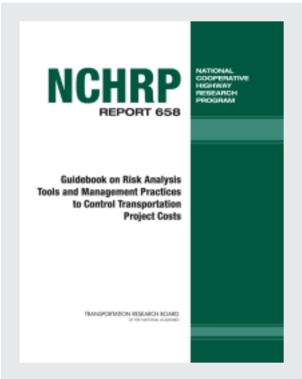


Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs

DETAILS

119 pages | | PAPERBACK
ISBN 978-0-309-15476-5 | DOI 10.17226/14391

AUTHORS

Stuart Anderson; Keith Molenaar; Cliff Schexnayder; Transportation Research Board

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 658

Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs

Keith Molenaar
UNIVERSITY OF COLORADO
Boulder, CO

Stuart Anderson
TEXAS TRANSPORTATION INSTITUTE
College Station, TX

AND

Cliff Schexnayder
DEL E. WEBB SCHOOL OF CONSTRUCTION
ARIZONA STATE UNIVERSITY
Tempe, AZ

Subscriber Categories
Administration and Management • Construction • Design • Environment • Highways • Planning and Forecasting

Research sponsored by the American Association of State Highway and Transportation Officials
in cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2010
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 658

Project 08-60
ISSN 0077-5614
ISBN 978-0-309-15476-5
Library of Congress Control Number 2010928846

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

The Transportation Research Board of the National Academies, the National Research Council, and the sponsors of the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

CRP STAFF FOR NCHRP REPORT 658

Christopher W. Jenks, *Director, Cooperative Research Programs*
Crawford F. Jencks, *Deputy Director, Cooperative Research Programs*
Lori L. Sundstrom, *Senior Program Officer*
Megan A. Chamberlain, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Margaret B. Hagood, *Editor*

NCHRP PROJECT 08-60 PANEL
Field of Transportation Planning—Area of Forecasting

Robert E. "Buzz" Paaswell, *City College of New York, New York, NY* (Chair)
Timothy A. Henkel, *Minnesota DOT, St. Paul, MN*
Terry L. Berends, *Washington State DOT, Wenatchee, WA*
Daryl James Greer, *Versailles, KY*
Dennis A. Randolph, *Calhoun County (MI) Road Commission, Marshall, MI*
Jennifer S. Shane, *Iowa State University, Ames, IA*
Robert Stuard, *Texas DOT, Austin, TX*
Jon Tapping, *California DOT, Sacramento, CA*
Steven F. Wilson, *Michael Baker, Jr., Inc., Moon Township, PA*
Robin K. Smith, *FHWA Liaison*
Martine A. Micozzi, *TRB Liaison*

FOREWORD

By Lori L. Sundstrom
Staff Officer
Transportation Research Board

This guidebook provides guidance to state departments of transportation for using specific, practical, and risk-related management practices and analysis tools for managing and controlling transportation project costs. Containing a toolbox for agencies to use in selecting the appropriate strategies, methods and tools to apply in meeting their cost-estimation and cost-control objectives, this guidebook should be of immediate use to practitioners that are accountable for the accuracy and reliability of cost estimates during planning, priority programming and preconstruction.

Identifying, analyzing, and managing the risk of project-cost escalation are fundamental challenges facing the transportation industry. *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction* focused on the issue of cost escalation and developed a guidebook on highway cost-estimation management and tools aimed at achieving greater consistency and accuracy in long-range transportation planning, priority programming, and preconstruction estimates. Building on *NCHRP Report 574, NCHRP Report 625: Procedures Guide for Right-of-Way Cost Estimation and Cost Management* details practical and effective approaches for developing right-of-way (ROW) cost estimates and for then tracking and managing ROW cost during all phases of project development from planning through final design. Again building on *NCHRP Report 574, NCHRP Report 658* provides an in-depth treatment of specific risk-related management practices and analysis tools.

Under NCHRP Project 08-60, the University of Colorado was asked to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs. Specifically, the guidebook addresses (1) the inconsistent application of contingency to risk management and cost estimation, (2) the lack of uniformity in methods of documenting and tracking risk within a comprehensive cost-control strategy or program, (3) insufficient procedures for determining timing of risk management within various phases of project development, the need for matching appropriate tools to different project scales, (4) insufficient organizational structure, (5) organizational commitment, performance measurement, and accountability within transportation agencies, (6) policy and political issues, and (7) the regulatory environment.

To meet the project objectives, the research team (1) conducted a comprehensive literature review, (2) reviewed current practice in defining and categorizing risk, and in assessing the degree of uncertainty in transportation project-cost estimation, (3) reviewed a range of well-established risk analysis tools and management practices, and (4) prepared a series of case studies that demonstrate effective application of risk-analysis tools and management practices. The contractor's project final report that contains documentation of the research teams' conduct of the research is available on the TRB project web site.

CONTENTS

SUMMARY

Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs

Project cost escalation is a serious problem facing state highway agencies (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. 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 uncertainty and its effect to the 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 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.

Risk Management Framework

The risk management framework described in this Guidebook is based on best practices in design and construction. In the Guidebook, those practices are adapted to the unique needs of highway project development. The iterative risk management framework is described in terms of the project development phases and project complexity. The framework 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

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.

Keys to Success

Lessons learned from the development of this Guidebook can be summarized in five keys to success for applying risk analysis tools and management practices 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 are often fraught with uncertainty. Engineers and construction managers who lead such projects must coordinate a multitude of human, organizational, technical, and natural resources. Quite often however, the engineering and construction complexities of transportation projects are overshadowed by economic, societal, and political challenges. The impact of not addressing these external challenges has often resulted in significant project cost escalation. If a SHA fails to deliver individual projects and programs within established budgets there is a detrimental effect on later programs and a loss of faith in the agency's ability to wisely use the public's money.

Project cost escalation is therefore a serious problem for SHAs. To aid SHA's in managing their construction programs the NCHRP conducted Project 8-49 that developed cost estimation and management guidance. This guidance can be found in *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, particularly in the long-range transportation planning, priority programming, and preconstruction stages of the project development process. Therefore, NCHRP executed Project 8-60 to produce a "Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs." The research objective of Project 8-60 was to develop tools and management practices to address:

- Consistent definitions for "cost escalation," "uncertainty," "risk," and "contingency";
- Guidance for consistent application of contingency to risk management and cost estimation;
- Systematic and uniformed approaches for documenting and tracking risk;
- Appropriate timing of risk management procedures given various levels of project complexity during the different project development phases;
- Anticipate and manage policy, political, and communications uncertainties;
- Appropriate organizational structures and required organizational commitment to achieve a risk management culture; and
- Appropriate performance measurements and accountability tools that can exist within transportation agency organizational structures.

Rigorous risk analysis and risk management has the potential to minimize the cost escalation problem. 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 U.S. SHAs.

1.1.1 Cost Escalation and Cost Containment

The problem of project cost estimates continuing to increase in magnitude as a project moves from the conceptual stage to construction 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 significantly above agency estimates in the case of the Wilson Bridge in Washington, D.C. and the San Francisco-Oakland Bay Bridge East Span, and to the significant cost escalation experience over just the construction phases of the Central Artery/Tunnel project in Boston (National Academy of Engineering 2003). These problems are pervasive in the transportation industry 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 were underestimated for approximately 90 percent of the projects examined, and that their actual costs average 28 percent higher than the estimated cost (Flyvbjerg, et. al 2002). Although highway projects fared better than rail and fixed-linked projects, the highway sample still displays an average increase in project costs of more than 20 percent. As a result of both higher bids and project cost growth, estimating for projects over $10 million was recently a topic of review by the Federal House Subcommittee on Transportation Appropriations (Federal-Aid 2003). The FHWA provides clear guidance that risks and an associated contingency must be addressed in major project cost estimates (projects above $500 million) (FHWA 2007). This guidance should apply to small projects as well as major projects because even small projects can be extremely complex. Clearly, a majority of SHAs are involved in numerous complex projects and additional guidance in the area of risk management to control transportation project costs will assist in better management of the project development process.

Managing development of major highway projects involves dealing with organizational, technical, and external issues which are oftentimes volatile. Uncertainty and risk play a major role in cost escalation throughout the project development process. 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 available resources, resulting in loss of benefits. If estimates are consistently low, more projects will be authorized than can be fully funded, resulting in project slowdowns, scope changes, and performance shortfalls, and generally higher costs and lower 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 constructed. All of these conditions result in misallocation of resources and a loss in benefits to the public.

The use of risk assessment, cost estimating, cost management, and cost containment techniques at the earliest stages in the project development process will yield substantial value to a SHA. Cost engineering research has repeatedly demonstrated that the ability to influence and manage cost is greatest at the earliest stages in a project development ("Pre-Project Planning: Beginning a Project the Right Way" 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 using risk analysis and management tools at 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 project development process – even if the transparency of uncertainty in the engineering and political process is difficult to define and manage.

1.1.2 Guidebook Concepts

This Guidebook presents a systematic approach for the application of risk analysis and management practices that are linked to the planning and the project development process and project complexity. This Guidebook defines risk in the project development process as:

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

The fundamental steps in the risk process remain consistent, but the application is affected by both a) when the analysis is being applied in the project development process and b) the level of project complexity. Risk analysis tools and management practices should align with the project development process and project complexity. The output of the process is a risk-based contingency for controlling project cost and a risk register for tracking, managing risks, and resolving contingency throughout the project development process.

The overall framework of the Guidebook includes three main elements. 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.

Figure 1.1. Risk management process framework (varies by project development phase and complexity).

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 in Figure 1.1 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 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 noncomplex projects to large and complex projects. The Guidebook directly addresses the interaction of these important elements.

1.2 Guidebook Development

This Guidebook was developed under NCHRP Project 8-60, "Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs." The research was conducted in two phases. The first phase focused on a state-of-practice review of cost risk analysis and management. The current state of practice was characterized by an extensive review of the literature supported by an industry survey representing responses from 48 SHAs and the FHWA. The survey found that very few SHAs were actively practicing risk analysis. The state of practice was further characterized through in-depth case studies into the practices of four SHAs identified by the survey as leaders in the use of risk management practices. Additionally, leading public agencies from outside the highway sector were studied including the FTA, the New York Metropolitan Transit Authority, and the Department of Energy. The literature, survey, and case studies were used to identify tools and management practices for inclusion in the Guidebook.

The second research phase research synthesized the tools and practices into a framework for application in this Guidebook. The Guidebook framework addresses 1) risk identification; 2) assessment; 3) analysis; 4) mitigation; 5) allocation; and 6) tracking and control in the planning, programming, and design phases of project development. This framework was tested and validated with three SHAs. These SHAs provided a critique of the Guidebook's content, structure, layout, and user friendliness. The NCHRP 8-60 panel reviewed and commented on this final version of the Guidebook.

1.3 Guidebook Organization

The Guidebook has eight chapters, including the introduction. The background information and fundamental concepts concerning the content of the Guidebook are developed in Chapters 2, 3, and 4. Chapter 2, "Project Cost Estimation and Management," demonstrates how cost estimation practice and cost estimation management are linked to planning and the project development process. Chapter 2 also summarizes the key strategies, methods, and steps for estimating that were developed in *NCHRP Report 574: Guidance for Cost Estimation and Management during Planning, Programming, and Preconstruction* (Anderson et al., 2007). Chapter 3, "Risk Management Overview" provides a detailed description of the risk analysis process. Chapter 3 opens with a discussion of how to use contingency as a means of controlling costs throughout the project development process. It presents the risk management definitions and steps used throughout this Guidebook. It closes with a discussion of how to form policies and performance measures for integrating risk management into the operation and culture of a SHA. Chapter 4, "Guidebook Framework," presents a consistent approach to describe the risk analysis tools and management practices found in the remainder of the Guidebook. Chapter 4 presents the framework that will be applied in the subsequent chapters.

Chapters 5, 6, and 7—"Guide to the Planning Phase," "Guide to the Programming Phase," and "Guide to the Design Phase," respectively, focus on the application of the fundamental concepts presented in Chapters 2, 3, and 4. These chapters provide guidance to risk analysis and management implementation during each phase of project development. Guidance is provided with a specific focus on the most appropriate tools for a specific project phase and project complexity. The risk analysis and contingency estimation framework is used to guide readers to the appropriate tools for application. The tools are presented in an extensive Appendix A, which provides support for implementation of the methods described in Chapters 5, 6, and 7. Appendix A provides information concerning tools, including examples and illustrations of the tools. This appendix is meant to be used in conjunction with the chapters of the Guidebook and not in á la carte fashion.

A strategic approach will be required to facilitate implementation of new risk analysis and management practices. Chapter 8, "Implementation," covers key implementation thrust areas and steps in the implementation process that must be considered when introducing changes to current cost estimation practice and cost estimation management within a transportation agency. Finally, Chapter 9 summarizes the main features of the Guidebook and challenges users may encounter when striving to improve agency risk analysis and management that can ultimately lead to more accurate and consistent cost estimating and cost management.

1.4 Guidebook Use

The Guidebook is designed to provide information to all levels of SHA personnel and their partners in a variety of ways. Therefore, some portions of the Guidebook are written at a strategic level and others contain more advice on "how to" implement risk analysis tools and management practices. The approach to implementing the Guidebook can be explained in the follow three levels of implementation.

1.4.1 Organizational Implementation

Implementing risk analysis and management practices across an organization will require a change in estimating procedures, but perhaps more importantly, it will require a cultural change. The use of risk-based cost estimates will require a communication of cost estimates in ranges and a transparent conveyance of uncertainties within agencies and external to the agency. Executive management will need to promote this change. Chapters 2, 3, and 4 of the Guidebook are written with executive managers in mind. These chapters provide a basic structure and approach for developing agencywide policies and procedures for implementing risk analysis and management practices. Additionally, Chapter 8 will provide assistance in implementing changes and management performance from an agency-wide perspective.

1.4.2 Programmatic Implementation

Program-level managers often lead and implement policy changes. If policy changes in risk analysis and management practices are necessary, then these managers should read Chapters 2, 3, 4, and the relevant Chapter 5, 6, and/or 7, depending on implementation issues. For example, planning directors can focus on Chapter 5, "Guide to the Planning Phase," while managers of engineering and environmental programs should focus on Chapter 7, "Guide to the Design Phase."

1.4.3 Project Implementation

Project-level managers, engineers, and discipline leaders (e.g., the chiefs of sections such as design, right-of-way, and/or estimating) who are directly responsible for cost estimation, risk analysis and risk management processes should read Chapter 3 and 4 and the relevant Chapters 5, 6, and/or 7, and Appendix A according to their area of expertise. Those leaders directly involved in estimating or cost-risk analysis should read the same chapters and Appendix A. If the estimator or manager has a specific area of expertise—such as the preparation of scoping estimates—then Chapter 7, "Guide to the Design Phase," should be studied in detail, including the relevant tools in Appendix A.

1.5 Limitations of the Guidebook

The Guidebook is not a procedures manual. In order to apply to multiple agencies across the country, the information is provided as guidance rather than procedures. The subtle differences relating to estimating and project development from agency to agency make it impossible to create a comprehensive "how to" procedures manual. The Guidebook does however, provide the necessary framework and information for an agency to create its own procedures manuals to meet its unique needs and culture. The second limitation relates to the amount of statistical information and guidance that the Guidebook provides. Sophisticated risk analysis techniques (e.g., Monte Carlo analyses, influence diagrams, decision trees, etc.) require a more in-depth knowledge of statistics than this Guidebook can provide. The Guidebook, therefore, focuses on the application of these techniques rather than on their development.

1.6 Summary

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 Guidebook was developed under NCHRP Project 8-60 "Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs." It 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

Project Cost Estimation and Management

2.1 Introduction

Based on a project's level of definition, cost estimates are prepared by a SHA during each phase of project development to establish the project's probable cost. These cost estimates are used by agency and external decision makers and management to support crucial project or program funding decisions.

A number of factors affect the accuracy of these estimates and the estimation techniques used to arrive at the estimated cost figures. Some of the most significant will be discussed further in detail later in this chapter: the available project information at the time of estimate preparation; the nature and magnitude of risks affecting the project cost; and the project complexity, project size, and timing.

Contingency planning is a critical part of the estimate preparation process. It is the estimate process component that seeks to address uncertainties inherent to each cost estimate. As a standard practice SHAs often provide some form of contingency in their cost estimates by allocating predetermined percentages of project cost as contingency or by performing some level of qualitative or quantitative risk assessment to determine risk impact on project cost and to thereby establish a contingency amount. This guidebook focuses on risk management practices and risk analysis tools to better estimate and control project cost. Cost control is accomplished through consistent and accurate estimates, and through proper contingency planning and management. In this chapter, risk practices are considered within the context of the project development phases common to state highway agencies, cost estimation and cost management processes, and project complexity.

2.2 Transportation Project Development Phases

Due to slight variations in the terms used by the state highway agencies to describe their project development phases, a generic set of terminologies are presented in this guidebook consistent with the *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction* project development phases: 1) Planning, 2) Programming, 3) Preliminary design, 4) Final design. These phases are described in Table 2.1 and shown in Figure 2.1. To ensure the applicability of terms SHAs from across the country participated in a vetting of the project development phases described in the Report 574. Typically, a SHA will prepare project cost estimates during each of the four phases of project development.

Figure 2.1 depicts an overlapping approach in the Planning, Programming, and Preliminary Design phases. This overlapping indicates the cyclical nature of these phases as transportation agencies identify needs and define projects to address those needs.

2.3 Cost Estimating and Cost Management Definitions

A key to implementing any new process or procedure within an agency is to have a common vocabulary for the process. The following definitions were developed with the intention of developing a common vocabulary and set of practices that promote learning and the exchange of new tools, ideas, and innovations relating to cost estimating and cost management. Definitions for risk management are

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.

provided in Chapter 3. The definitions rely heavily on published definitions from estimating and risk management standards to highway-specific risk management and cost control.[1]

2.3.1 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.

[1] Over 500 definitions were reviewed to create the concise list of 40 definitions for this Guidebook. These referenced definitions have been integrated and modified to specifically support highway project development processes, to incorporate common transportation language, and adhere to current agency cultures. The following references were used to support 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 (2007). 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, ww.wsdot.wa.gov/projects/projectmgmt/riskassessment>
- Wideman, R.M. (1992). Project and Program Risk Management: A Guide to Managing Project Risks. Newton Square, Pennsylvania.

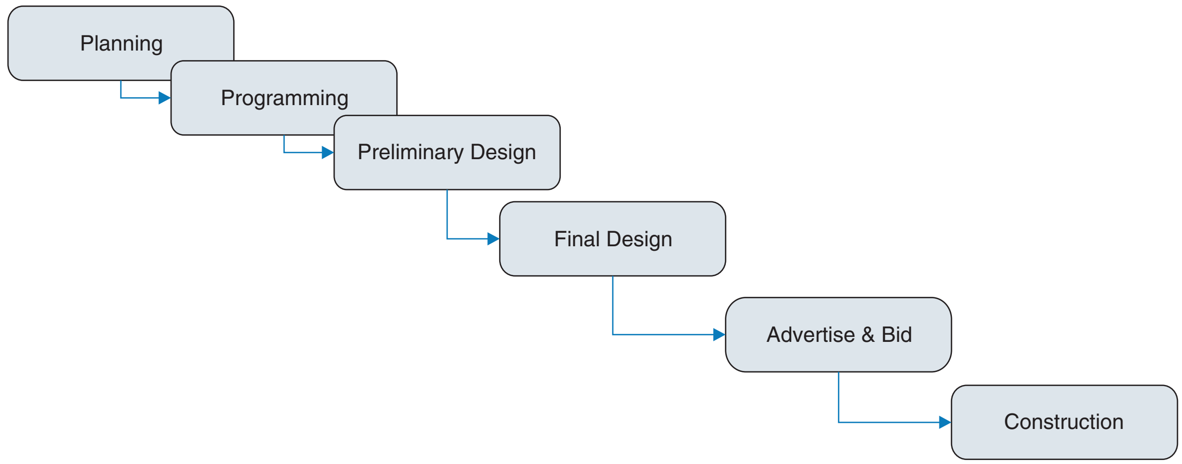


Figure 2.1. Project development phases (NCHRP 8-49).

Total Cost Estimate. The sum of the base cost estimate and contingency.

2.3.2 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.

2.4 Timeline of Cost Estimating and Cost Management

The cost estimates prepared and the estimation techniques used at each of the project development phases must be consistent with the project information available at the specific point in time when the estimate is prepared. When only concept information is available to describe a transportation program and its projects, the agency will have to apply conceptual estimating techniques in preparing the estimate. Subsequently it should be possible to prepare more detailed and accurate cost estimates as the project advances through the phases of project development with scope being defined in more detail and more definitive information becoming available. Similarly, cost estimate management techniques vary depending on the level of project scope definition, organization of the project team, and cost detail presented in the estimate. Cost estimation management ensures that program/project budgets are in line with budget projections and project goals through all phases of the development process.

Cost estimates prepared by SHAs often include a base estimate and a separate contingency covering project uncertainties (e.g., project definition development, engineering complexities, cost uncertainties, etc.). The level of project information available at the time of estimate preparation has a significant effect on the contingency value and, hence, the overall accuracy of the estimate. The contingency amount added to the base estimate should reduce as more project information becomes available at each phase of project development. The availability of more definitive project information across the project development phases enhances the risk assessment effort and that enables project teams to identify more risks and their corresponding impacts, especially those that were not recognized during the earlier phases of project development. As a result, by the final design phase, most of the project risks are known, their likely impacts have been determined, and mitigation measures should have been set in place. Hence fewer project unknowns are left unresolved at this point. Typically the quantification of risk impacts from the assessment effort results in lower and lower contingencies applied to an estimate in the later phases of project development compared to the contingency used in the earlier phases. To achieve better accuracy in project cost estimates and to keep project costs within budget, risk assessment and cost estimation management must be made an integral part of the estimation processes used throughout project development.

2.4.1 Planning Phase

The planning phase of project development has a significantly longer time horizon than the other phases, usually greater than 20 years. The individual agency approaches to this phase vary significantly. While some SHAs identify major projects, or even unique minor projects, most long-range plans do not identify specific projects, but rather establish strategic directions for state investment in the transportation system. Statewide plans often identify areas where more detailed planning is required. However, regional transportation plans are very different. These plans do identify specific projects that are to be implemented over the next 20 years.

The fundamental purpose of planning cost estimates that support long-range plans is to provide an order-of-magnitude estimate of the funds needed over a 20-year planning horizon. Planning-phase cost estimates by nature involve the use of conceptual estimating techniques due to the limited project information available at the point in time when they are prepared. Projects lack definition and their scope is not finalized; therefore, many project risks are unknown and cannot be readily identified. With this in mind, some SHAs often include a predetermined percentage of the project cost as contingency in the estimates to accommodate these unknowns. Other SHAs determine contingency percentages using historical data from similar past projects. In any case, planning cost estimates are best presented in a range of costs rather than a single number. A range more appropriately reflects the low level of definition associated with planning estimates. During the planning phase, cost estimation management focuses primarily on updating planning dollar amounts and communicating the cost updates through the long range plan.

2.4.2 Programming Phase

Project cost estimates have a significant effect on the overall transportation program and, thus, on the ability of state highway agencies and metropolitan planning organizations (MPOs) to meet transportation needs. Producing accurate programming phase cost estimates is critical to successful project development; however, at this early stage the project cost estimate is still produced based on only limited knowledge of project scope and requirements.

Programming phase estimates are often predicated on a baseline project scope and in many SHAs these estimates become the baseline project cost for managing project development scope and cost. The baseline cost estimate sets the project budget for inclusion in the agencies priority program. The priority program typically has a 10 year or less time horizon to the projected construction letting date. When a project is included in the priority program, authorization is often given for preliminary design to begin. The first four years of the priority program is considered the Statewide Transportation Improvement Program (STIP). Many SHAs prepare the baseline cost estimate just prior to incorporating a project in the STIP (year five from letting). This baseline cost estimate sets the budget for the project from which cost management is performed.

Historical bid-based estimation techniques in combination with percentages are often used during the programming phase of project development due to the availability of only limited project information. However, cost estimation is enhanced by the risk management process that involves the use of qualitative and quantitative techniques for determining the cost impact of the risks on the project base cost estimate and the corresponding contingency required. A risk management plan is prepared and used for managing risks throughout the project. The established contingency amount is typically lower than that used in the planning phase. Once preliminary design begins, this baseline cost estimate becomes the basis for cost management, particularly monitoring project scope and the impact of changes and new risks on the project contingency.

2.4.3 Preliminary Design Phase

During preliminary design the agency transforms the project scope from general requirements to detailed physical components. The preparation of costs estimates at various times (usually a specific points in completion of design such as 30 percent, 60 percent, etc.) throughout preliminary design validates project cost against current design detail and scope. If these estimates indicate cost growth above the baseline cost, this triggers cost management procedures to bring the project cost back in line with programmed amounts (e.g., value engineering studies, consideration of design alternatives). Alternatively, creation of a new revised baseline with additional funding approved by management may be required. These estimates are important because they support management monitoring and control of the project budget.

Cost management based on revised or updated estimates is an essential activity during the preliminary design phase when scope is transformed into construction details. Agencies should systematically compare periodic cost estimate updates and compare them to the baseline cost. If estimates are not preformed regularly during project design the department will experience what is known as cost blackout periods (Clark and Lorenzoni 1997) and these can lead to major budget problems when cost increases are identified later in project development. To effectively manage overall project cost, agencies must continuously evaluate changes in scope, design, risks, and project site or market conditions in relation to cost and time impacts against the project baseline scope, cost, and schedule. During this phase of project development the risks identified in the planning and programming phases may have been mitigated, but new risks may be identified and their corresponding impacts on cost determined. Risk registers are updated and the changes due to the resulting impacts are reflected in the overall contingency, which is then used to update earlier estimates. Management uses estimate updates to evaluate scope changes and other issues that affect project cost. Any deviation from budget and schedule must have documented management approval.

2.4.4 Final Design Phase

The final design phase typically represents that point in the project development process when plans and specifications are complete. At this stage the project is well defined and any construction related risks are embedded into the project line or pay items. This approach is necessary as the final estimate is compared with contractor's estimates by line or pay item. The contractor incorporates risk into its estimate of each pay item.

2.5 Cost Estimating Process

A successful cost estimating process provides a structured and systematic approach to determining project costs. *NCHRP Report 574* provides nine steps to describe the fundamental elements of cost estimation and cost estimation management practice. Four basic steps describe cost estimation practice. Table 2.2 presents these four steps together with a brief description of each. The descriptions are generic and, therefore, applicable to the estimation process across each development phase. These four steps convey the idea of a structured approach to cost estimation. The operational manner in which the steps are performed will vary depending on project development phase. The level of completeness in the project scope and refinement of project design will drive these variations. Further, the application of each step may change depending on the project component that is being estimated, such as costs for preliminary engineering/final design, right of way, and construction.

In this four step cost estimation process, a separate step focuses specifically on risk and contingency at the time of estimate preparation. Determine risks and set contingency requires some level of risk analysis to set an appropriate contingency consistent with the impact of the identified risks. In the context of this Guidebook and the risk management process shown in Figure 1.1, identifying risks and assessing/analyzing risks closely aligns with cost estimate step to determine project risks and evaluate the contingency value consistent with the project risks.

2.6 Cost Management Process

Cost estimation management should occur continuously throughout the project development process. Some efforts are exclusive to a particular stage of development, while others are inclusive throughout the process. The four phases—planning, programming, preliminary design, and final design—require the application of different cost management methods due to the level of project information that is available and the manner in which the estimate must be communicated internally and externally.

Even early in project development, agency management has the responsibility of reviewing, approving, and communicating the project estimate. Communication is very important in the case of early estimates and management must make both internal and external stakeholders aware of an estimate's precision and its limits of accuracy. Many times a cost for a particular project comes out early in the planning or programming phase and it is a number that stakeholders compare final costs to and judge the "success" of the project by, no matter how preliminary (and subject to further refinement) that initial estimate was. These management actions, the use of conceptual estimating techniques and proper communication of estimate uncertainty, have the potential to significantly improve proper use of early cost estimates.

Five steps describe the cost estimation management process (Anderson et al. 2007). Table 2.3 provides a description for each of these steps. Again, the descriptions are general and therefore applicable to the cost estimation management process across project development phases. Implementation of these steps will vary by development phase and the project component (preliminary engineering/final design, right of way, and construction). Similar to the cost estimation practice steps, the cost estimation management steps and their descriptions could be shown in greater detail, but five steps are sufficient to outline a structured approach to cost estimation management. As with

Table 2.2. Cost estimating process (Anderson et al. 2007).

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

the estimating steps, the project development phase dictates some level of variation in which the steps are performed.

During the cost management process, potential changes are monitored. Changes may include retiring previous risks or adding newly identified risks. These risks relating to changes may result in plus or minus adjustments to contingency and the overall project estimate. The impact of changes must be evaluated and estimates reviewed. In relation to the risk management process shown in Figure 1.1, the steps in Table 2.3 align with risk mitigation and planning, risk allocation, and monitoring and controlling risks.

2.7 Project Complexity and Impact on Estimation and Risk Management Process

The level of effort expended for planning and developing projects varies depending on project complexity. A project is described in a number of ways, with some descriptions relying on project attributes to convey the complexity of a project. For example, attributes related to roadways, traffic control approaches, structures, right of way, utilities, environmental requirements, and stakeholder involvement often are used to distinguish different levels of project complexity. This approach is used in the *NCHRP Report 574* and captured in that report as a tool, *Recognition of Project Complexity*. This same tool is included in the Appendix A of this guide (see Tool R1.1). Table 2.4 shows how the pavement attribute might change based on the three levels of complexity described in the *Recognition of Project Complexity* tool. The complexity scenario that describes a project will impact the need for and degree of the cost estimation, risk analysis and cost management efforts.

Projects in the highest complex category (major projects), which includes new highways, major relocations or reconstruction, may require a comprehensive quantitative assessment of the project risks to determine their impact on the overall cost and an appropriate amount of contingency to include in the cost estimate either at a project or program level. Moderately complex projects such as minor roadway reloca-

Table 2.3. Cost estimate management process (Anderson et al. 2007).

Cost Estimate Management Step	Description
Obtain appropriate approvals	Obtain management authorization to proceed by • review of current project scope and estimate basis; • securing of approvals from appropriate management levels; • approval of current estimate, including any changes from previous estimate; and • 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 • mechanism for communicating the cost estimate for its intended purpose; • level of uncertainty to be communicated in the estimate given the information upon which it is based, and; • mechanism to communicate estimate to external parties.
Monitor project scope and project conditions	Identify any potential deviation from the existing estimate basis, including • changes to scope; • changes due to design development; • changes in project risks; • changes due to external conditions; • the nature and description of the potential deviation; and • 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 • cost and time impact of the deviation; • risk impact on project contingency; and • recommendations as to whether to modify the project scope, budget, and/or schedule due to change.
Adjust cost estimate	Document changes to the baseline estimate, including • appropriate approval of the deviation; • the new project scope, new budget, and/or new schedule; and • notifiy project personnel of the change.

Table 2.4. Example complexity classification (pavement attributes).

Most Complex (Major) Projects	Moderately Complex Projects	Non-complex (Minor) Projects
• New highways; major relocations • New interchanges • Capacity adding/major widening • Major reconstruction (4R; 3R with multi-phase traffic control) • Congestion Management Studies are required	• 3R and 4R projects which do not add capacity. • Minor roadway relocations. • Certain complex (non-trail enhancements) projects. • Slides, subsidence.	• Maintenance betterment projects • Overlay projects, simple widening without right-of-way (or very minimum right-of-way take) little or no utility coordination • Noncomplex enhancement projects without new bridges (e.g., bike trails)

Note: 4R is rehabilitation, restoration, resurfacing, or reconstruction tions will typically require a less rigorous risk analyses. Quite often, a qualitative risk assessment will adequately capture associated risks and their cost impacts on the project. Noncomplex (minor) projects could include maintenance projects that may not necessarily require any major risk assessment efforts.

Project complexity is also often described by location, that is, whether the project is located in an urban or rural environment. Typically, urban settings tend to create more complex traffic control approaches. However, if a project is associated with an interstate roadway, even a noncomplex or minor roadway project may have increased traffic control requirements. This may change the perspective on a project's complexity.

The level of risk analysis effort and the risk estimation tools used are dependent on the level of project complexity. For noncomplex projects, qualitative assessment techniques may be used to identify project risks and contingency set based only on the perceived magnitude of impacts of the listed risks. If the same qualitative method is applied to a highly complex project, the likely risk impacts may be underestimated and the applied contingency inadequate to cover the probable cost consequences. Complex projects therefore would require the use of quantitative and probabilistic methods, in combination with qualitative methods, to be able to more accurately determine the likely impact of the risks and to set a contingency appropriate to the magnitude of possible impacts.

2.8 A Strategic Approach

A large number of research studies document the fundamental factors that cause project cost escalation (Merrow 1988, Touran and Bolster 1994, Ripley 2004). *NCHRP Report 574* identified 18 specific factors that lead to cost escalation. Each factor presents a challenge to every agency seeking to produce accurate project cost estimates and to manage costs. While every cause will not create problems on every project, the only way to consistently mitigate all of the causes is to use a strategic approach to cost estimation, risk analysis, and cost management.

Through an extensive review of estimating literature and discussions with SHAs, *NCHRP Report 574* defines eight strategies that converge to address the principal causes of project cost escalation. These eight strategies are:

- **Management strategy**—Manage the estimation process and costs through all stages of project development;
- **Scope and schedule strategy**—Formulate definitive processes for controlling project scope and schedule changes;
- **Off-prism strategy**—Use proactive methods for engaging external participants and assessing the macro-environmental conditions that can influence project costs;
- **Risk strategy**—Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed;
- **Delivery and procurement strategy**—Apply appropriate delivery methods to better manage cost because project delivery influences both project risk and cost;
- **Document quality strategy**—Promote cost estimate accuracy and consistency through improved project documents;
- **Estimate quality strategy**—Use qualified personnel and uniform approaches to achieve improved estimate consistency and accuracy; and
- **Integrity strategy**—Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates.

The risk strategy is the primary driver for addressing issues related to project uncertainties and risks and in determining appropriate amounts of contingency for estimates prepared in different project phases.

2.8.1 Inconsistent Application of Contingencies

Of the 18 factors identified in *NCHRP Report 574,* one factor is directly related to uncertainty and risk. *Inconsistent Application of Contingencies* causes confusion as to exactly what is included in the line items of an estimate and what is covered by contingency amounts. Contingency funds are typically meant to cover a variety of *possible* events and problems that are not specifically identified or to account for a lack of project definition during the preparation of planning and project development estimates. Misuse and failure to define what costs contingency amounts cover can lead to estimate problems. In many cases it is assumed that contingency amounts can be used to cover added scope, and planners and engineers seem to forget that the purpose of the contingency amount in the estimate is lack of design definition. SHAs run into problems when the contingency amounts are applied inappropriately. During project execution, contingency funds often are inappropriately used to cover project overruns instead of being applied to and available for their intended purpose. As a result, a risk strategy is suggested to address this inconsistent application of contingency among SHAs.

2.8.2 Risk Strategy

Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed. Rather than a single deterministic forecast of project cost, it must be understood that many variables contribute to a range of probable cost. In the case of state highway agency project estimates, any one cost number represents only one result based on multiple assumptions. These variables that influence project costs are not all directly controllable or absolutely quantifiable. Therefore, cost estimation must consider uncertainties and related risks. Management should use these identified risks and uncertainties to structure management procedures that mitigate, eliminate or account for the possible variation in the outcomes.

The risk strategy supports the need for a more specific focus on risk management practices and tools as presented in this Guidebook. However, implementation of new or improved management practices in such areas as risk requires commitment from top management.

2.9 Management Support for Estimating and Cost Management Practices

Cost estimation practice is highly dependent on how an agency manages project development and the support agency management provides to engineers executing project development, including estimate and schedule preparation. Senior agency managers should view themselves as investors, developers, and strategists. Management has the responsibility to invest and develop project staff and to provide the staff with the resources to effectively perform their jobs.

To consistently achieve accurate estimates agencies must do more than institute changes in estimating practices. Senior management must view project cost estimate management and estimate practice as interdependent systems that span the entire planning and project development process. Risk management plays a significant role in the project estimation process and should be embraced to ensure that estimates are accurate and consistent. Project managers must be given the authority to manage their projects, particularly authority to control scope, and with that authority acceptance of responsibility for results.

It is management's responsibility to assume the lead in propagating organizational change that recognizes the importance of 1) a structured strategic approach to estimate preparation; 2) the use of risk analyses in setting estimate contingency; 3) reviewing and approving all estimates; and 4) communicating the importance and accuracy of each estimate with internal and external stakeholders.

This Guide presents a variety of risk assessment and analysis tools, and their uses and applicability across the phases of project development. These serve to support the cost estimating and cost management processes and help senior management achieve their goal of producing accurate cost estimates.

2.10 Summary

This chapter provides an overview of the cost estimation and cost management process with particular reference to risk management and contingency planning. The typical transportation project development phases are described with emphasis on the use of estimating approaches consistent with available project information. The cost estimating process and cost management process are illustrated using four steps and five steps, respectively, while highlighting typical activities related to each step. Project complexity scenarios are presented in view of the fact that their effect on the cost estimation and cost management processes must always be understood and addressed when considering the affects of project risk. Emphasis is placed on the importance of management support in promoting a conducive working environment that can produce accurate estimates.

CHAPTER 3

Risk Management Overview

3.1 Introduction

This chapter defines risk management in terms of cost estimating and cost management and provides formal definitions for risk management and cost estimating terms for application throughout the Guidebook. The chapter focuses on the risk management process and presents each of the five risk management steps in detail with illustrative examples. The chapter concludes with a discussion of risk management policies and performance measures.

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 comprehensive management process, not as simply a tool or set of tools for cost estimating. The output of a risk-based cost estimate supports identification of critical cost containment issues and helps to effectively inform the design team about risks 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, the AACEI, or the Department of Energy use very similar steps, but slightly different terms, to describe their risk management approach (PMI 2004; AACEI 2000; DOE 2003). The process step terms that this Guidebook will use are: 1) risk identification; 2) risk assessment/analysis; 3) risk mitigation and planning; 4) risk allocation; and 5) risk monitoring and control.

The Guidebook provides risk analysis tools and management practices to help control transportation project costs. Proper risk management will facilitate agency efforts to avoid, mitigate or better plan for costs that result from identifiable risks during the project development process. Table 3.1 provides examples of typical risks and expected outcomes of applying risk management tools to the project development process.

The risk management process is shown in Figure 3.1 and forms the framework for this Guidebook. 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 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 depend on the project development phase and project complexity.

Brief descriptions for each of the five steps follows with complete descriptions and examples provided in Section 3.3 of this chapter.

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.

Table 3.1. Typical risks and outcomes across the project phases.

Project Phase	Planning	Programming	Design
Typical Risks	• Fatal or significant environmental economic impacts • Funding uncertainty • Uncertain political and public support • Competing interests and competing projects	• Changes in design requirements • Costs of environmental compliance • Right of way acquisition delays • Technical uncertainties • Funding uncertainty	• Changes in design requirements • Market conditions, permit requirement changes
Expected Outcomes	• Better understanding of environmental, engineering, and construction issues facing each project alternative • Order of magnitude risk costs and possible total cost range for each option	• List of major project risks • Reasonable estimate of risk costs, and probable total project costs and duration • Long list of risk mitigation strategies • Preliminary risk management plan, focused on design and constructability risks • Preliminary risk allocation planning	• Prioritization of risks based on impacts to total project cost and duration • Costs / benefits of risk mitigation and risk allocation strategies • Risk management and allocation plan

As discussed in Chapter 2, contingency is linked integrally to risk management in the context of cost estimating and cost control. However, contingency application is not listed as one of the five risk management steps. The application of contingency is part of the risk mitigation and planning step. If an agency chooses to accept an identified risk, it should include an appropriate contingency amount in case that the risk is realized. Tracking and resolution of contingency is part of the risk monitoring and control step.

These five risk management steps provide the framework for the discussion of risk management practices and tools in the remainder of this Guidebook. Each of these five steps is discussed in the context of project complexity and the project development phases.

Figure 3.1. Risk management process framework (varies by project development phase and complexity).

3.2 Risk Management in Support of Cost Estimating and Cost Management

Uncertainty and risk can play a major role in causing cost escalation if not properly treated during project development. Cost estimating methods and tools must relate and adapt to the various phases of project development. When estimating costs, particularly on large and complex projects, this becomes even more profound. In the Planning and Programming Phases of project development, estimators have very little information with which to develop a project cost, and the information that they do have is often fraught with uncertainty. The Washington State Department of Transportation (WSDOT) developed a cost estimate classification system based on a similar system developed by the Association for the Advancement of Cost Engineering International (AACEI). This system has five classifications and provides an expected range of accuracy for each classification given project maturity and a representative estimating methodology. Table 3.2 shows the estimate classification system as it corresponds to the project development phases described in this Guidebook. Planning estimates are based upon the lowest

Table 3.2. Cost estimate classification system (WSDOT).

Project Development Phase	Project Maturity (% project definition completed)	Purpose of the Estimate	Estimating Methodology	Estimate Range
Planning	0 to 2%	Conceptual Estimating – Estimate Potential Funds Needed (20-year plan)	Parametric (Stochastic or Judgment)	-50% to +200%
	1% to 15%	Conceptual Estimating – Prioritize Needs for Long Range Plans (HIP – 10-year plan)	Parametric or Historical Bid-Based (Primarily Stochastic)	-40% to +100%
Scoping (Programming)	10% to 30%	Design Estimating – Establish a Baseline Cost for Project and Program Projects (HIP and STIP)	Historical Bid-Based or Cost-Based (Mixed, but Primarily Stochastic)	-30% to +50%
Design	30% to 90%	Design Estimating – Manage Project Budgets Against Baseline (STIP, Contingency)	Historical Bid-Based or Cost-Based (Primarily Deterministic)	-10% to +25%
Final Design	90% to 100%	PS&E Estimating – Compare with Bid and Obligate Funds for Construction	Cost-Based or Historical Bid-Based Using CES. (Deterministic)	-5% to +10%

level of project definition, and Final Design Phase estimates are closest to full project definition and maturity.

Table 3.2 conveys several key concepts. First, it describes a number of end usages for estimates, which relate directly to the risk management practices and tools described in this Guidebook. Second, it describes the methodological approach to the estimate as either stochastic[2] or deterministic, depending upon the level of design and information available. While deterministic cost estimating methods have been the prevalent estimating method in highway development, they do not support robust risk management analysis and contingency estimation. This is an important concept and change.

Figure 3.2 depicts how identifying, quantifying, and managing cost uncertainty relates to cost management. Two primary points are illustrated in Figure 3.2, which applies to situations where the scope is unchanged and where an estimate includes uncertainty. 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 cost variable definition and eliminating uncertainty as cost factors are ultimately incorporated in the project budget. The second point is that, if the problems or uncertainties 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, a lower range of expected costs will likely result.

To help describe contingency, Figure 3.3 presents three basic types of cost estimate information or lack of knowledge. At any point in the project development process, an estimate should account for these three types of information. First, the estimate should clearly describe the known and quantifiable costs (also referred to as the known/knowns). Estimators should prepare their estimates considering what is defined in the project scope or drawings and apply the appropriate estimating method to determine the base estimate costs. A second type of costs consists of the known but not quantified costs (also referred to as the known/unknowns). These are the costs that are known to be in the project scope, but for which there are no definable quantities at the point in project development when the

[2] Stochastic estimates combine traditional estimating methods for known items and quantities with risk analysis techniques to estimate uncertain items, uncertain quantities, and risk events. The stochastic portion of the estimate typically focuses on a few key uncertain variables and combines Monte Carlo sampling and heuristics (rules-of-thumb) to rank critical risk elements. This approach is used to establish the range of the Total Project Cost Estimate and to define how contingency should be allocated among the Stochastic estimates apply only to most complex (major) projects, as explained later in this Guidebook.

