immediate and contractual, first from brainstorming and then from provided check list), and enter the cost-effectiveness factors for each. The cost-effectiveness of each candidate will be automatically determined. The most cost-effective actions should be selected.

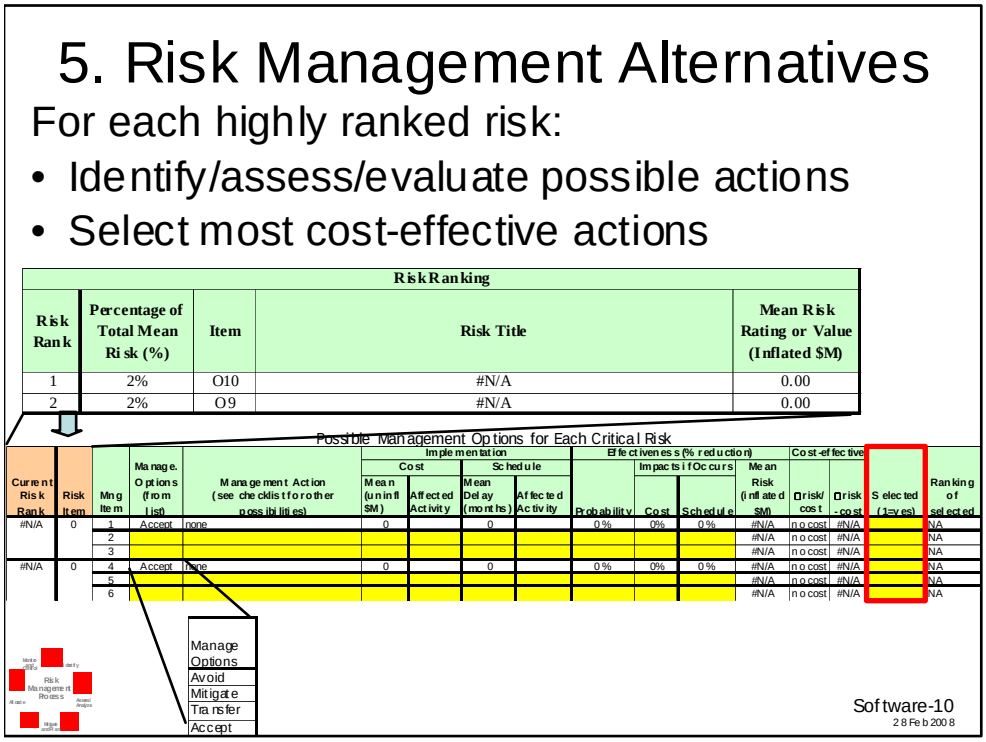


**Figure G-16. Software Template – Risk Management Alternatives**

**<6.Risk Management Plan> -** The selected (most cost-effective) set of actions to address the set of risks from <5.Risk Management Alternatives> are carried over onto this sheet. Spaces are provided to add implementation details. The workbook automatically determines revised base and residual risks, as well as mean total schedule and cost (unescalated and escalated). Inputs are highlighted, but each sheet is otherwise protected to prevent inadvertent changes. Also, many of the background calculations are hidden to prevent confusion. Figures G-17 and G-18 show the resulting risk management plan.

# 6.Risk Management Plan

For selected actions, plan their implementation:

Possible Management Options for Each Critical Risk

| Current Risk Rank | Risk Item | Mng Item | Manage. Options (from List) | Management Action (see checklist for other possibilities) | Implementation: Cost: Mean (uninflSM) | Implementation: Cost: Affected Activity | Implementation: Schedule: Mean Delay (months) | Implementation: Schedule: Affected Activity | Effectiveness (% reduction): Probability | Effectiveness (% reduction): Impacts if Occurs: Cost | Effectiveness (% reduction): Impacts if Occurs: Schedule | Mean Risk (inflated SM) | Cost-effective: Δrisk/cost | Cost-effective: Δrisk - cost | Selected (1=yes) | Ranking of selected |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #N/A | 0 | 1 | Accept | none | 0 | | 0 | | 0% | 0% | 0% | #N/A | no cost | #N/A | | NA |
| | | 2 | | | | | | | | | | #N/A | no cost | #N/A | | NA |
| | | 3 | | | | | | | | | | #N/A | no cost | #N/A | | NA |
| #N/A | 0 | 4 | Accept | none | 0 | | 0 | | 0% | 0% | 0% | #N/A | no cost | #N/A | | NA |
| | | 5 | | | | | | | | | | #N/A | no cost | #N/A | | NA |
| | | 6 | | | | | | | | | | #N/A | no cost | #N/A | | NA |

Risk Management Plan

| Rank | Mgt Item | Management Action | Risk | Risk Factors: Probability | Risk Factors: Cost (unescSM) | Risk Factors: Schedule (mos) | Implementation: Cost (unescSM) | Implementation: Schedule (mo) | Effectiveness (% reduction): Probability | Effectiveness (% reduction): Cost Impact | Effectiveness (% reduction): Schedule Impact | Responsibility | Schedule or Milestone Check | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #N/A | | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | | | |
| #N/A | | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | | | |

➔ *Remaining risks*

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**Figure G-17. Software Template – Risk Management Plan (part 1)**

# 6. Risk Management Plan - Update

- Based on schedule for updating Risk Assessment, document changes in Risk Register template (sign/date via "comments"):

Risk Register

| Item | Risk or Opportunity | Probability of Occurrence (0 to 1, or rating per rating scale*): Value | Rating | Assess-ment | Assessed Impacts (if occur): Mean Direct Cost Change (unescSM, or rating per rating scale*): Value | Rating | Assess-ment | Activity Affected (from list) | Mean Duration Change to Schedule Activity (months, or rating per rating scale*): Value | Rating | Assess-ment | Activity Affected (from list) | Mean Risks (escalSM, or rating per rating scale*) | Risk Ranking (based on mean risk) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | Cost Risks | | | | | | | | | | 0.00 | | 0.00 | |
| S1 | #N/A | | | | | | | | | | | | 0.00 | 1 |
| S2 | #N/A | | | | | | | | | | | | 0.00 | 1 |

- Based on monitoring plans, document changes in Risk Management Plan template:

Possible Management Options for Each Critical Risk

| Current Risk Rank | Risk Item | Mng Item | Manage. Options (from List) | Management Action (see checklist for other possibilities) | Implementation: Cost: Mean (uninflSM) | Implementation: Cost: Affected Activity | Implementation: Schedule: Mean Delay (months) | Implementation: Schedule: Affected Activity | Effectiveness (% reduction): Probability | Effectiveness (% reduction): Impacts if Occurs: Cost | Effectiveness (% reduction): Impacts if Occurs: Schedule | Mean Risk (inflated SM) | Cost-effective: Δrisk/cost | Cost-effective: Δrisk - cost | Selected (1=yes) | Ranking of selected |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #N/A | 0 | 1 | Accept | none | 0 | | 0 | | 0% | 0% | 0% | #N/A | no cost | #N/A | | NA |
| | | 2 | | | | | | | | | | #N/A | no cost | #N/A | | NA |
| | | 3 | | | | | | | | | | #N/A | no cost | #N/A | | NA |
| #N/A | 0 | 4 | Accept | none | 0 | | 0 | | 0% | 0% | 0% | #N/A | no cost | #N/A | | NA |
| | | 5 | | | | | | | | | | #N/A | no cost | #N/A | | NA |
| | | 6 | | | | | | | | | | #N/A | no cost | #N/A | | NA |

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**Figure G-18. Software Template – Risk Management Plan (part 2)**

## G.3 Summary

Risks and opportunities change over time as the project develops and the conditions change (due in part to implementation of a Risk Management Plan), but all risks and opportunities will eventually be resolved. A formal process is required, and the Risk Management Plan and related Risk Register are the key to communication among team members and the public. Monitoring the status of the RMP implementation, revising the RMP, and reassessing risks and opportunities (additional risk management for new or emerging risks and less risk management for resolved or decreasing risks, updating cost and schedule projections and implementing recovery plans) needs to happen. The Risk Monitoring and Updating process should be cost effective, but not overwhelming.

# Appendix H: FTA Case Study

## *Federal Transit Administration General Approach to Risk Management*

## *H.1 Introduction*

The Federal Transit Administration (FTA) is one of 10 modal administrations within the U.S. Department of Transportation. The FTA administers federal funding to support a variety of locally planned, constructed, and operated public transportation systems throughout the U.S., including buses, subways, light rail, commuter rail, streetcars, monorail, passenger ferry boats, inclined railways, and people movers.

### H.1.1 Research Methods

This case study was completed through a phone interview on March 27th, 2008. The interview was attended by Mr. Michael O'Connor, Team Leader, FTA and Dr. David Sillars, Oregon State University, a researcher working with FTA on their risk management initiatives. Dr. Molenaar and Craig Wilson from the University of Colorado attended for the research team. The interview was conducted using the case study protocol provided in Chapter 4 of this report.

## *H.2 Risk Management Overview*

The FTA employs a comprehensive risk management program. The FTA is currently in the process of amending their risk management guidelines. The description of the topics that follow are based on a draft guide which showcases some of the downfalls of "bottom-up" risk analysis, while emphasizing the benefits of a "top-down" approach. The goals and benefits of this restructuring are identified by the FTA as: "Increased emphasis on preparation work going into workshops to provide adequate project context using new tools, use of more holistic risk modeling to provide better assurance that ranges are adequate and means are more realistic, and use of mitigation models that span phases of project development, with milestones and effectiveness measures."

### H.2.1 Contingency

The FTA uses the following definition of contingency: "an amount added to a cost estimate to compensate for unexpected expenses resulting from incomplete design, unforeseen and unpredictable conditions, or uncertainties in the project scope."

The FTA also identifies several types of contingency:

- Engineering and Design contingency – mainly scope and unit cost, but should account for owners' allowance and schedule delays
- Construction contingency – mainly change orders, site conditions, force majeure, mitigation, market, material, subcontractors and permitting
- Owners' contingency – mainly stakeholder, schedule, funding and financing

The research team was provided with a PowerPoint presentation titled TPM/Office of Engineering Cost Contingency. The presentation compares different standards for applying percentage contingencies and concludes with the slide shown in Figure H-1. The FTA/PG40 is the guideline used by the FTA.

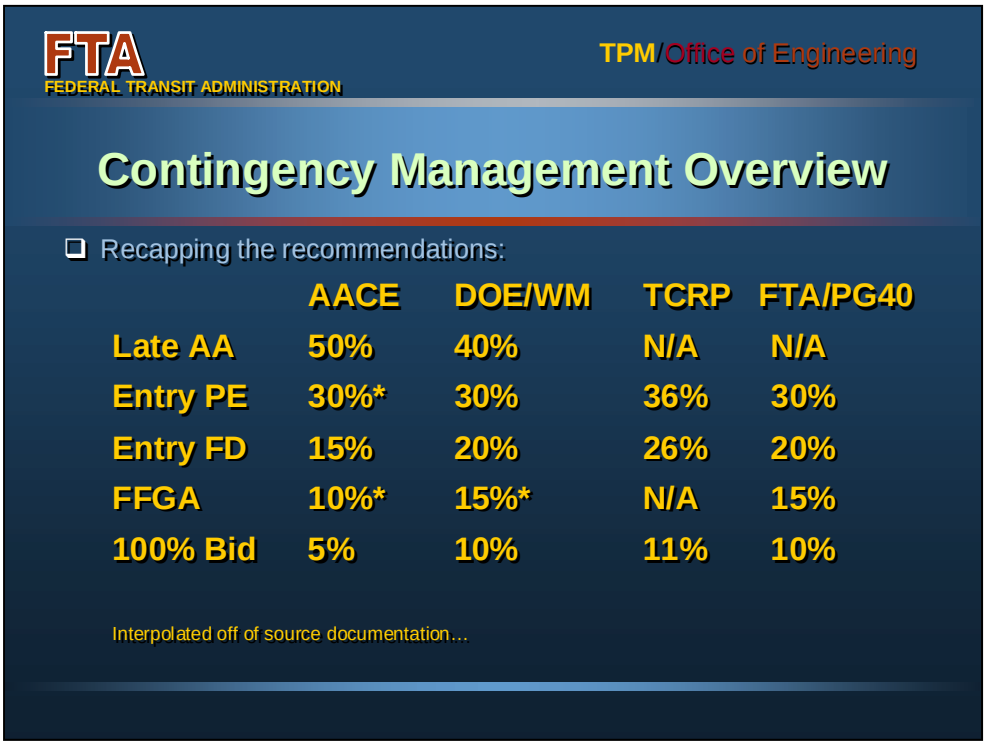


**Figure H-1. Contingency Percentages used by FTA as Compared to Other Standards**

### H.2.2 Risk Management Process

The process for risk management used at the FTA is described in the flowchart shown in Figure H-2 and described in the steps that follow.