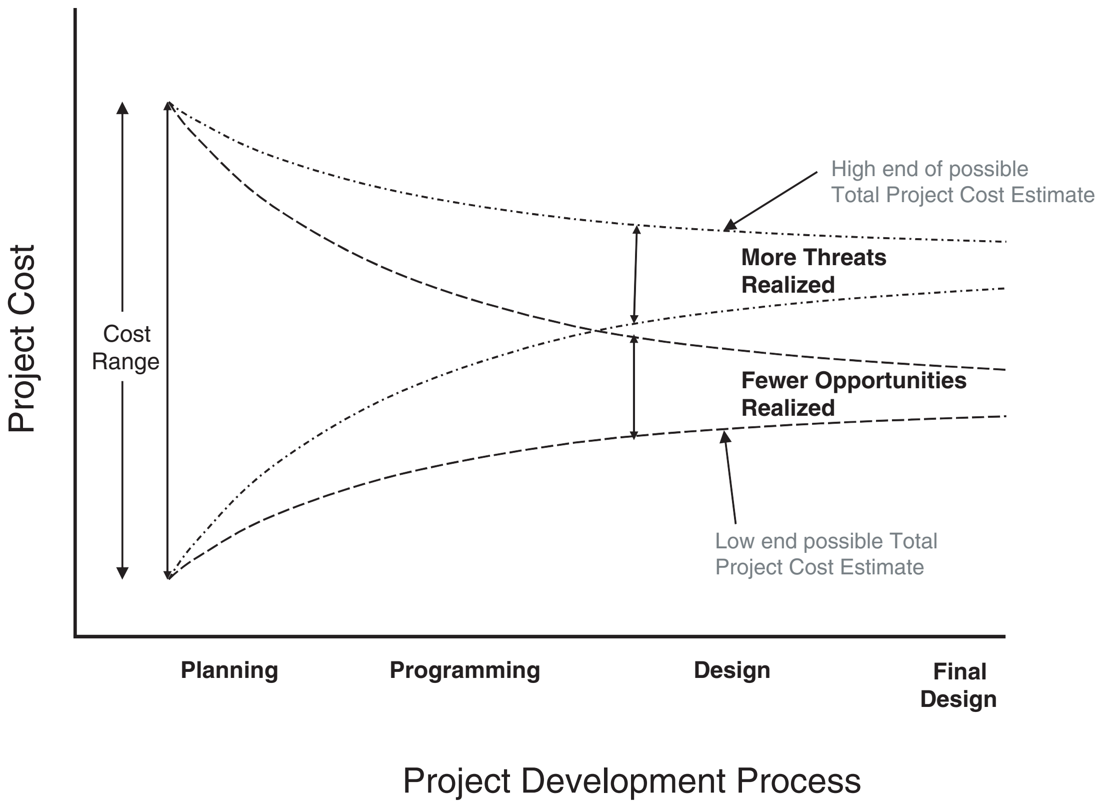


Figure 3.2. General refinement of a cost estimate.

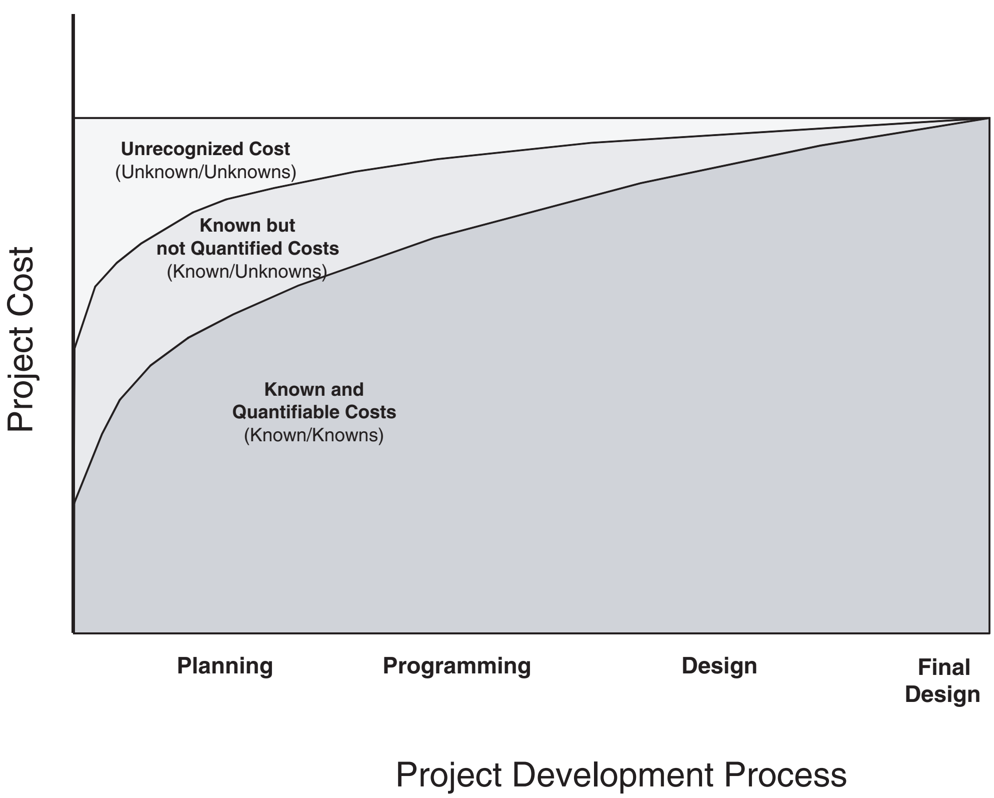


Figure 3.3. Need for estimate contingency.

estimate is prepared. An example for this could be that an estimator knows there is a need for noise walls on a project, but does not know the quantity that will be needed because a complete engineering study is not yet available. The final type of information is the unrecognized costs (also referred to as the unknown/unknowns). These are costs that an estimator typically will not account for in an estimate because they are unforeseeable or happen so infrequently that they would make the project estimate unrealistically high. Contingency is needed in an estimate to account for the known but not quantified costs and the unrecognized costs. Risk management practices and tools can assist in the calculation of appropriate contingencies to account for these costs.

Figure 3.4 builds from Figures 3.2 and 3.3 to illustrate how contingency can be resolved throughout the project development process. Figure 3.4 illustrates three key points. First, an estimate at any given point is made up of a base estimate component and a contingency component as described in Chapter 2. As the project progresses in development, the contingency amount is expected to decrease because the project information is refined. Often the base estimate increases as some of the contingency is realized and included as part of the base estimate. The second point is the transition from a range estimate to a baseline estimate when moving from the Planning to the Programming Phases. It is in the Programming phase that the baseline estimate is set and cost control begins. Third, Figure 3.4 illustrates a case where the final engineer's estimate is equal to the baseline estimate. In this case, risks were identified during early contingency estimation and the estimate of the contingency was accurate.

Figure 3.5 illustrates an excellent example of cost control and contingency management. Figure 3.5 illustrates a case where the engineer's estimate is less than the baseline estimate. In this case, risks were identified during early contingency estimation in the Programming Phase, but these risk were mitigated (or not realized) in the Design and Final Design Phases. In this case, the SHA should have a policy on what the project team should do with the unused contingency. If the purpose and need of the project is met, this policy would ideally ask the project team to return the contingency to the overall program instead of adding scope to the project baseline.

Figures 3.2 through 3.5 show how risk and contingency can be incorporated into cost estimating and cost management (or cost control) throughout the project development process. A few key points from these figures are summarized here:

- *Use of Cost Ranges at the Planning Phase*—Planning Phase estimates, particularly on a more complex (major) project should be communicated through a range. Planning Phase estimates contain the most uncertainty of any estimate

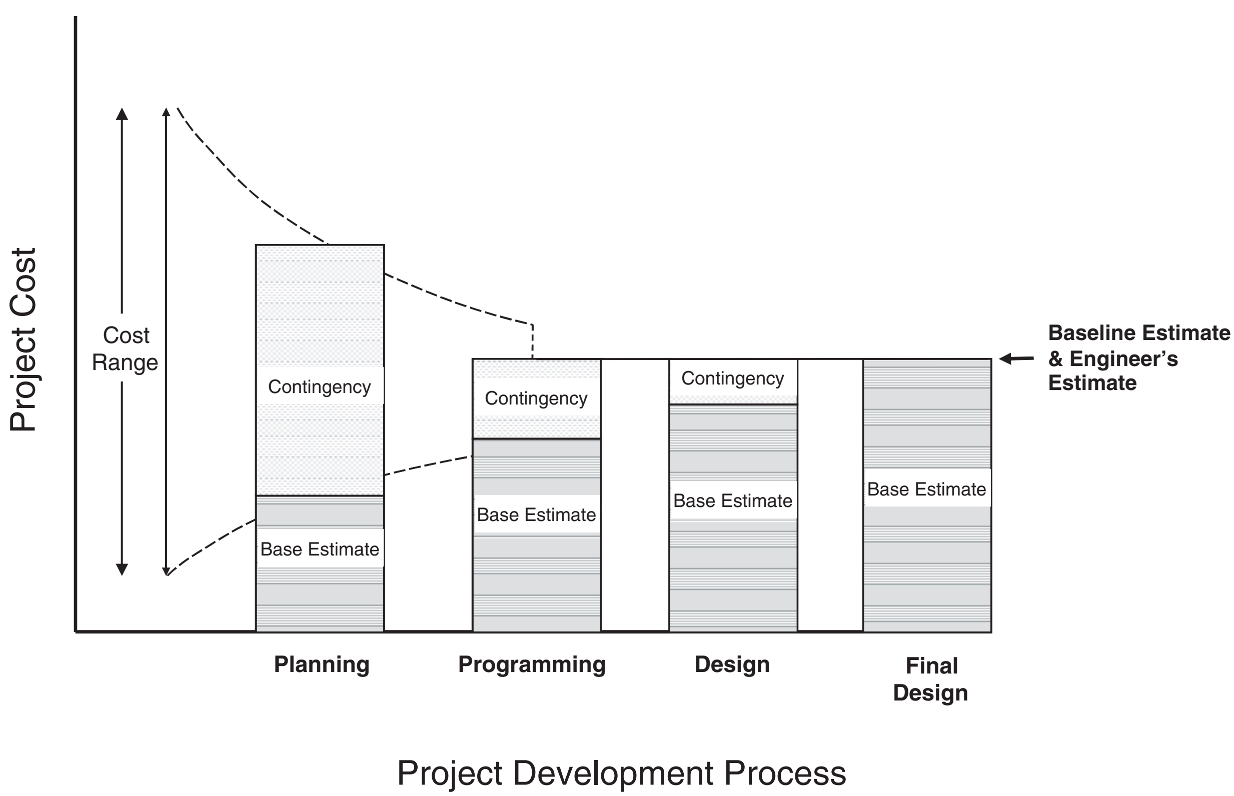


Figure 3.4. Refinement of a cost estimate with engineer's estimate equal to the baseline cost estimate.

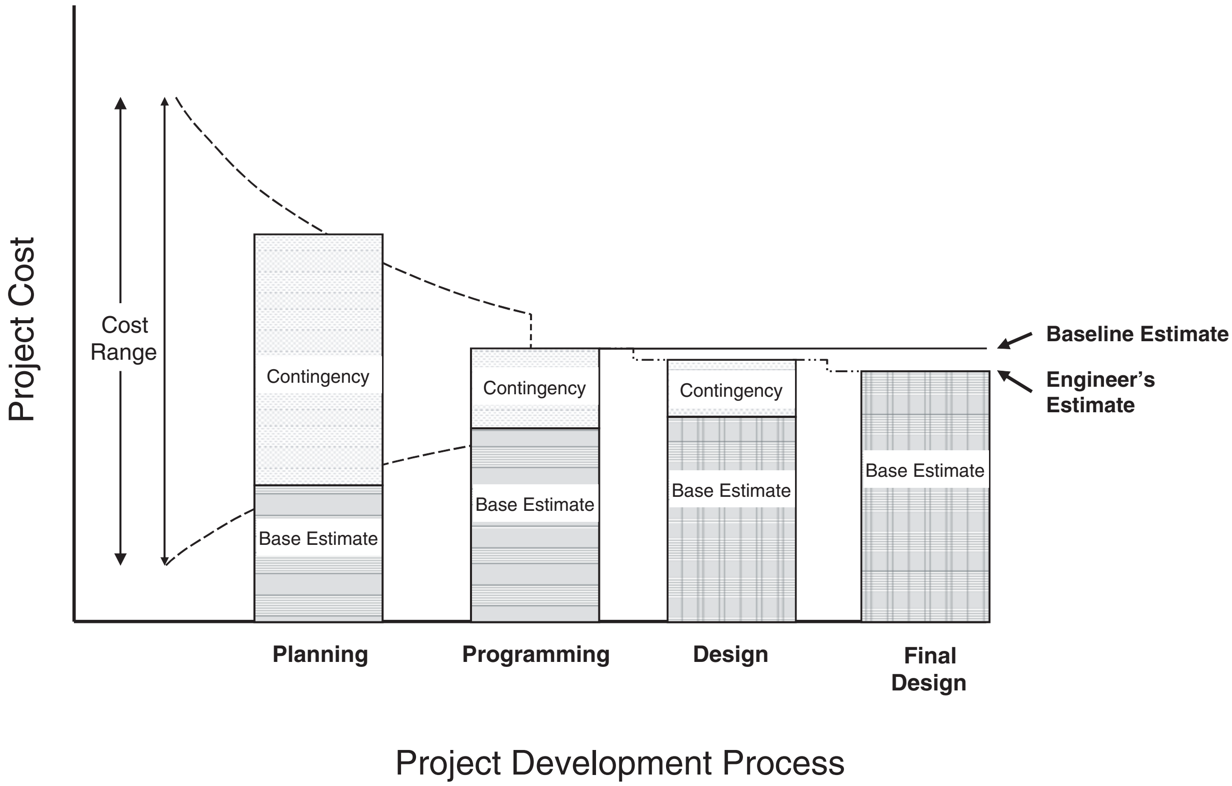


Figure 3.5. Refinement of a cost estimate with engineer's estimate less than baseline cost estimate.

throughout project development. The FHWA and the FTA now allow the use of range estimates in Planning Phase documents. As depicted in the cost estimate column at the Planning Phase (see Figure 3.5), the contingency can be very large. In fact, the contingency can potentially be larger than the base estimate if very little is known about the project's definition.

- *Application of a Baseline Cost Estimate at the Programming* Phase—As stated in Chapter 2, the Programming Phase estimate is frequently used to establish a baseline cost estimate. The baseline cost estimate is the basis for cost management. As delineated in Figures 3.4 and 3.5, the baseline cost estimate is made up of both a base estimate plus a contingency.
- *Contingency Resolution throughout the Design* Phases—As the project matures from Programming through Final Design, the contingency is lowered and the base estimate amount increases. The percentage of the contingency to the base estimate is a function of the project complexity and the level of project definition. Procedures and tools for estimating an appropriate contingency are provided throughout Chapters 5, 6, 7, and the Appendix A of this Guidebook.
- *Cost Management to the Baseline throughout the Design* Phases—As stated in Chapter 2, the baseline estimate sets the stage for cost management. Figure 3.5 shows a project in which the Design and Final Design Phase cost estimates were less than the baseline cost estimate. What is not shown in Figures 3.4 and 3.5 is a case where the current estimate exceeds the baseline cost estimate. Policies on this case will vary by SHA, but it is suggested that if the Design and Final Design Phase cost estimates are higher than the baseline, one of three options should be pursued: 1) the project's definition (scope) would be reduced to meet the baseline cost estimate and the baseline would remain unchanged; 2) a formal scope change would be submitted to program management, approved, and the baseline increased accordingly; or 3) a scope change would be submitted to program management, but not be approved and the project would be removed from the program due to the high potential for a cost overrun.

3.3 Risk Management Definitions

As discussed in Section 2.3, having a common vocabulary for implementing any new process or procedure within an agency is a key to success. The following definitions were developed with the intention of developing a common vocabulary and set of practices that promote learning and the exchange of new tools, ideas, and innovations relating to risk management. The definitions rely heavily on published definitions cited in Section 2.3.1

3.3.1 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 percent 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 to 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.

3.4 Risk Management Framework

This Guidebook will apply the five step risk management framework to the various phases of project development to provide a structure for the application of management tools and practices to control transportation project costs. Table 3.3

Table 3.3. Risk management framework relationship to project phases.

Risk Management Step	Planning	Programming	Design
Risk Identification	• Identification of highest level risks to project scope and feasibility	• Complete and non-overlapping identification of risks for baseline project estimate	• Appraisal of identified risks • Identification of new risks as design progresses
Risk Assessment/ Analysis	• Initial ranking of risks • Order of magnitude risk costs and total cost range	• Qualitative analysis/ ranking of risks on minor projects • Detailed quantitative risk analysis on major projects • Contingency for baseline cost estimate	• Updating of qualitative or quantitative risk analyses • Updating/resolution of contingency
Risk Mitigation and Planning	• Initial development of red flag list, risk register or formal risk management plan	• Finalization of risk register or risk management plan • Tradeoff analysis for mitigation options	• Completion of risk management plan • Continued tradeoff analysis for risk mitigation options
Risk Allocation	• Initial analysis or selection of project delivery method	• Trade-off analysis for risk allocation (e.g., contract provisions for time, payment, delay, etc).	• Final risk allocation in contract provisions
Risk Monitoring and Control	• Planning for risk monitoring and control	• Implementation of risk register or risk management plan • Establishment of key risk management milestones	• Active management of risk register or risk management plan • Active management and resolution of contingency

provides an overview of how each of the steps applies to the project development phases with some important notes on project complexity and the steps in the estimating process.

The next section provides a detailed description of the steps in the risk management process. Their ultimate relationships to the project phases and project complexity are detailed in Chapters 6 through 8.

3.4.1 Risk Identification

3.4.1.1 Objectives of Risk Identification

The objectives of risk identification are to identify and categorize risks that could affect the project and document these risks. The outcome of the risk identification is a list of risks. Ideally, the list of risks should be comprehensive and non-overlapping. What is done with the list of risks at that point depends on the nature of the risks and the nature of the project. On minor, low-cost projects with little uncertainty (few risks); the risks may simply be kept as a list of red flag items. The red flag items can then be assigned to individual team members to watch throughout the project development process and used for risk allocation purposes as described later in this document. On major, high-cost projects that are by nature uncertain (many risks), the risks can feed the rigorous process of assessment, analysis, mitigation and planning, allocation, and monitoring and updating described in this document.

The risk identification process should stop short of assessing or analyzing risks, so as not to inhibit the identification of "minor" risks. The process should promote creative thinking and leverage team experience and knowledge. In practice, however, risk identification and assessment are often completed in a single step and this process can be called risk assessment. For example, if a risk is identified in the process of interviewing a team member or expert, it is logical to pursue information on the probability of it occurring, 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. This document, however, will treat the two activities of risk identification and assessment discretely for clarity.

3.4.1.2 Risk Identification Process

The risk identification process begins with the team compiling the project's risk events. The identification process will vary depending upon the nature of the project and the risk management skills of the team members, but most identification processes begin with an examination of issues and concerns created by the project development team. These issues and concerns can be derived from an examination of the project description, work breakdown structure, cost estimate, design and construction schedule, procurement plan, or general risk checklists. Checklists and databases can be created for recurring risks, but project team experience and subjective analysis will almost always be required to identify project-specific risks.

The team should examine and identify project events by reducing them to a level of detail that permits an evaluator to understand the significance of any risk and identify its causes, that is, risk drivers. This is a practical way of addressing the large and diverse number of potential risks that often occur on highway design and construction projects. Risks are those events or conditions that team members determine would adversely affect the project.

Upon identification, the risks should be classified into groups of like exposures. Classification of risks helps to reduce redundancy and provides for easier management of the risks in later phases of the risk analysis process. Classifying risks aids in creating a comprehensive and non-overlapping list. Classifying risks also provides for the creation of risk checklists, risk registers, and databases for future projects. Figure 3.6 shows an example from the U.S. Department of Energy (DOE) of their highest level classification.

3.4.1.3 Risk Characteristics

During the risk identification step, risks can be characterized to aid in later assessment and planning. It is often helpful to think of risk in broader terms of uncertainty. Uncertainty involves both positive and negative events. Risk is defined in this document as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives (PMI 2004). However it is often helpful to separate uncertain events into those events that can have a negative effect (risks) and those that can have a positive effect (opportunities). Case studies developed in this research with the FTA, the WSDOT, and the DOE use the terminology of both risk and opportunity to characterize uncertainty in their risk management programs. However, teams must be cautious not to overlook risk or focus on solving problems with using the risk/opportunity characterization during the risk identification process. Engineers and project managers inherently have an optimistic bias when thinking about uncertain items or situations because they are, by nature, problem solvers. It is often better to focus on risks during the identification stage and explore opportunities during the mitigation process.

Another characteristic of risks is that many have triggers. Triggers, sometimes called risk symptoms or warning signs, are indications that a risk has occurred or is about to occur. Triggers may be discovered in the risk identification process and watched in the risk monitoring and updating process. The identification and documentation of triggers early in the process can greatly help the risk management process.

3.4.1.4 Risk Identification Summary

The risk identification process identifies and categorizes risks that could affect the project. It documents these risks and, at a minimum, produces a list of risks that can be assigned to a team member and tracked throughout the project development and delivery process. Risk identification is continuous and there should be a continual search for new risks that should be included in the process. The tools and techniques outlined in this section should support the risk identification process, but it will be the people involved in the exercises who are most critical to the success of the process.

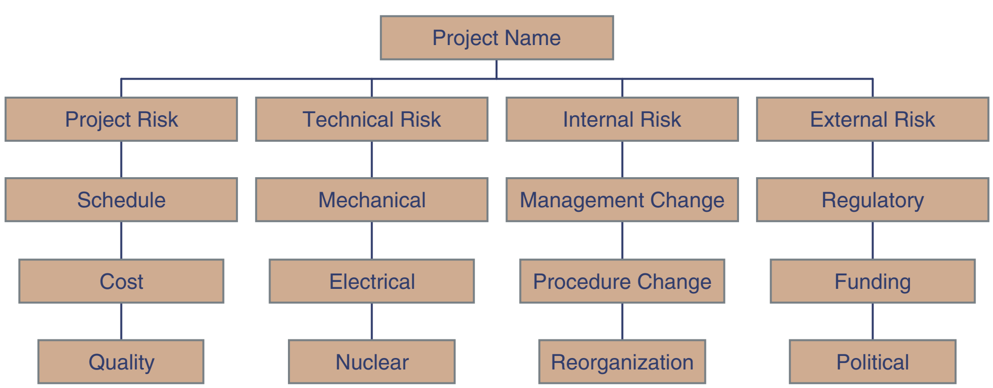


Figure 3.6. Risk identification classification (DOE 2003).

3.4.2 Risk Assessment

3.4.2.1 Objectives of Risk Assessment

Risk assessment is the process of quantifying the risk events documented in the preceding identification stage. Risk assessment has two aspects. The first determines the likelihood of a risk occurring (risk frequency); risks are classified along a continuum from very unlikely to very probable. The second judges the impact of the risk should it occur (consequence severity). Risks affect project outcomes in diverse ways. Risk effects are usually apparent in direct project outcomes by increasing cost or schedule. Some risks influence the project by affecting the public, public perception, the environment, or safety and health considerations. Risk can also affect projects in indirect ways by requiring increased planning, review, and management oversight activity. The risk assessment phase has as its primary objective the systematic consideration of risk events and their likelihood of occurrence and the consequences of such occurrences.

3.4.2.2 Conducting Risk Assessment

Risk assessment is fundamentally a management activity that is supported by individuals familiar with risk management activities. Managers and analysts approach risk using different but complementary viewpoints. Managers tend toward qualitative assessment of risks. They evaluate risks relative to their worst case effects and their relative likelihood of occurrence. What is more, managers tend to focus on strategies and tactics for avoiding risks or reducing a risk's negative impacts. Analysts, on the other hand, tend toward quantitative assessment of risks. They evaluate risk impacts in terms of a range of tangible results and they evaluate risk of occurrence in terms of probabilities. The analyst's focus is on the combined tangible effect of all the risks on project scope, cost, and schedule. A comprehensive risk assessment combines both a qualitative assessment and a quantitative assessment. The qualitative assessment is useful for screening and prioritizing risks and for developing appropriate risk mitigation and/or allocation strategies. The quantitative assessment is best for estimating the numerical and statistical nature of the project's risk exposure. This section will present qualitative risk assessments and the next section will discuss quantitative risk analysis.

It should be noted that risk assessment techniques are scalable. They can be applied to small highway reconstruction projects or to large corridor programs. An application of a risk assessment on a minor resurfacing project can yield a prioritized list of red flag items that should be monitored over the course of a projects development, design, and construction. An application of a risk assessment on a major highway corridor project can yield the basis for a detailed probabilistic cost estimate, and a comprehensive risk management plan will be discussed later in this document.

3.4.2.3 Risk Screening – Risk Frequency and Severity

Following the risk identification and qualitative risk assessment phases, a set of identified risks exists with individual risks characterized as to their frequency of occurrence and the severity of their consequences. Frequency and severity are the two primary characteristics that are used to screen risks and separate them into risks that are minor and do not require further management attention, and those that are significant and require management attention and possibly quantitative analysis. Various methods have been developed to help classify risks according to their seriousness. One very common method is to develop a two dimensioned matrix that classifies risks into three categories based on the combined effect of their frequency and their severity. This matrix method is commonly referred to as a "Probability times Impact" (P x I) matrix. Figure 3.7 requires classifying risks into one of five likelihood states (remote through near certain) and into five states according to their consequences (minimal through unacceptable). These assessments yield a five by five matrix that classifies a risk as either a "high" risk (red), a "moderate" risk (yellow) or a "low" risk (green).

Risks that are characterized as low (green) risks can usually be disregarded and eliminated from further assessment. As risk is periodically reassessed in the future, these "low" risks are either closed, retained or elevated to a higher risk category.

Moderate (yellow) risk events are either high likelihood/low consequence events or they are low likelihood/high consequence events. An individual high likelihood/low consequence event by itself would have little impact on project cost or schedule outcomes. However, most projects contain myriad such risks (material prices, schedule durations, installation rates, etc.); the combined effect of numerous high likelihood/low consequence risks can significantly alter project outcomes. Commonly, risk management procedures accommodate these high likelihood/low consequence risks by determining their combined effect and developing cost and/or schedule contingency allowances to manage their influence.

Low likelihood/high consequence events, on the other hand, usually warrant individualized attention and management. At a minimum, low likelihood/high consequence events should be periodically monitored for changes in either their probability of occurrence or in their potential impacts. The subject of risk registers or risk watch lists is discussed in more detail later in this Guidebook. Some events with very large, albeit unlikely, impacts may be actively managed to mitigate the negative consequences should the unlikely event occur.

High (red) risk events are so classified either because they have a high likelihood of occurrence coupled with, at least, a moderate impact or they have a high impact with, at least, moderate likelihood. In either case, specific directed management action is warranted to reduce the probability of their occurrence or to reduce the risk's negative impact.

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

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 needed

Low (Green)

Minimum impact. Minimum oversight needed to ensure risk remains low

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 achive key team or major program milestone		>10%

Figure 3.7. Risk assessment process (Adapted from DOE 2003).

3.4.2.4 Risk Assessment Summary

The goal of risk assessment is not to eliminate all risk from the project. Rather, the goal is to recognize the significant risk challenges to the project and to initiate an appropriate management response to their management and mitigation. This recognition of risk challenges is accomplished through an assessment of each risk's likelihood of occurrence and the impact if it does occur. A comparison of each risk's probability and impact yields a relative ranking of the risks that can be used for risk management or, if warranted by project complexity, a detailed quantitative risk analysis using probabilistic models to generate ranges of possible outcomes.

3.4.3 Risk Analysis

3.4.3.1 Objectives of Risk Analysis

Typically, a project's qualitative risk assessment will recognize some risks whose occurrence is so likely or whose consequences are so serious that further quantitative analysis is warranted. A key purpose of quantitative risk analysis is to combine the effects of the various identified and assessed risk events into an overall project risk estimate. This overall assessment of risks can be used by the transportation agency to make go/no-go decisions about a project. It can help agencies to view projects from the contractor's perspective through a better understanding of their risks. More commonly, the overall risk assessment is used to determine cost and schedule contingency values and to quantify individual impacts of high risk events. Ultimately however, the purpose of quantitative analysis is to not only compute numerical risk values but to provide a basis for controlling transportation project costs through effective risk management strategies.

There are many methods and tools for quantitatively combining and assessing risks. The selected method or tool will involve a trade-off between sophistication of the analysis and its ease of use. There are at least five criteria to help select a suitable quantitative risk technique.

- The tool should help determine project cost and schedule contingency.
- The tool should have the ability to include the explicit knowledge of the project team members concerning the site, the design, the political conditions, and the project approach.
- The tool should allow quick response to changing market factors, price levels, and contractual risk allocation.
- The tool should help foster clear communication among the project team members and between the team and higher management about project uncertainties and their impacts.

- The tool, or at least its output, should be easy to use and understand.

3.4.3.2 Risk Characterization for Risk Analysis

There are three basic analyses that one can conduct during a project risk analysis. There is technical performance analysis (will the project work or is the scope sufficient?), schedule risk analysis (when will the project be completed?) and cost risk analysis (what will the project cost?). A technical performance risk analysis can provide important insights into technology-driven cost and schedule growth for projects that incorporate new and unproven technology. However, this discussion of quantitative risk analysis will concentrate only on cost and schedule risk analysis. The following section will discuss the various alternative methods that can be used for quantitative risk analysis.

At a computational level there are two considerations about quantitative risk analysis methods. First, for a given method, what input data is required to perform the risk analysis? Second, what kind of data, outputs and insights does the method provide to the user?

3.4.3.3 Inputs for Risk Analysis

The most stringent methods are those that require as inputs a probability distribution for the various performance, schedule, and costs risks. Risk variables are differentiated based on whether they can take on any value in a range (continuous variables) or whether they can assume only certain distinct values (discrete variables). Whether a risk variable is discrete or continuous, two other considerations are important in defining an input probability: its central tendency and its range or dispersion. An input variable's mean and mode are two alternative measures of central tendency; the mode is the most likely value across the variable's range. The mean is the value where the variable has a 50 percent chance of taking on a value that is greater and a 50 percent chance of taking a value that is lower. The mode and the mean of two example continuous distributions are illustrated in the Figure 3.8.

The other key consideration when defining an input variable is its range or dispersion. The common measure of dispersion is the standard deviation which is a measure of the breadth of values that are possible for the variable. Normally, the larger the standard deviation the greater the relative risk. Probability distributions with different mean values and different standard deviation values are illustrated in Figure 3.9.

All four distributions have a single high point (the mode) and all have a mean value that may or may not equal the mode. Notice too that some of the distributions are symmetrical about the mean while others are not. Selecting an appropriate probability distribution is a matter of which distribution is most like the distribution of actual data. For transportation projects, this is a difficult choice because historical data on unit prices, activity durations, and quantity variations are often difficult to obtain. In cases where insufficient data is available to completely define a probability distribution, one must rely on a subjective assessment of the needed input variables.

3.4.3.4 Outputs of Risk Analysis

The type of outputs that a technique produces is an important consideration when selecting a risk analysis method or tool. Generally speaking, techniques that require more rigor, demand stricter assumptions, or need more input data generally produce results that contain more information and are more helpful. Results from risk analyses may be divided into three groups according to their primary output:

- Single parameter output measures;
- Multiple parameter output measures; and
- Complete distribution output measures.

The type of output required for an analysis is a function of the objectives of the analysis. If, for example, an agency needs approximate measures of risk to help in project selection

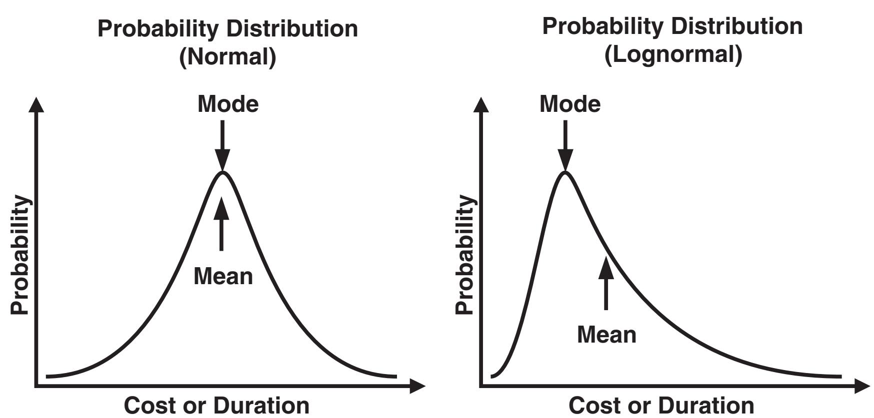


Figure 3.8. Mean and mode in normal and lognormal distributions.

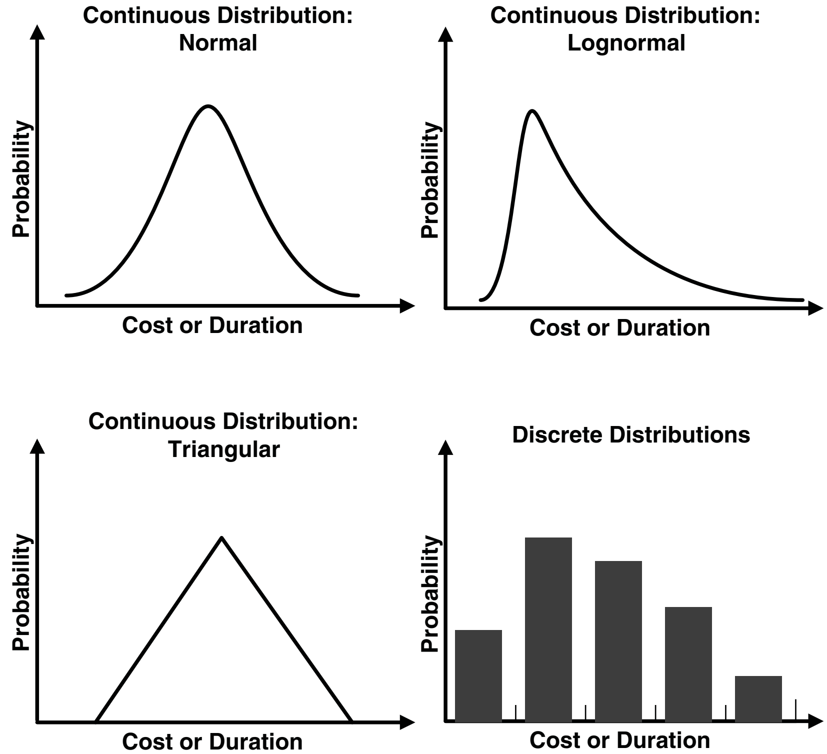


Figure 3.9. Distributions for risk analysis.

studies, simple mean values (a single parameter) or a mean and a variance (multiple parameters) may be sufficient. On the other hand, if an agency wishes to use the output of the analysis to aid in assigning a contingency amount to a project, knowledge about the precise shape of the tails of the output distribution or the cumulative distribution is needed (complete distribution measures). Finally, when the identification and subsequent management of the key risk drivers is the goal of the analysis, a technique that helps with such sensitivity analyses is an important selection criterion.

Sensitivity analysis is a primary modeling tool that can be used to assist in valuing individual risks, which is extremely valuable in risk management and risk allocation support. A "tornado diagram" is a very useful graphical tool for depicting risk sensitivity or influence on the overall variability of the risk model. Tornado diagrams graphically show the correlation between variations in model inputs and the distribution of the outcomes. They highlight the greatest contributors to the overall risk. Figure 3.10 is a tornado diagram for a portion of the San Francisco Oakland Bay Bridge project. The length of the bars on the tornado diagram corresponds to the influence of the items on the overall risk (in this case, risk to schedule duration).

3.4.3.5 Risk Analysis Methods

The selection of a risk analysis method requires an analysis of what input risk measures are available and which types of risk output measures are desired. The following paragraphs describe some of the most frequently used quantitative risk analysis methods and an explanation of the input requirement and output capabilities. These methods range from simple, empirical methods to computationally complex, statistically based methods.

Traditional methods for risk analysis are empirically developed procedures that primarily concentrate on developing cost contingencies for projects. The method assigns a risk factor to various project elements based on historical knowledge of the relative risk of various project elements. For example, pavement material cost may exhibit a low degree of cost risk, whereas acquisition of rights of way may display a high degree of cost risk. Project contingency is determined by multiplying the estimated cost of each element by their respective risk factors. Table 3.4 provides an example of a traditional risk analysis for the calculation of contingency through the expected value of each identified risk. This method profits from its simplicity and the fact that it does produce an estimate of cost contingency. However, the project teams' knowledge of risk is only implicitly incorporated in the various risk factors. Due to the historical or empirical nature of the risk assessments, traditional methods do not promote communication of the risk consequences of the specific project risks. Likewise, this technique does not support the identification of specific project risk drivers. These methods are not well adapted to evaluating project schedule risk.

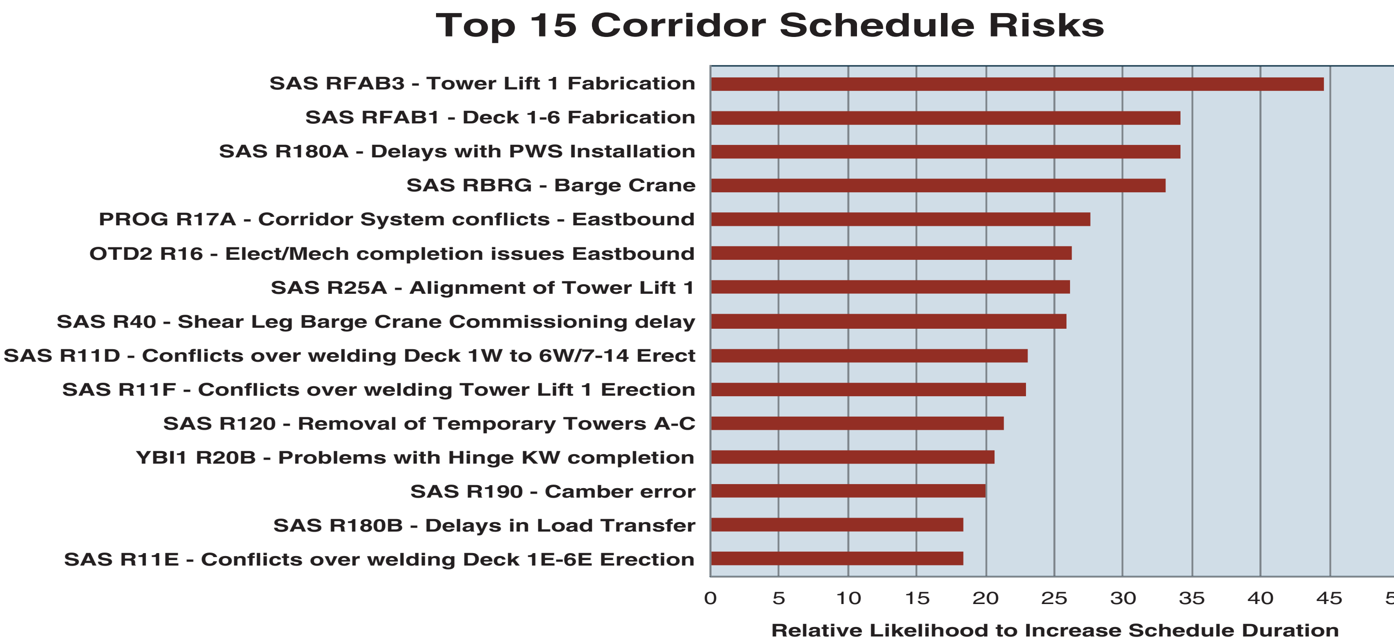


Figure 3.10. Example sensitivity analysis with tornado diagram.

While traditional methods are quite simple, they do not reflect the complexity of many highway projects. Risk analyses for major projects are most often modeled through simulation methods. Simulation models, also called Monte Carlo methods, are computerized probabilistic calculations that use random number generators to draw samples from probability distributions. The objective of the simulation is to find the effect of multiple uncertainties on a value quantity of interest (such as the total project cost or project duration). There are many advantages of Monte Carlo methods. They can determine risk effects for cost and schedule models that are too complex for common analytical methods. They can explicitly incorporate the risk knowledge of the project team for both cost and schedule risk events. They have the ability to reveal, through sensitivity analysis, the impact of specific risk events on the project cost and schedule.

However, Monte Carlo methods require knowledge and training for successful implementation. Input to Monte Carlo methods requires the user to know and specify exact probability distribution information; mean, standard deviation, and distribution shape. Yet, Monte Carlo methods are the most common method for project risk analysis for they provide detailed, illustrative information about risk impacts on the project cost and schedule.

Figure 3.11 shows typical probability outputs from a Monte Carlo analysis. The histogram information is useful for understanding the mean and standard deviation of analysis results. The cumulative chart is useful for determining project budgets and contingency values at specific levels of certainty or confidence. In addition to graphically conveying information, Monte Carlo methods produce numerical values for common statistical parameters such as the mean, standard deviation, distribution range, and skewness.

3.4.3.6 Risk Analysis Summary

The risk analysis process can be complex due to both the complexity of the modeling that is required and the subjective nature of the data available to conduct the analysis. However, the complexity of the process is not overwhelming and

Table 3.4. Traditional risk analysis method example.

Project Cost Element	Estimated Impact	Probability of Occurrence	Cost Contingency
Initial purchase of right of way	$1,200,000	20	$240,000
Known hazardous substance	125,000	10	12,500
Coordination with railroad companies	50,000	10	5,000
Treatment of water discharged from site	400,000	3	12,000
Total			**$269,500**

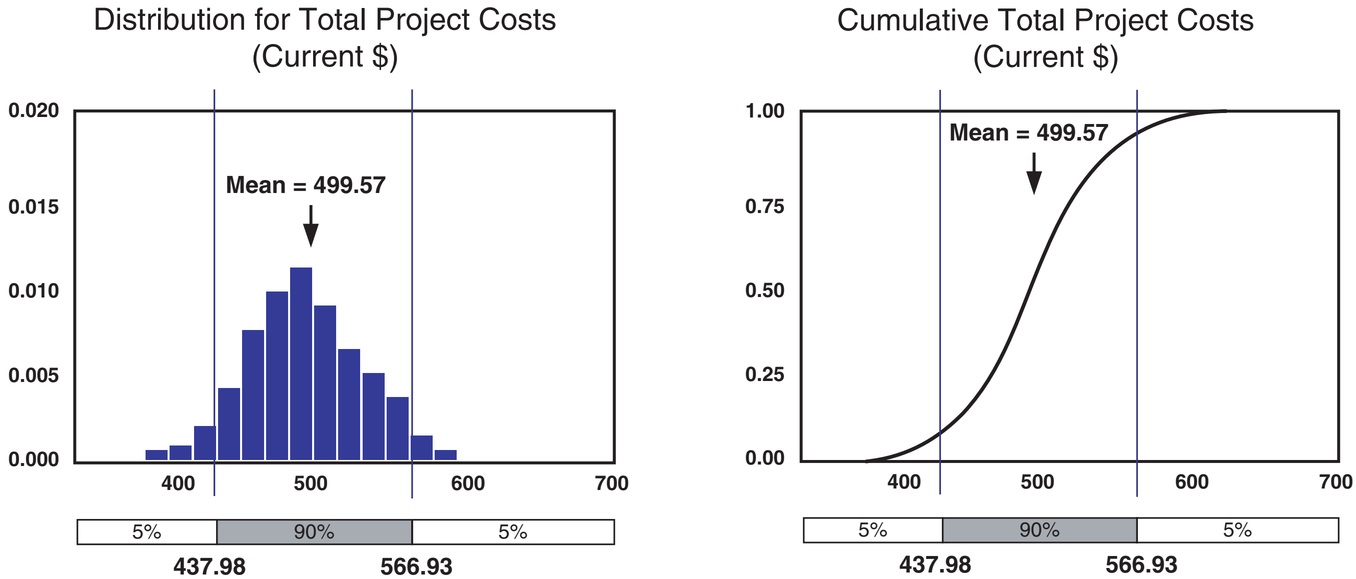


Figure 3.11. Typical Monte Carlo output for total costs.

the generated information can prove to be extremely valuable. There are many methods and tools for quantitatively combining and assessing risks. The selected method will involve a trade-off between sophistication of the analysis and its ease of use. Adherence to sound risk analysis techniques will lead to more informed decision making and a more transparent allocation of project risk.

3.4.4 Risk Mitigation and Planning

3.4.4.1 Objectives of Risk Mitigation and Planning

The objectives of risk mitigation and planning are to explore risk response strategies for the high-risk items identified in the qualitative and/or quantitative risk analysis. The process identifies and assigns parties to take responsibility for each risk response. It ensures that each risk requiring a response has an owner. The owner of the risk could be an agency planner, engineer, or construction manager depending upon the point in project development or it could be a private sector contractor or partner depending upon the contracting method and risk allocation.

Risk mitigation and planning efforts may require that agencies set policies, procedures, goals, and responsibility standards. Formalizing risk mitigation and planning throughout an agency will establish a risk culture that should result in better cost management from planning through construction.

3.4.4.2 Risk Response Options

Risk identification, assessment, and analysis exercises form the basis for developing sound risk response options. There are a series of risk response actions that can help agencies and their industry partners avoid or mitigate the identified risks. Wideman (1992), in the Project Management Institute standard, *Project and Program Risk Management; A Guide to Managing Risks and Opportunities,* states that a risk may be:

- Unrecognized, unmanaged, or ignored (by default);
- Recognized, but no action taken (absorbed by a matter of policy);
- Avoided (by taking appropriate steps);
- Reduced (by an alternative approach);
- Transferred (to other through contract or insurance);
- Retained and absorbed (by prudent allowances); or
- Handled by a combination of the above.

The above categorization of risk response options helps to formalize risk management planning. The Caltrans (California Department of Transportation) Risk Management Handbook (Caltrans 2007) suggests a subset of strategies from the categorization defined by Wideman. The Caltrans Handbook states that the project development team must identify which strategy is best for each risk and then design specific actions to implement that strategy. The four strategies and actions in the Caltrans Handbook include:

- Avoidance—The team changes the project plan to eliminate the risk or to protect the project objectives from its impact. The team might achieve this by changing scope, adding time, or adding resources (thus relaxing the so-called "triple constraint").
- Transference—The team transfers the financial impact of risk by contracting out some aspect of the work. Transfer-

ence reduces the risk only if the contractor is more capable of taking steps to reduce the risk and does so.

- Mitigation—The team seeks to reduce the probability or consequences of a risk event to an acceptable threshold. This is accomplished via many different means that are specific to the project and the risk. Mitigation steps, although costly and time consuming, may still be preferable to going forward with the unmitigated risk.
- Acceptance—The project manager and the project team decide to accept certain risks. They do not change the project plan to deal with a risk, or identify any response strategy other than agreeing to address the risk if and when it occurs.

Given a clear understanding of the risks, their magnitude, and the options for response, an understanding of project risk will emerge. This understanding will include where, when, and to what extent exposure will be anticipated. The understanding will allow for thoughtful risk planning.

3.4.4.3 Risk Planning

Risk planning involves the thoughtful development, implementation, and monitoring of appropriate risk response strategies. The DOE's Office of Engineering and Construction Management (2003) defines risk planning as the detailed formulation of a plan of action for the management of risk. It is the process to:

- Develop and document an organized, comprehensive, and interactive risk management strategy;
- Determine the methods to be used to execute a risk management strategy; and
- Plan for adequate resources.

Risk planning is iterative and includes describing and scheduling the activities and processes to assess (identify and analyze), mitigate, monitor, and document the risk associated with a project. For minor or moderately complex projects, the result should be a risk register. For major projects or moderately complex projects with a high degree of uncertainty, the result should be a formal risk management plan.

Planning begins by developing and documenting a risk management strategy. Early efforts establish the purpose and objective; assign responsibilities for specific areas; identify additional technical expertise needed; describe the assessment process and areas to consider; delineate procedures for consideration of mitigation and allocation options; dictate the reporting and documentation needs; and establish report requirements and monitoring metrics. This planning should address evaluation of the capabilities of potential sources as well as early industry involvement.

3.4.4.4 Risk Planning Documentation

Each risk plan should be documented, but the level of documentation detail will vary with the unique attributes of each project. Major projects or projects with high levels of uncertainty will benefit from having detailed and formal risk management plans that record all aspects of risk identification, risk assessment, risk analysis, risk planning, risk allocation, and risk information systems, documentation, and reports. Other projects that are smaller or contain minimal uncertainties may only require the documentation of red flag *item lists* that can be updated at critical milestones throughout the project development and construction.

A red flag item list is created at the earliest stages of project development and maintained as a checklist during project development. It is perhaps the simplest form of risk identification and risk management. Not all projects will require a comprehensive and quantitative risk management process. A red flag item list can be used in a streamlined qualitative risk management process.

The creation of a risk register is a more formal identification of risks than the simple red flag item listing. It is typically completed as part of a formal and rigorous risk management plan. The risk register provides project managers with a listing of significant risks and includes information about the cost and schedule impacts of these risks. It supports the contingency resolution process by tracking changes as a result of actual cost and schedule risk impacts, as the project progresses through the development process and the risks are resolved.

A risk register is used as a management tool to identify, communicate, monitor, and control risks. It provides assistance in setting appropriate contingencies and equitably allocating risks. As part of a comprehensive risk management plan, the risk register can help to control cost escalation. It is appropriate for large or complex projects that have significant uncertainty. A risk register is based on either a qualitative or quantitative assessment of risk, rather than simple judgmental decisions. The identified risks are listed with relevant information for quantifying, controlling, and monitoring them. The risk register may include relevant information such as:

- Risk Description
- Status
- Date Identified
- Project Phase
- Functional Assignment
- Risk Trigger
- Probability of Occurrence (%)
- Impact ($ or days)
- Response Actions
- Responsibility (Task Manager)

The most extensive risk planning, which is typically reserved for major projects, is through the creation of a formal risk management plan. The project development team's strategy to manage risk provides the project team with direction and basis for planning. The formal plan should be developed during the planning and programming phases, and then updated during the preliminary and final design phases. Since the ability of the agency's and the contractor's teams to plan and build the facility affects the project's risks, industry can provide valuable insight into this area of consideration.

The plan is the roadmap that tells the project team members how to approach all phases of risk management at a corporate level. Since it is a map, it may be specific in some areas, such as the assignment of responsibilities for agency and contractor participants and definitions, and general in other areas to allow users to choose the most efficient way to proceed. A risk management plan should contain some or all of the following items:

1. Introduction
2. Summary
3. Definitions
4. Organization
5. Risk management strategy and approach
6. Risk identification
7. Risk assessment and analysis
8. Risk planning
9. Risk allocation
10. Risk register and risk monitoring
11. Risk management information system, documentation and reports

As previously stated, each risk plan should be documented, but the level of detail will vary with the unique attributes of each project. Red flag item lists, risk registers, and formal risk management plans provide flexibility in risk management documentation.

3.4.4.5 Risk Planning Summary

Risk mitigation and planning utilizes the information from the risk identification, assessment, and analysis processes to formulate response strategies for key risks. Common strategies are avoidance, transference, mitigation, or acceptance. The mitigation and planning exercises must be documented in an organized and comprehensive fashion that clearly assigns responsibilities and delineates procedures for mitigation and allocation of risks. Common documentation procedures frequently include the creation of red flag item lists, risk registers, and formal risk management planning documentation. Risk mitigation and planning efforts may necessitate that agencies set policies, procedures, goals, and responsibility standards. Formalizing risk mitigation and planning throughout the agency will establish a risk culture that should result in better cost management from planning through construction.

3.4.5 Risk Allocation

3.4.5.1 Objectives of Risk Allocation

The contract is the vehicle for risk allocation. Whether the contract is for construction, construction engineering and inspection, design, or design-build, or some other aspect of highway construction management, the contract by defining roles and responsibilities assigns risks. Risk allocation in any contract affects cost, time, quality, and the potential for disputes, delays, and claims. In fact, contractual misallocation of risk has been found to be a leading cause of construction disputes in the United States (Smith 1995).

The Construction Industry Institute (CII) is a group of construction industry owners, contractors, and academics that study the industry and create best practices. In a 1990 study, CII states that:

> The goal of an optimal allocation of risk is to minimize the total cost of risk on a project, not necessarily the costs to each party separately. Thus, it might sometimes seem as if one party is bearing more of the risk costs than the other party. However, if both owners and contractors take a long-term view, and take into consideration the benefit of consistently applying an optimal method to themselves and to the rest of their industry, they will realize that over time optimizing risk allocation reduces everyone's cost and increases the competitiveness of all parties involved.

The objectives of risk allocation can vary depending upon unique project goals, but four fundamental tenets of sound risk allocation should always be followed.

- Allocate risks to the party that is best able to manage them.
- Allocate the risk in alignment with project goals.
- Share risk when appropriate to accomplish project goals.
- Ultimately seek to allocate risks to promote team alignment with customer-oriented performance goals.

3.4.5.2 Allocate Risks to the Party Best Able to Manage Them

A fundamental tenet of risk management is to allocate the risks to the party that is best able to manage the specific risk. The party assuming the risk should be able to best evaluate, control, bear the cost, and benefit from its assumption (ASCE 1990). For example, the risk of an inadequate labor force, a breakdown in equipment, or specific means of construction is best borne by the contractor, while a risk of securing of project funds or project site availability is best borne by the agency.

Following this principle of allocating the risks to the party that is best able to manage them will ultimately result in lowest overall price because contractors will not be forced to include contingency for possible financial losses or take gambles in an extremely competitive bidding environment. Inappropriate risk shifting from the owner to the contractor can result in misaligned incentives, mistrust, and an increase in disputes.

A second CII study (CII 1993) discusses the concept of allocating risks to the party that is best able to accept them:

> Because of the advantages and disadvantages associated with efficient and equitable allocation of risk, each project should be assessed individually and to determine for each risk what allocation consideration will reduce the overall cost to the project's total cost of risk.

3.4.5.3 Risk Allocation in Alignment with Project Objectives

Risks should be allocated in a manner that maximizes the probability of project success. The definition of a clear and concise set of project objectives is essential to project success and these objectives must be understood to properly allocate project risks. For instance, if the public needs a project completed sooner than would be achievable under traditional contracting and risk allocation methods, the agency may be forced to ask the contractor to assume more risk for timely or expedited completion and the agency must be willing to compensate the contractor for assuming this risk.

Allocating risks in alignment with project objectives begins with a clear understanding of the project objectives by the agency and clear communication of these objectives to the contracting, consulting, or design community. While this idea seems to be quite simple, in practice it is often difficult to identify and prioritize concise objectives due to the complex nature of many highway construction projects.

The importance of clearly understanding and defining project objectives cannot be overemphasized. Project objectives directly determine optimum risk allocation strategies, or when project risk allocation is justified in deviating from traditional industry standards. Additionally, project objectives can affect the procurement methods and contracting strategies. The objectives should be understood early in the project process and referred to before any important design, procurement, contracting, or construction management decision.

3.4.5.4 Share Risks Appropriately

The concept of risk sharing is often used synonymously with the concept of risk allocation. The American Society of Civil Engineers has gone as far as to define risk allocation as "the process of identifying risks and determining how—to what extent—they should be shared" (ASCE 1990).

However the term "risk sharing" can be somewhat misleading. In reality, there is no risk that is truly shared, but rather, exposure to the risk is split amongst the parties. Risk sharing is clearly defining the point at which the risk is transferred from one party to the other. These transfer points should be scrutinized for appropriateness, and then explicitly and clearly addressed in the contract. For example, a risk that is commonly shared is the risk for unusually severe weather. A contract provision for unusually severe weather may grant the contractor a right to a time extension while not providing for additional compensation of costs. In this situation, the agency is allocated the risk of delay while the contractor is allocated the risk of additional costs.

Another example of risk allocation comes from the WSDOT. The agency had traditionally maintained the risk for differing site conditions on drilled shafts for bridge piers. On a number of projects, they had experienced substantial cost growth for differing site conditions claims from contractors who were using equipment that was insufficient to remove small boulders in the drilled shafts. The agency determined that they had two choices: 1) specify the equipment and method for drilling the shaft so that these small boulders could be removed when encountered; or 2) allocate the risk for removing these boulders to the contractor in hopes that they will choose the appropriate method for removing the rocks. Unfortunately, both of these options were not aligned with standard agency policy. Because the agency foresaw too much risk in prescribing the means and methods of construction, they chose the second solution of allocating the risk of the differing site conditions to the contractor.

Communication between parties is a key to any sharing of risk allocation. Risk sharing provisions should be written with the principle of risk management and alignment of projects objectives as described above. All nontraditional allocation of risk should be clearly pointed out to the contractors.

3.4.5.5 Risk Allocation in Alignment with Customer-Oriented Performance Goals

The ultimate goal of risk allocation should be to help align the project team with customer oriented performance goals. A primary finding of the 2005 FHWA Construction Management Scan (FHWA 2005) was that the European highway community is allocating more risk to the private sector and this has resulted in better alignment of team goals with customer goals. For example, the Highways Agency in England has key performance indicators that deal with client satisfaction with the product, client satisfaction with the service, predictability of time, predictability of cost, safety, and process improvement. They have found that traditional risk allocation practices do not always align teams with these customer-oriented performance goals.

While the concept of allocating risks in alignment with customer-oriented performance goals may seem to be a significant departure from traditional practices in the United States, highway agencies are already doing this through the use of alternative contracting techniques. For example, A + B (cost + time) procurement is used on selected projects by many highway agencies in the United States. In essence, A + B procurement passes the risk for accurately setting the fastest construction completion date from the agency to the contractor. In an extreme example, the use of Public Private Partnership techniques is shifting the risk for customer satisfaction almost entirely to the private sector. Agencies and the industry should strive to innovate and develop new risk allocation techniques that align all team members with customer goals.

3.4.5.6 Conclusions

The rigorous process of risk identification, assessment, analysis, and mitigation described in this Guidebook allows for a more transparent and informed allocation of project risk. When risks are understood and their consequences are measured, decisions can be made to allocate risks in a manner that minimizes costs, promotes project goals, and ultimately aligns the construction team (agency, contractor, and consultants) with the needs and objectives of the traveling public.

3.4.6 Risk Monitoring and Control

3.4.6.1 Objectives of Monitoring and Control

The objectives of risk monitoring and control are to 1) systematically track the identified risks; 2) identify any new risks; 3) effectively manage the contingency reserve; and 4) capture lessons learned for future risk assessment and allocation efforts. Risk monitoring and updating occurs after the risk mitigation and planning processes. It precedes the risk allocation process in the planning phase, but is performed in conjunction with allocation during programming and design phases. It must continue for the life of the project. Risks are dynamic. The list of risks and associated risk management strategies will likely change as the project matures and new risks develop or anticipated risks disappear.

Periodic project risk reviews repeat the tasks of identification, assessment, analysis, mitigation, planning, and allocation. Regularly scheduled project risk reviews can be used to ensure that project risk is an agenda item at all project development and construction management meetings. If unanticipated risks emerge, or a risk's impact is greater than expected, the planned response or risk allocation may not be adequate. At this point, the project team must perform additional response planning to control the risk.

Risk monitoring and updating tasks vary depending upon unique project goals, but three tasks should be integrated into design and construction management plans:

1. Develop consistent and comprehensive reporting procedures;
2. Monitor risk and contingency resolution; and
3. Provide feedback of analysis and mitigation for future risk assessment and allocation.

3.4.6.2 Reporting

Risk reporting involves recording, maintaining, and stating assessments. Monitoring results and assessing the adequacy of existing plans are critical. The DOE's Office of Engineering and Construction Management (2003) states that primary criterion for successful management is formally documenting the ongoing risk management process. This is important because:

- It provides the basis for program assessments and updates as the project progresses;
- Formal documentation tends to ensure more comprehensive risk assessments than undocumented efforts;
- It provides a basis for monitoring mitigation and allocation actions and verifying the results;
- It provides project background material for new personnel;
- It is a management tool for the execution of the project; and
- It provides the rationale for project decisions.

A comprehensive risk register can form the basis of documentation for risk monitoring and updating. Caltrans has developed a standard risk register format that provides documentation for risk monitoring and updating. Table 3.5 provides a summary of the risk monitoring items contained in the Caltrans risk register template.

The output of risk registers and risk information systems can be graphically oriented. Figure 3.12 provides one example of a status presentation of top-level risk information that can be useful to management as well as others external to the program. The example has been adapted from the DOE's Office of Engineering and Construction Management (2003) and populated with risks for a typical highway project.

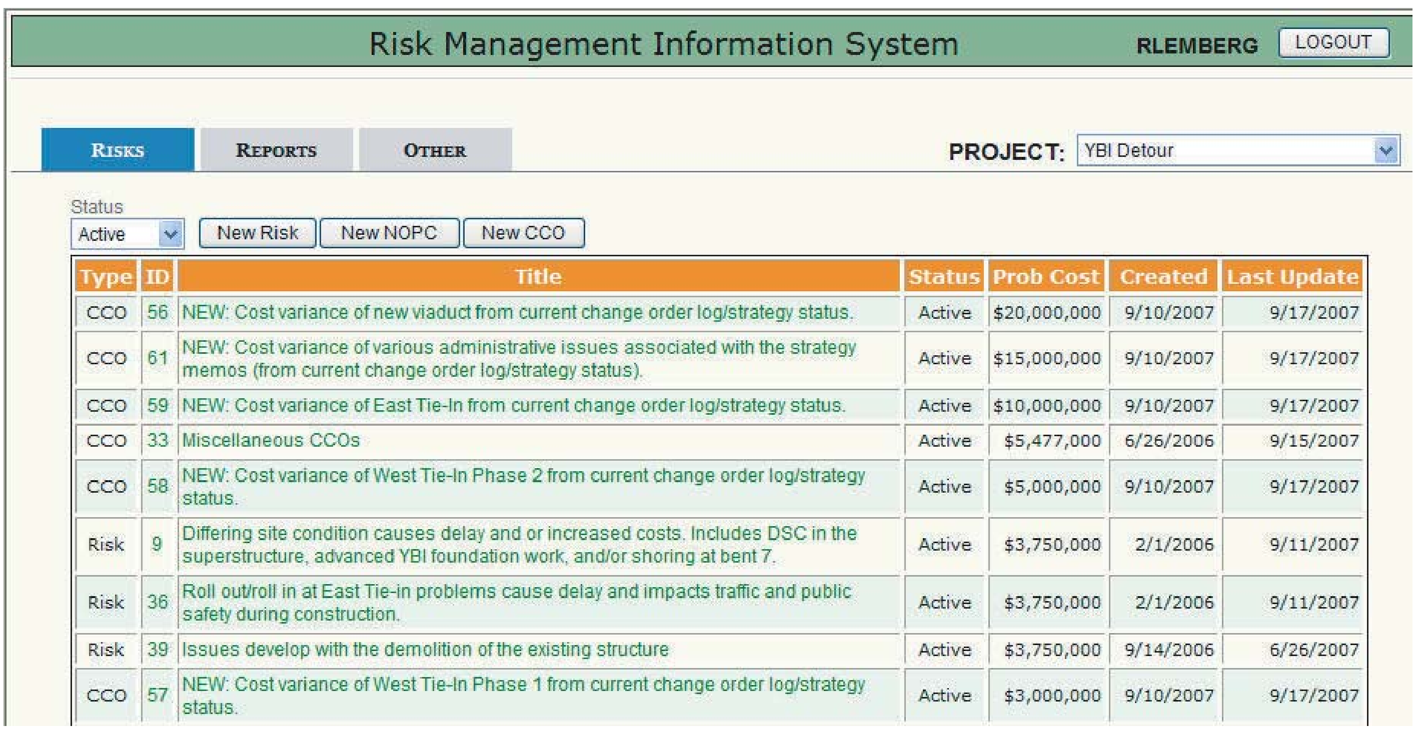
The most complex projects can employ a risk management information system. Risk management information systems can vary in form depending upon project or program needs, but the systems generally contain the same information that would be found in the most comprehensive risk registers in a database system that can be accessed by multiple users. Caltrans has created a very sophisticated risk management information system for the San Francisco Oakland Bay Bridge Project and the Toll Bridge Seismic Retrofit Program. The graphic in Figure 3.13 shows an input screen for the program's risk management information system. The risk management information system provides Caltrans staff with a variety of input methods and reporting functions. Caltrans is using the risk management information system to actively manage its

Table 3.5. Selected monitoring items from Caltrans risk register (Caltrans 2007).

Status	Functional Assignment	Risk Trigger	Assessment (Qualitative or Quantitative)	Monitor and Control
Active = risk is being actively monitored Dormant = risk is not currently high priority, but may become active in the future Retired = risk has been resolved	Capital delivery function (planning, design, right of way, environmental, engineering services, construction, etc.)	Event that indicates risk has occurred Used to determine when to implement the risk response strategy	Probability and impact of the risk This can be qualitative (very high, high, medium, etc.) or quantitative (involving a % probability of occurrence and impact in $ or days)	Responsibility = name of manager responsible for the risk Status Interval or Milestone Check = point of review Date, Status and Review Comments

Risk Plan #	Risk Issue	High	Moderate	Low	Status/Comment
T-01	Unexpected geotechnical issues				Soils investigations ongoing
T-02	Need for design exceptions			Closed	Design nearly complete
E-01	Landowners unwilling to sell				All property successfully acquired
E-02	Local community objections			Closed	Outreach plan complete
E-01	Inexperienced staff assigned				Training in progress

Figure 3.12. Example risk status report (Adapted from DOE 2003).



Type	ID	Title	Status	Prob Cost	Created	Last Update
CCO	56	NEW: Cost variance of new viaduct from current change order log/strategy status.	Active	$20,000,000	9/10/2007	9/17/2007
CCO	61	NEW: Cost variance of various administrative issues associated with the strategy memos (from current change order log/strategy status).	Active	$15,000,000	9/10/2007	9/17/2007
CCO	59	NEW: Cost variance of East Tie-In from current change order log/strategy status.	Active	$10,000,000	9/10/2007	9/17/2007
CCO	33	Miscellaneous CCOs	Active	$5,477,000	6/26/2006	9/15/2007
CCO	58	NEW: Cost variance of West Tie-In Phase 2 from current change order log/strategy status.	Active	$5,000,000	9/10/2007	9/17/2007
Risk	9	Differing site condition causes delay and or increased costs. Includes DSC in the superstructure, advanced YBI foundation work, and/or shoring at bent 7.	Active	$3,750,000	2/1/2006	9/11/2007
Risk	36	Roll out/roll in at East Tie-in problems cause delay and impacts traffic and public safety during construction.	Active	$3,750,000	2/1/2006	9/11/2007
Risk	39	Issues develop with the demolition of the existing structure	Active	$3,750,000	9/14/2006	6/26/2007
CCO	57	NEW: Cost variance of West Tie-In Phase 1 from current change order log/strategy status.	Active	$3,000,000	9/10/2007	9/17/2007

Figure 3.13. Risk management information system example (Caltrans).

contingency for competing the San Francisco Oakland Bay Bridge Project and the Toll Bridge Seismic Retrofit Program.

WSDOT developed an exceptional top-level risk status report, as seen in Figure 3.14 (Washington 2006). The "What's Changed" also acts as a high-level monitoring report. The status report uses a one-page format to communicate important cost and risk issues to both the DOT personnel and external stakeholders. It communicates key project information, project benefits, and project risks. It reports cost and schedule in a range rather than a single point. It also communicates the project design status. In some high-profile projects, the report is completed annually and updates information from the previous report. While the example shown is for a large corridor-level program, this format can be successfully implemented on smaller projects as well.

3.4.6.3 Contingency Resolution

Any party assuming a risk must be prepared for the financial burden associated with that risk. Figures 3.3 through 3.5 in this chapter graphically depicted how contingency is retired. Prudent contractors and agencies use the quantitative risk assessment techniques to estimate the contingency necessary to complete a project. Proper risk allocation will allow for the minimization of this contingency for both parties.

As the project matures from programming through final design, the contingency is lowered and the base estimate increases. The percentage of the contingency to the base estimate is a function of the project complexity and the level of project definition. Procedures and tools for estimating an appropriate contingency amount are provided throughout the remainder of this guidebook and the Appendix A.

3.4.6.4 Conclusions on Risk Monitoring and Control

A successful risk monitoring and updating process will systematically track risks, support the identification of new risks, and effectively manage the contingency reserve. The system will help to ensure successful completion of the project objectives. If documented properly, the monitoring and updating process will capture lessons learned and feed risk identification, assessment, and quantification efforts on future projects.

3.5 Risk Management Policies and Performance Measures

A survey conducted as part of this research found that less than 10 percent of the SHA have policies regarding risk management for cost control (Molenaar et al. 2009). Policies and performance measures will help to ensure consistent application of risk management processes and provide a means for documenting improvement. This section briefly describes policies and performance measures found in the research.

3.5.1 Policies

Policies statements on the application of risk and cost management will help to encourage better cost control. These policies are perhaps as important as the steps of the risk management process in the successful integration of risk management procedures within the organization. The process of implementation begins with the development of a policy statement.

Figures 3.15 and 3.16 illustrate portions of policy statements on risk management. The example in Figure 3.15 from Minnesota Department of Transportation (Mn/DOT) was developed as part of the agency's Cost Estimating Process Improvement and Organizational Integration initiative. It is one of five policies relating to cost estimating and cost management. The policy statement makes clear the use of contingency estimates on all early estimates.

The U.S. DOE policy statement highlighted in Figure 3.16 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.

3.5.2 Performance Measures

Performance measures help keep projects and programs on track by ensuring that the risk management process is meeting its goals. Performance measures such as cost, schedule, and safety measurements can be taken at predetermined times, or at significant milestones to evaluate the accuracy and effectiveness of risk management and project management procedures.

The development of risk management performance metrics is essential to risk monitoring success. The establishment of a management indicator system that provides accurate, timely, and relevant risk information in a clear, easily understood manner is key to risk monitoring. Early in the planning phase of the process, the team should identify specific indicators to be monitored and information to be collected, compiled, and reported. Specific procedures and details for risk reporting should be included in the risk management plans prepared by the agency and the contractor.

Caltrans has proposed performance measures for its risk management program. They are considering 1) percent of projects with risk management plans during the project initiation document (PID) phase (is it happening), and 2) percent of project change requests (PCRs) due to unidentified risks (builds into the quality of the PCRs). These measures will be

I-405 Congestion Relief and Bus Rapid Transit Projects

Revised July 2003

Scenario

Tukwila to Bothell (Option C)

Project Descriptions:

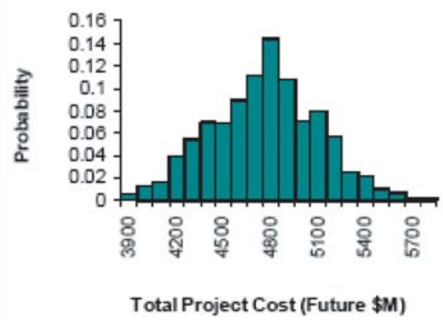
- Continuous multi-modal corridor improvement projects from I-5 in Tukwila to SR 522 in Bothell.
- Adds one lane each direction from I-5 to SR 181 in Tukwila.
- Adds two lanes each direction from SR 181 in Tukwila to I-90 in Bellevue.
- Adds one lane each direction from I-90 in Bellevue to SR 522 in Bothell.
- On SR 167, adds one lane between I-405 and S. 180th St.
- Constructs Bus Rapid Transit system with stations, HOV direct access ramps and Park & Ride lots and coaches.
- Expands the vanpool program.

Schedule:

Begin Construction Range: 2006-2007

End Construction Range: 2013-2014

CEVP Result:



Project Benefits:

- Reduces congestion and improves freight movement.
- Provides bus rapid transit system from SeaTac to Lynnwood.
- Constructs 2300 new Park & Ride spaces.
- Adds 600 new vanpools and increases commute reduction programs.
- Improves water resources.

Project Cost Range:

10% chance the cost < $ 4.2 Billion

50% chance the cost < $ 4.7 Billion

90% chance the cost < $ 5.1 Billion

Project Risks:

- Changing environmental requirements for project mitigation (stormwater, wetlands, fish resources and streams) may increase project costs--primarily for added right-of-way purchases.
- Delays in right-of-way purchases may result in construction delays and project cost increases.
- Early stage of project development leads to scope uncertainty.
- Legal challenges and delays in obtaining environmental permits may result in project delay.
- Utility relocations may require extra time to negotiate and complete.

What's Changed Since 2002:

- Scope: Project limits are smaller.
- Schedule: Begin construction range has been delayed up to one year. End construction range has been accelerated two years.
- Costs: Costs have gone down approximately $1 billion due to scope revisions.
- Risk Management: Identifying new strategies for improved environmental clearances and right-of-way processes. Coordinating decision strategies with FHWA.

Financial Fine Print (Key Assumptions):

- Full project funding becomes available in July 2005. State I-405 Nickel funds will roll-over into this package.
- Inflation escalation is to 2010, the approximate midpoint of construction.
- Additional federal, state, regional and local money may be needed.
- Project cost range includes $18.5 million in past expenses, beginning in 1999.
- Assumes funding decisions do not interrupt or cause construction delays.

Level of Project Design: Low — Medium — High

July 16, 2003

Washington State Department of Transportation

Figure 3.14. Washington State DOT cost and risk status report.

Mn/DOT Uncertainty, Risk, and Contingency Policy

The Total Project Cost Estimate for each of the project development phases will include an analysis of uncertainty and risk, and associated contingency estimates.

Draft Policy Guidelines:

a. Uncertainty, risk and associated contingencies will be acknowledged early for all projects in the project development process, starting with the planning phase, and updated in subsequent phases.

b. With the exception of the Letting Phase cost estimate, where project contingency is zeroed out, contingency will not be incorporated in individual line item costs; instead, contingency will be maintained in a separate category. As more is known about the project, the amount of estimated contingency and the Base Estimate would change (contingency resolution).

c. A contingency estimate based on a risk analysis will be developed for all projects. The level of risk analysis, including the possible use of a specialized risk-estimation unit or review panel, will be determined by each unique project's complexity, local impacts, or political interest.

Figure 3.15. Excerpt from MnDOT policy statement on uncertainty, risk, and contingency.

tracked and reported by division headquarters of project management (for the measure relating to PCRs) and planning (for the measure regarding PIDs).

Performance measures can be project specific rather than programwide. These project risk performance measures can deal with the number or magnitude of risks that have been successfully mitigated. The project risk performance measures also can resemble traditional construction management performance measures such as cost variance, schedule variance, estimate at completion, design schedule performance, management reserve, estimate to complete, or similar measures. Some examples of performance measures proposed for a state

DOE 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 these 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.

Figure 3.16. Excerpt from DOE risk management policy.

department of transportation are 1) the degree to which risks are identified in early estimates; and 2) the degree to which contingency resolution is tracked.

While the use of performance measures is critical to long-term process improvement and risk management program success, risk management should not be viewed purely as a measure of estimate accuracy. Comparisons of estimate accuracy between a stochastically based range estimate from planning and a deterministically based estimate at the end of design is not advisable due to the disparate nature of the information available in the estimates. Performance measures that deal with the number of magnitude of risks that have been mitigated during the project development process are likely a better indicator of program success.

3.6 Summary

This chapter provides an overview of the risk management process with particular reference to contingency planning and the risk management steps. The chapter provides a foundation and vocabulary that is used throughout the remainder of this Guidebook. Definitions for risk management terms are provided. A series of figures describe the need for contingency and the contingency resolution process. Each of the risk management steps is discussed in detail, including risk identification, risk assessment, risk analysis, risk mitigation and planning, risk allocation, and risk monitoring and control. The chapter concludes with a brief discussion of policies and performance measures relating to risk management.

CHAPTER 4

Guidebook Framework

4.1 Introduction

This chapter describes the Guidebook framework used to present information contained in Chapters 5, 6, and 7. Each chapter covers a different phase of the project development process—planning, programming, and design (both preliminary and final design). Each of these phases has its own unique challenges related to achieving the objectives of the five project risk management steps. Risk management approaches vary depending on the phase of project development and on a project's complexity. These approaches vary because different tools and management practices are required when implementing the risk management process within a project context. Although there is overlap and redundancy in the information presented, the overlap and redundancy is necessary to effectively implement risk management in the context of project complexity and the phase within which the project finds itself. The structure and format of Chapters 5, 6, and 7 is the same; however, the content varies depending on the project phase, the project information and data available, and the purpose of risk management and cost control as applied during that phase.

4.2 Guidebook Structure and Layout

Chapters 5, 6, and 7 focus on the application of the fundamental concepts presented in Chapters 1, 2, and 3. 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 risk management. The structure follows a hierarchical layout of project development phase, risk management step, and project complexity as shown in Figure 4.1.

Note that Chapter 7 combines the preliminary design and final design phases described in Chapter 2. These phases were combined to minimize redundancy and also due to the fact that the risk management approach does not vary substantially from the preliminary to final design phases. Figure 4.2 illustrates how the risk management process focus 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 risk management 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. These changes also are summarized in Table 3.2.

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 following structure:

- Inputs—the information required for the risk management step;
- Tools—a mapping of appropriate tools that are included in the Appendix A;
- Outputs—the information that will be produced from the risk management step;
- Complexity—relationship to project complexity; and
- Tips—advice for implementing the risk management step and the use of risk management tools.

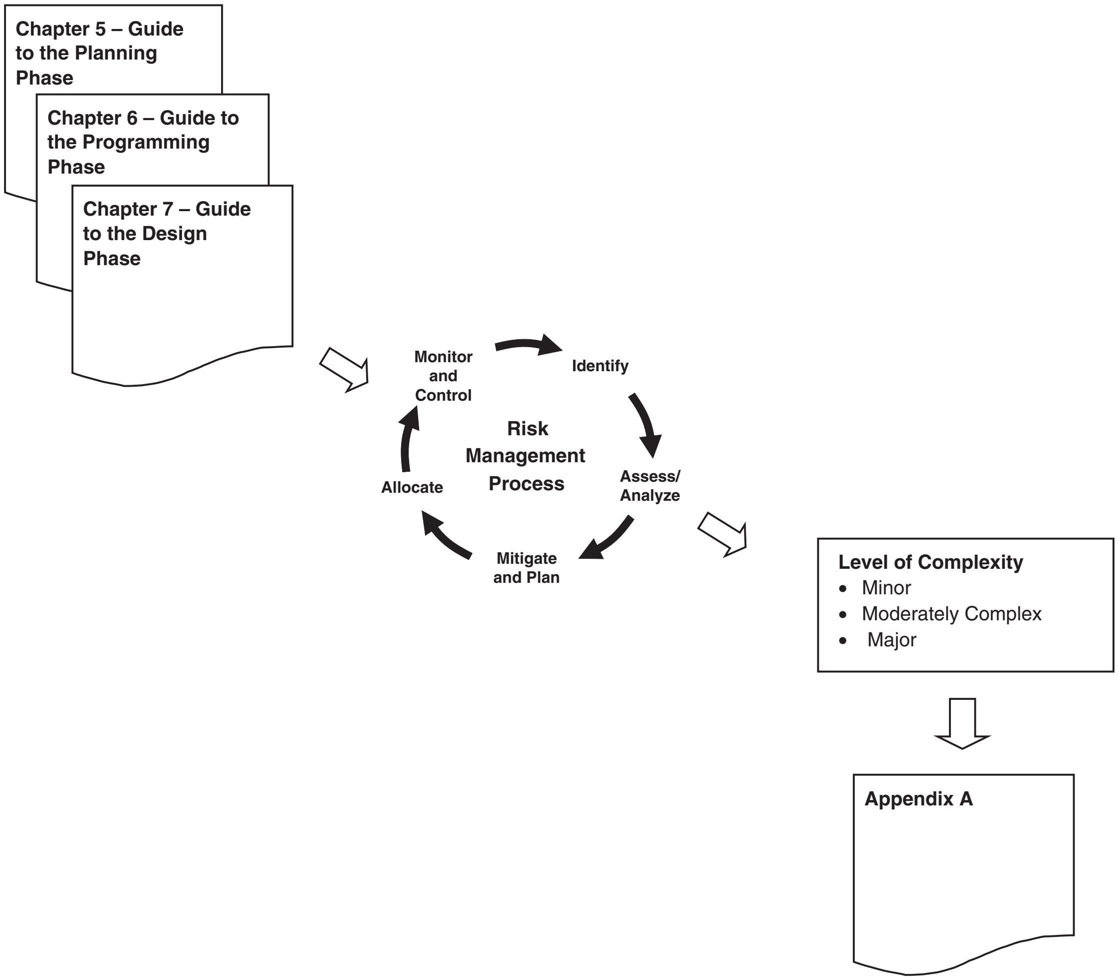


Figure 4.1. Guidebook structure.

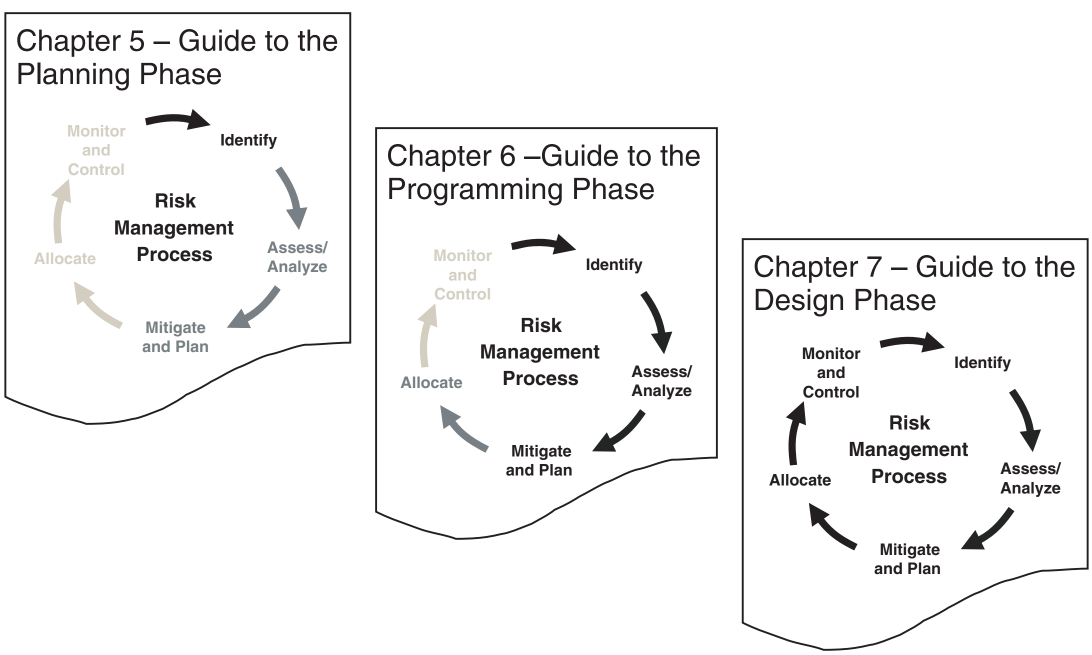


Figure 4.2. Risk management focus within the project development phases.

4.3 Appendix A

Appendix A describes all the tools referenced for each step in Chapters 5, 6, and 7. 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?

Table 4.1 summarizes these tools with the risk step and phase in which they apply. The description of project complexity is addressed within each chapter.

Note that the tools are numbered to correspond with *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction.*

4.4 Summary

This Guidebook applies a common framework in Chapters 5, 6, and 7 to describe how the risk management steps change throughout the project development phases and how they are impacted by project complexity. It provides a map to applying the tools presented in the Appendix A.

Table 4.1. Risk tool summary.

Tool	Description	Risk Management Step					Phases		
		Identify	Assess & Analyze	Mitigate & Plan	Allocate	Monitor & Control	Planning	Scoping	Design
D1 Delivery and Procurement Method									
D1.1 Contract Packaging	The manner in which work is subdivided into individual contracts. Contract packaging affects contract prices and must be accounted for when estimating project cost.				•				•
D1.2 Delivery Decision Support	The project delivery method involves the organization of the project team members, the procurement method, and the contract payment terms. The selection of a project delivery system can affect both risk allocation and project costs.				•			•	•
I2 Identification of Risk									
I2.1 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.	•		•		•	•	•	•
I2.2 Not Used									
I2.3 Risk 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.	•					•	•	•
I2.4 Assumption Analysis	The process of reviewing all assumptions for uncertainty that could generate risks.	•					•	•	•
I2.5 Expert Interviews	Speaking with experts in order to generate risks and/or assess risk probability/impact.	•	•				•	•	•
I2.6 Crawford Slip Method	A group risk identification technique. Useful in generating a large number of risks in a short amount of time.	•					•	•	
I2.7 SWOT Analysis	Strengths, Weaknesses, Opportunities, & Threats. A risk identification technique used to help generate risks and place them into categories.	•					•	•	
R1 Recognition of Project Complexity									
R1.1 Recognition of Complexity	The tool used to assign a project complexity level. This is based on predetermined criteria, and assigned based on project characteristics (new or reconstruction, urban or rural, etc.).	•	•	•	•	•	•	•	•

(continued on next page)

Table 4.1. (Continued).

Tool	Description	Risk Management Step					Phases		
		Identify	Assess & Analyze	Mitigate & Plan	Allocate	Monitor & Control	Planning	Scoping	Design
R3 Risk Analysis									
R3.1 Risk Management Plan	Project-specific document that comprehensively describes the philosophy and approach to risk management.	•	•	•	•	•	•	•	•
R3.2 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.		•				•	•	•
R3.3 Contingency – Identified	The process of estimating contingency on the basis of identified risks and the probability of their occurrence.		•		•		•	•	•
R3.4 Estimate Ranges – Three Point Estimates	A technique for generating range estimates by estimating an optimistic, most-likely, and pessimistic estimate.		•				•	•	
R3.5 Estimate Ranges – 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.		•	•	•		•	•	•
R3.6 Risk Workshops	Workshops that are conducted to identify and quantify the uncertainty involved in projects. Risk mitigation and planning are also often addressed.	•	•	•			•	•	•
R3.7 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.		•				•	•	•
R3.8 Probability x Impact Matrix (P x I)	Qualitative analysis tool to provide a ranking of risks based on probability and impact. It is a powerful visual tool to convey risk ranking.		•				•	•	•
R3.9 Risk Comparison Table	Analysis tool to compare all risks to each other to determine prioritization and importance.		•				•	•	•
R3.10 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.		•				•	•	•
R3.11 Risk Breakdown Structure	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.	•		•			•	•	•
R3.12 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.	•	•	•	•	•	•	•	•
R3.13 Risk Management Information System	A data management system that tracks risks and risk related information throughout the project development process.	•	•	•	•	•	•	•	•
R3.14 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.		•					•	•

CHAPTER 5

Guide to the Planning Phase

5.1 Introduction

This chapter presents guidance for risk management in the planning phase. The Planning Phase is defined in terms of its relevance to cost estimating and risk management. Each of the risk management steps is discussed in detail, including inputs, outputs, and tools used in the risk management process. Tips for tool application and how project complexity impacts risk management tools and practices are also discussed for each step.