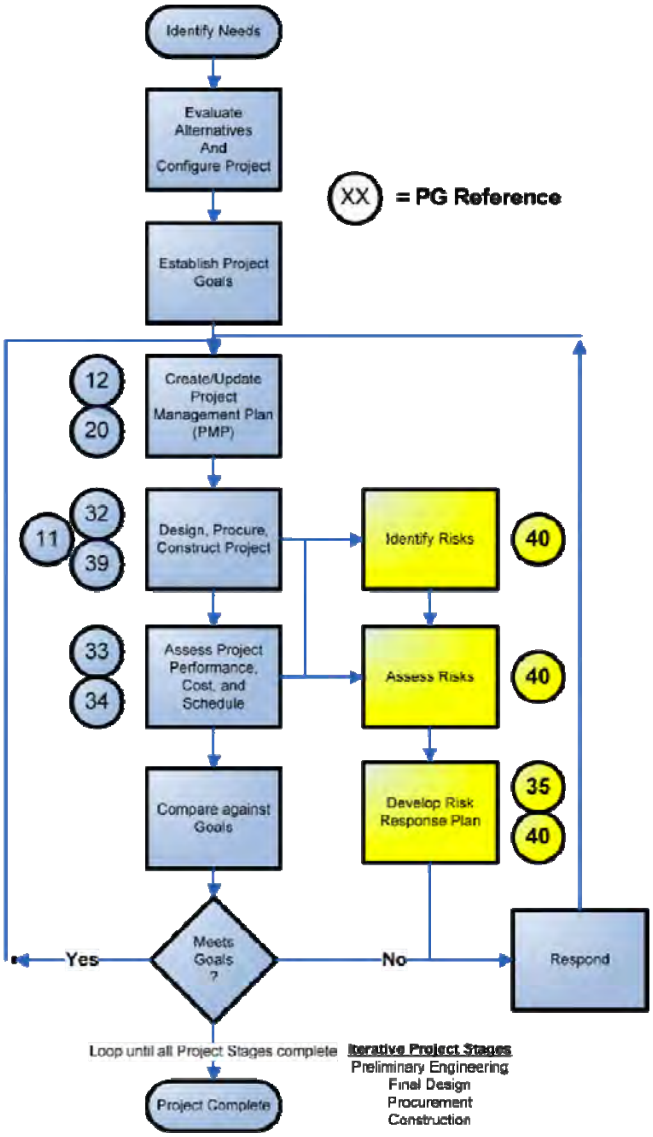


**Figure H-2: Steps in the FTA Risk Management Process**

### H.2.2.1 Risk Identification

Risks are identified by the Project Management Oversight Contractor (PMOC) as the project develops; there is no formal "workshop" to identify risks. The PMOC is made up of consultants that the FTA hires to review the project at various points. The PMOC establishes risks based on "activities or conditions for which the Grantee has made assumptions that may prove to be different as the project develops." All of these risks are identified and placed into the risk register. The FTA acknowledges a need for unique controls over each project, and allows for decisions and guidelines to be on a case-by-case basis.

### H.2.2.2 Qualitative Risk Analysis

No discussion was given to the qualitative risk analysis performed at the FTA. However, their quantitative risk analysis techniques employ some degree of quantitative analysis to generate results.

### H.2.2.3 Quantitative Risk Analysis

Through discreet risk identification and analysis, the PMOC generates a risk register which "scores" risks. The risk register is then used to identify the optimistic and pessimistic potential impact of each identified risk (see Figure H-3).

| A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|
| ID | SCC | Description of Issue | Impact on project goal(s) | Likelihood 1 = low 4 = high | Severity 1 = low 4 = high | Score (E*F) | Cost Impact-- Optimistic; Pessimistic | | Schedule Impact-- Optimistic; Pessimistic | |
| 001. | 10 | Advancement of Memorandum of Agreement by and between City and the Railroad Agency to a full purchase agreement. | Project may not advance without agreement. | 4 | 4 | 16 | | | 1 Month | Indefinite |
| 002. | 10 | Availability of construction equipment/sequencing/timeframe requirements for specially designed, or project specific equipment such as cranes, launching girders, pre mix plants, barges, etc. | Project may cost more (additional mobilization) and proceed more slowly without equipment for bridges, RBT, etc. | 3 | 3 | 9 | 50,000.00 | 500,000.00 | 1 Month | 6 Months |
| 003. | 10 | Emergency pedestrian egress will need further definition (aerial structures). Additional calculations and review | Project can not meet safety (OSHA, NFPA) standards without development | 4 | 2 | 8 | 10,000.00 | 200,000.00 | 2 months | 6 Months |
| 004. | 10 | Factor night work cost or road closure cost in GC for track work elements at CBD area. | Additional costs may be incurred for night work, overtime, road closures etc. | 4 | 4 | 12 | 250,000.00 | 3,500,000.00 | 3 Month | 18 Months |

**Figure H-3. Example of Quantitative Risk Analysis as shown in Risk Register**

### H.2.2.4 Risk Planning

The FTA utilizes avoidance, mitigation, transfer, and acceptance to handle risks. Their methods are in line with industry standard techniques for risk handling. The FTA does indicate that their risk handling approaches change throughout the lifecycle of a project. Figure H-4 indicates the shift from utilizing design solutions to employing monetary solutions towards the end of the bid phase.

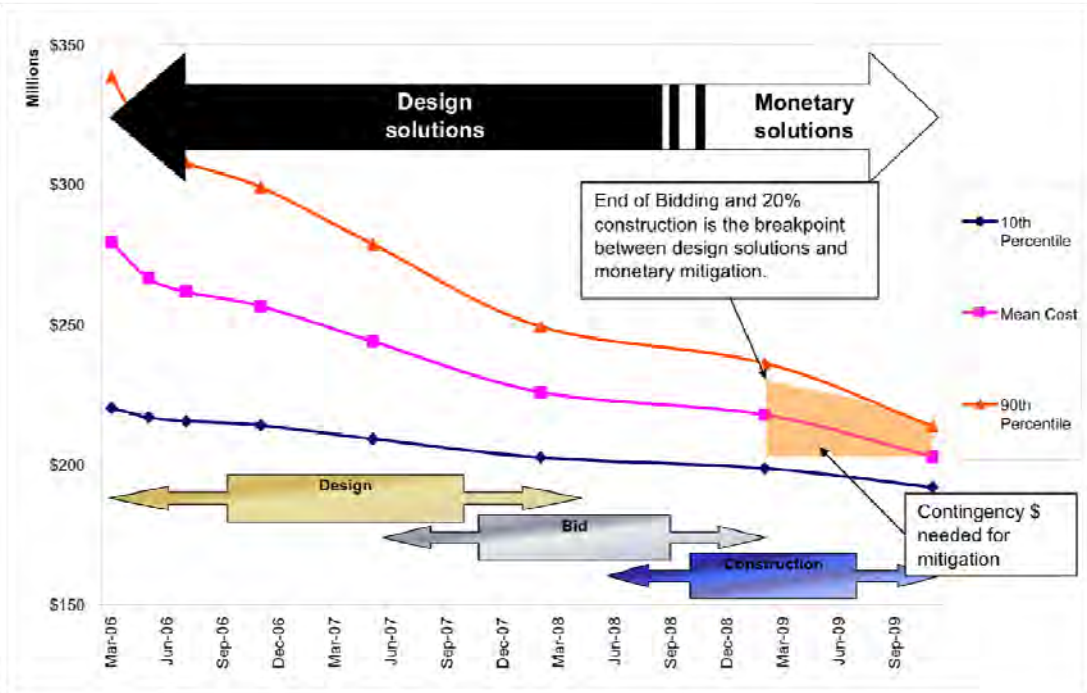


**Figure H-4. Example of Risk Planning Strategies**

### H.2.2.5 Risk Monitoring and Control

Specifically in regard to contingency allocation, Figure H-4 shows the "hold points" used to ensure adequate contingency is in place:

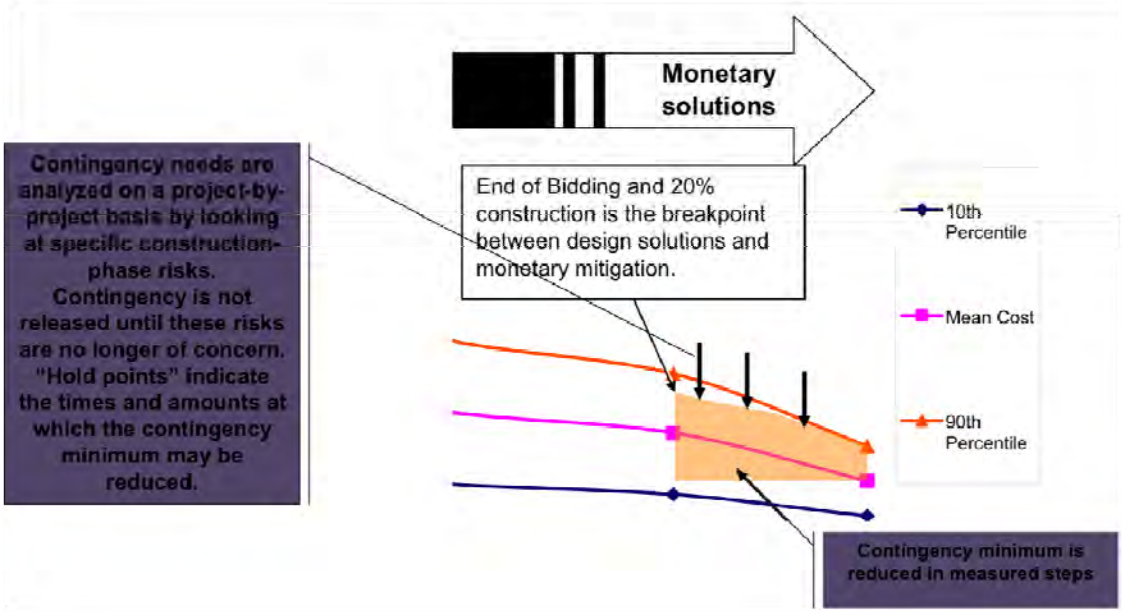


**Figure H-4. Example of Risk Hold Points**

### H.2.2.6 Risk Documentation

The FTA utilizes extensive documentation and review to monitor and control projects for which it has contributed funding. At two major points, the PMOC will review the project for potential risks and assess the project against its goals. These reviews are required to determine the "Readiness to Enter Preliminary Engineering" and "Readiness to Execute the Full Funding Grant Agreement." These reviews may also occur at other points throughout the project.

## H.2.3 Top-Down Risk Analysis

Figure H-5 shows the unique steps utilized in the top-down risk analysis approach:

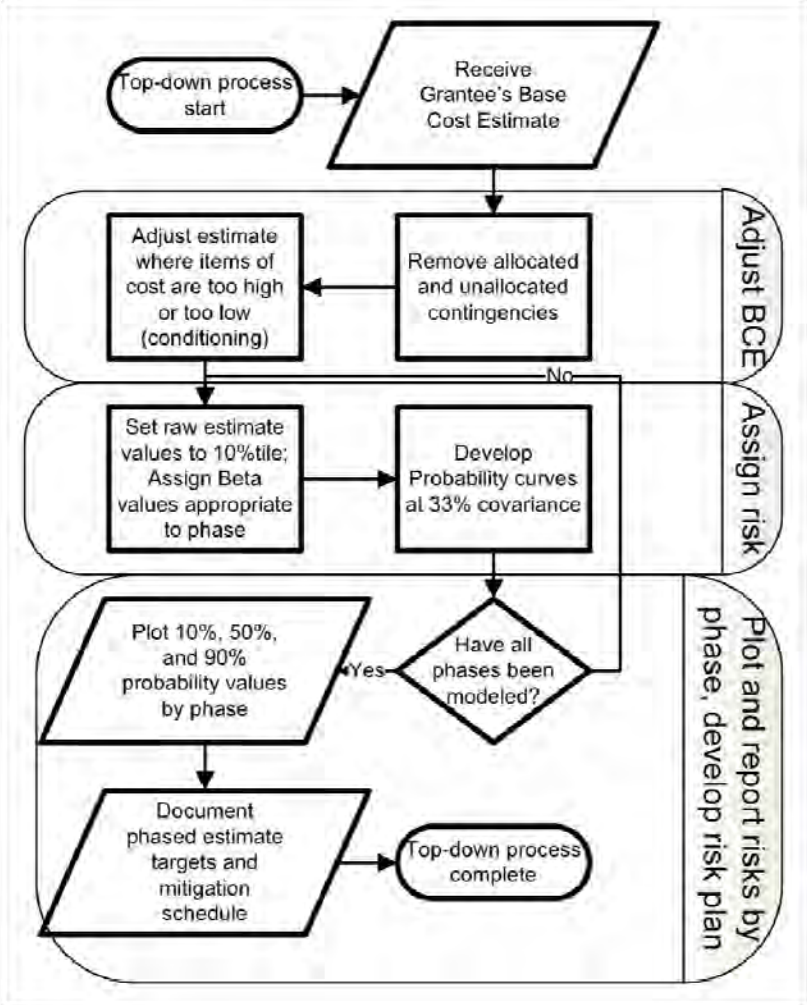


**Figure H-5. Top-Down Risk Analysis Approach**

During top-down risk analysis, the FTA uses the following steps:

Step 1: Adjusting the base estimate

The base cost estimate should be stripped of all costs allocated to account for future unknown costs. After this, the estimate should be evaluated for accuracy.