5.1.1 Planning Phase Overview

The purpose of transportation planning for both states and regional areas is to identify a set of the most cost effective approaches that achieve their stated system goals. Federal law requires that SHAs develop a statewide transportation plan and that MPOs develop a regional transportation plan (RTP). The horizon year for these long-range plans is usually 20 to 25 years into the future.

Approaches, or at least terminology, for statewide transportation planning vary across the country. While some states do identify major or even unique minor projects, most statewide transportation plans do not identify specific projects, but rather establish strategic directions for state investment in the transportation system and present future challenges that could constrain the ability of the SHAs to improve the performance of their systems.

The metropolitan RTP is very different. The RTP identifies specific projects that are to be implemented over the next 25 years. Federal law requires the RTP to be fiscally constrained, that is, the sum of the total project costs in the plan cannot exceed the amount of funding that is expected over the next 25 years. This places great importance on having valid and realistic cost estimates for the projects in the MPO's plan.

The term "conceptual estimating" is often used to describe the general method of estimating project costs during the planning phase. Planning level cost estimates can have a significant effect on the overall transportation program and on the ability of the SHA and MTO to meet their area transportation needs. The level of effort regarding cost estimating and risk management is limited due to a lack of detailed project definition and the type of estimate techniques available to prepare a planning phase cost estimate (e.g., lane mile, etc.). The expectations for accuracy must be realistic in an estimate for a project that may be 25 years in the future and is only defined by project limits (e.g., point A to point B). Proper application of cost estimating and risk management tools will result in the generation of credible ranges of costs and risk management plans to meet these cost estimates.

5.1.2 Planning Phase Risk Management Emphasis

The risk management process begins during the planning phase. As shown by the shading in Figure 5.1, risk identification is the primary focus of the risk management process during the planning phase. Detailed risk identification is useful in the preparation of planning documents, particularly in the RTP. Risk assessment and risk mitigation and planning can be conducted on the most complex projects when they are identified in the RTP. However, risk assessment and mitigation are limited in the planning phase due to a lack of project definition. Similarly, detailed risk management plans can be developed for identified major projects and groups of minor or moderately complex projects, but they are limited as tools to assist in cost control (again due to the lack of individual project definition). Although risk allocation and risk monitoring and control are not the focuses of the planning phase, they should be considered when major projects are identified.

The remainder of this chapter describes tools and management practices suggested for use during the planning phase of project development. A discussion of how project complexity impacts risk management tools and practices is also provided.

Figure 5.1. Risk management focus in the planning phase.

5.2 Planning Phase Risk Identification

As stated in Chapter 3, risk identification is paramount to successful risk management and contingency estimation at the planning phase. The objectives of risk identification are: 1) to identify and categorize risks that could affect the project and 2) to document these risks. The outcome of the risk identification is a list of risks. Ideally, the list of risks should be comprehensive and non-overlapping. This list of risks can be the basis for estimating project contingency and setting the baseline cost estimate. Please refer to Chapter 3, Section 3.4.1 regarding risk identification, specifically regarding:

- Why risk identification should stop short of risk assessment;
- The appropriate level of detail for risk identification; and
- When and how to apply risk checklists.

5.2.1 Planning Phase Risk Identification Inputs

The planning phase defines overarching transportation needs, groups of projects, and/or individual unique projects. The determination of project risk stems from a review of the planning assumptions made by the planning team and the estimating assumptions made by the project estimator. The planning team will necessarily make broad assumptions of transportation needs to define the groups or projects. Likewise, the estimator will need to make estimating assumptions at a very high level. These assumptions often will be in the form of a cost per lane mile on projects very early in the planning process. Projects that are identified later in the planning phase, but before they enter programming, may have more detail (e.g., estimate of structure size, right of way purchase required, etc.), but these projects generally have to be estimated in a very conceptual manner. Planning and estimating assumptions serve as triggers for risk identification.

The risk identification process should begin with a review of any risks identified during previous planning phase analyses or estimates as projects can remain in the planning phase for many years. When no previous analyses or estimates are available, the risk identification projects can begin with a review of the current planning report and cost estimate with a focus on the assumptions that were used to generate these reports and estimates.

It should be noted that planning phase project scopes can vary greatly and the risk analysis and assessment varies with the scope accordingly. Those projects that are identified early in the planning phase have minimal scope definition and provide challenges for conducting detailed risk analyses. Projects with clearly identified scopes near the end of the planning phase can benefit more from rigorous risk analysis and the application of defined contingency estimates.

5.2.2 Planning Phase Risk Identification Tools

Risk identification tools that can be used in the planning phase are listed in Table 5.1. Note that complex projects can use all risk identification tools. Refer to the Appendix A for complete tool descriptions.

5.2.3 Planning Phase Risk Identification Outputs

The key risk identification output is a list of risks. In its simplest form, the list of risks may take the form of a Red Flag Item list (I2.1). On some moderately complex and most major projects near the end of the planning phase, the list of risks

Table 5.1. Planning phase risk identification tools.

Tool	Minor (N/A)	Moderately Complex	Major
I2.1 Red Flag Items		•	•
I2.3 Risk Checklists		•	•
I2.4 Assumption Analysis		•	•
I2.5 Expert Interviews		•	•
I2.6 Crawford Slip Method		•	•
I2.7 SWOT Analysis		•	•
R3.1 Risk Management Plan		•	•
R3.6 Risk Workshops			•
R3.11 Risk Breakdown Structure			•
R3.12 Risk Register		•	•

should form the basis of a Risk Management Plan (R3.1) and Risk Register (R3.12) for later risk management and control.

Categorization of the risk list can be extremely helpful to ensure that no risks have been missed. Categorization of risks can be accomplished through a review of Risk Checklists (I2.3). On major projects near the end of the planning phase, categorization can be achieved through the application of Risk Breakdown Structure (R3.11).

Ideally, the list of risks should be comprehensive and nonoverlapping. This list of risks can be the basis for estimating project contingency and setting the baseline cost estimate. Comprehensive and nonoverlapping lists of risks are required for detailed risk and contingency modeling in the later steps (see Chapter 3 for more details).

5.2.4 Planning Phase Risk Identification Relationship to Project Complexity

Minor projects are typically not identified as individual projects until the programming phase or later. During the planning phase, minor projects are grouped into what can be classified as moderately complex or major projects. It is generally not until the programming phase that these are identified as individual projects. Please see Chapter 6 for details regarding risk identification on minor projects.

Risk identification on moderately complex projects will benefit from a large number of sources. Expert Interviews (I2.5) will be a key input and formal Assumptions Analysis (I2.4) is typically warranted. A Risk Register (R3.12) should always be employed and a Risk Management Plan (R3.1) can be warranted on moderately complex projects with a high level of uncertainty.

Major projects require the highest level of risk identification. All risk identification tools are applicable to major projects. The Risk Workshop (R3.6) is the principal tool employed on major projects that is not typically applied to moderately complex projects. Formal Risk Workshops (R3.6) are typically facilitated by a professional risk analyst and can have upwards of 20 experts participating, depending upon the specific project needs. The time to plan, conduct, and document the workshop should not be underestimated. The benefits of a workshop include a comprehensive list of risks and a firm basis for risk analysis and planning.

5.2.5 Planning Phase Risk Identification Tips

The use of appropriate risk identification techniques should be intense, but commensurate to project understanding, during planning.

- Risk identification should be a creative brainstorming process. It should not attempt to analyze risks or discuss mitigation procedures, which will be completed in the subsequent steps.
- Use risk checklists and experience from similar projects only to check for missing risks and to help categorize unique project risks.
- Upon completion of the risk list, categorize the risk into logical groupings. Use risk checklists and similar project risk analyses for possible categorizations.

5.3 Planning Phase Risk Assessment and Analysis

The primary objective of risk assessment is the systematic consideration of risk events focusing on their probability of occurrence and the consequences of such occurrences. The majority of risk management applications during planning will include only a qualitative risk assessment (or even stop at risk identification without any risk assessment due to the lack of scope definition in planning). Rigorous risk analysis is generally reserved for only those major projects that are identified in the Planning Phase.

Recalling from Chapter 3 (Section 3.4.2), risk assessment and analysis is the process of evaluating the risk events documented in the preceding identification step. Risk assessment and analysis has two aspects. The first determines the probability of a risk occurring (risk frequency); risks are classified along a continuum from very unlikely to very likely. The second aspect judges the impact of the risk should it occur (consequence severity).

Typically, a project's qualitative risk assessment will recognize some risks whose occurrence is so likely or whose consequences are so serious that further quantitative risk analysis is warranted. A key purpose of quantitative risk analysis is to combine the effects of the various identified and assessed risk events into an overall project risk analysis. The overall risk analysis is used to determine cost and schedule contingency values and to quantify individual impacts of high risk events. Ultimately however, the purpose of quantitative analysis is to not only compute numerical risk values but to provide a basis for controlling project costs through effective risk management practices.

5.3.1 Planning Phase Risk Assessment and Analysis Inputs

The key inputs for risk assessment and analysis are the probability of a risk occurring (risk frequency) and the impact of the risk should it occur (consequence severity). The physical input to risk assessment and analysis is the list of risks from the identification step. In the Planning Phase, this will likely be a high-level list of risks. Determining the risks' probability and impact allows for qualitatively ranking to help planners focus on the most critical risks or quantitatively modeled to determine cost and schedule contingency estimates.

The risk identification step will have identified risks, but the identification step should stop short of assessment or analysis. In the risk assessment and analysis step, risk inputs will be elicited from planners, functional experts, estimators, and analysts to gain a clear picture of the risks.

5.3.2 Planning Phase Risk Assessment and Analysis Tools

Risk assessment and analysis tools that can be used in the Planning Phase are listed in Table 5.2. Note that minor projects are not included in the Planning Phase as explained in Section 5.2.4. Refer to the Appendix A for complete tool descriptions.

5.3.3 Planning Phase Risk Assessment and Analysis Outputs

Planning Phase risk assessment and analysis outputs will depend on the type of decision required and the rigor in the selected tools for assessment or analysis. The use of qualitative expert input (I2.5 Expert Interviews) and the application of a Risk Priority Ranking (R3.7), Probability x Impact Matrix (P x I) (R3.8), or Risk Comparison Table (R3.9) tools will yield a ranked set of risks that can help focus management on managing the highest priority risks. The use of quantitative expert inputs and application of an Estimate Ranges – Monte Carlo Analysis (R3.5) tool will yield a definitive contingency estimate and detailed sensitivity analysis of the risks that contribute to the contingency.

Table 5.2. Planning phase risk assessment and analysis tools.

Tool	Minor (N/A)	Moderately Complex	Major
I2.5 Expert Interviews		•	•
R3.2 Contingency–Percentage		•	
R3.3 Contingency–Identified		•	•
R3.4 Estimate Ranges–Three Point Estimate			•
R3.5 Estimate Ranges–Monte Carlo Analysis			•
R3.6 Risk Workshops		•	•
R3.7 Risk Priority Ranking		•	
R3.8 Probability x Impact Matrix (P x I)		•	•
R3.9 Risk Comparison Table		•	•
R3.10 Risk Map			•
R3.13 Risk Management Information System			•

Recalling from Chapter 3 (Section 3.4.3.4), the type of outputs that a tool produces is a function of the analytical rigor, nature of assumptions, or amount of input data. Results from risk analyses may be divided into three groups according to their primary output: 1) single parameter output measures; 2) multiple parameter output measures; and 3) complete distribution output measures. Please refer to Sections 3.4.3 and 3.4.5 for a full description of risk assessment and analysis outputs.

5.3.4 Planning Phase Risk Assessment and Analysis Relationship to Project Complexity

Project complexity is a key indicator of which risk assessment and analysis tools to apply. Moderately complex projects will generally apply a qualitative risk assessment to produce a ranking of risks. Risk ranking is commonly accomplished through the use of Risk Priority Rankings (R3.7), P x I Matrixes (R3.8), Risk Comparison Tables (R3.9) and/or Risk Maps (R3.10). Early planning estimates are often described by ranges. An Estimate Range – Three Point Estimates (R3.4) can be used to produce the range on moderately complex projects. On those moderately complex projects that are identified during planning that need a separate contingency estimate, Contingency—Percentages (R3.2) or Contingency—Identified (R3.3) tools can be applied.

Major projects that are identified during the Planning Phase can use more rigorous risk ranking and contingency estimation tools. The risk management process often begins with Risk Analysis Workshops (R3.6) and generates a stochastic estimate of cost and schedule through an Estimate Range–Monte Carlo Analysis (R3.5). The resulting risk-based range estimate is then updated throughout project development.

Please see Chapter 6, Section 6.3.4 for a more detailed description of how risk analysis and contingency estimation are related to project complexity at the programming phase.

5.3.5 Planning Phase Risk Assessment and Analysis Tips

A clear understanding of risk significance is helpful in the planning phase. On major identified projects near the end of the planning phase, a rigorous estimate of contingency can also be helpful.

- The goal of risk assessment is not to eliminate all risk from the project. Rather, the goal is to recognize the significant

risk challenges to the project and to initiate an appropriate management response.
- A comparison of each risk's probability and impact yields a relative ranking of the risks that can be used for risk management or, if warranted by project complexity, a detailed quantitative risk analysis using probabilistic models to generate ranges of possible outcomes.

5.4 Planning Phase Risk Mitigation and Planning

The objectives of risk mitigation and planning are to explore risk response strategies for the high-risk items identified in the qualitative risk assessment or quantitative risk analysis. The process identifies and assigns parties to take responsibility for each risk response. It ensures that each risk requiring a response has an owner. The key output is the risk register or risk management plan.

As shown in Figure 5.1, risk mitigation and planning in the planning phase requires less effort than in later project development phases. This lower level of effort stems primarily from the fact that projects, project teams, and project management structures are generally not in place until the programming phase. Detailed risk mitigation and planning efforts are reserved only for those identified moderately complex and major projects in the planning phase.

5.4.1 Planning Phase Risk Mitigation and Planning Inputs

The ranked list of risks from the first two risk management steps is the key input to the mitigation and planning effort. Risks mitigation and planning begins by developing and documenting a risk management strategy focused on the key risks. Early efforts establish the purpose and objective; assign responsibilities for specific areas; identify additional technical expertise needed; describe the assessment process and areas to consider; delineate procedures for consideration of mitigation and allocation options; dictate the reporting and documentation needs; and establish report requirements and monitoring metrics. This planning should address evaluation of the capabilities of potential sources as well as early industry involvement.

The list of risks is used as the basis for the solicitation of mitigation and planning options from key managers and experts. The mitigation and planning options will require cost-benefit analyses (e.g., the cost of implementing a mitigation effort versus the reduction in probability or impact to a risk) to assess the viability or impact of the options. Estimators and risk analysts will therefore have key input into the mitigation and planning process.

The planning team will have the final input into the risk mitigation and planning efforts. They will determine who "owns" the risk and is responsible for ensuring that it is managed effectively. The risk management plan and/or risk register should clearly identify who is responsible for managing and resolving each individual risk.

5.4.2 Planning Phase Risk Mitigation and Planning Tools

Risk mitigation and planning tools that most generally apply the planning phase are listed in Table 5.3. Refer to the Appendix A for complete tool descriptions.

5.4.3 Planning Phase Risk Mitigation and Planning Outputs

The outputs of the risk mitigation and planning step are an organized and interactive risk management strategy and a plan for adequate resources. The Risk Management Plan (R3.1) tool in Appendix A provides a good example of this output from Caltrans. The example risk management plan from Caltrans describes a clear approach to the assignment of responsibility. It also provides items that require resource investment and a method for calculating their costs.

Risk mitigation and planning is iterative and includes describing and scheduling the activities and processes to assess (identify and analyze), mitigate, monitor, and document the risk associated with a project. For minor or moderately complex projects, the result should be a Risk Register (R3.12). For major projects or moderately complex projects with a high degree of uncertainty, the result should be a formal Risk Management Plan (R3.1).

5.4.4 Planning Phase Risk Mitigation and Planning Relationship to Project Complexity

The risk mitigation and planning effort should be congruent with project complexity. Each risk plan should be documented, but the degree of documentation will vary with project

Table 5.3. Planning phase risk mitigation and planning tools.

Tool	Minor (N/A)	Moderately Complex	Major
R3.1 Risk Management Plan		•	•
R3.12 Risk Register		•	•

complexity. Not all projects will require a comprehensive and quantitative risk management process. The creation of a Risk Register (R3.12) is a formal identification of risks. A risk register can be applied to all projects that are identified during the planning phase. The risk register provides planners with a listing of significant risks and includes a variety of information for each. The risk register creates a concise tool to manage the risks and the individuals assigned to each risk.

Major projects identified in the planning phase will benefit from having a detailed and formal Risk Management Plan (R3.1) that records all aspects of risk identification, risk assessment, risk analysis, risk planning, risk allocation, and risk information systems, documentation, and reports. Major projects should use a register that is integrated into the formal Risk Management Plan (R3.1).

5.4.5 Planning Phase Risk Mitigation and Planning Tips

Risk mitigation and planning will apply to those projects that are specifically identified during the planning phase.

- Document the risk mitigation and planning efforts at a level of detail that is appropriate for the level of project definition, project complexity and resources available for Planning Phase efforts.
- Rigorous documentation of risk mitigation and planning in the Planning Phase will assist in scoping during the Programming Phase.

5.5 Planning Phase Risk Allocation

The goal of risk allocation is accomplished by contractually assigning risks to the party that is best able to manage them. Risk allocation efforts do not typically begin until the programming phase and are most intensive during the design phase. However, some major projects that are identified in the planning phase will identify, or explore, project delivery and contracting options. For a detailed discussion of these projects, please refer to the risk allocation discussion in the programming phase, Section 6.5.

5.5.1 Planning Phase Risk Allocation Inputs

Risk allocation inputs at the planning phase include the outputs from the first three steps in the risk management process plus an examination of the available/allowable project delivery options for the project.

5.5.2 Planning Phase Risk Allocation Tools

As seen in Table 5.4, the only tool that applies in the planning phase is the Delivery Decision Support (D1.2) tool, which includes descriptions of numerous alternative project delivery methods.

Table 5.4. Planning phase risk allocation tools.

Tool	Minor (N/A)	Moderately Complex	Major
D1.2 Delivery Decision Support			•

5.5.3 Planning Phase Risk Allocation Outputs

The likely output of the risk allocation step at the planning phase will be an analysis of possible project delivery methods. However, the output will vary with the nature of the project. At the highest level of detail, a project delivery decision report can be generated that analyzes risk allocation in terms of project characteristics (e.g., cost, schedule and quality issues), agency characteristics (e.g., available staffing level, staff experience, etc.), market characteristics (e.g., market availability, market experience, etc.) and stakeholder characteristics. The final project delivery decision will not likely be made until the programming phase.

5.5.4 Planning Phase Risk Allocation Relationship to Project Complexity

Alternative delivery methods will only be explored on major projects during the planning phase.

5.5.5 Planning Phase Risk Allocation Tips

Risk allocation discussions can assist in appropriate project delivery method selection.

- Document risk allocation discussions in the planning phase to assist in making final project delivery and contract packaging decisions in the later phases.

5.6 Planning Phase Risk Monitoring and Control

The objectives of risk monitoring and control are to: systematically track the identified risks; identify any new risks; effectively manage the contingency reserve; and capture lessons learned for future risk assessment and allocation efforts. The application of risk monitoring and control will vary greatly with the level of project definition during the PLANNING PHASE. Risk monitoring and control effort are more intense during the programming and design phases of project development.

5.6.1 Risk Monitoring and Control Inputs

The key inputs to risk monitoring and control are the Risk Management Plan (R3.1) and Risk Register (R3.12). These tools provide a framework for managing risks through a formalized monitoring and control process. In some cases when fewer planning resources are available, a list of Red Flag Items (I2.1) can also be used for risk monitoring and control.

5.6.2 Planning Phase Risk Monitoring and Control Tools

Table 5.5 lists the risk monitoring and control tools suggested for the Planning Phase. More information on the tools can be found in Appendix A.

Table 5.5. Planning phase risk monitoring and control tools.

Tool	Minor (N/A)	Moderately Complex	Major
I2.1 Red Flag Items		•	
R3.1 Risk Management Plan		•	•
R3.12 Risk Register		•	•

5.6.3 Planning Phase Risk Monitoring and Control Outputs

The key output for risk monitoring and control in the planning phase is a strategy or plan that will support monitoring and control in the programming and design phases. Please see Sections 6.6.4 and 7.6.4 for a more detailed discussion of monitoring and control in those phases.

5.6.4 Planning Phase Risk Monitoring and Control Relationship to Project Complexity

A Red Flag Item (I2.1) list should only be applied for risk monitoring and control on those projects where planning resources are constrained. Risk Registers (R3.12) and Risk Management Plans (R3.1) are more appropriate tools to assist in monitoring and control in major projects with a large amount of uncertainty.

5.6.5 Planning Phase Risk Monitoring and Control Tips

Risk monitoring and control should be a continuous and repetitive activity during all phases of project development.

- For each project, develop a unique risk monitoring and control process that is appropriate for the size and complexity of the project. However, do not create monitoring and control processes that are burdensome or create undue paperwork.

5.7 Conclusions

This chapter discussed guidance for risk management in the planning phase. The outcome of this discussion is a map or guide to the risk management tools provided in Appendix A. The planning phase focuses efforts on risk identification. Moderately complex and major projects that are specifically identified in the planning phase can employ some level of risk assessment and analysis efforts – particularly near the end of the planning phase. Risk mitigation and planning, risk allocation, and risk monitoring and control are typically found only on identified major projects. Rigorous documentation of the risk management process in the planning phase will make the programming and design phase efforts more effective.

CHAPTER 6

Guide to the Programming Phase

6.1 Introduction

This chapter presents guidance for risk management in the programming phase. The programming phase is defined in terms of its relevance to cost estimating and risk management. Each of the risk management steps is discussed in detail, including inputs, outputs, and tools used in the risk management process. Tips for tool application and how project complexity impacts risk management tools and practices are also discussed for each step.

6.1.1 Programming Phase Overview

The programming phase focuses on converting the highest priority needs identified in the SHA's long-range plan into specific projects. This decision point marks the beginning of the project development process as individual projects are identified for definition, design, and construction letting. The time period, from project definition in programming to letting the project for construction, is typically between five and 10 years. This time duration between programming and construction letting is a function of project complexity and criticality. SHA policies and practices also influence this time duration.

Programming often marks the beginning of a project specific effort. Federal law requires that the transportation improvement program (TIP) for a metropolitan area become part of the state's transportation improvement program (STIP). It is common for state SHAs and MPOs to work closely identifying the likely costs associated with candidate projects.

Programming is often referred to as the project "definition or scoping phase." The primary goal of programming is to create a baseline scope, cost, and schedule for the project. Once this baseline is approved, the project is included in an authorized priority program. The priority program includes projects that are typically within 10 years or less from their anticipated letting date. The first four years of the priority program is usually the STIP. The priority program is the output from the programming phase of project development. Once projects are including in a priority program, the SHA must manage project scope, cost, and time as development continues during the design phase. The duration of time between when a project is included in the priority program and finally goes to construction letting varies across SHAs. Some SHAs program projects nine or 10 years before their expected construction letting date. Other SHAs only program a project when the project is ready to be included in the STIP. In the latter case, the STIP becomes the priority program.

During the programming phase, a project baseline cost estimate is prepared. This cost estimate becomes the basis for managing project costs during the design phase. The risk management process is tied to cost estimating through the risk identification, risk assessment and analysis, and risk mitigation and planning when preparing the baseline cost estimate.

6.1.2 Programming Phase Risk Management Emphasis

Risk management practices during the programming phase focus on comprehensive risk identification, detailed risk assessment and analysis, and risk mitigation and planning. The key output of the programming phase in terms of cost estimating and cost management is the baseline cost estimate. Recalling from Chapters 2 and 3, the baseline cost estimate is comprised of the base estimate and a contingency estimate. As shown by shading in Figure 6.1, these three primary risk management steps serve as the basis for estimating the contingency that must be included in the baseline cost estimate. Once risks are comprehensively identified and assessed/analyzed with regard to their potential impact and probability of occurrence, a justifiable contingency can be estimated. A detailed risk management plan will then be prepared and used

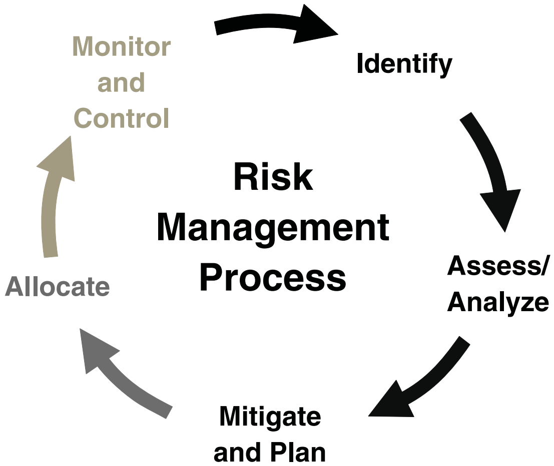


Figure 6.1. Risk management focus in the programming phase.

for managing risks related to the baseline scope, cost, and time. This risk management plan is incorporated into the approved project scope, budget and schedule. A risk management plan becomes the basis for risk mitigation, monitoring, and control during project development.

Although risk allocation and risk monitoring and control are not the focuses of the programming phase, they should be considered with a lower level of effort. Higher level risk allocation decisions are made during the programming phases. These decisions typically involve the choice of project delivery method (e.g., design-bid-build, design-build, etc.), but do not involve detailed risk allocation (e.g., contract provisions involving time, management of traffic, etc.). Risk monitoring and control approaches are planned, but they are not utilized until after the baseline cost and schedule estimates have been set at the end of the programming phase.

The remainder of this Chapter describes tools and management practices suggested for use during the programming phase of project development. A discussion of how project complexity impacts risk management tools and practices is also provided.

6.2 Programming Phase Risk Identification

Risk identification is paramount to successful risk management and contingency estimation at the programming phase. The objectives of risk identification are: 1) to identify and categorize risks that could affect the project; and 2) to document these risks. The outcome of the risk identification is a list of risks. Ideally, the list of risks should be comprehensive and non-overlapping. This list of risks can be the basis for estimating project contingency and setting the baseline cost estimate.

The risk identification process should generally stop short of assessing or analyzing risks so as not to inhibit the identification of minor risks. This identification process should promote creative thinking and leverage team member experience and knowledge.

Perhaps the most challenging aspect of risk identification is in defining issues at an appropriate level of detail. Issues defined too vaguely or lumped into gross generalizations are hard to assess. Defining too many separate, detailed risks can lead to overlapping among issues or the omission of larger issues (i.e., "missing the forest for the trees" problem). To the extent possible, define risks to be independent of each other, thereby eliminating overlap among risks through their descriptions.

Risk checklists and lists of risks from similar projects can be helpful, but use them only as a back check at the end of the risk identification process. Review these lists only at the end of the process as a means of ensuring that the list is not excluding any common risks. Avoid beginning the process with the risk checklists or similar project analyses as the team may overlook unique project risks or include too many risks in the analysis, and this will make the process less useful.

6.2.1 Programming Phase Risk Identification Inputs

The project scope generated in the programming process and the related base estimate package comprise the key inputs for risk identification. The determination of project risk stems from a review of the design assumptions made by the design team and the estimating assumptions made by the project estimator. The design team must make initial conceptual design assumptions that they will refine as the design progresses. Likewise, the estimator must make estimating assumptions in a programming level estimate because complete design information is not yet available. Design and estimating assumptions serve as triggers for risk identification when creating a contingency estimate.

The risk identification process should begin with a review of any risks identified during the planning phase. However, the risks identified during planning will likely have changed substantially by the programming phase. Risk identification at the programming phase must be rigorous. It is helpful to go through a new risk identification exercise at the programming phase and then use the planning phase risk identification outputs only as a check at the end of the process to ensure that no risks were overlooked.

6.2.2 Programming Phase Risk Identification Tools

Risk identification tools that can be used in the programming phase are listed in Table 6.1. Note that complex projects

Table 6.1. Programming phase risk identification tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	•	•	
I2.3 Risk Checklists	•	•	•
I2.4 Assumption Analysis	•	•	•
I2.5 Expert Interviews		•	•
I2.6 Crawford Slip Method		•	•
I2.7 SWOT Analysis		•	•
R3.1 Risk Management Plan		•	•
R3.6 Risk Workshop			•
R3.11 Risk Breakdown Structure			•
R3.12 Risk Register	•	•	•

can use all risk identification tools. Refer to Appendix A for complete tool descriptions.

6.2.3 Programming Phase Risk Identification Outputs

The key risk identification output is a list of risks. Risk identification can be initiated in the planning phase, especially where the plan identifies critical environmental resources or sensitive areas. A discussion of environmental mitigation activities is required in the current metropolitan and statewide planning regulations [see 23 CFR 450.214(j) and 23 CFR 450.322(f)(7)] and as the MPOs and states further refine their plans under current requirements, this sort of information should become more readily available. The planning regulations also require that transportation plans be compared against conservation plans and/or maps or inventories of natural resource or historic resources, providing another opportunity for identifying risk in the planning process [see 23 CFR 450.214(i) and 23 CFR 450.322(g)].

On minor projects, the list of risks may take the form of a Red Flag Item list (I2.1). On some minor project, and all moderately complex and major projects, the list of risks should form the basis of a Risk Management Plan (R3.1) and Risk Register (R3.12) for later risk management and control. Categorization of the risk list can be extremely helpful to ensure that no risks have been missed. Categorization of risks can be accomplished through a review of Risk Checklists (I2.3). On major projects, categorization can be achieved through the application of Risk Breakdown Structure (R3.11).

Ideally, the list of risks should be comprehensive and nonoverlapping. This list of risks can be the basis for estimating project contingency and setting the baseline cost estimate. Comprehensive and nonoverlapping lists of risks are required for detailed risk and contingency modeling in the later steps.

6.2.4 Programming Phase Risk Identification Relationship to Project Complexity

On minor projects, the number of inputs to the risk identification step can be small. An estimator or project manager may individually conduct the risk identification or with a small group. Information comes from preliminary estimates, preliminary schedules, the estimators' judgment, scoping documents, design assumptions, and other sources. Minor project risk identification tools may include only a Red Flag List (I2.1). However, consultation with experts (Expert Interviews, I2.5) can be a good idea if time and budget permits. The use of Risk Checklists (I2.3) is suggested at the end of the identification process to ensure that no risks have escaped detection.

Moderately complex projects will require risk identification from a greater number of sources. Expert Interviews (I2.5) will be a key input on moderately complex projects. Formal Assumptions Analysis (I2.4) is typically warranted. A Risk Register (R3.12) should always be employed and a Risk Management Plan (R3.1) can be warranted on moderately complex projects with a high level of uncertainty.

Major projects require the highest level of risk identification. All risk identification tools are applicable to major projects. The Risk Workshop (R3.6) is the principal tool employed on major projects that is not typically applied to moderately complex or minor projects. Formal Risk Workshops (R3.6) are typically facilitated by a professional risk analysis and can have upwards of 20 experts participating depending upon the specific project needs. The time to plan, conduct, and document the workshop should not be underestimated. The benefits of a workshop include a comprehensive list of risks and a firm basis for risk analysis and planning.

6.2.5 Programming Phase Risk Identification Tips

The use of appropriate risk identification techniques must be instituted during programming.

- Risk identification should be a creative brainstorming process. It should not attempt to analyze risks or discuss mitigation procedures, which will be completed in the subsequent steps.
- At a minimum, risk information should include assumptions, estimate basis uncertainties, and project issues and concerns from the estimator, project team, and any participating specialty groups.

- The resultant risk list should be comprehensive and nonoverlapping to be most useful in later risk analyses. Combine like risks. Separate overlapping risks.
- Use risk checklists and experience from similar projects only to check for missing risks and to help categorize unique project risks.
- Upon completion of the risk list, categorize the risk into logical groupings. Use risk checklists and similar project risk analyses for possible categorizations.

6.3 Programming Phase Risk Assessment and Analysis

Because the baseline estimate is set in the programming phase, risk assessment and analysis is generally more comprehensive and time consuming in programming than in any other project development phase. The primary objective of risk assessment is the systematic consideration of risk events focusing on their probability of occurrence and the consequences of such occurrences. Risk assessment and analysis is the process of evaluating the risk events documented in the preceding identification step. Risk assessment and analysis has two aspects. The first determines the probability of a risk occurring (risk frequency); risks are classified along a continuum from very unlikely to very likely. The second aspect judges the impact of the risk should it occur (consequence severity).

Typically, a project's qualitative risk assessment will recognize some risks whose occurrence is so likely or whose consequences are so serious that further quantitative risk analysis is warranted. A key purpose of quantitative risk analysis is to combine the effects of the various identified and assessed risk events into an overall project risk analysis. The overall risk analysis is used to determine cost and schedule contingency values and to quantify individual impacts of high risk events. Ultimately however, the purpose of quantitative analysis is to not only compute numerical risk values but to provide a basis for controlling project costs through effective risk management practices.

6.3.1 Programming Phase Risk Assessment and Analysis Inputs

The physical input to risk assessment and analysis is the list of risks from the identification step. In the programming phase, this will likely be a long list that must be filtered through the assessment and analysis step to help focus the project team on a subset of the most critical risks.

The risk identification step will have identified risks, but the identification step should stop short of assessment or analysis. In the risk assessment and analysis step, risk inputs will be elicited from project managers, functional experts, estimators, and analysts to gain a clear picture of the risks. Managers and functional experts tend toward qualitative assessment of risks. They evaluate risks relative to their worst case effects and their relative likelihood of occurrence. Analysts and estimators tend toward quantitative assessment of risks. They evaluate risk impacts in terms of a range of tangible results and they evaluate risk of occurrence in terms of probabilities. The analyst's focus is on the combined tangible effect of all the risks on project scope, cost, and schedule. A comprehensive risk strategy combines both a qualitative assessment and a quantitative analysis.

Recalling from Chapter 3, the key inputs for risk assessment and analysis are the probability of a risk occurring (risk frequency) and the impact of the risk should it occur (consequence severity). Knowing the probability and impact, risks can be qualitatively ranked to help managers focus on the most critical risks or quantitatively modeled to determine cost and schedule contingency estimates.

6.3.2 Programming Phase Risk Assessment and Analysis Tools

Risk assessment and analysis tools that can be used in the programming phase are listed in Table 6.2. Note that project complexity has a significant impact on the use of risk assess-

Table 6.2. Programming phase risk assessment and analysis tools.

Tool	Minor	Moderately Complex	Major
I2.5 Expert Interviews	•	•	•
R3.2 Contingency—Percentage	•	•	
R3.3 Contingency—Identified	•	•	•
R3.4 Estimate Ranges – Three Point Estimate	•	•	
R3.5 Estimate Ranges – Monte Carlo Analysis		•	•
R3.6 Risk Workshop		•	•
R3.7 Risk Priority Ranking	•	•	
R3.8 Probability x Impact Matrix (P x I)	•	•	•
R3.9 Risk Comparison Table	•	•	•
R3.10 Risk Map	•	•	•
R3.13 Risk Management Information System			•
R3.14 Self Modeling Worksheet		•	•

ment and analysis tools. Refer to Appendix A for complete tool descriptions.

6.3.3 Programming Phase Risk Assessment and Analysis Outputs

Risk assessment and analysis outputs will depend on the type of decision required, the detail in the input analysis, and the level of rigor in the selected tools for assessment or analysis. The use of qualitative expert input (I2.5 Expert Interviews) and the application of a Risk Priority Ranking (R3.7), Probability x Impact Matrix (P x I) (R3.8), or Risk Comparison Table (R3.9) tools will yield a ranked set of risks that can help focus management on managing the highest priority risks. The use of quantitative expert inputs and application of a Estimate Ranges – Monte Carlo Analysis (R3.5) tool will yield a definitive contingency estimate and detailed sensitivity analysis of the risks that contribute to the contingency.

Recalling Chapter 3, Section 3.4.3.4, the type of outputs that a tool produces is a function of the analytical rigor, nature of assumptions, or amount of input data. Results from risk analyses may be divided into three groups according to their primary output: 1) single parameter output measures; 2) multiple parameter output measures; and 3) complete distribution output measures. Please refer to Sections 3.4.3 and 3.4.5 for a full description of risk assessment and analysis outputs.

6.3.4 Programming Phase Risk Assessment and Analysis Relationship to Project Complexity

Risk assessment and analysis are directly tied to project complexity. This can best be seen in the tie between risk analysis and contingency calculation. The research team has observed numerous methods for analyzing risks and developing contingency estimates. These methods fall into three categories (Type I, II, and III Risk Analysis), which directly relate to project complexity (minor, moderately complex, and major).

Type I Risk Analysis – Risk Identification and Percentage Contingency

A Type I risk analysis is the simplest form of risk analysis and applies only to minor projects. A Type I risk analysis involves the development Red Flag Items (I2.1) and the use of a Contingency—Percentage (R3.2) tool to estimate the contingency. To estimate contingency, the estimator should examine the list of risks and use judgment within percentage contingency range of acceptable standards set by the agency policies or estimating guidance.

Type II – Qualitative Risk Analysis and Identified Contingency Items

A Type II risk analysis applies to moderately complex projects and involves more rigorous risk assessment and tools [e.g., P x I Matrix (R3.8), Risk Comparison Table (R3.9), etc.] and the estimate of specific contingency items using the Contingency—Identified (R3.3) tool that complements the percentage-based contingency in the Type I analysis. A qualitative ranking of the risks and expected values estimates for contingency on the critical risks are key outputs of this method. When estimating an appropriate contingency in a Type II risk analysis, the range of contingency from the Contingency—Percentage (R3.2) tool is first consulted. The next step is to review approximately the top 20 percent of the prioritized risks to ensure that the contingency is adequate. An expected value estimate for estimating the top-ranked risks can be calculated by multiplying the product of the impact should the risk occur by the probability of the occurrence (e.g., $1,000,000 x 0.50 = $500,000). Contingency in addition to the predetermined percentage can be included if warranted by the expected value analysis.

Type III – Quantitative Risk Analysis and Contingency Management

A Type III risk analysis applies to major projects. This method is generally facilitated by risk analysts who are experts in the area of quantitative risk management practices. The process most often begins with a Risk Workshop (R3.6) and generates a stochastic estimate of cost and schedule through a Estimate Range – Monte Carlo Analysis (R3.5). The resulting risk-based range estimate is then updated throughout project development.

In all cases, the list of risks should be related to the contingency amount. In a Type I analysis, the tie between the risks and contingency is loose, but the list of risks can justify the need for the contingency estimate to both internal and external stakeholders. In the Type III analysis, the tie is direct as the list of risks forms the basis for the stochastic model that drives the contingency estimate.

6.3.5 Programming Phase Risk Assessment and Analysis Tips

There must be a clear understanding of risk significance and a description of what the contingency amount (included in a cost estimate) covers in terms of project risks.

- The goal of risk assessment is not to eliminate all risk from the project. Rather, the goal is to recognize the significant risk challenges to the project and to initiate an appropriate management response to their management and mitigation.

- All projects, regardless of project size and project complexity, will require some form of risk assessment and analysis. The framework of risk assessment and analysis remains the same, but the tools and level of effort vary with project complexity and the decisions that need to be made.
- A comparison of each risk's probability and impact yields a relative ranking of the risks that can be used for risk management or, if warranted by project complexity, a detailed quantitative risk analysis using probabilistic models to generate ranges of possible outcomes.
- Recalling from Chapter 3, there are five criteria that can be applied to help select risk assessment and analysis tools. The selected method or tool will involve a trade-off between sophistication of the analysis and its ease of use.
  - The tool should help determine project cost and schedule contingency.
  - The tool should have the ability to include the explicit knowledge of the project team members concerning the site, the design, the political conditions, and the project approach.
  - The tool should allow quick response to changing market factors, price levels, and contractual risk allocation.
  - The tool should help foster clear communication among the project team members and between the team and higher management about project uncertainties and their impacts.
  - The tool, or at least its output, should be easy to use and understand.
- The risk analysis process can be complex due to the complexity of the modeling required and the subjective nature of the data available to conduct the analysis. However, the complexity of the process is not overwhelming and the generated information is extremely valuable.

6.4 Programming Phase Risk Mitigation and Planning

Risk mitigation and planning efforts at the programming phase are the foundation for risk management throughout the remainder of the project development. The objectives are to explore risk response strategies for the high-risk items identified in the qualitative risk assessment or quantitative risk analysis. The process identifies and assigns parties to take responsibility for each risk response. It ensures that each risk requiring a response has an owner. The key output is the risk register or risk management plan.

6.4.1 Programming Phase Risk Mitigation and Planning Inputs

The ranked list of risks from the first two risk management steps is the key input to the mitigation and planning effort. Risks mitigation and planning begins by developing and documenting a risk management strategy focused on the key risks. Early efforts

- Establish the purpose and objective;
- Assign responsibilities for specific areas;
- Identify additional technical expertise needed;
- Describe the assessment process and areas to consider;
- Delineate procedures for consideration of mitigation and allocation options;
- Dictate the reporting and documentation needs; and
- Establish report requirements and monitoring metrics.

This planning should address evaluation of the capabilities of potential sources as well as early industry involvement.

The list of risks is used as the basis for the solicitation of mitigation and planning options from key managers and experts. The mitigation and planning options will require cost-benefit analyses (e.g., the cost of implementing a mitigation effort versus the reduction in probability or impact to a risk) to assess the viability or impact of the options. Estimators and risk analysts will therefore have key input into the mitigation and planning process.

The project management staff will have the final input into the risk mitigation and planning efforts. They will determine who "owns" the risk and is responsible for ensuring that it is managed effectively. The risk management plan and/or risk register should clearly identify who is responsible for managing and resolving each individual risk.

6.4.2 Programming Phase Risk Mitigation and Planning Tools

Risk mitigation and planning tools that can be used in the Programming Phase are listed in Table 6.3. Refer to Appendix A for complete tool descriptions.

Table 6.3. Programming phase risk mitigation and planning tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	•	•	
R3.1 Risk Management Plan	•	•	•
R3.5 Estimate Ranges–Monte Carlo Analysis		•	•
R3.6 Risk Workshops		•	•
R3.11 Risk Breakdown Structure		•	•
R3.12 Risk Register	•	•	•
R3.13 Risk Management Information System		•	•

6.4.3 Programming Phase Risk Mitigation and Planning Outputs

The outputs of the risk mitigation and planning step are an organized, comprehensive, and interactive risk management strategy and a plan for adequate resources. The Risk Management Plan (R3.1) tool in Appendix A provides a good example of this output from Caltrans. The example risk management plan from Caltrans describes a clear approach to the assignment of responsibility. It also provides items that require resource investment and a method for calculating their costs.

Risk mitigation and planning is iterative and includes describing and scheduling the activities and processes to assess (identify and analyze), mitigate, monitor, and document the risk associated with a project. For minor or moderately complex projects, the result should be a Risk Register (R3.12). For major projects or moderately complex projects with a high degree of uncertainty, the result should be a formal Risk Management Plan (R3.1).

6.4.4 Programming Phase Risk Mitigation and Planning Relationship to Project Complexity

The risk mitigation and planning effort should be congruent with project complexity. Each risk plan should be documented, but the degree of documentation will vary with project complexity. Not all projects will require a comprehensive and quantitative risk management process. The simplest minor projects may only require a Red Flag Items (I2.1) tool to manage the most important risks. The list can be reviewed at key project milestones to ensure that the key risks are being managed.

The creation of a Risk Register (R3.12) is a more formal identification of risks than the simple Red Flag Items (I2.1). A risk register is highly recommended for all projects; it provides project managers with a listing of significant risks and includes information about the cost and schedule impacts of each risk. It supports the contingency resolution process by tracking changes as a result of actual cost and schedule risk impacts, as the project progresses through the development process and the risks are resolved.

The level of detail in the register will vary with project complexity. Registers can be applied to minor projects and the effort to create and maintain them can be relatively minimal. All moderately complex projects should use a register; it creates a concise tool to manage the risks and the individuals assigned to each risk. Major projects or moderately complex projects with high levels of uncertainty will benefit from having a detailed and formal Risk Management Plan (R3.1) that records all aspects of risk identification; risk assessment; risk analysis; risk planning; risk allocation; and risk information systems, documentation, and reports. Major projects should use a register that is integrated into the formal Risk Management Plan (R3.1).

6.4.5 Programming Phase Risk Mitigation and Planning Tips

Project cost is subject to many variables but actions to mitigate the impacts of risks can have a significant effect in controlling cost.

- Begin risk planning efforts early. Formal risk management plans can begin concurrently with risk identification and analysis steps.
- Clearly assign responsibility for risk ownership. Individuals responsible for managing risks should be informed on the costs of mitigation efforts and which risks must be resolved.
- When planning for risk responses, keep in mind the common strategies of avoidance, transference, mitigation, or acceptance.
- Risk mitigation and planning efforts may necessitate that agencies set policies, procedures, goals, and responsibility standards.
- Document the risk mitigation and planning efforts at a level of detail appropriate for the project complexity and resources available to management.

6.5 Programming Phase Risk Allocation

The goal of risk allocation is to minimize the total cost of risk on a project, not necessarily the costs to each party separately. Risk allocation begins in the Programming Phase with the project delivery decision. The identified project risks should align with the selected project delivery method to provide an optimal allocation of risk to minimize the total cost or meet other project objectives. The traditional design-bid-build delivery system is most commonly used by SHAs and its risk allocation tenets are well understood in the industry. However, alternatives to the traditional delivery method exist. Design-build, construction management at risk, and public–private partnerships are among the alternative delivery options that can benefit from innovative risk allocation opportunities.

6.5.1 Programming Phase Risk Allocation Inputs

Risk allocation inputs at the Programming Phase include the outputs from the first three steps in the risk management process plus an examination of the available/allowable project delivery options for the project. The decision makers who will determine the project delivery method should be aware of the most critical risks that could impact project delivery performance. For example, if the design-build delivery method is being considered to save time, the decision makers should review all identified risks concerning schedule and examine how these risks would be allocated in the design-build project delivery method. The decision makers will need to know what delivery methods are available under state laws or agency policies and then determine how the risks can be allocated optically under the method.

6.5.2 Programming Phase Risk Allocation Tools

Table 6.4 lists Programming Phase tools discussed in this Guidebook for risk allocation. The Delivery Decision Support (D1.2) tool includes descriptions of numerous alternative project delivery methods.

6.5.3 Programming Phase Risk Allocation Outputs

The likely output of the risk allocation step at the Programming Phase will be a final project delivery decision and plan for developing a contract packaging strategy. However, the output will vary with the nature of the project. At the highest level of detail, a project delivery decision report can be generated that analyzes risk allocation in terms of project characteristics (e.g., cost, schedule, and quality issues); agency characteristics (e.g., available staffing level, staff experience, etc.); market characteristics (e.g., market availability, market experience, etc.); and stakeholder characteristics. Detailed risk allocation decisions may be discussed in this phase, but when the contract method is finalized the allocation will be set in the design phase.

6.5.4 Programming Phase Risk Allocation Relationship to Project Complexity

Minor projects tend toward the use of traditional delivery and contract packaging strategies. Typically, risk allocation in minor projects requires only a cursory review of the risks to ensure that they are allocated properly in the contracts. Moderately complex and major projects require careful consideration of both delivery and contract packaging techniques. Alternative delivery methods should be explored on moderately complex projects and are becoming common for major projects.

Table 6.4. Programming phase risk allocation tools.

Tool	Minor	Moderately Complex	Major
D1.1 Contract Packaging			•
D1.2 Delivery Decision Support	•	•	•

6.5.5 Programming Phase Risk Allocation Tips

Risk allocation affects the amount of contingency that must be included in a project estimate.

- Explore alternatives to traditional risk allocation techniques in both delivery and contract packaging strategies.
- Gain industry input concerning risk allocation whenever possible.
- Follow the four fundamental tenets of sound risk allocation:
  - Allocate risks to the party best able manage them.
  - Allocate the risk in alignment with project goals.
  - Share risk when appropriate to accomplish project goals.
  - Ultimately seek to allocate risks to promote team alignment with customer-oriented performance goals.

6.6 Programming Phase Risk Monitoring and Control

The objectives of risk monitoring and control are to 1) systematically track the identified risks; 2) identify any new risks; 3) effectively manage the contingency reserve; and 4) capture lessons learned for future risk assessment and allocation efforts. The strategy for risk monitoring and control is developed in the Programming Phase, but it is not implemented in earnest until the Design Phase. Therefore, only a concise description of risk monitoring and control is presented in this section.

6.6.1 Risk Monitoring and Control Inputs

The key inputs to risk monitoring and control are the Risk Management Plan (R3.1) and Risk Register (R3.12). These tools provide a framework for managing risks through a formalized monitoring and control process. On moderately complex and major projects with a high degree of uncertainty, an agency may invest in a Risk Management Information System (R3.13) to better monitor and control impacts.

6.6.2 Programming Phase Risk Monitoring and Control Tools

Table 6.5 lists the risk monitoring and control tools suggested for the Programming Phase. More information on the tools can be found in Appendix A.

6.6.3 Programming Phase Risk Monitoring and Control Outputs

The key output for risk monitoring and control in the Programming Phase is a formal strategy or plan that will

Table 6.5. Programming phase risk monitoring and control tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	●	●	
R3.1 Risk Management Plan	●	●	●
R3.12 Risk Register	●	●	●
R3.13 Risk Management Information System		●	●

support monitoring and control in the Design Phase. The monitoring and control strategy is typically described in the risk management plan. The monitoring and control strategy should define how the risk management process will be supported by:

- Providing consistent and comprehensive reporting procedures;
- Developing a set of key milestones for risk resolution;
- Monitoring changes to risk probabilities or impacts;
- Supporting active contingency resolution procedures; and
- Providing feedback of analysis and mitigation for future risk assessment and allocation.

Perhaps the most important output of the Programming Phase risk monitoring and control step is a list of key milestones for when risks will be resolved. This information can be used to create a "risk resolution schedule" to assist in the monitoring and control process. Key milestones will include dates when more information will be known about a given risk or dates when a risk must be resolved or allocated into the contract.

6.6.4 Programming Phase Risk Monitoring and Control Relationship to Project Complexity

Only the simplest minor projects will use a Red Flag Item (I2.1) list for risk monitoring and control. A Risk Register (R3.12) is suggested for all projects. Risk registers can be tailored to project size and complexity so that they do not require undue effort for monitoring and control. Risk Management Plans (R3.1) and Risk Management Information Systems (R3.13) can assist in monitoring and control of moderately complex and major projects with a large amount of uncertainty.

6.6.5 Programming Phase Risk Monitoring and Control Tips

Risk monitoring and control should be a continuous and repetitive activity during all phases of project development.

- For each project, develop a unique risk monitoring and control process that is appropriate for the size and complexity of the project. Do not create monitoring and control processes that are burdensome or create undue paperwork.
- A successful risk monitoring and updating process will systematically track risks, support the identification of new risks, and effectively manage the contingency reserve.

6.7 Conclusions

This chapter discussed guidance for risk management in the Programming Phase. The programming phase focuses efforts on risk identification, risk assessment and analysis, and risk mitigation and planning. Risk allocation and risk monitoring and control in the Programming Phase primarily address planning for these steps in the Design Phase. For each of the risk management steps, a discussion of inputs, outputs, and tools was provided. Tips for application and how project complexity impacts risk management tools and practices were discussed for each step. The outcome of this discussion is a map to the risk management tools provided in Appendix A.

CHAPTER 7

Guide to the Design Phase

7.1 Introduction

This chapter presents guidance for risk management in the design phase, defined in terms of its relevance to cost estimating and risk management. It then discusses each of the risk management steps in detail, including inputs, outputs, and tools for the risk management process. Tips for tool application and how project complexity impacts risk management tools and practices also are discussed for each step.

7.1.1 Design Phase Overview

The design phase focuses on designing projects to meet the transportation needs defined in the planning phase. Design initiates project plan development and begins development once the project is incorporated into the STIP. At this point, the baseline cost estimate has been established for purposes of cost management. The goal of cost management throughout the design phase is to support the design of projects at or below the baseline cost estimate established in the programming phase. From the time a project enters the design phase to the beginning of construction letting can be as long as four years for complex projects and as short as a few months for non-complex projects. This time duration between the start of design and construction letting is a function of project complexity and project criticality. SHA policies and practices also influence this time duration.

Once a project is included in the STIP, the Design Phase commences. Plan development focuses on detailed design and, if applicable, right-of-way plan development for property acquisition if it is required. The designer makes use of project programming information and data to prepare detailed right-of-way and construction plans. Right-of-way is typically purchased later in the design phase; most necessary outside agency permits are typically obtained during design. The design phase sometimes overlaps with the programming phase on small projects and/or in other special cases. In summary, activities that occur during the design phase include:

- Right-of-way development and acquisition;
- Final pavement and bridge design; and
- Final traffic control plans, utility drawings, hydraulics studies/drainage design, and updating cost estimates.

Risk management and cost management are two primary focuses during the design phase. Risk management concerns the identification of new risks and monitoring and control of previously identified risks from the planning and programming phases. Cost management is concerned with the impact of changes due to additions or deletions to the project baseline definition or changes resulting from design development, site conditions, or realization of risks that could not be avoided or mitigated. Change is likely to occur as the project is fully defined through the design effort. Changes may be identified throughout the design process. Their potential cost impact is determined through either project estimate updates or an assessment of the impact of an individual change that is significant in terms of its potential dollar magnitude. Both risk management and cost management are focused on actively managing and retiring the contingency that was established with the baseline estimate. The key output of the design phase, in terms of cost estimating and cost management, is the engineer's estimate. Ideally, this engineer's estimate will be an amount equal to the baseline estimate.

7.1.2 Design Phase Risk Management Emphasis

Design phase risk management practices focus on monitoring and controlling risks and their associated cost contingency. However, all five steps in the risk management process must be actively addressed in this phase. Recalling from Chapters 2 and 3, the baseline cost estimate is comprised of

Figure 7.1. Risk management focus in the design.

the base estimate and a contingency estimate. The goal of the design phase risk and cost management processes is to actively manage risk and changes in design so that, ideally, the contingency is retired at the time of letting and the engineer's estimate is equal to the baseline estimate (see Figures 3.3 to 3.5 and associated text).

As shown in Figure 7.1, all of the risk management steps are actively applied in the design phase. Risk identification will continue throughout design. While the majority of risk should be identified during planning, programming, and early in design, the project team should continuously identify risks throughout design. Risk assessment and analysis is also an active process. As design progresses, existing risk assessments will need to be updated and new risks will be analyzed. The risk management plan is the key document for planning and mitigation and should be actively maintained. During the design phase, important risk allocation decisions will need to be made. If a risk cannot be mitigated or avoided during the design phase, the SHA will need to decide how to allocate the risk in the contract. The SHA will either accept the risk and maintain an appropriate contingency during construction or contractually transfer the risk to a contractor and add cost to the engineer's estimate to align with the contractor's pricing of the risk. The final risk management step, monitoring and control, is addressed in earnest during design. Through the risk management plan, all risks should be actively managed and controlled.

The remainder of this chapter describes tools and management practices suggested for use during the Design Phase of project development. A discussion of how project complexity impacts risk management tools and practices is also provided.

7.2 Design Phase Risk Identification

As stated in previous chapters, risk identification is paramount to successful risk management and contingency estimation and this remains true at the Design Phase. The objectives of risk identification are to identify and categorize risks that could affect the project and to document these risks. The outcome of the risk identification is a list of risks that is, ideally, comprehensive and nonoverlapping. This list of risks can be the basis for estimating and managing project contingency. It is also the basis for the risk management plan that is used to monitor and control risks and manage contingency throughout design.

Although risks will have been previously identified during the planning and programming phases, risk indemnification during the design phase should invite new risks as design develops. As engineering progresses, new information can lead to new risks. Changes in design can also lead to new risks. Risk identification should be a continuous process throughout design.

The risk identification process should generally stop short of assessing or analyzing risks so as not to inhibit the identification of "minor" risks. This identification process should promote creative thinking and leverage team member experience and knowledge.

Perhaps the most challenging aspect of risk identification is in defining issues at an appropriate level of detail. Issues defined too vaguely or "lumped" into gross generalizations are hard to assess. Defining too many separate, detailed risks can lead to overlapping among issues or the omission of larger issues (i.e., "missing the forest for the trees" problem). To the extent possible, define risks to be independent of each other, thereby eliminating overlap among risks through their descriptions.

Risk checklists and lists of risks from similar projects can be helpful, but use them only as a back check at the end of the risk identification process. Review these lists only at the end of the process as a means of ensuring that the list is not excluding any common risks. Avoid beginning the process with the risk checklists or similar project analyses as the team may overlook unique project risks or include too many risks in the analysis, and this will make the process less useful.

7.2.1 Design Phase Risk Identification Inputs

The project scope (generated during the programming phase) and the related base estimate package comprise the key inputs for risk identification at the start of the design phase. Each subsequent design milestone package will create a new set of inputs for the risk identification process. However, waiting to identify new risks only at the time of a major design milestone submittal can cause a "cost blackout" as discussed in Section 2.4.3 of this Guidebook. The project team must continuously evaluate changes (in scope, design, risks, and project site or market conditions) in relation to cost and time impacts against the project baseline scope, cost, and schedule. Any of these changes can trigger the identification of new risks.

The determination of project risk stems from a review of the design assumptions made by the design team and the estimating assumptions made by the project estimator. The design team must make initial conceptual design assumptions that they will refine as the design progresses. Likewise, the estimator must make estimating assumptions in a design level estimate because complete design information is not yet available. Design and estimating assumptions serve as triggers for risk identification.

The design phase risk identification process should begin with a review of any risks identified during the planning and programming phases. However, risks identified during the planning and programming phases likely will have changed substantially by the design phase. Changes to the risks from the earlier phases can include a change to the probability or impact of the risk, a partial mitigation of the risk, or why the risk may have occurred. Risk identification at the design phase must be rigorous. It can be helpful to go through a new risk identification exercise at the beginning of the design phase and then use the planning phase risk identification outputs as a check at the end of the process to ensure that no risks were overlooked. Throughout the design phase, it is important to continue to identify new risks and not rely solely on those risks which have been previously identified.

7.2.2 Design Phase Risk Identification Tools

Risk identification tools that can be used in the design phase are listed in Table 7.1. Note that complex projects can use all risk identification tools. Refer to Appendix A for complete tool descriptions.

Table 7.1. Design phase risk identification tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	•	•	
I2.3 Risk Checklists	•	•	•
I2.4 Assumption Analysis	•	•	•
I2.5 Expert Interviews	•	•	•
I2.6 Crawford Slip Method		•	•
I2.7 SWOT Analysis		•	•
R3.1 Risk Management Plan		•	•
R3.6 Risk Workshops			•
R3.11 Risk Breakdown Structure			•
R3.12 Risk Register	•	•	•

7.2.3 Design Phase Risk Identification Outputs

The key risk identification output is a list of risks. On minor projects, the list of risks may take the form of a Red Flag Item list (I2.1). On some minor projects, and all moderately complex and major projects, the list of risks should form the basis of a Risk Management Plan (R3.1) and Risk Register (R3.12) for later risk management and control.

Categorization of the risk list can be extremely helpful to ensure that no risks have been missed. Categorization of risks can be accomplished through a review of Risk Checklists (I2.3). On major projects, categorization can be achieved through the application of Risk Breakdown Structure (R3.11).

Ideally, the list of risks should be comprehensive and nonoverlapping. This list of risks can be the basis for estimating project contingency and setting the baseline cost estimate. Comprehensive and nonoverlapping lists of risks are required for detailed risk and contingency modeling in the later steps.

7.2.4 Design Phase Risk Identification Relationship to Project Complexity

On minor projects, the number of inputs to the risk identification step can be small. An estimator or project manager may individually conduct the risk identification or with a small group. Information comes from preliminary estimates, preliminary schedules, the estimators' judgment, scoping documents, design assumptions, and other sources. Minor project risk identification tools may include only a Red Flag Items (I2.1) list. However, consultation with experts (Expert Interviews, I2.5) can be a good idea if time and budget permits. The use of Risk Checklists (I2.3) is suggested at the end of the identification process to ensure that no risks have escaped detection.

Moderately complex projects will require risk identification from a greater number of sources. Expert Interviews (I2.5) will be a key input on moderately complex projects and they may be used on some minor projects if there is an area for which the project design lead or cost estimator does not have expertise. Formal Assumptions Analysis (I2.4) is typically warranted on projects of all complexity. A Risk Register (R3.12) should always be employed and a Risk Management Plan (R3.1) can be warranted on moderately complex projects with a high level of uncertainty.

Major projects require the highest level of risk identification. All risk identification tools are applicable to major projects. The Risk Workshops (R3.6) is the principal tool employed on major projects that is not typically applied to moderately complex or minor projects. Formal Risk Workshops (R3.6) are typically facilitated by a professional risk analysis and, depending upon the specific project needs, can have upwards of 20 experts participating. The time to plan, conduct and document the workshop should not be underestimated. The benefits of a workshop include a comprehensive list of risks and a firm basis for risk analysis and planning.

7.2.5 Design Phase Risk Identification Tips

The use of appropriate risk identification techniques must be instituted during Design.

- Risk identification should be a creative brainstorming process. It should not attempt to analyze risks or discuss mitigation procedures, which will be completed in the subsequent steps.
- At a minimum, risk information should include assumptions, estimate basis uncertainties, and project issues and concerns from the estimator, project team, and any participating specialty groups.
- To be most useful in later risk analyses, the resultant risk list should be comprehensive and non-overlapping. Combine like risks and separate overlapping risks.
- Only use risk checklists and experience from similar projects to check for missing risks and to help categorize unique project risks.
- Upon completion of the risk list, categorize the risk into logical groupings. Use risk checklists and similar project risk analyses for possible categorizations.
- When updating the risk lists, identify new risks. Do not rely on previous identification exercise to detect all risks.
- Beware of cost blackouts. Conduct a risk identification exercise whenever new information is discovered during the design process or whenever there is a significant change to the project scope.

7.3 Design Phase Risk Assessment and Analysis

The level of effort needed for thorough risk assessment and analysis varies in the design phase, with the purpose of the risk analysis. If a thorough risk analysis is completed for the baseline estimate at the end of the programming phase as suggested in this guide, then risk assessment and analysis involves an updating process. If a thorough analysis is not conducted with the baseline estimate or if the project changes substantially during the design process, then a rigorous and comprehensive risk analysis will need to be conducted to properly quantify project risk and determine an appropriate contingency. As design progresses, risk assessment and analysis continues with the purpose of managing risk and retiring contingency.

The primary objective of risk assessment is the systematic consideration of risk events focusing on their probability of occurrence and the consequences of such occurrences. Risk assessment and analysis is the process of evaluating the risk events documented in the preceding identification step. Risk assessment and analysis has two aspects. The first determines the probability of a risk occurring (risk frequency); risks are classified along a continuum from very unlikely to very likely. The second aspect judges the impact of the risk should it occur (consequence severity).

Typically, a project's qualitative risk assessment will recognize some risks whose occurrence is so likely or whose consequences are so serious that further quantitative risk analysis is warranted. A key purpose of quantitative risk analysis is to combine the effects of the various identified and assessed risk events into an overall project risk analysis. The overall risk analysis is used to determine cost and schedule contingency values and to quantify individual impacts of high risk events. Ultimately, however, the purpose of quantitative analysis is not only to compute numerical risk values but to provide a basis for controlling project costs through effective risk management practices.

7.3.1 Design Phase Risk Assessment and Analysis Inputs

The physical input to risk assessment and analysis is the list of risks from the identification step. Early in the design phase, this will likely be a long list that must be filtered through the assessment and analysis step to help focus the project team on a subset of the most critical risks. Later in the Design Phase, this will be a list of risks maintained in a risk register that must be updated with new risk assessments and analyses as the project design evolves.

The risk identification step will have identified risks, but the identification step should stop short of assessment or analysis. In the risk assessment and analysis step, risk inputs will be elicited from project managers, functional experts, estimators, and analysts to gain a clear picture of the risks. Managers and functional experts tend toward qualitative assessment of risks. They evaluate risks relative to their worst case effects and their relative likelihood of occurrence. Analysts and estimators tend toward quantitative assessment of risks. They evaluate risk impacts in terms of a range of tangible results, and they evaluate risk of occurrence in terms of probabilities. The analyst's focus is on the combined tangible effect of all the risks on project scope, cost, and schedule. A comprehensive risk strategy combines both a qualitative assessment and a quantitative analysis.

Recalling from Chapter 3, the key inputs for risk assessment and analysis are the probability of a risk occurring (risk frequency) and the impact of the risk should it occur (consequence severity). Knowing the probability and impact, risks can be qualitatively ranked to help managers focus on the most critical risks or quantitatively modeled to determine cost and schedule contingency estimates.

7.3.2 Design Phase Risk Assessment and Analysis Tools

Risk assessment and analysis tools that can be used in the Design Phase are listed in Table 7.2. Note that project complexity has a significant impact on the use of risk assessment and analysis tools. Refer to Appendix A for complete tool descriptions.

7.3.3 Design Phase Risk Assessment and Analysis Outputs

Risk assessment and analysis outputs will depend on the type of decision required, the detail in the input analysis, and the level of rigor in the selected tools for assessment or analysis. The use of qualitative expert input (I2.5 Expert Interviews) and the application of a Risk Priority Ranking (R3.7), Probability × Impact Matrix (P × I) (R3.8), or Risk Comparison Table (R3.9) tools will yield a ranked set of risks that can help focus management on managing the highest priority risks. The use of quantitative expert inputs and application of an Estimate Ranges—Monte Carlo Analysis (R3.5) tool will yield a definitive contingency estimate and detailed sensitivity analysis of the risks that contribute to the contingency. All of these tools can produce updates to previous risk assessments or analyses throughout the design process.

Recalling from Chapter 3 (Section 3.4.3.4), the type of outputs that a tool produces is a function of the analytical rigor, nature of assumptions, or amount of input data. Results from risk analyses may be divided into three groups according to their primary output: single parameter output measures; multiple parameter output measures; and complete distribution output measures. Please refer to Sections 3.4.3 and 3.4.5 for a full description of risk assessment and analysis outputs.

Table 7.2. Design phase risk assessment and analysis tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	•	•	
I2.5 Expert Interviews	•	•	•
R3.2 Contingency – Percentage	•	•	
R3.3 Contingency – Identified	•	•	•
R3.4 Estimate Ranges – Three Point Estimate	•	•	
R3.5 Estimate Ranges – Monte Carlo Analysis		•	•
R3.6 Risk Workshop		•	•
R3.7 Risk Priority Ranking	•	•	
R3.8 Probability x Impact Matrix (P x I)	•	•	•
R3.9 Risk Comparison Table	•	•	•
R3.10 Risk Map	•	•	•
R3.13 Risk Management Information System			•
R3.14 Self Modeling Worksheet		•	•
R3.15 Influence Diagrams		•	•
R3.16 Decision Trees Analysis		•	•

7.3.4 Design Phase Risk Assessment and Analysis Relationship to Project Complexity

Risk assessment and analysis are directly tied to project complexity. This can best be seen in the tie between risk analysis and contingency calculation. The research team has observed numerous methods for analyzing risks and developing contingency estimates. These methods fall into three categories (Type I, II, and III Risk Analysis), which directly relate to project complexity (minor, moderately complex, and major).

Type I Risk Analysis – Risk Identification and Percentage Contingency

A Type I risk analysis is the simplest form of risk analysis and applies only to minor projects. A Type I risk analysis involves the development Red Flag Items (I2.1) and the use of a Contingency—Percentage (R3.2) tool to estimate the contingency. To estimate contingency, the estimator should examine the list of risks and use judgment within percentage contingency range of acceptable standards set by the agency policies or estimating guidance.

Type II – Qualitative Risk Analysis and Identified Contingency Items

A Type II risk analysis applies to moderately complex projects and involves the use of more rigorous risk assessment and tools (e.g., P × I Matrix (R3.8), Risk Comparison Table (R3.9), etc.) and the estimate of specific contingency items using the Contingency – Identified (R3.3) tool that complements the percentage-based contingency in the Type I analysis. A qualitative ranking of the risks and expected values estimates for contingency on the critical risks are key outputs of this method. When estimating an appropriate contingency in a Type II risk analysis, the range of contingency from the Contingency—Percentage (R3.2) tool is first consulted. The next step is to review approximately the top 20 percent of the prioritized risks to ensure that the contingency is adequate. An expected value estimate for estimating the top-ranked risks can be calculated by multiplying the product of the impact should the risk occur by the probability of the occurrence (e.g., $1,000,000 x 0.50 = $500,000). Contingency in addition to the predetermined percentage can be included if warranted by the expected value analysis.

Type III – Quantitative Risk Analysis and Contingency Management

A Type III risk analysis applies to major projects. This method is generally facilitated by risk analysts who are experts in the area of quantitative risk management practices. The process most often begins with a Risk Workshop (R3.6) and generates a stochastic estimate of cost and schedule through an Estimate Ranges – Monte Carlo Analysis (R3.5). The resulting risk-based range estimate is then updated throughout project development.

In all cases, the list of risks should be related to the contingency amount. In a Type I analysis, the tie between the risks and contingency is loose, but the list of risks can justify the need for the contingency estimate to internal and external stakeholders. In the Type III analysis, the tie is direct as the list of risks forms the basis for the stochastic model that drives the contingency estimate.

7.3.5 Design Phase Risk Assessment and Analysis Tips

There must be a clear understanding of risk significance and a description of what the contingency amount included in a cost estimate covers in terms of project risks.

- The goal of risk assessment is not to eliminate all risk from the project. Rather, the goal is to recognize the significant risk challenges to the project and to initiate an appropriate management response to their management and mitigation.
- All projects, regardless of project size and project complexity, will require some form of risk assessment and analysis. The framework of risk assessment and analysis remains the same, but the tools and level of effort vary with project complexity and the decisions that need to be made.
- A comparison of each risk's probability and impact yields a relative ranking of the risks that can be used for risk management or, if warranted by project complexity, a detailed quantitative risk analysis using probabilistic models to generate ranges of possible outcomes.
- Recalling from Chapter 3, there are five criteria that can be applied to help select risk assessment and analysis tools. The selected method or tool will involve a trade-off between sophistication of the analysis and its ease of use.
  - The tool should help determine project cost and schedule contingency.
  - The tool should have the ability to include the explicit knowledge of the project team members concerning the site, the design, the political conditions, and the project approach.
  - The tool should allow quick response to changing market factors, price levels, and contractual risk allocation.
  - The tool should help foster clear communication among the project team members and between the team and higher management about project uncertainties and their impacts.
  - The tool, or at least their output, should be easy to use and understand.
- The risk analysis process can be complex due to the complexity of the modeling that is required and the subjective nature of the data available to conduct the analysis. However, the complexity of the process is not overwhelming and the generated information is extremely valuable.
- The risk analysis process is continuous throughout the design phase. Risk analysis at key milestones in the design phase will allow for active risk management and the resolution of contingency.

7.4 Design Phase Risk Mitigation and Planning

Risk mitigation and planning efforts are active and continuous throughout the Design Phase. The objectives of risk mitigation and planning are to explore risk response strategies for the high-risk items identified in the qualitative risk assessment or quantitative risk analysis. The process identifies and assigns parties to take responsibility for each risk response. It ensures that each risk requiring a response has an owner. The key output is the risk register or risk management plan. The design and estimating teams will revisit these plans at major design milestones or whenever a design change occurs.

7.4.1 Design Phase Risk Mitigation and Planning Inputs

In the initial risk mitigation and planning efforts, the ranked list of risks from the first two risk management steps is the key input. As the project progresses, the risk register or risk management plan is the key input, along with any newly identified risks. Risk mitigation and planning begins by developing and documenting a risk management strategy focused on the key risks. Early efforts establish the purpose and objective; assign responsibilities for specific areas;

identify additional technical expertise needed; describe the assessment process and areas to consider; delineate procedures for consideration of mitigation and allocation options; dictate the reporting and documentation needs; and establish report requirements and monitoring metrics. This planning should address evaluation of the capabilities of potential sources as well as early industry involvement.

The list of risks (or risk register) is the basis for the solicitation of mitigation and planning options from key managers and experts. The mitigation and planning options will require cost-benefit analyses (e.g., the cost of implementing a mitigation effort versus the reduction in probability or impact to a risk) to assess the viability or impact of the options. Estimators and risk analysts will have key input into the mitigation and planning process.

The project management staff will have the final input into the risk mitigation and planning efforts. They will determine who "owns" the risk and is responsible for ensuring its effective management. The risk management plan and/or risk register should clearly identify who is responsible for managing and resolving each individual risk.

7.4.2 Design Phase Risk Mitigation and Planning Tools

Risk mitigation and planning tools that can be used in the Design Phase are listed in Table 7.3. Refer to Appendix A for complete tool descriptions.

7.4.3 Design Phase Risk Mitigation and Planning Outputs

The outputs of the risk mitigation and planning steps are an organized, comprehensive, and interactive risk management strategy and plan for adequate resources. The Risk

Table 7.3. Design phase risk mitigation and planning tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	•	•	
R3.1 Risk Management Plan	•	•	•
R3.5 Estimate Ranges – Monte Carlo Analysis		•	•
R3.6 Risk Workshop		•	•
R3.11 Risk Breakdown Structure		•	•
R3.12 Risk Register	•	•	•
R3.13 Risk Management Information System		•	•

Management Plan (R3.1) tool in Appendix A provides a good example of this output. This example from Caltrans describes a clear approach to the assignment of responsibility. It also provides items that require resource investment and a method for calculating their costs.

Risk mitigation and planning is iterative and includes describing and scheduling the activities and processes to assess (identify and analyze), mitigate, monitor, and document the risk associated with a project. For minor or moderately complex projects, the result should be a Risk Register (R3.12). For major projects or moderately complex projects with a high degree of uncertainty, the result should be a formal Risk Management Plan (R3.1).

Updates to the risk management plan and risk register should occur frequently during the design phase. The nature of each risk will change as the design evolves. Some mitigation efforts will be successful and others will fail. Other risks will change as project conditions change over time. The risk register should reflect the current status of each risk. Triggers for updating the risk register and/or risk management plan include: major design milestones; a change to project scope; identification of a new risk(s); and/or change to an existing risk.

7.4.4 Design Phase Risk Mitigation and Planning Relationship to Project Complexity

The risk mitigation and planning effort should be congruent with project complexity. Each risk plan should be documented, but the degree of documentation will vary with project complexity. Not all projects will require a comprehensive and quantitative risk management process. The simplest minor projects may only require a Red Flag Items (I2.1) tool to manage the most important risks. The list can be reviewed at project milestones to ensure that the key risks are being managed.

The creation of a Risk Register (R3.12) is a more formal identification of risks than the simple Red Flag Items (I2.1). A risk register is highly recommended for all projects. The risk register provides project managers with a listing of significant risks and includes information about the cost and schedule impacts of each risk. It supports the contingency resolution process by tracking changes as a result of actual cost and schedule risk impacts, as the project progresses through the development process and the risks are resolved. The level of detail in the register will vary with project complexity. Registers can be applied to minor projects and the effort to create and maintain them can be relatively minimal. All moderately complex projects should use a risk register. The risk register creates a concise tool to manage the risks and the individuals assigned to each risk.

Major projects or moderately complex projects with high levels of uncertainty will benefit from having a detailed and formal Risk Management Plan (R3.1) that records all aspects of risk identification, risk assessment, risk analysis, risk planning, risk allocation, and risk information systems, documentation, and reports. Major projects should use a risk register that is integrated into the formal Risk Management Plan (R3.1).

7.4.5 Design Phase Risk Mitigation and Planning Tips

Project cost is subject to many variables, but actions to mitigate the impacts of risks can have a significant effect in controlling cost.

- Begin risk planning efforts early. Formal risk management plans can begin concurrently with risk identification and analysis steps.
- Clearly assign responsibility for risk ownership. Individuals responsible for managing risks should be informed on the costs of mitigation efforts and in which the risks must be resolved.
- When planning for risk responses, keep in mind the common strategies of avoidance, transference, mitigation, or acceptance.
- Risk mitigation and planning efforts may necessitate that agencies set policies, procedures, goals, and responsibility standards.
- Document the risk mitigation and planning efforts at a level of detail that is appropriate for the project complexity and resources available to management.
- Actively update risk management plans and risk registers. Update these documents whenever there is a major design milestone, a change to project scope, identification of a new risk(s), and/or change to an existing risk.

7.5 Design Phase Risk Allocation

The goal of risk allocation is to minimize the total cost of risk on a project and not necessarily the costs to each party separately. Risk allocation begins in the programming phase with the project delivery decision and contract packaging decisions. It then continues in the design phase with careful consideration of those contract provisions impacted by the identified risks. The identified project risks should align with the selected project delivery method, contract packaging, and individual contract provisions to provide an optimal allocation of risk to minimize the total cost and meet other project objectives.

The traditional design-bid-build delivery method is most commonly used by SHAs and its risk allocation tenets are well understood in the industry. However, alternatives to the traditional delivery method exist. Design–build, construction management at risk, and public–private partnerships are among the alternative project delivery options that can benefit from innovative risk allocation opportunities. In all of these project delivery decisions, consideration must be given to the scope and size of the contract packages. For example, design-build projects are most frequently used on large and complex projects, but they have been successful on moderately complex projects of a size for which the design-builders can innovate to offset the additional risk of taking on design liability.

Project managers and designers should examine each contract provision closely. They should not treat standard contract language as a "one size fits all." For example, the application of unit price contracts has traditionally allocated risks equitably for items in which field quantities can vary (e.g., earthwork quantities). However, the application of lump sum payment provisions can allocate risk equitably when design-build delivery is being used or when schedule is a primary project goal. Similarly, the risk for undiscovered site conditions has typically been borne by the agency, but some agencies have found success in sharing this risk with the contractor (see Section 3.4.5.4 for examples). The determination of project time is a risk that agencies are commonly allocating to contractors through A + B (cost + time) procurement. In essence, A + B procurement passes the risk for accurately setting the fastest construction completion date from the agency to the contractor. All of these examples show a thoughtful approach to allocating risks that have been identified through a thorough and structured risk management process.

7.5.1 Design Phase Risk Allocation Inputs

Risk allocation inputs at the design phase include the outputs from the first three steps in the risk management process plus an examination of the detailed contract provisions for the project. Designers who are developing the plans, specifications, and contract decisions must have a clear understanding of the project risks. They must also have a clear understanding of project goals as inputs to their decisions. Take for example the risk of unusually severe weather. If achieving the lowest project cost is a primary goal, a contract provision for unusually severe weather can be written to share the risk for delays while not providing for additional compensation costs. However, this provision may lead to longer project duration. If shortening project duration is a primary project goal, then the highway agency may wish to allocate the risk for unusually severe weather to the contractor to develop innovative methods avoiding the risk. However, this provision will undoubtedly lead to higher bid costs from the contractor. Risk allocation decisions require clear inputs of the project goals, the identified risks, and understanding of the contract provisions.

7.5.2 Design Phase Risk Allocation Tools

Table 7.4 lists Design Phase tools discussed in this Guidebook for risk allocation. The Delivery Decision Support (D1.2) tool includes descriptions of numerous alternative project delivery methods.

Table 7.4. Design phase risk allocation tools.

Tool	Minor	Moderately Complex	Major
D1.1 Contract Packaging			•
D1.2 Delivery Decision Support	•	•	•

7.5.3 Design Phase Risk Allocation Outputs

The final project delivery decision and contract packaging strategy should be known from decisions made in the programming phase. If they are not, the project delivery and contract packaging will need to be determined as a first order of business in the design phase. At the end of the design phase, detailed risk allocation decisions regarding the individual contract provisions will be made.

7.5.4 Design Phase Risk Allocation Relationship to Project Complexity

Minor projects tend toward the use of traditional risk allocation strategies. Typically, risk allocation in minor projects requires only a cursory review of the risks to ensure that they are allocated properly in the contracts. Moderately complex and major projects require careful consideration of all contract provisions affected by risks that could not be avoided or mitigated. Alternative delivery methods and contract provisions should be explored on moderately complex projects and are becoming common for major projects.

7.5.5 Design Phase Risk Allocation Tips

Risk allocation affects the amount of contingency that must be included in a project estimate.

- Explore alternatives to traditional risk allocation techniques in both delivery and contract packaging strategies.
- Gain industry input concerning risk allocation whenever possible.
- For each risk that cannot be avoided or fully mitigated, examine the affected contract provisions closely. Risks allocated to the contractor will result in higher bid costs.
- Follow the four fundamental tenets of sound risk allocation:
  - Allocate risks to the party best able manage them.
  - Allocate the risk in alignment with project goals.
  - Share risk when appropriate to accomplish project goals.
  - Ultimately seek to allocate risks to promote team alignment with customer-oriented performance goals.

7.6 Design Phase Risk Monitoring and Control

The objectives of risk monitoring and control are to systematically track the identified risks; identify any new risks; effectively manage the contingency reserve; and capture lessons learned for future risk assessment and allocation efforts. The strategy for risk monitoring and control is developed in the programming phase and implemented in earnest in the design phase.

7.6.1 Risk Monitoring and Control Inputs

The key inputs to risk monitoring and control are the Risk Management Plan (R3.1) and Risk Register (R3.12). These tools provide a framework for managing risks through a formalized monitoring and control process. On moderately complex and major projects with a high degree of uncertainty, an agency may invest in a Risk Management Information System (R3.13) to better monitor and control impacts.

During the design phase, it is imperative that the risk management plans and risk registers are kept current. Periodic project risk reviews repeat the tasks of identification, assessment, analysis, mitigation, planning, and allocation and update the risk register for monitoring and control. Regularly scheduled project risk reviews can be used to ensure that project risk is an agenda item at all project development and construction management meetings. If unanticipated risks emerge, or a risk's impact is greater than expected, the planned response or risk allocation may not be adequate. At this point, the project team must perform additional response planning to control the risk. Active risk monitoring and control ensures that the response is timely and adequate (refer to Section 3.4.6.2 for more information on reporting methods).

The other primary goal of risk monitor and control is to ensure an accurate resolution of the contingency that was developed for the baseline estimate. As the design phase progresses, the contingency should be resolved as risk are mitigated, avoided, or allocated to the contractor. If a risk is accepted by the agency, contingency must remain to help control project costs if the risk is in fact realized. As the project progresses through the design phase, the contingency is lowered and the base estimate increases.

7.6.2 Design Phase Risk Monitoring and Control Tools

Table 7.5 lists the risk monitoring and control tools suggested for the design phase. More information on the tools can be found in Appendix A.

Table 7.5. Design phase risk monitoring and control tools.

Tool	Minor	Moderately Complex	Major
I2.1 Red Flag Items	•	•	
R3.1 Risk Management Plan	•	•	•
R3.12 Risk Register	•	•	•
R3.13 Risk Management Information System		•	•

7.6.3 Design Phase Risk Monitoring and Control Outputs

The key output for risk monitoring and control early in the design phase is a formal strategy or plan that will support monitoring and control. The monitoring and control strategy is typically described in the risk management plan. The monitoring and control strategy should define how the risk management process will be supported by:

- Providing consistent and comprehensive reporting procedures;
- Developing a set of key milestones for risk resolution;
- Monitoring changes to risk probabilities or impacts;
- Supporting active contingency resolution procedures; and
- Providing feedback of analysis and mitigation for future risk assessment and allocation.

The list of key milestones for when risks will be resolved is an imperative output from early in design. This information can be used to create a "risk resolution schedule" to assist in the monitoring and control process. Key milestones will include dates when more information will be known about a given risk or dates when a risk must be resolved or allocated into the contract.

Documentation of the ongoing risk management process is another key output of the monitor and control process during the Design Phase. Formal documentation provides the basis for project assessment and updates. It ensures more comprehensive risk assessment and risk planning. It provides a basis for monitoring mitigation and allocation actions and verifying results. A comprehensive Risk Register (R3.12) will typically form the basis of documentation for risk monitoring and updating, but project complexity can drive the choice of other tools.

7.6.4 Design Phase Risk Monitoring and Control Relationship to Project Complexity

Only the simplest minor projects will use a Red Flag Item (I2.1) list for risk monitoring and control. A Risk Register (R3.12) is suggested for all projects. Risk registers can be tailored to project size and complexity so that they do not require undue effort for monitoring and control. Risk Management Plans (R3.1) and Risk Management Information Systems (R3.13) can assist in monitoring and control of moderately complex and major projects with a large amount of uncertainty.

7.6.5 Design Phase Risk Monitoring and Control Tips

Risk monitoring and control should be a continuous and repetitive activity during all phases of project development.

- For each project, develop a unique risk monitoring and control process that is appropriate for the size and complexity of the project.
- Document risk management during the design phase will be a key to success. However, do not create monitoring and control processes that are burdensome or create undue paperwork.
- Develop a successful risk monitoring and updating process that will systematically track risks, support the identification of new risks, and effectively manage the contingency reserve.
- Develop key milestones for risk resolution will help to ensure active risk management.
- Actively monitor project contingency. Develop a contingency resolution schedule early in the Design Phase and monitor the contingency in relation to the project risks.

7.7 Conclusions

This chapter discussed guidance for risk management in the Design Phase. The Design Phase engages all of the steps in the risk management process. A comprehensive and non-overlapping set of risks is developed early in the Design Phase and new risks are identified as the design progresses. Risks assessments are periodically updated, and risk analyses are used to monitor and control the contingency throughout design. Risk planning and mitigation efforts attempt to minimize the effects of risks on the project goals. Risks that cannot be avoided or fully mitigated are thoughtfully allocated to the contractors through the choice of the project delivery system and through the language in the contract provisions.

CHAPTER 8

Implementation

8.1 Introduction

Risk management is integral to the project management process. This Guidebook offers a systematic approach for the application of risk management practices that link to planning and preconstruction phases of project development and the level of a project's complexity. One specific outcome of implementing risk management is to help control project costs. In this context, risk management provides a structured approach to estimating contingency dollars for a project. Through the risk management process, a project's contingency can then be managed effectively as the level of project definition increases.

Risk Management is described as a five-step process. A number of risk management tools support the process at the appropriate phases of project development. While implementation of individual steps and tools is essential, they should not be implemented in an "al la Carte" approach. Implementation requires that all five steps be applied to integrate risk management into other agency processes that impact project cost and control these costs over the project's development phases.

Although risk management integration with other agency processes can begin at the organizational level, ultimately all levels must participate to create the cultural change necessary to address the challenges from instituting risk management at the organization, program, and project levels. Table 8.1 summarizes the implementation goals for the three levels. Achieving these goals will likely require organizational change and a commitment of agency resources.

8.2 Step One – Implementation of Risk Strategy: Organizational Change

NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction provided a strategic approach to addressing the cost escalation problem. The basis behind this approach was eight strategies to address a number of cost escalation factors. One strategy was the Risk Strategy, which has the following focus: Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed.