Step 2: Assigning Levels of Risk

Using historical data and professional judgment, the PMOC assigns risk levels to the different categories of risk. Using the base cost estimate as a guide, the 10% likelihood level is established for each category. Using Beta values based on historical data, the 90% likelihood level is then established. Guidelines for the beta values used for the 4 categories by the FTA are provided in Figure H-6 and Table H-1.

| *Implementation Phase>>* | *Requirements* | *Design* | *Market* | *Construction* |
|---|---|---|---|---|
| ***Initial β estimate*** | β>2.5 | 2.5 to 2.0 | 2.0 to 1.75 | 1.75 to 1.05 |

**Figure H-6. Beta Values**

**Table H-1. Beta Value Descriptions**

| **β Value or Range *** | **Description** |
|---|---|
| Above 2.5 | Implies increasing uncertainty associated with project requirements. |
| 2.5 | All requirement risks have been mitigated. |
| 2.0 | All design risks have been mitigated |
| 1.75 | All market risks inclusive of bidding risk have been mitigated through availability of a firm price/quote. |
| 1.35 | All early construction risks composed of geotechnical/utility/major claims, usually associated with 20% complete, have been mitigated |
| 1.20 | All mid-construction risks inclusive of major claims, delays, impacts, etc., usually associated with 75% complete, have been mitigated. |
| 1.05 | All start-up / substantial completion of construction risks, usually associated with 90% complete, have been mitigated. |
| 1.0 | Implies there are no risk or uncertainty of any kind associated with this item and represents the perfectly mitigated state of the project scope item, or the expected value of perfect mitigation. |

Step 3: Projecting and Reporting Phased Risk Values

Using probabilistic summing, the different categories are added together to generate the probability curve for the total project cost. The method for summing involves assuming both of the following: total correlation between categories and no correlation between categories.

Using to-down analysis, Figure H-7 shows how risk is expected to diminish in terms of the total project cost throughout the life-cycle of the project.

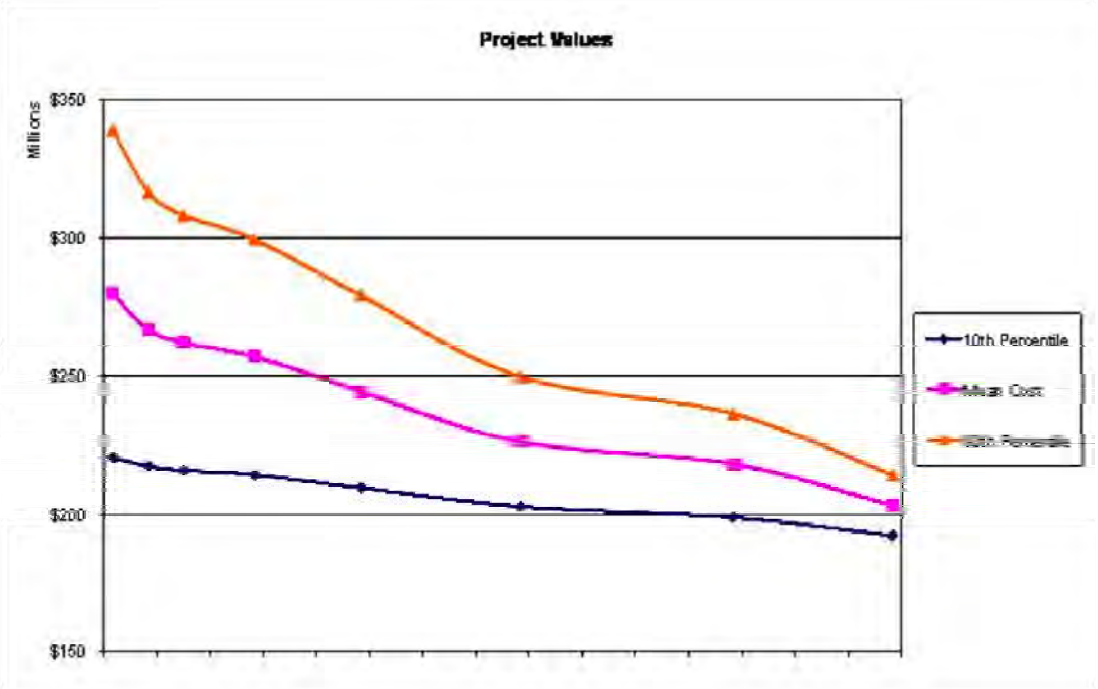


**Figure H-7. Risk and the Project Lifecycle**

## *H.3 Summary*

The FTA is employing comprehensive methods to risk management that are integrally tied to their project management processes. The top-down risk analysis and contingency application is currently yielding FTA with better cost control results than what they were experiencing with a more traditional bottom-up approach to risk management and contingency setting. Cost control is extremely important from the FTA's perspective. The use of these methods in combination with hold points is assisting FTA to alleviate past problems that the agency has experienced with cost escalation.

# Appendix I: NYMTA Case Study

## *The New York Metropolitan Transit Authority (NYMTA) Risk Management Approach*

## *I.1 Introduction*

The MTA Capital Construction Company was formed in 2003 to manage the major transportation and infrastructure projects of Downtown Manhattan. The Company focuses all of its efforts on "mega projects." The five projects currently being managed by the Company are:

1. Second Avenue Subway – This project involves the construction of a new, 8.5 mile long subway down the East side of Manhattan. This project is currently estimated at $4.05 billion and is scheduled to be complete in 2014. This differs from the original estimate which was $3.8 billion. The schedule was originally 6 months shorter. This project is currently in the first of four phases of construction.
2. East Side Access – This project will connect two subway lines in Queens to a new Long Island terminal underneath Grand Central Terminal. The total estimated project cost is currently $6.3 billion, with $2.7 billion of that being funded from FTA. This project underwent elaborate risk analysis in 2007. The risk analysis plan is currently being reviewed given new market conditions. This project is currently scheduled to be completed in 2013.
3. South Ferry Terminal – This $400 million project is to build a new terminal for the #1 subway line adjacent to Battery Park. This project also underwent the Company's risk analysis process.
4. Fulton Street Transit Center – This $880 million project is scheduled for completion in 2010. The line will organize and merge the existing 12 lines built by different companies. The project is scheduled for completion in mid-2009. Parts of the new station are already open to the public.
5. Far West Side Subway Extension – This $2.1 billion project is aimed at the redevelopment of the Hudson Yards area on the west side of Manhattan. This project is fully funded by the City of New York.

### I.1.1 Research Methods

This case study was completed through an interview on January 25th, 2008. Dr. Clifford Schexnayder attended the interview at the MTA offices in Manhattan and the remainder of the research team attended via conference call from Colorado and Texas. The interview participants included: Mysore Nagaraja, President, MTA Capital Construction; Veronique (Ronnie) Hakim, VP & General Counsel; Shawn Kildare, VP, Program Controls & Quality/Safety; George Blank, Manager, Cost Control; Dr. Keith Molenaar, University of Colorado; Dr. Stuart Anderson, Texas A&M. The interview was conducted using the case study protocol provided in Chapter 4 of this report.