The implementation of the risk strategy will require a long-term commitment to change. Implementation should be approached as a continuous process of assessment, planning, assigning responsibility, and measuring performance. Assessment at the organizational level focuses on the understanding of risk, what it is and why it is an important process to implement. An understanding of risk will provide a basis for developing a plan for staffing and committing the resources for implementing risk management. The outcome of assessment and planning is the assignment of responsibility. A key to implementing the Risk Strategy is to find a "Champion" of risk management within the upper level management hierarchy of the agency. This champion must have a passion for risk management and then a vision for how risk management can be implemented across the agency. The champion should ensure that performance measures are in place so that the status of implementation can be periodically reported. The process will create a loop of continuous improvement as depicted in Figure 8.1.

8.2.1 Establish Steering Committee

An effective initial effort in the implementation process is to form a steering committee with the right mix of members. Since risk management is a focused area, steering committee members should have some knowledge of the risk management process or, at a minimum, possess a willingness to learn risk management as detailed in this Guidebook. A cross section of disciplines that will need to be involved in program and project risk management should be included on the committee. Consideration should be given to including an expert in risk management even if this expert comes from outside of the agency. The committee should follow the approach shown in

Table 8.1. Implementation goals.

Implementation Thrusts	Implementation Focus	Implementation Goals
Organizational Level	Risk Strategy	Implement Risk Strategy Across the Agency ▪ Assess current status of risk management implementation ▪ Plan for long term implementation ▪ Assign responsibility for implementation ▪ Measure results of implementation
Program Level	Risk Management Steps	Implement Risk Management Steps Across Programs ▪ Assess current status of step implementation ▪ Develop policies ▪ Commence use of Risk Management Guide ▪ Develop training and education
Project Level	Risk Management Tools	Implement Risk Management Tools Across Projects ▪ Assess current status of tool implementation ▪ Determine subject matter experts required ▪ Conduct pilot studies for new implementation ▪ Develop/revise agency specific tools

Figure 8.1 for determining a specific implementation effort around the Risk Strategy.

In assessing current implementation and planning for future implementation, the steering committee must also understand that risk management often is closely related with other critical project management processes, such as cost estimating, cost management, and project development. For example, the risk management process is used in cost estimating to quantify contingency dollars assigned to a project. Understanding this type of relationship is vital because the impact of risk management on other processes may increase the difficulty of implementation of the Risk Strategy successfully.

8.2.2 Develop Action Plan

Over time, the agency will need to develop a risk awareness culture. This effort begins with a vision that sets an overarching direction for an agency related to the implementation of risk management. The vision should make a case for change, especially when risk management is new to the agency. Change should be explained in terms of why change is needed and then what are the corresponding benefits for change. Accountability for implementation should be determined to confirm successful implementation. This comprehensive vision must be communicated to agency personnel. Management commitment to the vision is essential. Finally, an action plan should be developed to describe the processes, training, skill development, and other resources needed to carry out the vision.

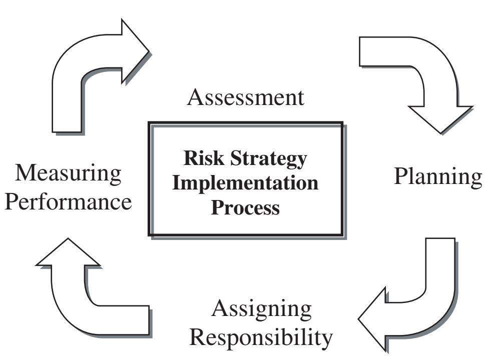


Figure 8.1. Strategy implementation process.

8.2.3 Determine Organizational Structure for Risk Management

Implementing a new or significantly improving an existing process requires organization structures to support the process improvement. Risk management is no different. However, the type of structure followed will certainly vary depending on the agency organizational culture and the approach to risk management. Organizational approach to risk management might range from a stand alone office to support the risk management process used on projects to several agency personnel who promote risk management within the organization but are not fully dedicated to the risk management effort. In either case, typical functions of the risk management support group could include, but not be limited to, developing policy, training materials, supporting risk applications on projects, and communicating risk related information to users. Setting up an organization structure to implement risk management requires support and decisions from upper management of the agency. A key issue is the resource commitment to risk management in terms of personnel and other support costs.

The WSDOT initiated a risk office when its Cost Estimate Validation Process (CEVP) commenced. This office has been active in drafting policy, supporting risk assessment workshops, and developing risk related tools among other focus areas. The office has four full-time personnel that support the risk management process. An alternate approach was used by Caltrans. While Caltrans did not establish a specific office to initiate the risk management process, they did have personnel that worked on developing a risk management process. This process is captured in a handbook designed to support project management and includes some tools used to implement risk management at the District level. Caltrans also has developed a dedicated course for risk management. This course is included as one of several training courses under the Caltrans project management curriculum.

Agency implementation of the risk management process will require organizational change to support this new process. Each agency will have to determine an organizational approach to risk management that fits within the agency culture and resources available. Commitment to such a structured approach is vital to successful implementation.

Figure 8.2. Risk management process framework (varies by project development phase and complexity).

8.3 Step Two – Implementation of Methods: Programmatic Change

The second implementation step involves change at the program level with the institution of the risk management process steps as shown in Figure 8.2. Chapter 3 and Chapters 5 through 7 described the implementation of the five risk management steps that support implementing the Risk Strategy. At the program level, current practice is first examined. Next, policies and procedures regarding risk management should be developed. Finally, the development of training and education materials is prepared to support implementation.

8.3.1 Assess Current Practice

The first task for implementation of the risk management process is an assessment of the current state of practice within the agency. This assessment should be conducted by project development phase such as for the programming phase as indicated in Table 8.2. Current use should consider not only if the particular step is being used, but also the level of understanding of the step and how it is being applied in practice. Comments then can be gathered on issues to consider for future implementation of the step. Since many agencies include contingencies in their cost estimates, it is important to capture definitions of contingency and how risk is related to the contingency value that is incorporated into each estimate.

8.3.2 Determine Policies and Procedures

Once an understanding of the use of the risk management steps is achieved, the agency should begin to formulate policies related to risk management and, in particular, contingency. These policies should address the relationship between risk and contingency and specific issues such as how is contingency determined, who owns the contingency, and when should contingency be retired, all in relation to risk management process steps.

A general policy statement related to evaluating risk and contingency was developed by the Minnesota Department of

Table 8.2. Example assessment of risk management steps in the programming phase.

Step	Currently in Use	Comments on Future Implementation
Identify		
Assess and Analyze		
Mitigate and Plan		
Allocate		
Monitor and Control		

Transportation (Mn/DOT) to aid in implementing risk management. An example portion of this policy is:

> Total project cost estimates for each of the project development phases will include an analysis of uncertainty and risk, and associated contingency estimates. (Anderson et al. 2008)

A second general policy statement that focuses on managing risk and contingency also developed by Mn/DOT is illustrated in the following statement:

> A process will be implemented for removing contingencies as project scope becomes better defined and risk management steps are taken (contingency resolution). (Anderson et al. 2008)

Example guidelines to implement these general policy statements are:

> Uncertainty, risk and associated contingencies will be acknowledged early for all projects in the project development process, starting with the planning phase, and updated in subsequent phases.
>
> Risks that are beyond project-related risks and contingency (e.g., revenue over estimation, unanticipated events or conditions) will be considered in a program contingency.
>
> With the exception of the Letting Phase cost estimate, where project contingency is zeroed out, contingency will not be incorporated in individual line item costs; instead, contingency will be maintained in a separate category. As more is known about the project, the amount of estimated contingency and the Base Estimate would change (contingency resolution). (Anderson et al. 2008)

These guidelines are a final step that Mn/DOT employed to set a program context for implementing risk management including contingency issues.

Policy formulation related to risk and contingency must support the Risk Strategy and the vision for risk management as articulated in the action plan prepared at the organizational level. The policies must provide guidance for implementing risk management practices at the project level through the use of risk management steps and tools.

Agencies should also consider policies relating to the use of range estimates to express risks and uncertainty. The FHWA allows ranges in long-range plans prepared during the planning phase. Further, cost estimates for other phases can be shown as cost ranges based on probabilities of overrun. However, this approach would require the agency to establish a policy for budgeting purposes in which a single number is included in an intermediate plan (say six to 10 years) and the STIP. The policy might direct that the project cost be budgeted at an 80 or 90 percent probability of underrun. Careful consideration should be given to the selection of the specified percent for all projects, before creating an agency policy around this percentage.

Once risk policies are determined and approved, risk procedures can be developed. This guidebook can serve as the basis for customizing the risk management process to fit an agency's culture and level of expertise. Future implementation should address how this manual might be enhanced and improved over time.

8.3.3 Develop Education and Training

It is very likely that agency personnel will need to gain an understanding of risk management in general and then training on how to apply risk management process steps. Managers and engineers at all phases of project development should be educated on the meaning of risk management, why risk management is important, and how risk management adds value in terms of controlling program and project costs. Education is required at all levels; however, the details of educating agency personnel may vary depending on the person's role in program and project management. Thus, training courses can include content that ranges from high level risk management concepts to the details of applying risk management during a specific project phase using the steps and appropriate tools.

Since the risk management process is used in conjunction with other processes, training materials can be developed for incorporation into a cost estimating or cost management course or within a project management course. More detailed training on risk management can then be achieved through a standalone course wherein detailed applications of the steps and tools can be the focus of such a course.

Depending on the expertise and knowledge of the agency in risk management, consultants in this area may be required to help develop training materials and then conduct the training courses until such time that the agency has gained sufficient expertise in risk management. In many states, consultants prepare project estimates and also manage project cost. As such, there is a need to train consultant engineers in the risk management process. This is especially necessary when the agency has its own approach to risk management.

8.4 Step Three – Implementation of Tools: Project Change

The third level of implementation involves the application of tools at the project level. Tools should be developed and evaluated on a trial basis before they become agency standard practice as dictated by policy and through procedure manuals. Many of the tools described in Appendix A have been used on projects, but not necessarily in the agency environment.

Table 8.3. Example assessment of programming phase tools.

Tools			Examples of Use	Subject Matter Experts	Comments on Future Implementation
Identification of Risks					
	I2.1	Red Flag Items			
	I2.3	Risk Checklists			
Risk Analysis					
	R3.1	Risk Management Plan			
	R3.2	Contingency—Percentage			
	R3.3	Contingency—Identified			
Additional Tools					
		Additional Tools			

8.4.1 Assess Current Practices

The agency should also assess the current use of tools that support the risk management process at the project level. Table 8.3 provides an example of how to assess tool use in one project development phase. A similar table can be used to assess tool use in other phases. The agency will want to examine how the tool is being used and how successful it has been in a specific project application.

To realize the full potential of this approach, Table 8.3 should be used in conjunction with a detailed review of the tools in Appendix A and the steps described in Chapters 5, 6, and 7. This is necessary because the detailed application of the tools can vary, even within an agency. For example, the tool R3.2, Contingency to Percentage, can be applied in a number of different ways. Some agencies use a sliding scale contingency band that ties to project development phases. Others provide standard contingency values for use in each project development phase. The key in this example is to find the approach that would best fit into the agency level of expertise related to implementing risk management in relation to setting contingency amounts.

If there are subject matter experts they should be identified. Often times, the more sophisticated risk management tools will require an outside consultant to aid in implementing the tool. This is particularly true for those tools that involve probabilistic estimating.

8.4.2 Test New Tools

The adoption of new or the revision of existing risk management tools should involve testing and verification of their effectiveness. The consequences of implementing inappropriate tools that do not support risk management steps can lead to unanticipated cost and schedule impacts. Two methods can be followed when implementing new tools: testing the new tool in parallel with existing tools or conducting pilot studies on appropriate projects. Again, depending on the tool, this effort might require the expertise of a risk management consultant.

With the use of either method of testing new tools, the agency needs to have measures to determine if the tool is producing the result intended. Users should comment on benefits, deficiencies, and changes needed to improve tool implementation. The tool may be dropped from consideration as a permanent tool if the results are not satisfactory.

8.4.3 Customize Tools to Fit Agency

The final activity of the project-level implementation would involve the development of agency-specific tools. The tool must fit within the policy directives regarding risk and the resources available to fully develop a customized tool for the agency. Any customization effort should consider the impact and level of tool use across projects.

8.5 Step Four – Integrating the System: A Strategic Plan

The previous sections describe the implementation of a risk management strategy, risk management steps, and risk management tools at the organizational, program, and project levels, respectively. While each of these elements is individually important, success will only be realized when the agency integrates these elements as a comprehensive long-term strategic initiative. The basis of any comprehensive strategy starts with a vision that articulates management commitment and direction. This vision addresses change and the need for a new process such as risk management.

Table 8.4 provides an implementation framework to integrate the risk steps and tools in support of achieving the Risk Strategy across the project development phases. The first column identifies the project phase, in this case, planning. The second column identifies each of the five steps in the risk man-

Table 8.4. Example implementation framework.

Project Development Phase	Performance Improvement Opportunity/Action (Steps)	Implementation Steps (Tools)	Responsible Party and Performance Measurement
Planning	Risk Identification – Develop appropriate tools to support the identification of risks	Red Flag Items – Develop tool application approach for documenting identified risks	Program or party responsible for implementation with performance measurement
Planning	Risk Assessment/Analysis – Develop tools that provide for a contingency estimate	Contingency Percentage – Prepare guidance for selecting contingency values consistent with planning phase	Program or party responsible for implementation with performance measurement
Planning	All Steps	Training – Develop training modules to incorporate risk identification and risk assessment/analysis for contingency applications for planning	Program or party responsible for implementation with performance measurement
Continue with Programming Phase…	*Continue with opportunity/actions from methods…*	*Continue with implementation steps from tools…*	*Continue with assignment of responsibilities and measures*

agement process. A short statement might be provided to focus the step for the particular project phase of interest. The third column identifies the tools that might be used in this project phase in support of the risk management step. Column four provides for the assignment of responsible parties for managing implementation of the steps and tools. Column four should also include performance measures to guide whether the tool is working as intended.

While Table 8.4 focuses on specific risk management issues, an integrated implementation plan must consider the interaction between the risk management process and other project management processes such as cost estimating and cost management. Both of these processes use inputs and outputs of the risk management process. The risk management process also provides information to these two processes. There may be other processes that are influenced by the use of risk management. The user of the Guidebook is encouraged to make an assessment of those related process that are impacted by implementing risk management.

Further, to successfully implement risk management, organization structures must be in place to provide the necessary resources to develop the implementation framework described in Table 8.4. The first decision is the type of structure that will be used and the resource dedicated to the risk management approach under this structure. Once the structure is in place, the resources used to implement risk management will need to focus on policies, training, procedural development, and eventually development of tools.

8.6 Summary

This chapter illustrates a purposeful approach to integrating and implementing the concepts and content found in this Guidebook. The framework proposed in the final section of the chapter is one method for creating a strategic path forward with the goal of controlling project costs through risk management. Agencies can develop other approaches that use the steps and tools presented in this Guidebook. A systematic approach to risk management is essential to aid in controlling costs. The use of expert consultants in this area is encouraged, especially when the more sophisticated tools are implemented in support of certain risk management steps.

CHAPTER 9

Path Forward

9.1 Industry Problem

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. 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 uncertainty and its effect to the 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 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.

9.2 Guidebook Development

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 as particularly crucial for the long-range transportation planning, priority programming, and preconstruction stages of the project development process.

In the initial effort of this Guidebook, the research team conducted a survey of current SHA risk management practices. It was revealed that while risk is indeed inherent in every capital transportation project, the survey found that 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 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 the Caltrans agency, the Caltrans San Francisco-Oakland Bay Bridge project, WSDOT, the US DOE, the FHWA, the FTA, 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, 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.

9.3 The Risk Management Framework

The risk management framework described in this Guidebook is based on best practices in the 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:

- Risk Management Process: risk identification; assessment; analysis; planning and mitigation; allocation; and monitoring and control;
- Project Development Phases: planning, programming, and design; and
- 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 9.1.

Of particular note in Figure 9.1 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 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 noncomplex projects to large and complex projects. There are five imperative steps to managing project risk.

- *Risk identification* is the process of determining which risks might affect the project and documenting their characteristics using such tools as brainstorming and checklists.

Figure 9.1. Risk management process framework (varies by project development phase and complexity).

- *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.
- *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, 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.
- *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.

9.4 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 also will 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 principles 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 five additional keys to success for risk analysis tools to control project cost.

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

References

American Society of Civil Engineers (1990). *Construction Risks and Liability Sharing, Volume II,* the American Society of Civil Engineers, Washington, D.C.

Anderson, S. D., and Blaschke, B.C., (2004). "Statewide Highway Letting Program Management," National Cooperative Highway Research Program, Project 20-5, Topic 33-9, Synthesis of Practice, Final Draft Submitted for Review.

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

Anderson, S., Molenaar, K.R., Shane, J.S, and Patil, S. (2008) *Technical Reference Manual on Cost Estimating and Management,* Minnesota Department of Transportation, St. Paul, MN.

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 (2007). *Project Risk Management Handbook.* Report of the California Department of Transportation (Caltrans), Office of Project Management Process Improvement. Sacramento, CA.

Clark, F. D. and A. B. Lorenzoni (1997). *Applied Cost Engineering,* Marcel Dekker.

Construction Industry Institute (1990). *Assessment of Construction Industry Practices and Performances.* Construction Industry Institute, Austin, Texas.

Construction Industry Institute (1993). *Allocation of Insurance-Related Risks and Costs on Construction Projects.* Construction Industry Institute, Austin, Texas.

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.

Federal Highway Administration (2005). *Construction Management Practices in Canada and Europe,* Report # FHWA-PL-05-010, International Technology Program, Federal Highway Administration, Washington, DC.

Federal Highway Administration. (2007). *Final Guidance on Cost Estimation.* U.S. Department of Transportation. Washington, D.C.

Federal-Aid Highways Cost and Oversight of Major Highway and Bridge Project – Issues and Options, (2003) U.S. General Accounting Office, Report GAO-03-764T. Washington, D.C.

Flyvbjerg, Bent; Holm, Matte Skamris; Buhl, Soren (2002). "Underestimating costs in public works projects: Error or lie?" *Journal of the American Planning Association,* 68(3), American Planning Association, Chicago, IL., 279–295.

Merrow, Edward W.; McDonnell, Lorraine M.; Yilmaz Arguden, R. (1988). *Understanding the Outcomes of Mega-Projects: A Quantitative Analysis of Very Large Civilian Projects.* Rand Corp.

Molenaar, K.R., Anderson, S., and Schexnayder, C. (2009) *Research Report for Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs.* Draft final report, NCHRP Project 8-60. University of Colorado, Boulder, CO.

Molenaar, K.R., Diekmann, J.E, and Ashley, D.B. (2006). *Guide to Risk Assessment and Allocation for Highway Construction Management,* Report # FHWA-PL-06-032, Federal Highway Administration, U.S. Department of Transportation, American Association of State Highway Transportation Officials, and the National Cooperative Highway Research Program, Washington, DC, October 2005, 73 pp.

National Academy of Engineering (2003). *Completing the "Big Dig": Managing the Final Stages of Boston's Central Artery/Tunnel Project.* National Academy of Engineering, Board on Infrastructure and the Constructed Environment, Washington, D.C.: The National Academies Press.

Pre-Project Planning: Beginning a Project the Right Way (1994). Construction Industry Institute, Research Summary 39-1, The University of Texas at Austin.

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

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

Smith, R.J. (1995). Risk Identification and Allocation: Saving Money by Improving Contracting and Contracting Practices, *The International Construction Law Review,* pp 40–71.

Touran, Ali, and Paul J. Bolster (1994). *Risk Assessment in Fixed Guideway Transit System Construction,* Federal Transit Administration.

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

APPENDIX A

Tools

D1.1 Contract Packaging

On December 13, 2001, Maryland DOT opened bids for the Woodrow Wilson Bridge superstructure contract. A single bid, 75 percent higher than the engineer's estimate for the contract, was received. In reviewing the situation, it became clear that market forces had a substantial impact on the bid prices, a much greater impact than anticipated by the project planners and estimators. The manner in which work is packaged into individual contracts affects contract prices and must be accounted for when estimating project cost. State highway agencies should seek to package projects in such a way that there is effective management of cost, schedule, and risk. Heeding the recommendations of an independent review committee, Maryland DOT repackaged the contract into three contracts and rebid the project approximately a year later. The first rebid contract came in 11 percent over the estimate, but there were five bidders and it was a workable bid, and the other two contracts both came in below the estimates, one by 28 percent and the other by 25 percent. Contract packaging is important for maintaining competition and receiving competitive bids.

What is it?

In packaging contracts, there must be a weighing between economy (usually measured as competition) and work efficiency. Based on thoughtful analysis and consideration of a program or project's physical work elements and on the market conditions existing at the work location, contract packages that minimize the total cost of construction are developed. Contract packaging, which is based on such forethought, requires interaction between estimators, the project development team, and the state highway agency personnel responsible for managing project construction as the estimator and construction management personnel will be able to call attention to packaging affects on project cost.

Why use it?

Project size (contract dollar), equipment requirements, physical features, and the responsibilities (i.e., risk) imposed on the contractor are all critical factors impacting the bid price of work. There are opportunities to reduce contract cost by conscientiously considering the contract package in respect to these factors. At the same time, estimators must consider the impacts of contract packaging when developing the project estimate.

A Caltrans study on the impact of competition on final bid results found a clear and undeniable relationship between the number of bids received and the contact low bid compared with the engineer's estimate. Strategies that increase competition (i.e., the number of bidders per project) will lower project cost. Contract packaging is particularly important in the case of large aggregate dollar value work and work of a specialized nature. The geographical location of a contract or work sites is an additional factor that should be considered. Any factor that affects the number of bidders that can be expected on a project should be evaluated.

Caltrans found that the relationship between the average number of bidders and the bid price changes based on project dollar size, as shown in Table D1.1.1. This table makes it clear that even for small dollar jobs, it is important to consider the effects of competition.

What does it do?

Contract packaging affects project cost; therefore, knowledge of such impacts can result in contracting packages structured to achieve the work at lower cost. By structuring contracts to facilitate maximum participation by the contracting community, state highway agencies can often lower bid prices. Increasing competition also leads to the continued potential for long-term savings by maintaining a viable base of competition.

Table D1.1.1. Relationship bid price to estimate considering project size (Caltrans study).

Project Size, $	Ave. No. Bids	Percent over PS&E if only one bid	Expected reduction by increasing the ave. by one biddder
Less than 1 Mil.	5.2	+17%	-2.3%
1 to 5 Mil.	5.3	+5%	-2.0%
5 to 10 Mil.	5.0	+5%	-2.1%
Greater than 10 Mil.	5.7	+3%	-1.8%

PS&E = plans, specifications, and estimates

When to use it?

Contract packaging decisions should be made in the programming phase or very early in the design phase. The contract packaging approach should be known when the baseline estimate is created. In some instances, contract packaging decisions will be made later in the design phase due to a change in scope or realization of a major risk. However, this should be avoided as it will often cause design rework and a delay in project letting.

How to use it?

Contract packaging decisions should be made with information from all team members. Cost estimating is a key in the decision. A thorough understanding of the design constraints and opportunities is also necessary to make logical contract packaging decisions. An understanding of market conditions (e.g., number and type of contractors available, etc.) is also an important input into making the contract packaging decisions.

Example

A review of the Maryland SHA estimate compared to the single bid for the Woodrow Wilson Bridge superstructure contract found:

- There were only a small number of contractors with the ability to undertake a project of such magnitude.
- There were several other major bride projects being bid concurrently with the Woodrow Wilson project.
- The size of the project necessitated that joint-venture teams be formed, further reducing the competition.

The work was repackaged into three contracts. The first contract was successfully bid with five contractors competing. The second contract had six bidders and came in 28 percent below the Engineer's Estimate. The third contract had four bidders and was 25 percent below the Engineer's Estimate.

Tips

SHAs should consider the following when packaging contracts:

- Coordination with adjacent contracts.
- Traffic control limitations.
- Accomplishment of utility relocation activities before the prime contract (advance utility relocation).
- Accomplishment of hazardous remediation work as a separate contract in advance of the prime contract
- Large-dollar contracts (such contracts can limit competition because contractors are not able to obtain bonding. In the case of mega-dollar projects, there is a limit to the risk that the bonding community is willing to assume. To protect themselves, the bonding companies join together to write large bonds. This practice further limits the availability of a contractor to obtain a bond.)

During the design phase of project development, thought should be given to the strategic separation of projects within a corridor, allowing for efficient use of earthwork (balancing cut and fill requirements).

In respect to all these consideration there must be a balance between the cost of administration for multiple contracts and the potential benefits from having multiple contracts.

Resources

While the Caltrans report is specific to conditions in that state, it provides a good indication how competition impacts project cost (see Impact of Competition on Final Bid Results for Transportation Related Construction Project, Nov. 15, 2001, Caltrans, Division of Engineering Services).

Maryland DOT (MDOT) information on the Woodrow Wilson Bridge contract packaging can be found at www.mdot.state.md.us/News/2003/May2003/Wilson%20Bridge

D1.2 Delivery Decision Support

The selection of a project delivery system can affect both cost-estimating practices and cost-estimating management. The design-bid-build delivery system approach, in which unit price construction contracts are awarded to the lowest bidder, is the traditional system for U.S. highway projects and used in the majority of highway projects today. However, the traditional project delivery system has received criticisms stemming from long delivery times, excessive cost growth, and litigious relationships. Continuing to face increasing demands of the traveling public with declining staffs, federal, state and local agencies are employing alternative project delivery, procurement and contracting methods to improve the efficiency and effectiveness of public sector project delivery.

What is it?

Project delivery decision support is a tool that assists SHAs in the choice alternative project delivery systems. It should provide a clear understanding of the advantages and disadvantages of alternative delivery systems so that SHAs can make informed decisions about the most effective choice for the available alternatives to meet the specific project goals. Sample of alternatives in use by SHAs at the time that this document was published includes:

Project Delivery Systems
- Construction Management at Risk
- Design-Build (and variations – Operate-Maintain, -Warranty)
- Indefinite Quantity/Indefinite Delivery
- Job Order Contracting
- Public-Private Partnerships

Procurement Systems
- Cost + Time Bidding (A+B)
- Multi-parameter Bidding (A+B+C)
- Best-Value Procurement
- Alternate Designs
- Alternate Bids
- Additive Alternates
- Negotiated or Qualifications-Based Selection (for construction)

Contracting and Payment Systems
- Lane Rental
- Incentive/Disincentive Payments
- Warranty Contracting
- Lump Sum Payment Methods

When selecting alternative project delivery systems, SHA personnel should consider issues such as risk allocation, legal implications, statutory restrictions, and administrative issues. The decision to use an alternative delivery method invariably involves a tradeoff between cost and some other factor such as time, user delays, or quality. Delivery decision tools can help to make this tradeoff decision.

Why use it?

The choice of project delivery system often hinges on a project's cost or time constraints, and estimators must understand how to estimate the cost tradeoffs involved in the decision to use an alternative delivery system. For example, the design-build project delivery system can be used to award a lump-sum contract for both design and construction of a project much earlier in the project development process than the traditional design-bid-build method. This early award offers a high potential for project delivery-time savings and, in essence, fixes a project's cost earlier in the project development process than the traditional process. When design-build is selected, different approaches must be taken for cost estimating and cost management. Cost estimating will involve the use of more rigorous conceptual estimating tools because designs will not be complete and quantities will not be known at the time of project award. Cost estimate management will require different change management procedures because the design-builder develops the design under a lump sum contract.

What does it do?

Given a set of unique project goals, project delivery decision support provides an understanding of why an alternative delivery method might be appropriate for a project. It provides guidance for cost estimating practices and cost estimating management.

When to use it?

Project delivery decisions should be made as early as possible in the project development process to optimize their impact. Decisions for the overall project delivery system (i.e., design-build, public-private partnership, etc.) should preferably be made during the Programming Phase or shortly thereafter. In cases of large projects, the decision may be made as early as the Planning Phase. Decisions regarding innovative procurement methods, such as best-value or qualifications-based procurements, should be made in the Programming Phase or very early in the Design Phase. Other less significant procurement and contracting decisions (i.e., A+B bidding, additive alternates, lane rental, etc.) can be made sometime in the Design Phase.

How to use it?

Project delivery decisions should be made with information from all team members. Cost estimating is a key in the decision. A thorough understanding of the design constraints and opportunities is also necessary to make logical contract packaging decisions. An understanding of market conditions (e.g., number and type of contractors available, etc.) is also an important input into making the contract packaging decisions.

Example

There are numerous examples of project delivery decision tools. Five national examples are provided here, but numerous states have developed decision support tools as well.

Utah State University Innovative Contracting Website

The FHWA sponsored the development of an innovative contracting website to provide decision support for innovative contracting methods. A screen clip of the website is provided in Figure D1.2.1. The Utah State University's Innovative Contracting website includes information concerning various construction contracting techniques such as design-build, warranties, cost-plus-time bidding, lane rental, job order contracting, and many other non-traditional contracting techniques. State DOT work plans and evaluation reports from FHWA's Special Experimental Project No. 14, "Innovative Contracting," are provided. The site also features a best practices guide and a decision tree for selecting the appropriate contracting technique.

NHI Alternative Contracting Course (Course No. 134058)

The FHWA's National Highway Institute (NHI) developed a course on "Alternative Contracting" (Course No. 134058), and it is now available. A short description of the course is listed below and more information on the course availability can be found on the NHI website at http://www.nhi.fhwa.dot.gov/.

Course Objective
The estimated 2-day training course will teach participants how to select the appropriate projects for alternative project delivery strategies, choose the correct alternative contract provisions, and recognize the legal and programmatic implications associated with these techniques. The course design is to be flexible, allowing the requesting agency to customize the presentation for increased emphasis on topics of interest to the agency.

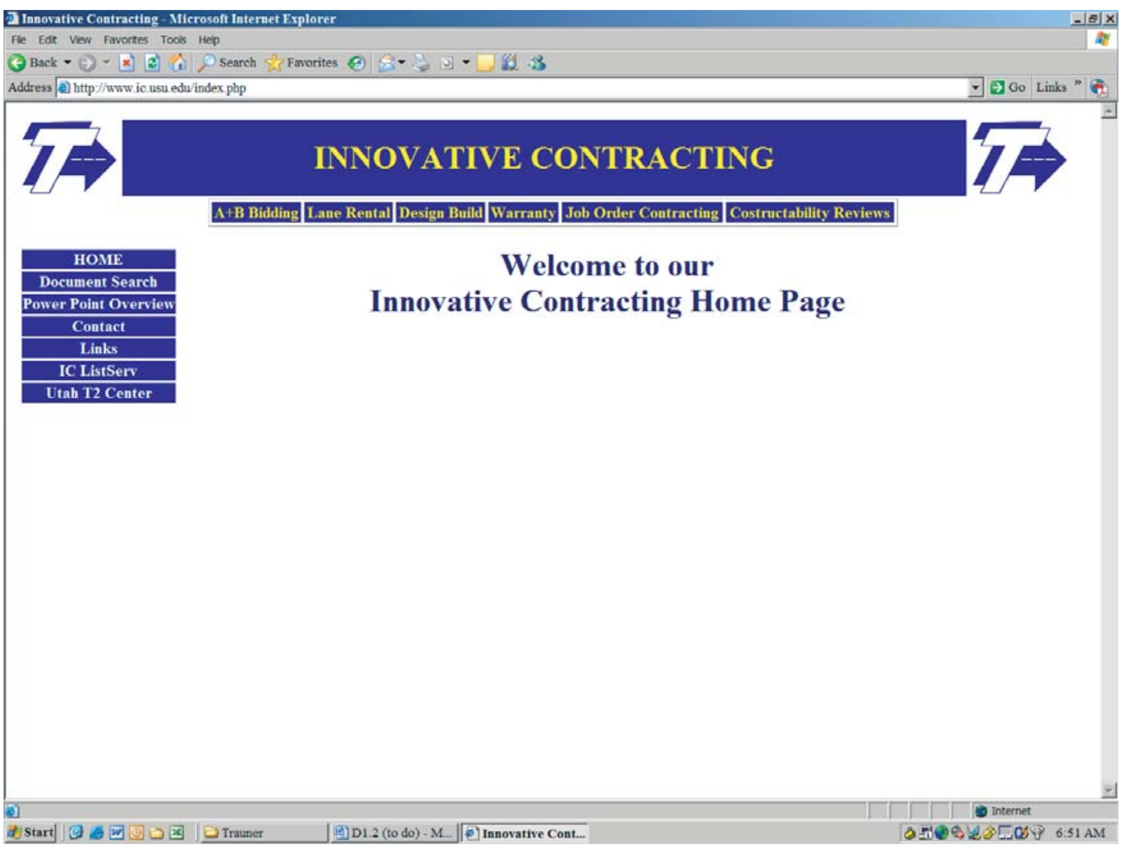


Figure D1.2.1. Utah State University Innovative Contracting website http://www.ic.usu.edu.

The target audience includes personnel working in contract administration, project development and design, and the management of highway construction, including contribution of information in contract provisions.

Upon completion of the course, participants will be able to:

- Identify alternative project delivery, procurement, and contract management methods for highway construction;
- Identify objectives for the use of alternative project delivery, procurement, and contract management methods;
- Differentiate among traditional design-bid-build and alternative project delivery, procurement, and contract management methods based on relative advantages and risks;
- Define how project risks are reallocated using various project delivery, procurement, and contract management methods;
- Select appropriate alternative contracting methods for use with a given project or select appropriate projects for use with a given alternative contracting method or methods; and
- Identify contract requirements appropriate for alternative contracting methods.

AASHTO Primer on Contracting for the 21st Century

The *Primer on Contracting for the 21st Century* is an updated version of the *Primer on Contracting 2000* (1997). The new *Primer* describes various contracting and contract administration techniques that are currently being used by contracting agencies in their transportation programs and provides contacts within these agencies for use in obtaining additional information. This report was prepared by the Contract Administration Task Force of the AASHTO Highway Subcommittee on Construction. The document can be found in the references section of the AASHTO Subcommittee on Construction's website http://construction.transportation.org.

NCHRP 10-49 Improved Contracting Methods for Highway Construction Projects

The project reviewed relevant domestic and foreign literature; surveyed the construction industry; identified and evaluated contracting practices with consideration to compatibility with the low-bid system, impact on SHA resources, product quality, and risk allocation; and developed guidelines for three nontraditional contracting methods: warrant, multi-parameter, and best value. The agency's final report that contains the findings of the literature review, discussions of current use, and analysis of survey results has been distributed to all state highway agencies. The guidelines for nontraditional contracting methods have been published as *NCHRP Report 451: Guidelines for Warranty, Multi-Parameter, and Best Value Contracting.* http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+10-49

NCHRP 10-61 - Best Value Procurement Methods for Highway Construction

NCHRP Project 10-61 provides decision support for best-value procurement of U.S. highway construction. The resulting report outlines a comprehensive process that state transportation agencies can use to create best-value methods in their individual states. The research effort investigated best-value concepts currently in use in the construction industry, evaluated their relative effectiveness, and recommended a best-value system or systems that may be used in conjunction with a traditional design-bid-build delivery system for highway construction.

The research products include:

- A common definition and a conceptual framework for the use of best-value procurement methods for highway construction projects.
- A best-value procurement system that allows for flexibility in the choice of parameters and award methods.
- An implementation plan that includes a project screening system for selecting candidate projects, and a step-by-step process for selecting appropriate parameters, criteria, and award algorithms.
- Recommendations regarding models to use for legislation and procurement regulations.
- A compendium of case studies for best-value procurement in the highway construction industry.
- A training tool to assist agencies with implementation.

The results of NCHRP 10-61 have been published as *NCHRP Report 561: Best-Value Procurement Methods for Highway Construction Contracts.* http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+10-61

Tips

Choose delivery methods that better align goals and allocate risk properly. The U.S. highway industry must evolve from the traditional "one size fits all" project delivery method. A renewed focus should be given to alternative delivery methods that promote early industry involvement and life cycle design solutions to maximize the entire project team's input into meeting customer needs.

Resources

AASHTO Subcommittee on Construction's Website – see References for *Primer on Contracting for the 21st Century* http://construction.transportation.org.

Anderson, S.D., and Russell, J.S. (2001). *Report No. 451: Guidelines for Warranty, Multi-Parameter and Best-Value Contracting.* TRB, National Research Council, Washington, DC.

Federal Highway Administration's National Highway Institute http://www.nhi.fhwa.dot.gov/

National Cooperative Highway Research Program, Project 10-49 Website http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+10-49

National Cooperative Highway Research Program, Project 10-61 Website http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+10-61

Scott, S., Molenaar, K.R., Gransberg, D.D., and Smith, N. (2006). *Report No. 561: Best-Value Procurement Methods for Highway Construction Contracts.* Transportation Research Board of the National Academies, Washington, DC.

Utah State University, Technology Transfer (T2) Center, Innovative Contracting Website http://www.ic.usu.edu

I2.1 Red Flag Items

A red flag item list is perhaps the simplest risk identification and risk management tool. It is created at the earliest stages of project development and maintained as a checklist during project development. The list helps estimators to better understand the required contingency for a project and helps managers control scope growth more effectively throughout the project development process. Not all projects will require a comprehensive and quantitative risk management process. A red flag item list can be used in a streamlined qualitative risk management process.

What is it?

A red flag item list is a technique used to identify risks and focus attention on critical items with respect to critical cost and schedule impacts to the estimate. Issues and items that can potentially impact project cost or schedule in a significant way are identified in a list or red flagged, and the list is kept current as the project progresses through development.

Why use it?

By listing items that potentially can impact a project's cost or schedule, and by keeping the list current, the project team has a better perspective for setting proper contingencies and controlling cost escalation. Occasionally, items that are considered a risk are mentioned during the Planning phase of project development but soon forgotten. The red flag item list facilitates communication between estimators and designers concerning these impacting items. By maintaining a running list, these items will not disappear from consideration and then later cause problems.

What does it do?

At the earliest stages of project development, an agency develops a list of impacting items, based primarily on engineering judgment or historical records of problems. The red flagging of these items may not involve any formal qualitative or quantitative risk analysis of the factors, but it keeps the team mindful of their existence. The list reminds the team to devote attention to risk issues as the design progresses so that they can be removed from contingency and placed in the base estimate or reduce the overall project cost as appropriate.

When to use it?

The red flag item list should be compiled during the earliest stages of project development. The list should then be updated at each major milestone or as new items are identified. The list will be most useful if it is maintained and updated throughout the project development process.

How to use it?

Red flag item lists should be developed by different members of the team in collaboration. The list should be shared by Designers and Estimators.

Example

Figure I2.1-1 provides an example from the Ohio DOT:301.6 Red Flags

Tips

The list of red flag items should be developed in an interdisciplinary team environment. This activity works well during the Scoping Process. Consider brainstorming sessions with representatives from multiple discipline areas. In addition to Scoping Documents or lists of standard items, individuals

> **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 I2.1-1. Ohio DOT Red Flag example.

should use their own knowledge of the project and consult with others who have significant knowledge of the project or its environment.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

Curran, Michael W. (1998). *Professional Practice Guide 2: Risk Association for the Advancement of Cost Engineering International.*

FHWA (2004). *Major Project Program Cost Estimating Guidance.*

Grey, S. (1995). *Practical Risk Assessment for Project Managers.* John Wiley and Sons, Chichester, England.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3.

NCHRP (2005). NCHRP Project 20-7/172 Final Report, Recommended AASHTO Design-Build Procurement Guide, Washington, DC.

I2.2 Not Used

This tool is not used, but the numbering remains for consistency with NCHRP Report 574 Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction.

I2.3 Risk Checklists

Risk checklists are a tool for risk identification that can be used at the earliest stages of risk identification to learn from past projects and past team member experience. The list helps estimators to better understand the required contingency and helps managers to more effectively control scope growth throughout the project development process. The use of a risk checklist is the final step of risk identification to ensure that common project risks are not overlooked.

What is it?

Risk checklists are a historic list of risks identified or realized on past projects. Risk checklists are meant to be shared between estimators and discipline groups.

Why use it?

The risk checklists capture corporate knowledge within a state highway agency and ensure that common risks are not overlooked in the estimating or risk management process. Risk checklists are simple to maintain if the agency has a central estimating or risk management sections. Risk checklists also can be maintained by individual estimators or project managers.

What does it do?

Risk checklists serve as a final step in the risk identification process to ensure that common risks are not overlooked.

When to use it?

Risk checklists should be used only after the team has sought to identified risks on its own (e.g., through an examination of scope and estimating assumptions, brainstorming of issues and concerns, or the creation of a red flag list). Risk checklists should not be used as the first step in risk identification because they may not contain important project-specific risks. If a project team relies too heavily on a risk checklist, it could easily overlook project-specific risks, and the risks may not be phased correctly for the unique aspects of the project.

How to use it?

A risk checklist should be reviewed at the start of a project and potentially several more times throughout the project. The list should be reviewed by a project team, and the risks that may have impacts should be documented and added to the risk register and possibly marked for quantitative analysis.

Example

Caltrans has a sample list of risks in its *Project Risk Management Handbook.* This sample list of risks can be used as the basis for creating a list of red flag items for an individual project or by an agency to create its own risk checklist. Caltran's list is quite comprehensive, and any single project's list of risks should not include all of these elements.

Caltrans Sample Risk List (Caltrans 2007)

Technical Risks

- Design incomplete
- Right of Way analysis in error
- Environmental analysis incomplete or in error
- Unexpected geotechnical issues
- Change requests because of errors
- Inaccurate assumptions on technical issues in planning stage
- Surveys late and/or surveys in error
- Materials/geotechnical/foundation in error
- Structural designs incomplete or in error
- Hazardous waste site analysis incomplete or in error
- Need for design exceptions
- Consultant design not up to Department standards
- Context sensitive solutions
- Fact sheet requirements (exceptions to standards)

External Risks
- Landowners unwilling to sell
- Priorities change on existing program
- Inconsistent cost, time, scope, and quality objectives
- Local communities pose objections
- Funding changes for fiscal year
- Political factors change
- Stakeholders request late changes
- New stakeholders emerge and demand new work
- Influential stakeholders request additional needs to serve their own commercial purposes
- Threat of lawsuits
- Stakeholders choose time and/or cost over quality

Environmental Risks
- Permits or agency actions delayed or take longer than expected
- New information required for permits
- Environmental regulations change
- Water quality regulation changes
- Reviewing agency requires higher-level review than assumed
- Lack of specialized staff (biology, anthropology, archeology, etc.)
- Historic site, endangered species, wetlands present
- EIS required
- Controversy on environmental grounds expected
- Environmental analysis on new alignments is required
- Formal NEPA/404 consultation is required
- Formal Section 7 consultation is required
- Section 106 issues expected
- Project in an area of high sensitivity for paleontology
- Section 4(f) resources affected
- Project in the coastal zone
- Project on a scenic highway
- Project near a wild and scenic river
- Project in a floodplain or a regulatory floodway
- Project does not conform to the state implementation plan for air quality at the program and plan level
- Water quality issues
- Negative community impacts expected
- Hazardous waste preliminary site investigation required
- Growth inducement issues
- Cumulative impact issues
- Pressure to compress the environmental schedule

Organizational Risks
- inexperienced staff assigned
- losing critical staff at crucial point of the project
- insufficient time to plan
- unanticipated project manger workload
- internal "red tape" causes delay getting approvals, decisions
- functional units not available, overloaded
- lack of understanding of complex internal funding procedures
- not enough time to plan
- priorities change on existing program
- new priority project inserted into program
- inconsistent cost, time, scope and quality objectives

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 clearly defined or understood
- No control over staff priorities
- Too many projects
- Consultant or contractor delays
- Estimating and/or scheduling errors
- Unplanned work that must be accommodated
- Communication breakdown with project team
- Pressure to deliver project on an accelerated schedule
- Lack of coordination/communication
- Lack of upper management support
- Change in key staffing throughout the project
- Inexperienced workforce/inadequate staff/resource availability
- Local agency issues
- Public awareness/support
- Agreements

Right-of-Way Risks
- Utility relocation may not happen in time
- Freeway agreements
- Railroad involvement
- Objections to Right-of-Way appraisal takes more time and/or money

Construction Risks
- Inaccurate contract time estimates
- Permit work windows
- Utility
- Surveys
- Buried man-made objects/unidentified hazardous waste

Regulatory Risks
- Water quality regulations change
- New permits or new information required
- Reviewing agency requires higher-level review than assumed

Sample Risk Checklist from the Minnesota DOT:

No. of lanes
- Traffic volumes
- Level of Service (LOS) analysis

- Lane continuity
- High-occupancy vehicle, single-occupancy vehicle, etc.
- Policies, purpose, and need

Access
- Functional classification of roadways
- Traffic volumes
- Traffic movements
- Traffic forecasts
- Right-of-way impacts
- Environmental issues
- Existing interchange/conditions
- Municipal land use planning
- Design speed/engineering standards
- Access category
- Bike/pedestrian
- Crash data

Horizontal
- Right-of-way impacts
- Environmental issues
- Soils
- Utilities
- Existing conditions
- Topography
- Pavement condition
- Staging/detour
- Municipal community planning
- Design speed
- Enforcement issues
- Engineering standards
- Park and ride
- HOV/transit elements

Vertical
- Design speed/engineering standards
- Soils – rock, muck, water
- Utilities
- Topography
- Bridges
- Municipal community planning
- Noise
- Adjacent land use
- Drainage
- Airports

Bridge
- Cross section – mainline
- Cross section – cross street
- Profiles
- Skew
- Type selection
- Aesthetics
- Bike/Pedestrian trails
- Airport location
- Lighting and signing
- Soils/Foundations
- Waterway analysis
- Bridge clearance (overlays)
- Utilities
- Staging/detour
- Bridge approach costs
- Temps and shoefly

Retaining walls
- Type
- Cross sections
- Aesthetics
- Drainage
- Right-of-way impacts
- Utilities
- Soils/foundations

Traffic
- Design speed
- Functional classification
- Roadway type
- Access locations
- Traffic movements
- Traffic volumes
- LOS analysis
- Signal warrant analysis
- Crash data
- Safety systems
- Lighting warrants
- Signing
- Striping determination
- Airports
- Foundation analysis

Water Resources Engineering (WRE)
- Alignments
- Profiles
- Cross sections
- Drainage areas
- Existing conditions
- Impervious areas
- Banking
- Waterway analysis
- DNR
- Corps
- Watersheds/WCA/BWSR
- NPDES/PCA/MS4
- City/county coordination

- Right of way impacts
- Soils
- Drinking water areas
- Airports
- Ponding

Pavement
- Soils
- Cross sections
- Traffic volumes
- Vehicle classification
- Profiles
- Water table
- Drainage
- Pavement selection
- Shoulder use
- Traffic staging/control
- Dynamic shoulders
- Transit shoulders
- Pavement condition

Utilities
- As-builts (Mn/DOT and city)
- Surveys
- Gopher 1
- Aerial photography
- Right-of-way (R/W) maps
- Plats
- Site plans
- Coordinate with city/county
- Permits
- Alignments
- Profiles
- Cross sections
- Drainage elements
- Retaining walls
- Noise walls
- Bridges
- Construction staging

Railroad
- Aerial photos
- Alignments
- Profiles
- Cross sections
- Drainage
- Retaining walls
- Noise walls
- Bridges
- R/W maps
- Plats
- Railroad office coordination
- Construction staging

Earthwork
- Alignments
- Profiles
- Soil borings
- Intersections
- Drainage elements
- Subsurface drains
- Foundation analysis
- Contaminated soils – remediation

Noise walls
- Alignments
- Profiles
- Land use maps
- Traffic volumes
- LOS
- Traffic classifications
- Utilities
- R/W impacts
- Municipal consent
- Historic property review
- Drainage elements
- Airports
- Aesthetics
- Wall type
- Foundation analysis

Maintenance
- Maintenance elements/issues
- Drain tile
- Anti-icing
- HOV bypass
- Snow storage
- Snow control

Transportation Management System
- Traffic Management System (TMS), Intelligent Transportation System (ITS), Intelligent Vehicle Highway System (IVHS) elements

Construction
- Innovative construction services
- Detours
- Staking
- Extraordinary enforcement
- Extraordinary public relations
- Seasonal impacts
- Vibration and noise

Surveys
- Survey

Tips

This method is only useful when the project team members think about every item on the list as a jumping off point for further risks analysis. Each item must be thought about in detail to ensure that the risk is truly a project risk. The thought process should be documented in order to build on this in future discussions of the risks.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3.

I2.4 Assumption Analysis

During the course of developing a design or creating an estimate, many assumptions must be made. This is particularly true in the early phases of project development. Assumptions can carry risks. An analysis of each assumption for its possible impacts on cost and schedule can be essential to creating an accurate project estimate.

What is it?

Assumption analysis is taking a close look at the assumptions in the cost and schedule estimates, documenting these assumptions as potential risks, and analyzing each assumption. Each assumption should be examined for validity, accuracy, consistency, completeness, and context. If uncertainties in these assumptions are identified, then risks should be developed surrounding these uncertainties.

Why use it?

In most cases, assumptions possess substantial risks. The documentation of these assumptions and the potential items that may cause these assumptions to change will assist in the risk identification process.

What does it do?

Documenting assumptions and their associated risks can help to identify the consequences of assumptions buried within the cost or schedule estimates. The team can identify these risks and even generate additional uncertainties that may stem from assumptions.

When to use it?

Use assumption analysis during the risk identification process. Risk identification can occur at a set time or anytime the project development team makes an assumption that can significantly impact the project cost or schedule estimates. While ideally these assumptions should be analyzed as soon as the assumptions are identified, it is more efficient to make the analysis during the risk analysis process after a number of assumptions have been collected and documented. This will allow a larger group to participate in the analysis and also may lead to better brainstorming of potential risks stemming from those assumptions.

How to use it?

Assumption analysis should be used to bring assumptions to the attention of a larger group in order to analyze each assumption and identify the potential risks that results from the assumption. Moreover, assumption analysis can be used as a way to brainstorm additional risks.

Example

The following is a list of assumptions that may generate potential risks, taken from the WSDOT "Basis of Estimate" document (Washington State DOT 2008).

- Construction funding will occur all at once
- Will need to replace bridge SR###/Bridge No.
- Stormwater retrofit of ######
- Environmental regulations don't change
- Today's dollars, unknown inflation rate and energy cost
- Midpoint of construction will not change
- Undeveloped properties remain undeveloped. At this time there are no known proposed developments on the properties, although some of the properties are for sale.
- There are good soils
- Captured major bid items
- Traffic control cost based on past experience and region philosophy doesn't change
- Right of way is not needed to relocate the gas line

Tips

Identification of assumptions can come from many sources. Planners and designers often document assumptions in their designs before they complete their full technical analyses. When compiling conceptual estimates without significant design information, estimators often document assumptions regarding project scope or costs. Be certain to review these documented assumptions.

However, many assumptions often go undocumented and can only be found through direct discussions with project team members (e.g., planners, designers, estimators, etc.). When identifying risks, be certain to contact the team members directly and ask if they make assumptions in their plans, designs, or estimates that might result in cost or schedule increases if the assumptions prove to be incorrect.

Resources

National Highway Institute (2006). Risk Management Instructor Guide, NHI Course 134065, National Highway Institute, Washington, DC.

Washington State DOT (2008). *Basis of Estimate* http://www.wsdot.wa.gov/NR/rdonlyres/76111703-D435-4CB7-A965-1297F7F00599/24275/BasisofEstimateFormAug2006rev.doc (Viewed June 1, 2008).

I2.5 Expert Interviews

Expert interviews serve to provide the project team and risk analysts with additional input from expert sources. Using their insights and expertise, experts may identify risks that are not apparent to the project team. They also can assist with subsequent risk assessments.

What is it?

Expert interviews are simply the solicitation of expert opinions. Interview questions are generally open ended, and the discussion can cover all areas that the expert may be knowledgeable about. Documentation of the discussion is important, as the discussion may reveal a number of different risks, and the expert may provide information beyond the identification of the risk, such as probability and impact. The WSDOT has important guidelines (Washington State 2008) they follow when selecting a subject matter expert:

> Subject matter experts (SMEs) are people who are qualified in their fields to make reasonable subjective assessments on project costs and schedules without bias; subject matter experts provide relevant technical, management, and political insight to the project and critically examine the project estimate to validate cost and quantity components. Subject matter experts use their real-world construction, risk analysis, and cost estimating knowledge to identify and quantify uncertainties. Subject matter experts must not have personal agendas and must be willing to work as part of a team. Subject matter experts can be internal or external and can be local or national.

Why use it?

Expert interviews provide additional and informed minds to aid in generating a comprehensive list of risks. Experts provide knowledge and experience in specific fields that may not be available to the project team.

What does it do?

The expert interviews provide well developed and informed consideration of risks. The interviews provide for a way to begin describing, whether qualitatively or quantitatively, the probability and impact of risks.

When to use it?

Subject matter experts should be brought in early in the process, but generally not until sufficient scope has been defined to warrant their expert opinions. Experts can be utilized during risk identification, risk assessment, planning, or any other point where the project team would appreciate additional opinions.

How to use it?

During the expert interviews allow the expert to speak freely and try to draw as much information for documentation as possible. It is best if the experts remain on-call to clarify risks that have been identified earlier or to help identify new risks.

Tips

While reviewing the expert interview documentation, make sure not to include any of the team's own biases. Let the information speak for itself, and if necessary, talk to the expert about his or her opinion and clarify any confusion.

Resources

National Highway Institute (2006). Risk Management Instructor Guide, NHI Course 134065, National Highway Institute, Washington, DC.

Washington State DOT (2008). A Policy for Cost Risk Assessment, http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment (Viewed June 1, 2008).

I2.6 Crawford Slip Method

The Crawford Slip method allows for individuals to identify risks in a group setting without influence from other team members. The method can be helpful for eliciting risks from an entire group without one group member dominating. However, it can provide an overwhelming number of risks to analyze.

What is it?

The Crawford Slip is a rapid, independent brainstorming session. A facilitator begins by introducing the process to the team members. For 10 minutes, each participant *writes down one risk each minute.* After each minute, the current risk is set aside and each member starts a new one. This forces each participant to write down one, and only one, risk during each minute. At the end of the ten minutes, the facilitator collects all of the risks. The facilitator later collates and organizes the risks, eliminating duplicates. This can be done by the facilitator alone or in a group setting.

Why use it?

The Crawford Slip solicits each participant's opinion of project risks independently. The benefit of this is that each mind is working independently to identify risks, rather than being guided by the opinion of the group.

What does it do?

The Crawford Slip can generate a large number of potential risks. With a group of 10 participants, within 10 minutes the group will have generated 100 risks, excluding duplicates. This creates a significant amount of information for the facilitator to sift through to identify risks.

When to use it?

Use the Crawford Slip method when the project team needs to generate risks in a short period of time. The process will create a large number of risks, but it may not be as thorough as some of the other risk identification tools. The risks identified in this process can later be examined in more detail to identify further potential risks.

How to use it?

Use the Crawford Slip as a starting point for risk identification. The results of the Crawford Slip can be presented to the group afterward to clarify the intention of the risk identifiers, as well as to evaluate each risk as a group.

Tips

Since the Crawford Slip method generates a large number of risks, allow for time to collate like risks. This can be done independently by the facilitator or it can be done in a group setting.

Do not rely solely on the Crawford Slip for risk identification. While it is a powerful tool, it cannot be comprehensive of risks on the project because of the nature in which risks are identified.

Resources

National Highway Institute (2006). *Risk Management Instructor Guide,* NHI Course 134065, National Highway Institute, Washington, DC.

12.7 SWOT Analysis

SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. The tool is often used for strategic planning purposes, but it is helpful in risk identification. The tool is used to solicit potential risks (threats or opportunities) that a project may need to face.

What is it?

SWOT analysis is a listing of all strengths, weaknesses, opportunities, and threats as identified by the project team or a panel of professionals. The process can be viewed as brainstorming within each of the categories. Each factor is examined in turn and all discussion is documented. The final step is to use the identified strengths, weaknesses, opportunities, and threats to identify risks within the project.

Why do we use it?

The SWOT analysis generates a great deal of information. This can be useful in coming up with risks that would not necessarily be identified in traditional brainstorming. The process can also examine internal and external risks separately. This can be useful in establishing a risk breakdown structure.

What does it do?

SWOT analysis, when used with other risk identification techniques, provides a comprehensive picture of potential risks. The tool identifies risks with potential, as well as the greatest source for threats or opportunities (internal or external). This can be used for more effective risk planning.

When to use it?

SWOT analysis should be used early in risk identification. The SWOT analysis can be used to begin brainstorming, but can also be used to supplement existing risk identification.

How to use it?

SWOT analysis is used as a part of risk planning, but the items identified in the SWOT analysis can be used as discussion points for possible risks.

Example

Sample SWOT Analysis from American Association of Motor Vehicle Administrators:

AMERICAN ASSOCIATION OF MOTOR VEHICLE ADMINISTRATORS

Strategic Plan for 2006 – 2009

THE ENVIRONMENTAL CONTEXT: SWOT Analysis

Strengths:

1. AAMVA has represented the motor vehicle community since 1933, is a recognized national authority, is a dynamic, progressive association and has an enhanced public profile.
2. The association provides the mechanism for uniformity, policies, procedures, best practices, training and model laws for its membership.
3. The association's members and staff are experts in motor vehicle, driver licensing administration and enforcement issues which are essential in developing standards.
4. We have committed and active volunteers.
5. AAMVA offers several methods for information exchange and has a secure private network that connects all U.S./Canada jurisdictions.
6. AAMVA has a positive and respected image on Capitol Hill and among its member jurisdictions and federal and law enforcement partners.
7. The Association and its jurisdictional and associate members continue to build a strong alliance through grassroots efforts with state and Federal legislators and key Federal agencies such as Department of Transportation, Department of Justice and Department of Homeland Security
8. AAMVA has strong leadership at the staff and Board of Director levels.
9. AAMVA is a well-managed and fiscally sound organization.
10. AAMVA Headquarters projects a positive image of the association.
11. AAMVA is a flexible and dynamic organization.
12. AAMVA's associate members offer solutions to improve our business processes.

Weaknesses:

1. Many jurisdictions delay implementation of AAMVA standards, programs and systems.
2. Outside factors and limited resources impact delivery of programs and services
3. The association is dependent upon a small, diminishing, volunteer workforce.
4. Many AAMVA members have limited access to and influence upon governors, state legislators, the National Governor's Association (NGA), the National Conference of State Legislatures (NCSL) and members of Congress.
5. There is a lack of participation in voluntary programs that are funded with federal dollars.
6. AAMVA is too dependent upon CDLIS revenue.
7. Associate members' interests sometimes conflict with AAMVA's.
8. Politics

Opportunities:

1. The constant, urgent and increasing demand for secure identification presents AAMVA -- through its members – an opportunity to take an active role to address these issues.
2. There is a growing need for training on AAMVA-related programs for members and non- members.
3. There is a need for international standards and uniformity within jurisdictions.
4. AAMVA can work with the groups and agencies that produce other identification documents in order to achieve a secure North American identification system.
5. Use of AAMVA's name recognition to promote products, services and new memberships resulting in increased revenue.
6. Recent natural disasters provide public awareness on the necessity of tracking vehicle history information through NMVTIS and exchanging motor vehicle records between states.
7. There is an opportunity to analyze and understand jurisdictional issues related to the implementation of AAMVA standards, programs and systems and provide solutions.
8. The new committee structure creates new opportunities to increase volunteerism and committee deliverables.
9. REAL ID creates an opportunity to implement an all-driver pointer system to enhance highway safety and administrative efficiency.
10. Build and maintain relationships with other associations/organizations to promote the membership's interests.

Threats:

1. Stock market fluctuations result in uncertain returns on AAMVA's long-term investments.
2. Increased demands on AAMVA (i.e. single-issue focus) can overextend resources that can result in revenue and commitment losses needed for other issues.
3. Loss of member and jurisdiction commitment and/or funds could weaken the association.
4. Absence of federal funding for the implementation of NMVTIS is threatening AAMVA's financial stability and/or credibility.
5. Lawsuits/litigation arising out of IRP/other activities could adversely affect the association's fiscal soundness and insurability.
6. Power grid failures, SPAM and computer viruses, if they become more prevalent, could impact on the delivery of AAMVA services (CDLIS, Clearinghouse, on-line communication, etc.).
7. AAMVA's reputation can be adversely impacted by missteps.
8. Lack of a complete disaster recovery plan.
9. Ability to recruit qualified technical staff.
10. There has been a steady reduction in customer support from AAMVA's network services provider.

Figure I2.7-1. SWOT analysis example.

Resources

National Highway Institute (2006). *Risk Management Instructor Guide,* NHI Course 134065, National Highway Institute, Washington, DC.

R1.1 Recognition of Complexity

Project complexity significantly influences the methods and tools an estimator uses to prepare and manage project cost estimates. Project complexity also can be used to identify proper risk management techniques. Mn/DOT is using this tool to create a standard definition for project complexity in order to communicate the issue to project team members and stakeholders.

What is it?

Recognition of complexity, through a formal definition, results in a classification of project complexity that can be applied to all projects. The tool use three definitions for project complexity: 1) minor projects; 2) moderately complex projects; and 3) major projects. These complexity definitions drive the choice of many other tools. For example, the Level I through Level III risk analysis correlate directly to the three levels of project complexity.

Complexity definitions can include a definition of project type (such as new or reconstruction), project setting (rural or urban), project location, available level of design detail, and other factors. The goal is to explicitly define project complexity through the use of this classification system.

Why do we use it?

Providing a standard definition of project complexity promotes transparent communication of a project's characteristics. The complexity classification can be used to assist in selecting appropriate estimating methods and tools or to invoke specific cost estimating management or risk management procedures. It helps to ensure that projects of varying complexity levels are subject to appropriate reviews and attention. This allows for a common language for communication regarding project complexity.

What does it do?

This tool defines complexity based on specific criteria. The definitions help classify projects according to their level of complexity, which in turn helps to identify the appropriate strategies, methods, and tools for cost estimating, cost management, and risk management.

When to use it?

A project's level of complexity must be established early in the project development process and revisited as design develops or if any major changes in scope are realized. Understanding project complexity is a key element of the approach for preparing estimates during all phases of project development.

How to use it?

Refer to the Tables R1.1.1 through R1.1.3. First, review the project using Table R1.1.1 for minor projects. If the project meets all of these criteria, it can be considered minor. If the project exceeds one or more criteria, it cannot be considered minor and should be reviewed next using Table R1.1.2 for moderately complex projects. If the project meets all of these criteria, it can be considered moderately complex. If the project exceeds one or more criteria, it should be considered major. Table R1.1.3 can be reviewed to verify that the project should be classified as major.

Tips

Early in the project development process, use the complexity definitions to establish a project's level of complexity. The assigned complexity serves as a basis to select the methods and tools for project cost estimating and cost management. Reassess project complexity at key milestones. If the project becomes more or less complex as it proceeds through development, the definitions can be used ensure that appropriate resources are employed.

Examples

Mn/DOT will be using a set of complexity definitions developed by the Pennsylvania Department of Transportation (PADOT) and cited in *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction.* Tables R1.1.1 through R1.1.3 should be used for defining project complexity.

Resources

PennDOT has established a system to define the level of complexity. See PennDOT's Design Manual: Part 1A: Transportation Engineering Procedures, Publication 10A, available from PennDOT.

R3.1 Risk Management Plan

A formal risk management plan is a detailed plan of action for the management of risk. Risk management planning involves the thoughtful development, implementation, and monitoring of appropriate risk response strategies. It is the process to develop and document an organized, comprehensive, and interactive risk management strategy; determine the methods to be used to execute a risk management strategy; and plan for adequate resources.

Table R1.1.1. Noncomplex (minor) project attributes (*NCHRP Report 574* and PennDOT).

	Noncomplex (MINOR) Projects
Roadway	• Maintenance betterment projects • Overlay projects, simple widening without right-of-way (or very minimum right-of-way take) little or no utility coordination • Noncomplex enhancement projects without new bridges (e.g. bike trails)
Traffic Control	• Single traffic control/management projects • Non-ITS but minor safety improvements
Structures	• Bridge resurfacing or repairs that do not require re-analysis of bridge capacity • Pipes, box culverts or minor culvert replacements where design can be picked directly from design manual or standards or using simple software where detailed interpretation is not necessary • Sign structures for which the design can be picked up directly from either the standards or using design computer software • Noise walls or retaining walls for which the design can be picked up directly from either the standards or using design computer software
Right-of-Way	• Involve minor right-of-way acquisitions with no displacements, maintain existing access control
Utilities	• Minimal, if any
Environmental	• Categorical Exclusion (Level 1A or 1B) • Minimum interaction with environmental and permitting agencies • Do not involve cultural resources, hazardous waste, Section 4(f) evaluations or substantial flood plain encroachments
Stakeholders	• No public controversy

The risk management plan may be specific in some areas and general in others. The key to this tool is its scalability. Every project should have a formal risk management plan, but the level of detail varies with the project complexity.

What is it?

The formal risk management plan is a document that gives a summary of the project and outlines the different steps of the risk management process and how the agency is approaching them. The risk management plan employed will vary based on the complexity of the project, but most projects should include an outline similar to the following:

1. Introduction
2. Summary
3. Definitions
4. Organization and roles
5. Risk management strategy and approach
6. Risk identification
7. Risk assessment and analysis
8. Risk mitigation and planning
9. Risk allocation
10. Risk monitoring and control

Why use it?

A risk management plan is a formal document that explains how an agency manages risk. It provides guidance and requirements, and serves as a communication tool for those who wish to be informed of a project's risk management approach. The plan formalizes the ideas presented during the risk management process and may clarify some of the assumptions the project team has regarding the risk management process.

What does it do?

The risk management plan provides specific guidance for the project team members in all steps of the risk management process. The risk management plan documents the processes to use throughout the project for identifying, assessing, and managing risk.

When to use it?

The formal plan should be developed during the Planning and Scoping Process and updated during subsequent project development phases.

Table R1.1.2. Moderately complex project attributes (*NCHRP Report 574* and PennDOT).

	Moderately Complex Projects
Roadway	• 3R and 4R projects that do not add capacity • Minor roadway relocations • Certain complex (nontrail enhancements) projects • Slides, subsidence
Traffic Control	• Non-ITS but major safety improvements • Interconnected traffic control/management projects
Structures	• Noncomplex (straight geometry with minimal skew; designs using AASHTO description factors; minimal seismic analysis; footings on rock or conventional piles and abutments) bridge replacements with minor (<610m [2,000 ft]) roadway approach work. • Bridge rehabilitation that requires re-analysis of bridge capacity. • Bridge mounted signs. • Tie back walls. • Noise walls. • Proprietary/nonproprietary walls.
Right-of-Way	• Right-of-way plans needed with less than 20 moderate to significant claims and very few relocations or displacements
Utilities	• Some utility relocations, most of it prior to construction, but no major utility relocations
Environmental	• Categorical Exclusion Level 2 or mitigated Environmental Assessment projects. • Cultural resources (e.g., historical, archeological, etc.). • Wetland mitigation • Water and air pollution mitigation • Endangered species
Stakeholders	• Involvement of public and public officials is moderate due to noncontroversial project type • General communication about project progress is required

How to use it?

The risk management plan is developed early in the project by collaboration with as many members of the team as possible. It should be consulted and revised throughout the project development process to guide the project through to completion.

Example

Caltrans has developed a strong risk management plan template (Figure R3.1-1) that it uses on its projects to define how the risk management process will be carried out. This template follows (Figure R3.1-1) and is available at: http://www.dot.ca.gov/hq/projmgmt/documents/prmhb/risk_management_plan_template_sample_20070502.doc.

Tips

Use a risk management plan on every project no matter the size. The detail included in the plan can be minimized, but the value that the formalized plan provides is important for successful risk management.

Resources

http://www.dot.ca.gov/hq/projmgmt/documents/prmhb/risk_management_plan_template_sample_20070502.doc.

Guide to Risk Assessment and Allocation for Highway Construction Management, October 2006.

R3.2 Contingency—Percentage

On noncomplex projects utilizing a Level I risk analysis, add a contingency as a percentage of the base estimate to arrive at the Total Project Cost Estimate. While estimators must include a contingency with each estimate, noncomplex projects do not warrant a detailed risk analysis and contingency development. However, estimators should clearly document the contingency percentage. Base the documentation on historic ranges of contingency and a list of risks for the particular project. As the project proceeds with development, the

Table R1.1.3. Highly Complex (major) Project Attributes (Adapted from *NCHRP Report 574* and PennDOT).

Most Complex (MAJOR) Projects	
Roadway	• New highways; major relocations • New interchanges • Capacity adding/major widening • Major reconstruction (4R; 3R with multi-phase traffic control) • Congestion Management Studies are required
Traffic Control	• Multi-phased traffic control for highway or bridge construction that would mandate CPM during construction • Major ITS (electronic surveillance, linkages) corridor project
Structures	• Replacement, new or rehabilitation of: - Unusual (nonconventional like segmental, cable stayed, major arches or trusses, steel box girders, movable bridges, etc.) - Complex [sharp skewed (less than 70 degree) superstructure, nonconventional piers or abutments, horizontally curved girders, three dimensional structural analysis, nonconventional piles or caisson foundations, complex seismic analysis, etc.] - Major (bridge cost of $5 million or more, federal definition) - Unusual formations (e.g., caissons, uncommon piles, mines, etc.)
Right-of-Way	• Right-of-way plans are needed and numerous relocations of residences or displacement of commercial and/or industrial properties are required. A few to over 20 property owners are involved. Major involvement of environmental clean-up. Before and after analysis
Utilities	• Major utility (transmission lines, substations) relocations or heavy multi-utility coordination is involved
Environmental	• Environmental Impact Studies are required or complex Environmental Assessment without mitigated finding of no significant impact • Studies of multiple alternatives • Continued public and elected officials involvement in analyzing and selecting alternates • Other agencies (e.g., FHWA, Corps of Engineers, etc.) are heavily involved to protect air; water; games; fish, threatened and endangered species; cultural resources (historical, archaeological, parks, wetlands, etc), etc.
Stakeholders	• Controversial (lack of consensus) and high profile projects (e.g., fast track design/construction, high public impact, high interaction of elected officials, etc.) • Major coordination among numerous stakeholders is required

estimated contingency percentage reduces because the level of uncertainly associated with the project also reduces. If extraordinary conditions exist that call for higher contingencies than what historically has been used, document the basis and rationale in the estimate.

What is it?

Recognizing that cost estimation is inherently difficult because estimators are trying to predict the future, it is prudent to provide contingency in all estimates, particularly planning, programming and preliminary design estimates. The contingency amount can be set as a percentage of the project's base cost estimate with the percentage being established by analysis of historical cost experience from past projects.

Why use it?

At any stage in the development of a project, cost estimates will be composed of three components for which there are differing amounts of information: 1) known and quantifiable costs; 2) known but not quantified costs; and 3) costs that are unknown and therefore cannot be quantified in advance. The base estimate includes the known and quantifiable costs. The contingency percentage is intended to include both the known but not quantified and the unknown costs.

What does it do?

A contingency percentage in an estimate is meant to provide funds for cost growth resulting from necessary but

Risk Management Plan

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 work plan
- 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.

Figure R3.1-1. Caltrans risk management plan template.

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). (Appendix D, Project Risk Management Handbook).

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 (Appendix B, Project Risk Management Handbook) and Sample Risk List. (Appendix C, Project Risk Management Handbook) will be 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.

Figure R3.1-1. **(*Continued*).**

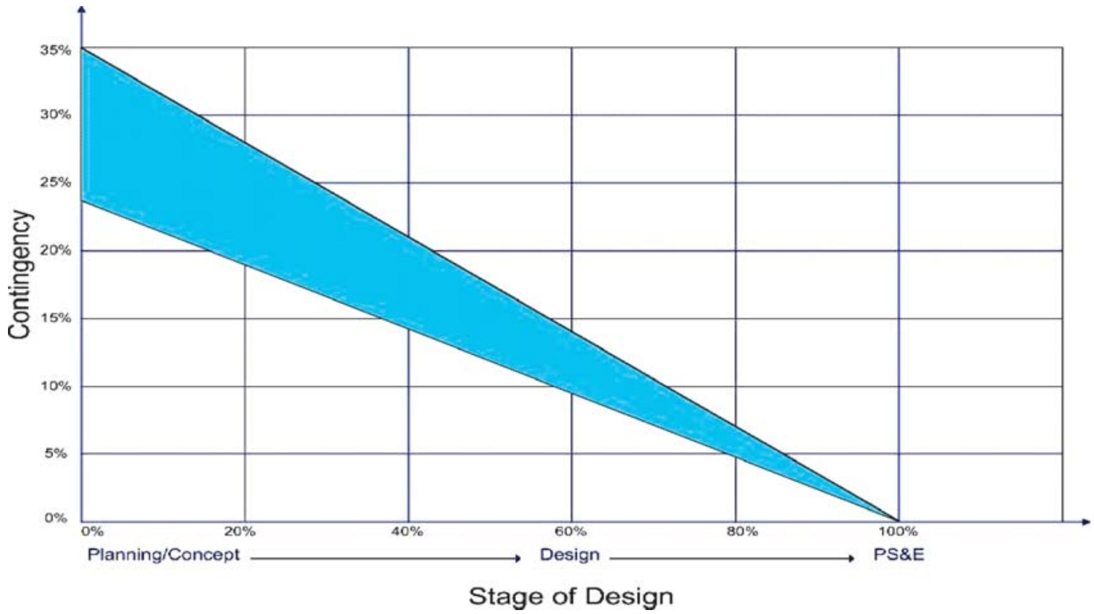


Figure R3.3-2. Ohio DOT design completion contingency guidelines for cost estimating of major projects.

unforeseeable items, such as project scope changes, underestimation of real project costs, or errors in projecting the rate of inflation. Increases in the prices for construction services due to inflation are not to be considered covered by the contingency amount. Inflation should be handled by applying an appropriate inflation rate to the calculated project cost. However, some agencies include a contingency for errors in calculating the rate of inflation, which can be included in the contingency percentage.

When to use it?

The contingency percentage added to an estimate is a valid means of reflecting the uncertainties that remain in the project as design progresses. Include a contingency percentage in every project estimate from the earliest planning stage of project development to the final PS&E; however, as shown in Figure R3.3-2 and Table R3.3.1, the magnitude of the contingency decreases as the scope is defined and the design progresses.

How to use it?

Contingency percentage is the most prevalent approach that project teams use when resources for more sophisticated risk and contingency analysis are limited or unavailable. In its simplest form, a reference table or graph is provided to the project teams for estimating contingency as a percentage of the base estimate. Based on the project's level of design completion or other factors such as development milestones, the estimator or the project manager determines the corresponding contingency percentage to include in the cost estimate.

Example

Figure R3.3-2 and Table R3.3.1 illustrate the contingency percentages used by the Ohio and California state DOTs, respectively.

Tips

When using a contingency percentage, two steps are needed to make the process work effectively:

1) Define the purpose of the contingency amount carefully. Estimators and management must understand that the

Table R3.3.1. Caltrans contingency percentages.

Design/Estimation Milestone	Percent Contingency
Project Feasibility Cost Estimate	30% to 50%
Project Study Report Cost Estimate	25%
Draft Project Report Cost Estimate	20%
Project Report Cost Estimate	15%
Preliminary Engineer's Cost Estimate	10%
Final Engineer's Cost Estimate	5% or less

Adapted from Chapter 20 of the Caltrans Project Development Procedures Manual (available online at http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm).

contingency is intended to account for specific unforeseen, unexpected, unidentified, or undefined costs. The project risks that cause the occurrence of these costs must be delineated in the state highway agency's estimation manual with the percentages.

2) Establish contingency percentages on actual experience (i.e., historical data). It is important for both estimators and management to know the level of accuracy achieved with the prescribed contingency.

Resources

FHWA (2004). "Contingency Fund Management for Major Projects." www.fhwa.dot.gov/programadmin/mega/contingency.htm.

FHWA (2004). "Major Project Program Cost Estimating Guidance." www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Caltrans *Project Development Procedures Manual,* Chapter 20 www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm.

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

Caltrans (1998). *State Administrative Manual,* Chapter 6000, Section 6854: CONSTRUCTION. http://sam.dgs.ca.gov/TOC/6000/6854.htm.

Ohio DOT (2007). Ohio Procedure for Budget Estimating. www.dot.state.oh.us/contract/estimating/default.htm.

U.S. Army Corps of Engineers. "Military Program-Specific Information—REF8011G," http://bp.usace.army.mil/robo/projects/pmbp_manual/PMBP_Manual/REF8011G.htm.

Uppal, Kul B. (Ed.) (2005). *Professional Practice Guide #8: Contingency* (CD), Association for the Advancement of Cost Engineering International(AACEI). www.aacei.org/technical/ppg.shtml.

R3.3 Contingency—Identified

On moderately complex projects utilizing a Level II risk analysis, add a contingency based on identified line items to the base estimate to arrive at the Total Project Cost Estimate. This tool should start with the percentage contingency (Tool R3.2) and then add any additional identified contingency items to arrive at the final contingency. The estimator must use his or her judgment to determine if these identified contingency items can be captured within the standard percentage contingency or if they provide justification for the specific project contingency to exceed the standard percentage contingency.

What is it?

This tool creates a process whereby the contingency amount included in an estimate is set on the basis of identified risks and the probability of their occurrence. This contingency-identified tool should ideally be used in conjunction with a comprehensive risk management process. When used in conjunction with a qualitative risk assessment or expected values for the risk items, the contingency is set using the cost estimator's judgment with the information generated from the risk identification and analysis process and in accordance with SHA policy. The specific identified contingency items can then be used for contingency management and resolution throughout the project development process. In other words, as the risks are realized or resolved, the identified contingency amount can be added to the base estimate or removed from the Total Project Cost Estimate, respectively.

Why use it?

The identification of project risks gives the estimator a much firmer basis for developing a reliable contingency amount than the typical top-down assignment of a percentage based on the estimated direct cost of the project. Additionally it provides a sound contingency resolution process to manage the total project cost.

What does it do?

Because risks are specifically delineated as a project is developed, specific strategies can be implemented to mitigate, transfer, or avoid significant risks. In addition, with the risks identified and quantified, control and tracking procedures can be implemented to monitor risk items on an ongoing basis.

When to use it?

The tool should be employed early and risks tracked throughout the project development process. Projects of an unusual or complex nature require a more in-depth evaluation of potential risks and their contributions to estimated cost. The opportunities to expand the identification and quantification of risks should be pursued as design progresses and more is known about potential risk factors.

How to use it?

Identified contingency can be used as an overarching principle of contingency estimation. At every stage of the project, risks must be identified and contingency extracted. This extraction leads to greater understanding of the cost and project uncertainty.

When choosing the appropriate contingency percentage in a Type II risk analysis, consult the range of contingency from the percentage contingency tool and then review the top 20 percent of the prioritized risks to ensure that the contingency is adequate. Use an expected value estimate for estimating the top-ranked risks. Calculate the expected value by multiplying the product of the impact should the risk occur by the probability of the occurrence (e.g., $1,000,000 × 0.50 = $500,000). Use additional contingency if warranted by the expected value analysis.

Example

The Cost Estimating Validation Procedure (CEVP®) developed by the WSDOT is a peer-level review on the scope, schedule, and cost estimate for transportation projects throughout the state of Washington. The objective of the CEVP process is to evaluate the quality and completeness, including anticipated uncertainty and variability, of the projected cost and schedule.

The outcomes of the CEVP process include the following:

- An estimate validation statement in the form of a CEVP Project Summary Sheet that more accurately represents the project cost ranges and the uncertainty involved.
- Findings and recommendations that allow WSDOT project teams and senior management to better understand the basis, content, and variability of cost estimates.
- Identification and characterization of the high-risk project elements, which will enable project teams to address appropriate mitigation strategies.

The Caltrans Risk Management Handbook calls for a quantitative assessment of project risk items representing the highest degree of exposure. This quantification is important for adjusting/updating the contingency amount to be included in the project estimate (Caltrans 2007, www.dot.ca.gov/hq/projmgmt/documents/prmhb/project_risk_management_handbook.pdf).

Tips

To successfully confront the effects of project risk, risk analysis must be applied with a broad view of risk; concentration on the technical risks can lead to oversights in other project dimensions. The analysis should consider local authority/agency impacts, industry and market risks, elements of political uncertainty, and public and/or permit approval processes that might impact timing.

Scope changes must also be considered from a broad perspective. Identification of risk goes beyond the internal "project risks," such as pile driving depth, and includes exogenous factors, such as market conditions, business environment, global construction activities/demand, macroeconomic environment, and weather. Namely, any major uncertainties that might influence the primary project outcomes of cost, schedule, or quality should be included.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

Washington State Department of Transportation (2008). *A Policy for Cost Risk Assessment* http://www.wsdot.wa.gov/NR/rdonlyres/EF230F3B-1FC1-4A2A-9FC9-B66CF0300E1E/0/PolicyforCostRiskAssessment20050805.pdf (Viewed June 1, 2008).

R3.4 Estimate Ranges—Three-Point Estimates

Expressing a cost estimate in terms of an estimate range transparently communicates the uncertainty associated with an estimate. The generation of a range can be as simple as applying a historic plus-minus factor to estimated cost (i.e., -10 percent to +20 percent). Alternatively, an estimate range may be generated through sophisticated probabilistic models or simply as a three-point estimate ranging from an optimistic amount to a pessimistic amount and a most likely amount in between.

What is it?

A project cost estimate is a prediction of the quantities, cost, and/or price of resources required by the scope of an activity or project. As a prediction, an estimate must address risks and uncertainties. Consequently, engineers realize that any estimate can lead to a potential range of final costs. When appropriate, the estimate itself can be expressed as a cost range. Communication of the estimate as a range is simply a statement of project cost variability.

Why use it?

Communicating the uncertainty involved in an estimate helps to ensure that decisions based upon the estimate are appropriate considering its precision. Estimate ranges better convey the uncertain nature of project costs, particularly in the conceptual phase of project development and even during later project development phases.

Currently, most project cost estimates are conveyed in terms of a single point value. The use of a point estimate early in the project development process can lead to a false sense of precision and accuracy as even the best engineers cannot predict all future events that can and will impact a project's cost. Through use of an estimate range, the agency can convey the certainty and uncertainty inherent in the project and educate the stakeholders about cost variability. This is also helpful within the agency to demonstrate the certainty and uncertainty about the project to other personnel who may not be intimately familiar with the project.

What does it do?

The communication of a range of values representing the possible array of ultimate project costs creates a better understanding of estimate precision. The optimistic and pessimistic values at the ends of the range do not necessarily represent the very least or the very most that the project will cost, but typically the most probable range of project costs. The size of the range will be determined by the identified uncertainties. The interpretation and use of the range depends on how aggressive the agency is with the results.

When to use it?

Ranges may be considered throughout project development, but should be utilized on projects in earlier stages of development to communicate the level of knowns and unknowns (risks) about the project.

How to use it?

Federal planning regulations indicate that a three-point estimate or cost ranges/cost bands in the outer years of the metropolitan transportation plan are acceptable. Therefore, single point estimates should be avoided before sufficient detail about the project is known, when it is unrealistic to prepare a reasonably accurate single-point estimate. A three-point estimate is prepared at any point during this period by estimating the lowest possible, the most likely, and the highest probable cost estimate based on a combination of available project data and informed judgment.

Example

Caltrans uses three-point estimates for some elements of project costs and is planning to make wider use of this technique (Figure R3.4-1). Although the math may appear complex at first glance, it is easy to implement with a simple spreadsheet. The three point estimating process uses these steps:

- Have subject matter experts develop three estimates for each item of work:
  - An optimistic estimate (o): the lowest credible cost assuming that everything goes right.
  - A most-likely estimate (m): the expert's best guess of the cost.
  - A pessimistic estimate (p): the highest credible cost, assuming that virtually everything goes wrong.
- The average cost of the item is (o+4m+p)/6. The average is always greater than the most likely estimate. This is because there is a finite lowest-possible cost. Even in the most optimistic situation, the work package will have a cost that is greater than zero. At the other end of the scale, there is no highest-possible cost. It is always possible to spend more money.

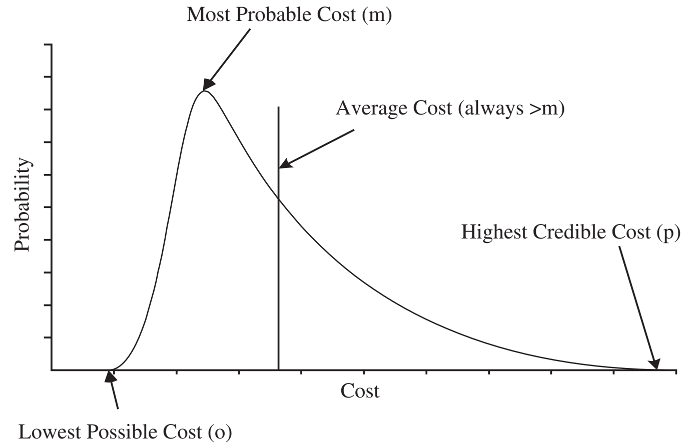


Figure R3.4-1. Caltrans three-point estimate to generate estimate range.

Tips

While estimate ranges transparently convey the uncertainty involved in a project, they can be misunderstood. The range theoretically shows the highest probable cost for a project. If people focus on the high end of the range, the project can be slowed or stopped. The range should be used as part of a comprehensive risk management plan. If the risks and uncertainties that are driving the range can be understood, they can likely be mitigated and the project can be completed at the lowest possible cost.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities*, 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

R3.5 Estimate Ranges—Monte Carlo Analysis

Expressing a cost estimate in terms of an estimate range transparently communicates the uncertainty associated with an estimate. Monte Carlo analysis is part of a sophisticated probabilistic model process that can be used to generate a range estimate through simulation methods. The use of Monte Carlo analysis is typically facilitated by experts in this field who work closely with estimators, project team members, and subject matter experts.

What is it?

Monte Carlo analysis is a computerized probabilistic simulation modeling technique that uses random number generators to draw samples from probability distributions. Monte Carlo analysis uses repetitive trials to generate overall probability distributions for project cost or schedule. It relies upon multiple inputs of probabilities for risk events and for uncertainty in cost and duration of line items. A trial consists of the simulation engine selecting a value for each of the line items based on their probabilities and generating a final estimate based on that trial. This process is repeated many times (usually several thousand) to generate a distribution for the total cost or schedule.

Why use it?

Monte Carlo analysis has many advantages. It can determine risk effects for cost and schedule models that are too complex for common analytical methods. The output of a Monte Carlo simulation can provide a graphical distribution of project cost or schedule. This distribution can be used to generate an estimate range. It also can be used to calculate a contingency. Monte Carlo analysis can explicitly incorporate the risk knowledge and judgment of the estimators, project team, and subject matter experts for both cost and schedule risk events. The technique can reveal, through sensitivity analysis, the impact of specific risk events on the project cost and schedule.

What does it do?

The tool allows the project team to visualize the uncertainty relating to the total project cost and schedule. Monte Carlo analysis can be used to determine project cost and schedule ranges and the most likely values for each. Figure R3.5-1 shows typical probability outputs from a Monte Carlo analysis. The histogram is useful for understanding the mean and dispersion of the results. The cumulative chart is useful for determining project budgets and contingency values at specific levels of certainty or confidence. In addition to graphically conveying information, Monte Carlo analyses produce numerical values for common statistical parameters, such as the mean, standard deviation, distribution range, and skewness.

When to use it?