## *I.2 Risk Management Overview*

The majority of the policies governing the operation of the Metro Transit Authority are driven by Federal Transit Administration. Because the majority of funding for MTA projects comes from the FTA, the risk management policies also strictly follow the guidelines set forth by the FTA.

### I.2.1 Contingency

MTA does have a documented definition of contingency. This contingency involves "known-unknowns" and "unknown-unknowns." Contingency is variable throughout the construction phases. Contingency at the early phases is usually around 20-25% depending on historical knowledge. Typically, when documents are 100% complete, the team still carries 5% contingency. During the Risk Analysis workshops, the team attempts to strip all contingency out of the estimate.

### I.2.2 Risk Management Steps

In the six months prior to the interview, as the FTA established improved procedures for Risk Analysis, the MTA became more comfortable with the FTA guidelines. This level of comfort allowed the MTA to stop using their independent process and rely on the FTA guidelines. The MTA described their risk management process in the steps described in the case study protocol found in Appendix I of this report.

#### I.2.2.1 Risk Identification

During intensive, week-long workshops, the potential risks are identified by the key players in each project. Workshops usually consist of 20 to 30 people who are designers, constructors, estimators, and FTA staff. These workshops strive to identify the top 10 to 15 risks facing any given project. Throughout the design process, these risks are monitored and the "Top 10" list is updated to highlight the risks with the greatest potential risk.

#### I.2.2.2 Qualitative Risk Analysis

The MTA always tries to carry their risk analysis past the qualitative level. The identification of risks will place each risk into a high, medium, or low category. However, this ranking is only used to rank the risk in the "Top 10" list. The FTA has published guidelines for using qualitative risk analysis, but MTA found the guidelines to be confusing and opted to focus more on quantitative risk analysis.

#### I.2.2.3 Quantitative Risk Analysis

In their quantitative risk analysis, MTA identifies high and low impacts for each risk and assigns a probability to each. Within this analysis, global risks are separated to try and effectively keep estimators' bias (on material prices and market conditions) tracked separately. For their quantitative analysis, MTA uses @Risk and Primavera PERT modeling for risk analysis. MTA used to try to model both cost and schedule risks together, but found the practice ineffective.

#### I.2.2.4 Risk Planning

The FTA takes a standard approach to risk planning. The research team and MTA did discuss any unique features of risk planning within the organization.

#### I.2.2.5 Risk Monitoring and Control

At various points throughout the design, the FTA establishes "hold points" at which time the risk management plan can be reanalyzed to assess budget, contingency, and schedule.

#### I.2.2.6 Risk Documentation

As part of the Project Management Plan the risk process is heavily monitored and submitted to the FTA for review.

## *I.3 Summary*

The MTA is comfortable with the level oversight that FTA is providing for risk management and they have adapted their own risk management processes within the FTA guidelines. Their procedures follow the general steps discussed in this report. The large size of the projects undertaken by MTA necessitates detailed risk management plans as part of their overall project management efforts.

# Appendix J: OHDOT Case Study

## *The Ohio Department of Transportation (ODOT) Approach to Risk Management*

## *J.1 Introduction*

The Ohio Department of Transportation (ODOT) oversees the construction and maintenance for Ohio's highways, railways, transit, aviation, and port facilities. From the ODOT website, of note about Ohio's infrastructure is: "Ohio has the 10th largest roadway system and 2nd largest bridge inventory in the nation. The system carries the 5th largest traffic volume and 4th largest truck traffic volume. Ohio also ranks in the top 10 nationally for transit ridership, number of transit miles traveled and number of transit vehicles operating in the state."

### J.1.1 Research Methods

This case study was completed through a phone interview on 28 February 2008. The interview was attended by Mr. Jeffery Hisem and member of the staff from the Estimating Office at the ODOT. Dr. Keith Molenaar and Craig Wilson from the University of Colorado and Dr. Stuart Anderson from Texas A&M attended for the research team. The interview was conducted using the case study protocol provided in Chapter 4 of this report.

Prior to and during the interview, the website for the Office of Estimating was consulted. The website is rich with information and guidance on ODOT's cost estimating process. The website can be found at www.dot.state.oh.us/CONTRACT/estimating/

Additionally, the ODOT utilizes the FHWA Risk Management Initiative as guidance for their risk management policies and procedures. The processes outlined in this document are based upon the FHWA literature provided by the ODOT.

## *J.2 Risk Management Approach*

As previously stated, ODOT utilizes the FHWA Risk Management Initiative as guidance for their risk management procedures. However, they do not employ these rigorously on every project. A brief summary of the FHWA document is provided below.

### J.2.1 Risk Analysis

Risk analysis is performed using basic tools. PxI matrices are utilized by the DOT to perform analysis and prioritization steps of their risk management process.

### J.2.2 Steps of Risk Management

The Ohio DOT utilizes a different set of 6 steps than is presented in other guides. The 6 steps are:

1. Gather Information About Your Risks
2. Identify Your Risks
3. Assess Your Risks
4. Your Risk Response Strategies
5. Prioritize Your Risks

6. Monitor, Evaluate, and Adjust Your Strategies

The DOT adds the step "Gather Information About Your Risks" and the removes the formal "Risk Analysis" step, instead using Risk Assessment. Each of their steps is outlined briefly below.

1. *Gather Information About Your Risks*
   This step is essentially brainstorming ideas about where risks will be coming from in the project. It involves identifying strengths and weaknesses as well as opportunities and threats. This step is more general and categorical in identifying risk sources than the next step.

2. *Identify Your Risks*
   This step is more formalized brainstorming of potential risks. The step emphasizes if-then statements as the basis for risk definition.

3. *Assess Your Risks*
   In this step, risks are characterized by their probability of occurrence and their potential impact. The step describes a process that closely resembles the Probability and Impact matrices developed by other organizations. There is some discussion of the development of a future process to identify recurring events at the agency level.

4. *Your Risk Response Strategies*
   The Ohio DOT uses four risk response strategies: Avoid, Transfer, Accept, and Mitigate/Enhance. Basic definitions are used for each of these strategies.

5. *Prioritize Your Risks*
   The DOT prioritizes risks based on the results of a spreadsheet calculation (Likelihood x Impact). However, the DOT also adjusts their prioritization based on program area needs. They also admit that Opportunity risks are undervalued and are often prioritized higher. The involvement of stakeholders is emphasized in prioritizing risks.

6. *Monitor, Evaluate, and Adjust Your Strategies*
   This step focuses on the evaluation of existing strategies and adjusting the expected values. No specific strategies for monitoring, evaluating, or adjusting risks are given in the documentation.

### J.2.3 Contingency

The topic of contingency was discussed at length with the estimating staff. ODOT does not employ a formal risk process to set its contingency. The Office of Estimating does provide project managers with guidance for contingency on major projects in its extensive ODOT's

Procedure for Budget Estimating.[7] A graphic that illustrates ODOT's approach to setting contingency is shown in Figure J-1.

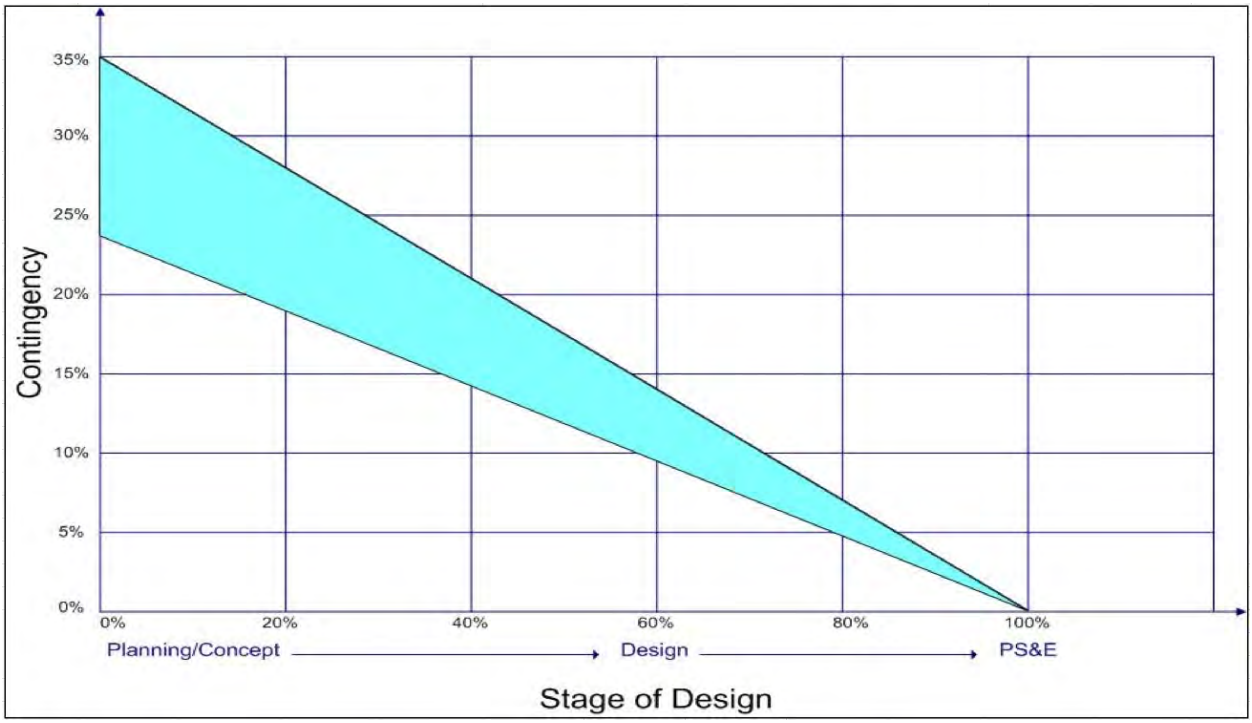


**Figure J-1. ODOT Design Completion Contingency Guidelines for Cost Estimating of Major Projects**

## *J.3 Conclusions*

The ODOT Estimating Office provides clear guidance to their estimators concerning contingency. They are currently developing more rigorous policies and procedures for formal risk management. The main hurdle noted by the ODOT interviewees in developing additional risk management practices was resources needed for training and implementation.

7 http://www.dot.state.oh.us/CONTRACT/estimating/Cost%20Estimating%20Support/Cost%20Estimation%20Support.htm

# Appendix K: State-of-Practice Web Survey

## Contingency & Risk Analysis Practices

NCHRP 8-60 GUIDEBOOK ON RISK ANALYSIS TOOLS AND MANAGEMENT PRACTICES TO CONTROL TRANSPORTATION PROJECT COSTS

Fifteen-minute Questionnaire on Contingency and Risk Analysis Practices
Introduction

You are being invited to participate in a study of contingency and cost estimating practices for cost estimating. The research objective is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs. Your individual privacy will be maintained in all published and written data resulting from this study. We expect the project to benefit you by providing methods for more consistent and accurate cost estimates. You will receive no compensation for your participation.

1

I understand the above information and voluntarily consent to participate in the research project entitled NCHRP 8-60 Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs.

- Yes
- No

SUBMIT

Survey Page 1

## Contingency & Risk Analysis Practices

The National Cooperative Highway Research Program (NCHRP) is sponsoring a research project aimed at creating a guidebook on risk analysis tools and management practices (NCHRP Project 8-60). The University of Colorado is teaming with Texas A&M University, Arizona State University, and TDC Partners to develop the guidebook.

The research objective is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling

transportation project costs. The guidebook will include a plain language toolbox for transportation agencies to use in selecting appropriate strategies, methods, and tools to apply in meeting their cost-estimation and cost-control goals and objectives.

The purpose of this questionnaire is to identify how different agencies and organizations determine contingency and manage risk-related costs throughout the project development process. While the guidebook is being developed specifically for highway planning and construction, we are striving to collect data from all sectors of design and construction as a means of comparison and to generate new ideas across the industry.

SUBMIT

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## Contingency & Risk Analysis Practices

Contingency and risk management practices vary throughout the project development process. For purposes of this questionnaire, we would like to ask questions about the following three distinct phases of the project development process.

Planning – The initial phase of project development in which the project purpose and need is determined. This phase can include benefit-cost analysis for ranking projects and including them in the 25-year planning horizon. Projects in this phase include a range of design that is approximately less than 5% complete as a general point of reference.

Programming/Schematic Design – This phase of project development involves project scoping. It often includes the development of environmental analyses, right-of-way impacts, design criteria and parameters, survey utility locations and drainage, and alternative selections. Projects in this phase include a range of design that is approximately 5%-30% complete as a general point of reference.

Detailed Design – The final design phase of project development in which detailed designs are completed for construction. This phase includes acquisition of right of way, and final development of plans, specifications, and estimates (PS&E). Projects in this phase include a range of design that is approximately 30%-100% complete as a general point of reference.

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## Contingency & Risk Analysis Practices

**2**

Please fill in the following information.

First Name

Last Name

Organization

State in which you are employed

**3**

We are asking for your email so that we may contact you with the results of this effort.

- [ ] Please do not contact me with the results.
- [ ] I am available for additional questions.
- [ ] Email

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## Contingency & Risk Analysis Practices

**4**

Please check the item below which best describes your organization.

- [ ] State Department of Transportation
- [ ] Other public agency, please describe

**5**

Organization's primary construction sector:

- Highway
- Transit
- Other - please explain

**6**

Organization's approximate annual program size (include all sources federal, state, etc.). Answer is approximate $/yr in revenue/volume/funding ($xxx,xxx,xxx).

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## Contingency & Risk Analysis Practices

**7**

For the following project development phases, does your organization use 1) solely a separate estimating section, 2) solely designers and project managers for estimating, or 3) both an estimating section and distributed project designers and managers for estimating?

| | 1<br>Separate section | 2<br>Designers & Managers | 3<br>Both |
|---|---|---|---|
| Planning | 1 | 2 | 3 |
| Programming/Schematic Design | 1 | 2 | 3 |
| Detailed Design | 1 | 2 | 3 |

**8**

If your agency does have separate estimating sections for any of the phases above, can you provide the section names and/or a Web address?

**9**

Does your organization have a formal published definition for contingency that is used consistently throughout the estimating process?

YES NO

**10**

If yes to question 9, please provide this definition.

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## Contingency & Risk Analysis Practices

**11**

Which of the following best describes your organizations method for setting contingency?

- A standard pre-determined contingency is applied across all projects.
- A unique project contingency is set by engineers, estimators or project managers.
- A formal risk analysis process is used to set contingency on each project.

Other - please explain in text box on Question 12.

**12**

If other for Question 11, please explain other method(s) for setting contingency.

**13**

If your organization uses a standard pre-determined contingency, what percentages are applied across the project development phases?

% Planning

% Programming/ Schematic Design

% Final Design

Please fill N/A if not applicable

**14**

For Question 13, please briefly explain what is represented in the % contingency (e.g., design development, construction changes, etc.).

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## Contingency & Risk Analysis Practices

**15**

If your organization uses a standard pre-determined contingency, are standard variations made for any of the following (check all that apply)?

- [ ] Phase in the project development process
- [ ] Project type
- [ ] Project complexity
- [ ] Market conditions
- [ ] No standard deviations
- [ ] Other - please explain in text box on Question 16

**16**

If other for Question 15, please explain any other standard variations.

**17**

If your organization uses a unique project contingency, do engineers, estimators or project managers use any of the following methods or tools when determining this contingency? Please check all that apply.

- [ ] Engineering judgment
- [ ] Statistical analysis of historic data
- [ ] Correlation of historic data with current market prices
- [ ] Identification of specific risks and assignment of associated contingency
- [ ] No unique project contingencies
- [ ] Other - please explain in text box on Question 18

**18**

If other for Question 17, please explain any other methods or tools.

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## Contingency & Risk Analysis Practices

**19**

Does your organization communicate or present project cost estimates in terms of ranges vs. point estimates?

| | 1 Never | 2 Sometimes | 3 Always |
|---|---|---|---|
| Planning | 1 | 2 | 3 |
| Programming/Schematic Design | 1 | 2 | 3 |
| Detailed Design | 1 | 2 | 3 |

**20**

Does your organization apply a contingency at 1) the individual project level, 2) a program level (e.g. contingency that is spread across project in your State Transportation Improvement Program (STIP)), 3) at both the project and program level, or 4) none?

| | 1 Project level | 2 Program level | 3 Both | 4 None |
|---|---|---|---|---|
| Planning | 1 | 2 | 3 | 4 |
| Programming/Schematic Design | 1 | 2 | 3 | 4 |

Detailed Design

1 2 3 4

**21**

If your organization applies contingency at a program level in Planning, Programming/Schematic Design, or Detailed Design, please briefly explain the method for setting this contingency.

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## Contingency & Risk Analysis Practices

**22**

Does your organization have a formal, published project risk management policy or procedures?

YES NO

**23**

If your organizations policies or procedures are available in electronic form, can you share them with us via email or via the Web?

- [ ] Policies and procedures will be emailed to Keith.Molenaar@colorado.edu
- [ ] Not available
- [ ] They are available at the following Web address

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## Contingency & Risk Analysis Practices

**24**

Does your organization conduct formal risk analyses in any of the following areas? If yes, please approximate the percent of projects.

Project scope (%) _____
Project schedule (%) _____
Project cost (%) _____
Contracting risk (%) _____
Other - please explain _____
Other - please explain _____
Other - please explain _____

**25**

Does your risk analysis process change for any of the following areas? Please check all that apply.

- ☐ Project size or scale
- ☐ Project value/dollar amount
- ☐ Project complexity
- ☐ N/A
- ☐ Other - please explain in text box on Question 26

**26**

If other in Question 25, please expalin the change in the risk analysis process.

_____

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## Contingency & Risk Analysis Practices

**27**

Does your organization use any of the following risk identification techniques? Please check all that apply.

- [ ] Standard checklists
- [ ] Brainstorming
- [ ] Scenario planning
- [ ] Expert interviews
- [ ] Delphi methods
- [ ] Influence or risk diagramming
- [ ] N/A
- [ ] Other - please explain in text box on Question 28

**28**

If other in Question 27, please explain other risk identification techniques.

**29**

Does your organization use any formal qualitative or quantitative risk assessment techniques? Please check all that apply.

- [ ] Qualitative risk assessment techniques (e.g., categorization of probability and impact)
- [ ] Use of expected values through statistical analysis of historic data for assigning cost to risks
- [ ] Use of expected values through engineering judgment for assigning cost to risks for Monte Carlo or simulation methods
- [ ] Influence diagramming
- [ ] Probability or decision trees
- [ ] Probabilistic Evaluation Review Techniques (PERT)
- [ ] N/A
- [ ] Other - please explain in text box on Question 30

**30**

If other in Quesiton 29, please explain other formal qualitative or quantitative risk assessment techniques.

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## Contingency & Risk Analysis Practices

**31**

Does you organization use any of the following risk management techniques? If yes, please approximate the percent of projects.

| | |
|---|---|
| Risk register (%) | |
| Risk management plan (%) | |
| Risk mitigation plan (%) | |
| Other - please explain | |

Other - please explain

Other - please explain

Please fill in no if not applicable

**32**

Does your organization employ any formalized risk tracking and monitoring for risk management during the project development process?

YES NO

If yes, please explain

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## Contingency & Risk Analysis Practices

**33**

Does your organization employ any formalized risk allocation techniques to draft the contract provisions?

YES NO

If yes, please explain

**34**

In your opinion, how confident is you organization in its current risk analysis methods?

- Confident
- Comfortable
- Questionable

- Not Confident
- N/A

**35**

In your opinion, how often is the organization successful in implementing the proper risk analysis to its projects.

- Always
- Frequently
- Seldom
- Never
- N/A

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