Monte Carlo analysis is applied on complex projects and is used as the basis for a Type III risk analysis. The tool requires that the project team be familiar with all project risks and be able to quantitatively describe the risks. Application of Monte Carlo analysis requires knowledge and training for successful implementation. Input to Monte Carlo analysis requires the user to know and specify probability distribution information, mean, standard deviation, and distribution shape. While complex and requiring significant modeling experience, Monte Carlo analyses are the most common tool for quantitative risk analysis because they provide detailed, illustrative information about risk impacts on the project cost and schedule.

How to use it?

Monte Carlo analysis can be used to generate a number of different decision-making tools for the project team. In order to produce these tools, the input must be assessed to accurately model project risks. Each risk can be given a different

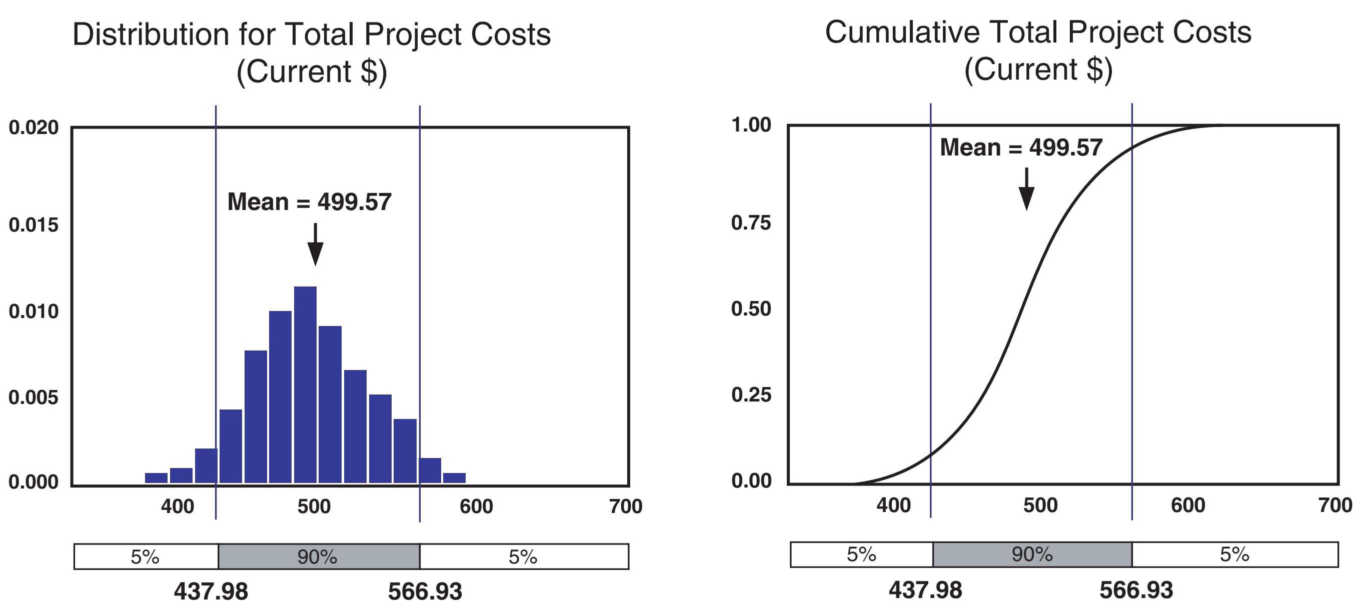


Figure R3.5-1. Typical Monte Carlo output for total costs.

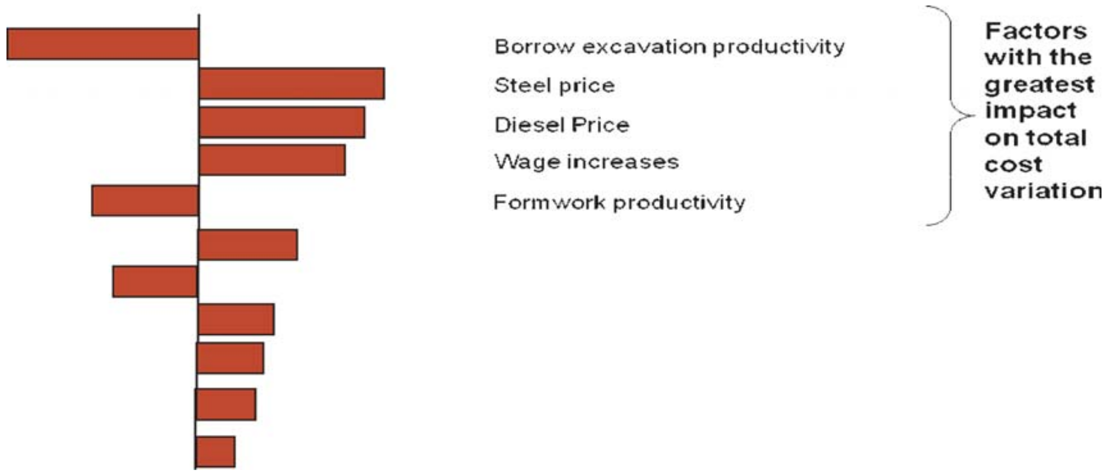


Figure R3.5-2. Example tornado diagram output from a Monte Carlo analysis.

risk profile indicating where the most likely and least likely values are. Among these different distributions are Triangular, Uniform, Normal, BetaPert, BetaPert modified, LogNormal, Discrete, Trigen, and any custom-defined distribution.

In addition to the total cost ranges shown in Figure R3.5-1, an additional output of a Monte Carlo analysis is a tornado diagram. The tornado diagram is a graphic depiction of a sensitivity analysis. The tornado diagram can be used to show which risks will have the greatest positive or negative effect on project cost and schedule. Figure R3.5-2 indicates the correlation that project risks have to the total project schedule. The risks with the longest bars have the largest impact on the overall cost or schedule variability.

Several commercial software packages exist to help teams run Monte Carlo analyses. As well as software that integrates within existing spreadsheet programs, spreadsheet macros can be developed to produce simple Monte Carlo analyses. For example, the WSDOT has developed its own Monte Carlo analysis package in Microsoft Excel using macros. Additionally, some stand-alone software exists to generate cost and schedule Monte Carlo simulations. The most common stand-alone software is "Pertmaster."

Example

WSDOT has developed a risk-based approach to cost estimating in CEVP. CEVP is used to convey project cost through estimate ranges. Figure R3.5-3 provides an example of how CEVP is used to convey an estimate range. The project represented has a 10 percent chance of being completed for $651 million or less, while there is a 90 percent chance that the project will cost $693 million or less. However, there is a chance

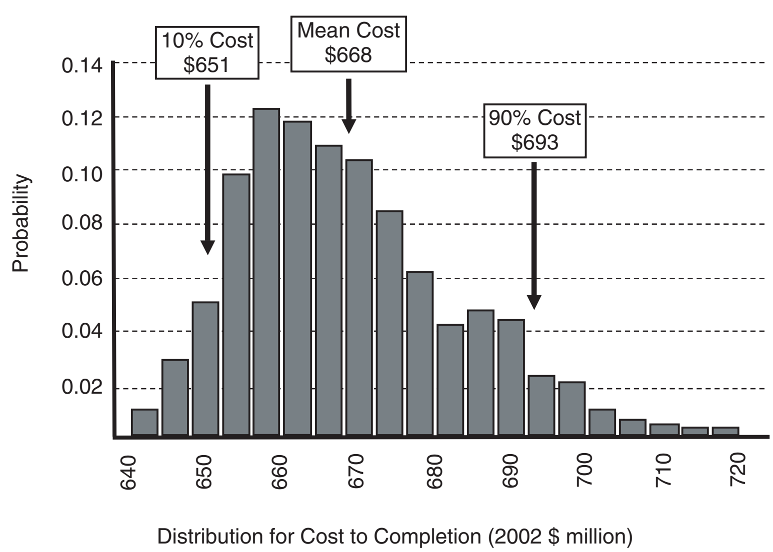


Figure R3.5-3. Example of an estimate range.

that the project will cost as little as $640 million and as much as $720 million.

Tips

Monte Carlo analysis can provide insights into complex projects that might not be apparent through conventional estimating and scheduling techniques. It can provide cost and schedule ranges with graphical outputs. It also can provide insights into which risks have the greatest influence on these ranges. All too often, however, the output is used only for go/no-go decisions or a one-time generation of a baseline cost. Estimators and project managers should leverage this information in a holistic risk management process. The results can be better project performance interims of cost, time, and utilization of resources, but only if it is used to help actively manage the project development process and control project costs.

Monte Carlo analyses should only be conducted or facilitated by trained professionals. It is important to understand that the output of the model is only as accurate as the assumptions used to generate the output and the ability of the model to represent the actual project.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

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

Federal Highway Administration (2004). *Major Project Program Cost Estimating Guidance,* Federal Highway Administration, Washington, D.C.

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

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 (2008). CEVP and Cost Risk Assessment (CRA) website. http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/ (Viewed June 1, 2008).

R3.6 Risk Workshops

Risk workshops are formal meetings where estimators, project team members, subject matter experts, and risk analysis facilitators work together to identify and analyze project risks. Project stakeholders also can be invited to identify risks, if appropriate. The workshops can focus on either qualitative or quantitative risk analysis techniques. Qualitative analyses typically identify and rank risks. Quantitative analyses typically identify risks, quantify uncertainty in project performance (e.g., for generating ranges for total project cost and schedule), and quantify the significance of each risk (e.g., for subsequent risk management cost-benefit analysis).

What is it?

These workshops are conducted to identify and rank project risks (or quantify uncertainty in the case of a quantitative analysis). They can involve a variety of estimators, project team members, project stakeholders, discipline experts, and risk analysis facilitators.

Why use it?

A comprehensive risk analysis requires the elicitation of risks from all project team members, as well as other stakeholders that can potentially influence the project. A focused workshop works well to assemble all those who can influence the project with the goal of identifying risks and helping the project team understand and plan for project uncertainty.

What does it do?

The products of risk workshops vary depending upon the complexity of the project being studied, the current phase in the project development process, and time available for the workshop. Common products are listed below from least to most complex:

- A listing of project risks with complete descriptions;
- A quantification of risk for both probability and impact;
- A range of project cost and schedule to support contingency estimates;
- Initial risk mitigation plans; and
- Preliminary risk register and risk management plan.

In addition to these products, risk workshops generally help to align project team members' understanding of project risks and focus resources in the areas that are most affected.

When to use it?

Risk workshops are valuable in each project development phase. In the earliest phases, they benefit risk identification, and in the latest stages they benefit risk management. When used, the workshops must be conducted well in advance of finalizing the cost estimate because project managers and cost estimators need sufficient time to incorporate the findings into the project plans and estimates. Risk workshops involving expert facilitators are typically required for large or complex projects that meet one or more of the following criteria:

- Project is unique or unusual and has no historical basis of estimate.
- Project has a high degree of local impacts or political interest.
- Project has multiple solutions that meet the stated intent in the planning report, with potentially significant difference in the scope or cost or risk for each alternative.
- Project is complex and may include any or all of the following:
  - Few alignment or bypass sections,
  - Capacity improvements that widen an existing highway,
  - Multiple permanent structures,
  - Interchanges on multilane facilities,
  - Difficulty in acquiring material,
  - Major traffic control activities,
  - Schedule that spans many years,
  - Major reconstruction,
  - Extensive or expensive environmental or geotechnical scope, and/or
  - Numerous right-of-way and/or utility issues.
- Project is estimated to cost more than X percent of the district program budget.

How to use it?

To be effective, risk workshops must be conducted only after adequate preparation, which includes preparation of an agenda and objectives for the workshop. Figure R3.6-1 illustrates how WSDOT uses this tool.

Example

The WSDOT 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 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. The CEVP was scaled down in 2003 to a less intense version known as the cost risk assessment (CRA), with procedures similar to the CEVP. Figure R3.6-1 illustrates how WSDOT uses this tool.

Tips

Workshop pre-planning and proper facilitation are keys to success. The workshops generally begin with a presentation of the project background and issues. This presentation should be concise so that workshop participants can move on to the workshop objectives. Risk identification and quantification are typically the primary objectives of the workshops. Without proper facilitation, participants can deviate from these objectives to risk mitigation, value engineering, or issue solving rather than identifying and quantifying them for later mitigation efforts.

Resources

Washington State Department of Transportation (2008). CEVP and Cost Risk Assessment (CRA) website. http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/ (Viewed June 1, 2008).

R3.7 Risk Priority Ranking

Risk prioritization is an important step in the risk management process. The proper ranking of risks will help the team focus resources on the risks most needing analysis, planning, and mitigation.

What is it?

Through the use of qualitative or quantitative risk analysis, or through the use of estimator's judgment, risks are prioritized or ranked. The criterion used to prioritization is often a perception of the potential impact to project objectives. Other criteria for prioritization may depend on the agency and specific project objectives.

Why do we use it?

We use the prioritization of risks to best use the resources available for analysis, planning and mitigation. The risks that pose a greater threat to project objectives are most likely the ones in greatest need of qualitative and quantitative analysis. Since limited resources are available for analysis, the risks with the highest probability and greatest impact (positive or negative) should be prioritized to be analyzed. These principles apply when looking at mitigation strategies as well. By prioritizing risks, the greatest potential for the best use of funds and resources can be available for mitigation.

What does it do?

Prioritization helps the estimating and design teams focus their energy on high priority risks. The risk allows for effective communication between the design team and the estimating team as to the items with the highest risk impact.

Figure R3.6-1. Example of WSDOT cost risk analysis/cost estimating validation process workshop.

When to use it?

Risk priority ranking should be employed prior to performing analysis, planning for risks or developing mitigation strategies.

How to use it?

Use prioritization as a team exercise to rank risks. This can employ the use of other tools such as the probability and impact (PxI) matrix or risk map.

Tips

Choose the appropriate risk ranking tool for the complexity of the project and the point in project development. Do not choose overly complicated risk ranking tools for non-complex projects. If the goal of a ranking exercise is only to help narrow the list of potential risks in a red flag list, a simple discussion among team members may suffice. If the goal is to allocate scarce resources, a PxI matrix approach may be more applicable. If the goal is to rank risks for contingency management and resolution, a Monte Carlo analysis may be warranted.

Resources

National Highway Institute (2006). *Risk Management Instructor Guide,* NHI Course 134065, National Highway Institute, Washington, DC.

R3.8 Probability × Impact Matrix (P × I)

A P × I matrix is used for qualitative analysis of risks on a project. It is formed by combining each risk's probability of occurrence (frequency) with its impact (severity) on project objectives to rank risks or determine the level of priority to be assigned to that risk on the project (e.g., high, medium, low, etc.). These assessments can be used as a first step in a quantitative analysis.

What is it?

The P × I matrix is formed using each project risk's probability and its corresponding impact. These matrices can take many forms, but a simple illustration is shown in Figure 3.8-1. For each of the project objectives, the combinations could fall into one of these three categories:

- RED: Indicates that the activity is high risk. High risk events are so classified either because they have a high likelihood of occurrence coupled with, at least, a moderate impact, or they have a high impact with, at least, moderate likelihood. In either case, specific directed management action is warranted to reduce the probability of occurrence or reduce the risk's negative impact.
- YELLOW: Indicates that the activity is moderate risk. Moderate risk events are either high likelihood/low consequence events, or they are low likelihood/high consequence events. An individual high likelihood/low consequence event by itself would have little impact on project cost or schedule outcomes. However, most projects contain a myriad of such risks (material prices, schedule durations, installation rates, etc.); the combined effect of numerous high likelihood/low consequence risks can significantly alter project outcomes. Commonly, risk management procedures accommodate these high likelihood/low consequence risks by determining their combined effect and developing cost and/or schedule contingency allowances to manage their influence. Low likelihood/high consequence events, on the other hand, usually warrant individualized attention and management. At a minimum, low likelihood/high consequence events should be periodically monitored for changes in either their probability of occurrence or in their potential impacts. Some events with very large, albeit unlikely, impacts may be actively managed to mitigate the negative consequences should the unlikely event occur.
- GREEN: Indicates that the activity is low risk. Risks that are characterized as low risk can usually be disregarded and eliminated from further assessment. As risk is periodically reassessed in the future, these low risks are resolved with minimal effort, retained, or elevated to a higher risk category.

The assessment guide in Figure R3.8-2 illustrates the key elements of a probability and impact analysis.

Why use it?

Each risk is likely to have a different probability of occurrence and a corresponding impact on the project. Therefore, the project team members need to consider the interaction between the probability and the impact when evaluating the risks. The PxI matrix facilitates such evaluation.

What does it do?

The P × I matrix helps a project team rank the myriad of project risks so that the project manager can direct the majority of the available resources to the high and medium impact items.

When to use it?

A P × I matrix can be used when evaluating project risks in any phase of the project. It is typically used in conjunction with the risk register. The P × I matrix can be used as the sole tool for ranking risks in a qualitative analysis. In a quantitative risk analysis, the P × I matrix can be used for an initial assessment of risks before a more precise measure of probability and impact is made for probabilistic calculations.

How to use it?

The estimator, project team member, or appropriate subject matter expert uses his or her professional judgment to determine the probability of occurrence and the corresponding likely impact for each risk. This is typically done using adjectives (e.g., high, medium, low, etc.) rather than direct probabilities (e.g., 10 percent, 25 percent, etc.) or impacts (e.g., $1 million, 3 months, etc.). The adjectives correspond to color coding for graphical presentation. This information is used to prioritize the risks so that the project team can effectively allocate the resources to the risks that have the highest potential to adversely affect the project.

Example

Figure R3.8-1 shows a sample P × I matrix with brief descriptions for the various combinations of probabilities of occurrence and impact. This example was taken from the Caltrans Risk Management Handbook.

Figure R3.8-2 shows a color-coded assessment guide that project teams can use for rank-ordering project risks. This example is taken from the U.S. Department of Energy.

Tips

The P × I matrix is most effective when used to prioritize the limited resources at a project team's disposal. A key requirement of successful use of this tool is the involvement of subject matter experts who can provide informed judgments about the probabilities of occurrence and the likely impact based on past experience, as well as data, when available.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

U.S. 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.

R3.9 Risk Comparison Table

The risk comparison table is a powerful tool to specifically prioritize a number of risks, in order, based on their potential impact.

What is it?

The risk comparison table is a method to compare risks, side-by-side against one another. The comparison is generated by each member of the project team. Risks are compared side by side and the team votes on the risk that they think should have priority between the two. This process is repeated for comparisons among all of the project risks (A and B, A and C, A and D, B and C . . . etc).

Why use it?

We use the risk comparison table method for much the same reasons we use risk prioritization. The prioritization of risks allows resources to be allocated and spent on the most

	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%

Note: TBPOC stands for the Toll Bridge Program Oversight Committee

Figure R3.8-1. Sample P × I matrix.

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

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 needed

Low (Green)

Minimum impact. Minimum oversight needed to ensure risk remains low

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%

Figure R3.8-2. Definition of impact and probability levels.

deserving risks. The resources include those expended for analysis and mitigation efforts.

What does it do?

The risk comparison table provides a direct comparison of risks for prioritization purposes. The end result is a scrutinized list of risks in order of their potential impact to project objectives.

When to use it?

Risk comparisons should be used before risk analysis or mitigation is performed.

How to use it?

We use the risk comparison table by assembling the project team, and asking the group to discuss two risks at a time. After discussion of the risks, the team votes which risk they believe should be prioritized higher. The votes are then recorded and the group moves onto the next comparison.

Tips

By shortening the list of risks to compare, the process can be much less time intensive. Risks should be included that are judged by the group to have the highest impact, or as the FTA suggests, risks that have the most current importance.

Example

Figure R3.9-1 shows a risk comparison table method used by FTA to prioritize risks.

Resources

National Highway Institute (2006). *Risk Management Instructor Guide,* NHI Course 134065, National Highway Institute, Washington, D.C.

R3.10 Risk Map

The risk map is an important communication tool because it visualizes the probability and impact of risks in a project or program. The risk map also can be used to reveal risk prioritization strategies.

What is it?

A risk map is simply a chart like the one shown in Figure 3.10-1 that summarizes the likelihood and impact of all risks

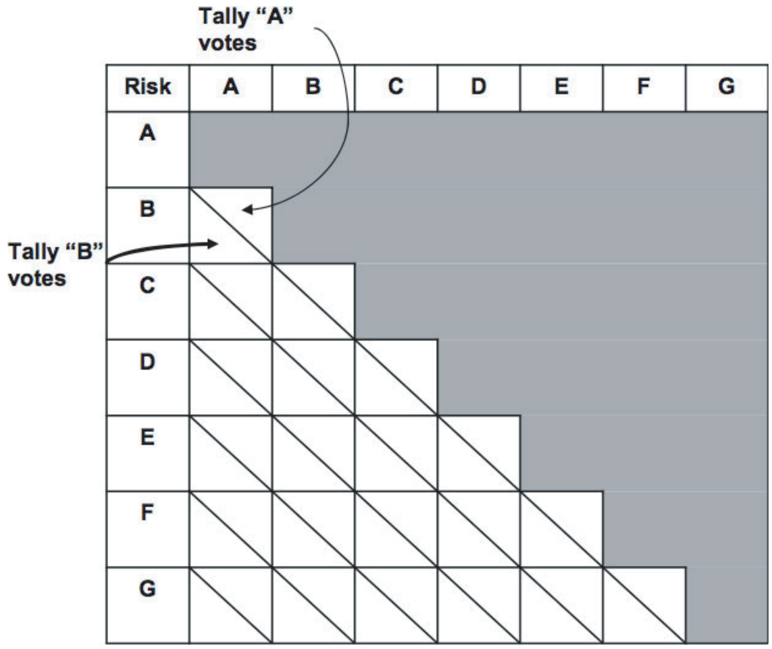


Figure R3.9-1. Risk comparison table.

(or the highest ranking risks) within an organization or on a specific project.

Why use it?

The risk map puts all of the risks in one place in an easy-to-read and understand format. The risks can be conveyed quickly and more intuitively than with a standard risk register.

What does it do?

The map conveys the highest and lowest likelihood of impact to the team and others.

When to use it?

The risk map is employed after risk analysis has been completed. It can then be used as a communication tool or as a tool for risk planning.

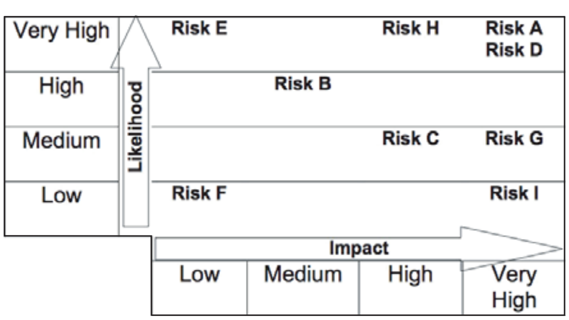


Figure 3.10-1. Risk map example.

How to use it?

The risk map should use the data from either the quantitative or qualitative risk analysis to "plot" each risk on the map. Alternately, the risk map can be used without previously performing risk analysis by placing the risks based on estimators' judgment or project team judgment.

Tips

If using the risk map without performing risk analysis, the process should follow steps outlined in the guide for producing unbiased results.

Example

Figure 3.10-2 is an image taken from FHWA Risk Management Instructor Guide that shows the use of the tool for indi-

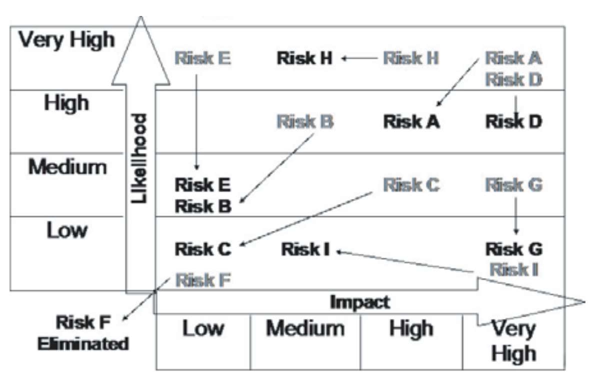


Figure 3.10-2. Risk map with response strategy effectiveness illustrated.

cating response strategies. The arrow indicates where the risk was previously ranked and how the mitigation strategy moved the risk to have lower likelihood or impact.

Resources

National Highway Institute (2006). *Risk Management Instructor Guide,* NHI Course 134065, National Highway Institute, Washington, D.C.

R3.11 Risk Breakdown Structure

A Risk Breakdown Structure (RBS) is conceptually similar to a Work Breakdown Structure, used to illustrate interrelationships between manageable components of a larger project or program.

What is it?

A risk breakdown structure is an extension of a risk register that is typically used to document, evaluate, and allocate risks. It is used to illustrate the interrelationships between risks pertaining to different aspects of a project.

Why use it?

For a comprehensive and consistent understanding of project risks across the project team and among project stakeholders when appropriate, "a picture is worth a thousand words." Although specifications and contracts address most risks, a risk breakdown structure can be very effective in preparing project team members to successfully mitigate or resolve risks as the project moves forward.

What does it do?

A risk breakdown structure shows the relationships between project components that may be difficult to explain using only words.

When to use it?

A risk breakdown structure is appropriate for use on projects with scope in all or most elements of the total project cost, or on complex projects. The risk breakdown structure is used to facilitate risk identification, and assist in the other steps of the risk management process.

How to use it?

We use the risk breakdown structure to help categorize risks. The use of an RBS helps us handle risks systematically, rather than individually. Similar risks, as classified by their RBS can utilize similar management strategies.

Tips

Ensure that the risk breakdown structure reflects the most useful categorizations for the project team. A common principle is that the categorization should focus on risk cause rather than risk effect. It is helpful to try and standardize the risk breakdown structure across several projects, or throughout the agency. This can aid in the use of other tools that rely on a historical database of risks.

Example

Figures R3.11-1 and R3.11-2 show example risk breakdown structures. Figure R3.11-1 is a DOE example of a hazardous waste remediation risk breakdown structure. Figure 3.11-2 is a Caltrans example for a generic program risk breakdown structure.

R3.12 Risk Register

A risk register is a tool that project teams can use to address and document project risks throughout project development. The risk register should be maintained as part of the project file that also includes information related to the cost estimate.

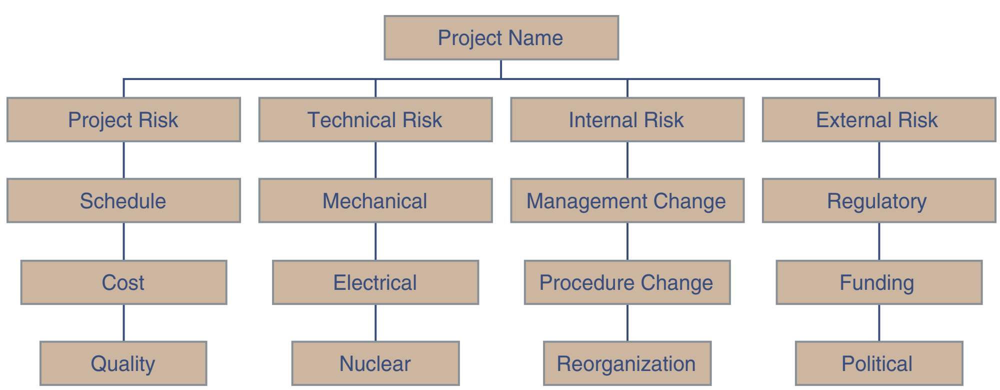


Figure R3.11-1. DOE sample risk breakdown structure.

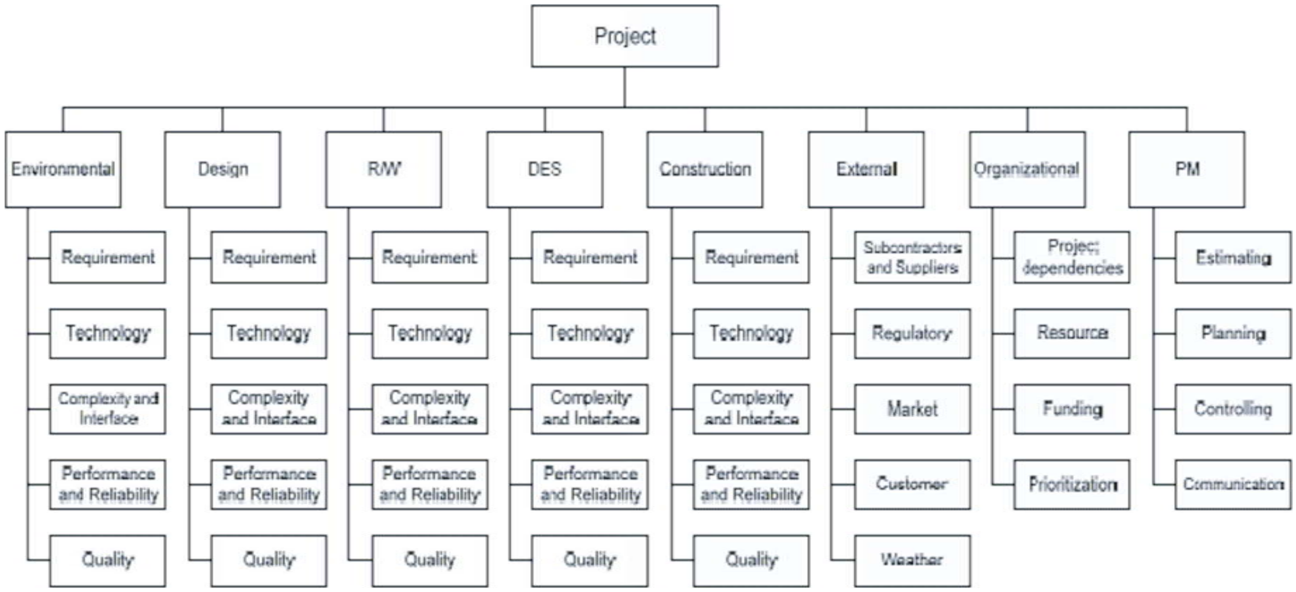


Figure R3.11-2. Caltrans sample risk breakdown structure.

What is it?

The risk register is a living document throughout project development that describes all identified risks, causes, probability of occurrence, impact(s) on project/agency objectives, team responses, individual(s) assigned to monitor the evolution and the resolution of each risk, and current status. It is a comprehensive listing of risks and the manner in which they are being addressed as part of the holistic risk management process. It is generally organized in the form of a spreadsheet so that it can be easily categorized and updated throughout the project development process.

Why use it?

A new project team is formed for every project and disbanded when the project is complete. Although not desirable, project team members sometimes change, and the project itself experiences changes over the course of the project. Communication between project team members about the project objectives, costs, risks, etc., is key. The risk register serves the purpose of communicating project risks and helping the team members understand the status of the risks as a project moves from inception to completion.

What does it do?

The risk register documents the identified risks, the assessment of their root causes, the areas of the project affected (e.g., work breakdown structure elements), the analysis of their likelihood of occurring, their impact should they occur, 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). It includes the risk triggers, the response strategies for high-priority risks, and the assigned risk owner who will monitor the risk.

When to use it?

A risk register should be prepared in conjunction with the first published cost and schedule estimate of a project. Thereafter, a full review and update of the risk register should be undertaken at the beginning of each subsequent phase of the project and during each phase as deemed necessary by the project team or the project approving authority.

How to use it?

A risk register is best used as a living document throughout project development to record the evolution of project risks. There is no prescription for how extensive a project team's risk register should be. Based on the example, the project team needs to decide upon the most beneficial use of the risk register, with the objective of minimizing the risk impact.

Example

Figure 3.12-1 shows an example risk register from the Caltrans *Project Risk Management Handbook.* Caltrans project teams use this tool per the formal guidance at http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

ITEM	DIST- EA 06-12345					Project Name:			Project Manager:
						Co - Rte - PM:			Telephone:
ITEM	ID #	Status	Threat / Opport-unity	Category	Date Risk Identified	Risk Discription	Root Causes	Primary Objective	Overall Risk Rating
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	i)
1	06-12345-01	Active	Threat	CON	03/26/07	Risk Description	Root Cause(s)	TIME	Probablility 4=High (40-59%) **High** Impact 8 =High
2									Probablility Impact
3									Probablility Impact
4									Probablility Impact

Figure 3.12-1. Sample risk register (Caltrans).

(continued on next page)

		Date Created:

Cost/Time Impact Value	Risk Owner	Risk Trigger	Strategy	Response Actions w/ Pros & Cons	Adjusted Cost/Time Impact Value	WBS Item
(j)	(k)	(l)	(m)	(n)	(o)	(p)
Cost/Time Impact Value	Risk Owner (545) 454-5454 (212) 121-2121 Risk Owner@dot.ca.gov	Risk Trigger(s)	AVOID	Response Actions	Adjusted Cost/Time Impact Value	165 PERFORM ENVIRONMENTAL STUDIES AND PREPARE DRAFT ENVIRONMENTAL DOCUMENT □Additional WBS

Figure 3.12-1. (Continued).

Tips

A risk register is an important part of the project file for all projects, regardless of size or type. The level of detail in the risk register can vary depending upon the project size, and complexity.

Resources

Caltrans Office of Statewide Project Management Improvement (2007). *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., May 2007, Caltrans, Sacramento, CA. http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

Washington State Department of Transportation (2008). CEVP and Cost Risk Assessment (CRA) website. http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/ (Viewed June 1, 2008).

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

R3.13 Risk Management Information System

Throughout the planning, scoping, and design phases of project development, identified project risks need to be documented and the list kept up to date, because risks evolve throughout project development. A Risk Management Information System (RMIS) helps a project team document the risks as they are identified.

What is it?

RMIS is a web-based interactive data management system that tracks risks and risk-related information at various stages of the cost estimating 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.

Why use it?

Regardless of the tools used for analyzing risks and estimating contingency, project teams need an effective mechanism to monitor the risks and communicate their effects on contingency. Such a mechanism is needed because risk and contingency are inter-related, and they constantly evolve as the project progresses.

What does it do?

RMIS provides the project team the mechanism to periodically evaluate and retire the risks that have been addressed already and keep the risk register up to date.

When to use it?

RMIS can be most effective when used starting with the first published estimate, usually in the planning phase, all the way through the completion of the design phase. The system can potentially be used for risk allocation at the time of contract award and then passed on to the contractor for use during project execution.

How to use it?

RMIS requires significant information technology prework for effective use. When such a system is developed and in place, project team members can use it to create and maintain a risk register that individual team members can access and use for decision support.

Tips

RMIS is a sophisticated computer-based tool that in essence is a risk register, but with automated forms and reports for risk management. If the project team is working in an agency that does not already have an RMIS, then the project team should proceed with using a risk register (which is a separate tool that is described elsewhere in this guide).

Example

Figures 3.13-1 and 3.13-2 show the example of the RMIS used in the Caltrans.

R3.14 Self Modeling Worksheet

The WSDOT utilizes a detailed spreadsheet to list, quantify, and analyze risks. The self modeling worksheet is required on project between $10 and $25 million.

What is it?

The WSDOT self modeling worksheet uses the process of Monte Carlo simulations to take listed uncertainties and generate distributions of probable project cost and schedule.

Why use it?

The worksheet can be used in place of schedule risk analysis software. The spreadsheet can be seen as less complex than schedule risk analysis software, and therefore easier for project teams to use.

What does it do?

The worksheet takes a three point estimate for each risk (threat or opportunity) and provides a distribution of the project cost and schedule based on the risk information.

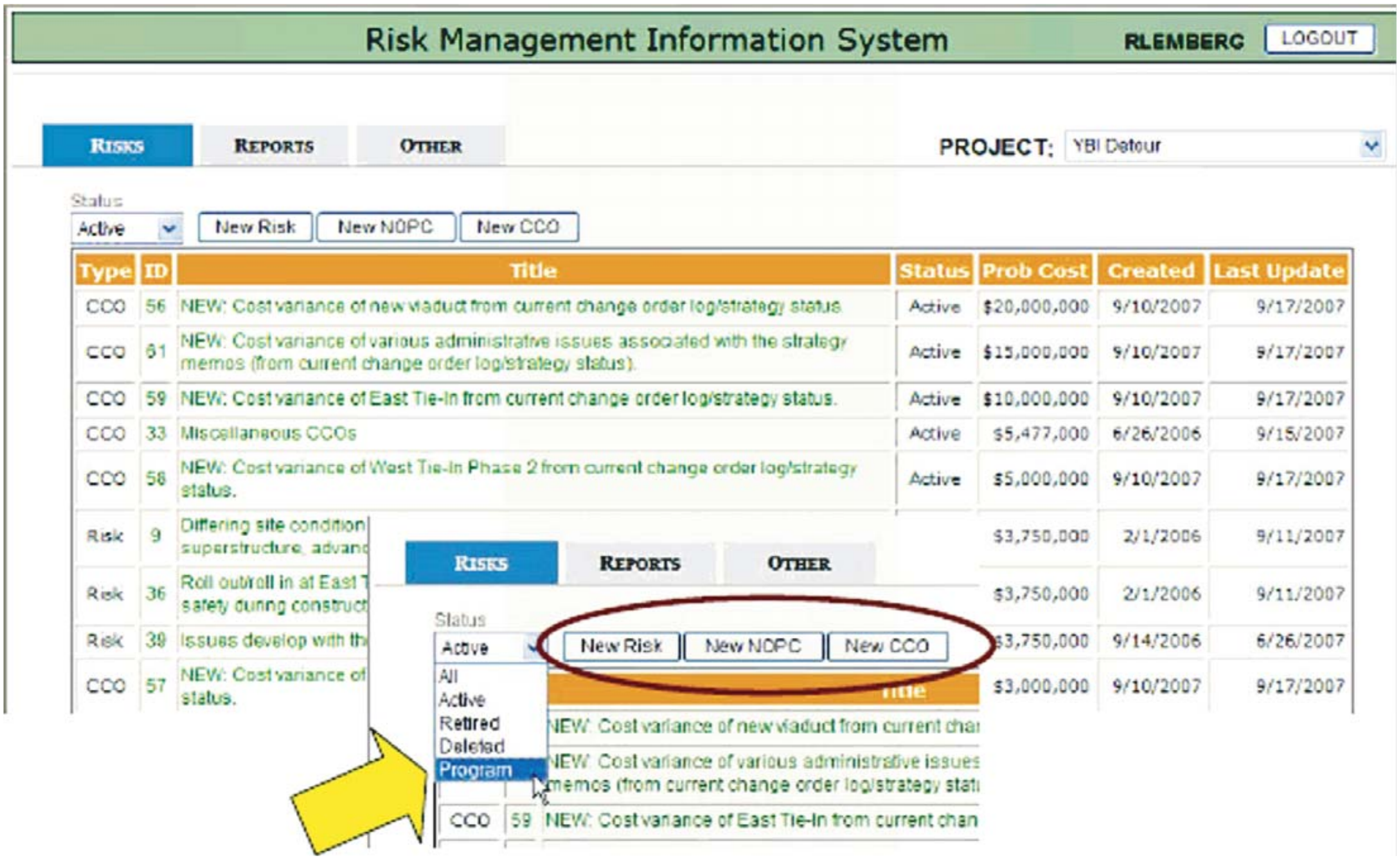


Figure 3.13-1. Risk management information system.

When to use it?

The tool can be used as a risk register, as well as a risk analysis tool. Thus, the tool can be used during identification, assessment, analysis, planning, and control. The tool also includes a way to retire risks after they no longer pose a threat to project objectives.

How to use it?

The worksheet is used by entering data into the assigned cells and running the simulation. The output of the simulation is generated in charts on subsequent tabs. The information in these charts can be used to convey project risk and uncertainty.

Tips

While the tool is immense, it can be customized to fit the needs of the department utilizing it. Someone with a background in writing code could manipulate the spreadsheet to address specific needs.

Example

A copy of the WSDOT self modeling worksheet is available at http://www.wsdot.wa.gov/Projects/ProjectMgmt/Risk Assessment/Information.htm

Resources

WSDOT website, including the self modeling worksheet and "Read Me First" support file.

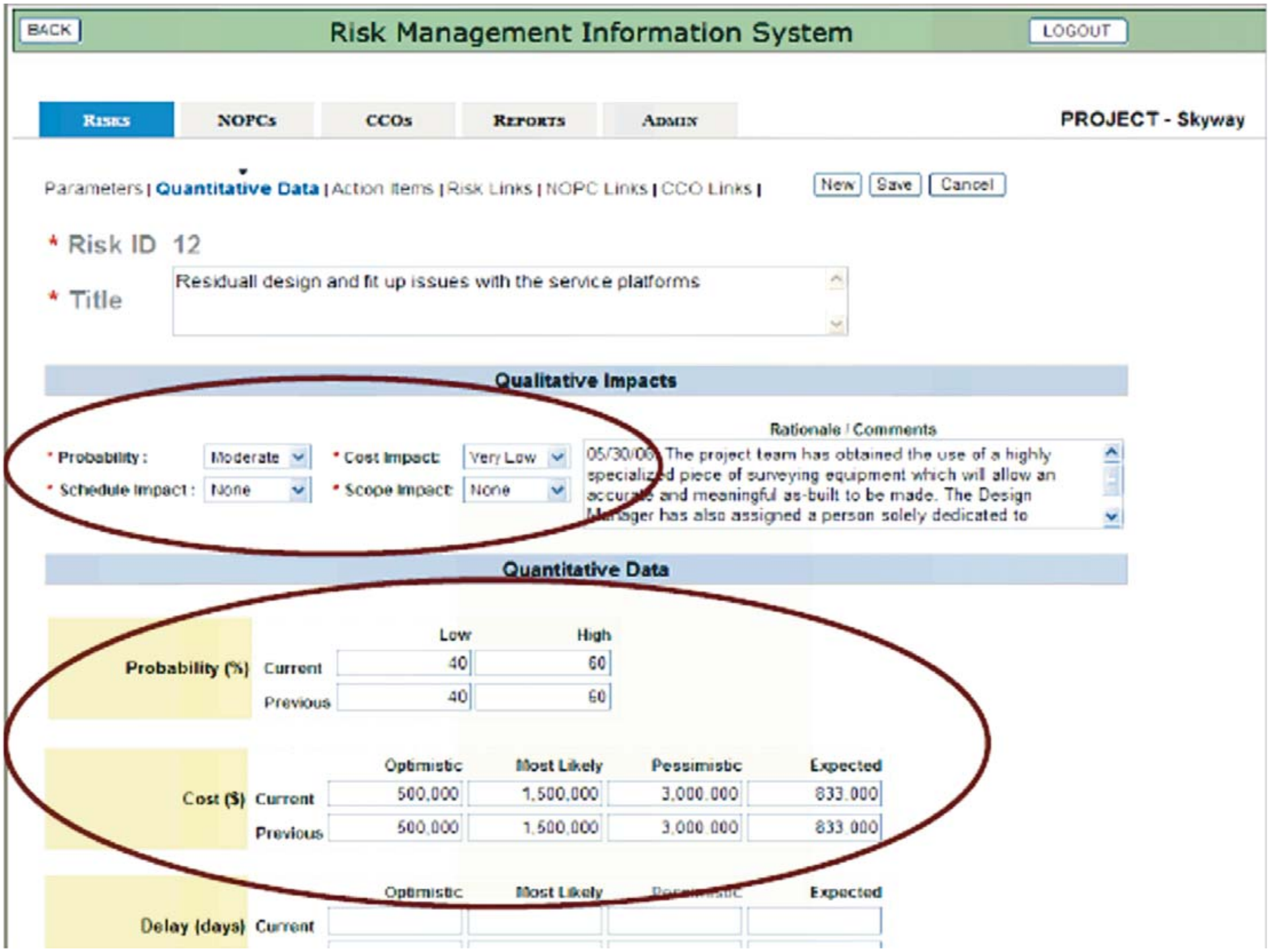


Figure 3.13-2. Risk data in the risk management information system.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation