INTERNATIONAL TECHNOLOGY SCANNING PROGRAM

GUIDE TO

Risk Assessment and Allocation for Highway Construction Management

U.S. Department of Transportation
Federal Highway Administration

OCTOBER 2006

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16. Abstract

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

One significant scan finding was that the countries visited had an advanced awareness of risk assessment and allocation techniques that are just now evolving in U.S. highway agencies. This instructional report was developed as part of the scan team's implementation plan to raise awareness of risk management techniques and begin the process of incorporating risk management elements into the institutional structures of highway agencies. The report is designed to be used in conjunction with workshops on implementing risk management.

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GUIDE TO

Risk Assessment and Allocation for Highway Construction Management

Prepared by the Construction Management Expert Technical Group of the Construction Management International Scanning Study Team

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U.S. Department of Transportation

American Association of State Highway and Transportation Officials

National Cooperative Highway Research Program

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Preface

In May 2004, a delegation of U.S. officials from the Federal Highway Administration (FHWA), State departments of transportation (DOTs), industry, and academia visited Canada, Finland, Germany, the Netherlands, Scotland, and the United Kingdom. The purpose of this International Technology Scanning Program study was to identify practices that might be evaluated and applied in the United States to improve construction management.

One significant scan finding was that the countries visited had an advanced awareness of risk assessment and allocation techniques that are just now evolving in U.S. highway agencies. This instructional report was developed as part of the scan implementation plan to help raise awareness of risk management techniques and to begin the process of incorporating elements of risk management into the institutional structures of DOTs.

The Highways Agency in England has developed Highways Agency Risk Management (HARM) to model the uncertainties of estimates for cost and time to ensure robust and realistic budgets for publicly financed projects. The Ministry of Transport, Public Works, and Water Management in the Netherlands has developed the Public Sector Comparator and the Public-Private Comparator (PSC/PPC) to assist with these same analyses. Both agencies have dedicated staff that support project teams in identifying and quantifying project risk using probabilistic techniques, and then choosing delivery and contracting strategies that can best control and mitigate these risks.

While few U.S. State highway agencies use formalized risk assessment and management programs like HARM and PSC/PPC, awareness is developing in the United States. In particular, the Washington State Department of Transportation (WSDOT) has developed the Cost Estimate Validation Process® (CEVP) and Cost Risk Assessment (CRA) process. The California DOT (Caltrans) now employs a risk management program. There are also a number of excellent examples in the United States of project-based risk management plans.

> ✔ Construction management is the totality of activities that address the managerial and technological aspects of highway construction, conducted during the planning, design, construction, and post-construction phases of a project, for the purpose of achieving scope, quality level, cost, schedule and other project performance objectives.

It is hoped that this report will raise awareness within the highway construction management community that risk can be understood and managed. The more strategic goal is that DOTs and contractors, as appropriate, will actually identify, assess, analyze, mitigate, allocate, and monitor risk in a structured and cooperative way of doing business.

This report was prepared by the Construction Management Expert Task Group (CM ETG), formed by FHWA and the American Association of State Highway and Transportation Officials to implement the scan findings. The CM ETG is working to implement the concepts and promote them in the United States. The group is distributing this report in print and on the Web as part of the initial awareness effort. In addition, the CM ETG is involved in workshops with volunteer DOTs that are evaluating risk management in their construction management organizations. If these efforts prove successful, it is hoped that other DOTs will follow suit and use these implementation tools as catalysts to examine and adopt risk management in their own organizations.

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European Bridge Structures (1995)

All publications are available on the Internet at *www.international.fhwa.dot.gov*.

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Abbreviations and Acronyms

A+B
time plus cost

A+B+Q
multiparameter bidding

AACEI
Association for the Advancement of Cost Engineering International

AASHTO
American Association of State Highway and Transportation Officials

BAM
bid-averaging method

Caltrans
California Department of Transportation

CEVP
Cost Estimate Validation Process®

CII
Construction Industry Institute®

CM ETG
Construction Management Expert Technical Group

CRA
Cost Risk Assessment

DBOM
design-build-operate-maintain

DBOM-F
design-build-operate-maintain-finance

DOE
U.S. Department of Energy

DOT
Department of Transportation

FHWA
Federal Highway Administration

FMEA
failure modes and effects analysis

FTA
Federal Transit Administration

HARM
Highways Agency Risk Management

PCR
project change request

PID
project initiation document

PSC/PPC
Public Sector Comparator and Public-Private Comparator

SEP 14
Special Experimental Projects 14

VFM
value for money

WSDOT
Washington State Department of Transportation

CHAPTER 1

The Introduction

1.1 Project Management Approach

Successful delivery of national and State highway facilities requires the application of a broad set of program and project management tools. Scope, design, cost, and schedule management are all regarded as essential for every major project. Highway agencies and their partners in the contracting community are well versed in cost estimating and scheduling techniques for these facilities and often apply them numerous times on each project. The treatment of risk is much less uniform and understood across the transportation community. Risk management processes, tools, documentation, and communication are less standardized than any other dimension of transportation project management. The goal of this document is to provide a concise guide to the risk assessment and allocation process in highway construction, as well as to draw on other infrastructure and major project areas for examples of risk management practice.

> - ✔ Highway agencies and their partners in the contracting community are well versed in cost estimating and scheduling techniques. The treatment of risk is much less uniform and understood across the transportation community.
> - ✔ This report focuses on risk assessment and allocation techniques that will ultimately lead to alignment of the entire project team with customer-oriented performance goals.

The international community has an awareness of risk assessment and allocation techniques that is just now evolving in U.S. highway agencies. The Highways Agency in England has developed Highways Agency Risk Management (HARM) to model the uncertainties of estimates for cost and time to ensure robust and realistic budgets for publicly financed projects.[1] The Ministry of Transport, Public Works, and Water Management in the Netherlands has developed the Public Sector Comparator and the Public-Private Comparator (PSC/PPC) to assist with these same analyses.[2] Both agencies have dedicated staff that support project teams in identifying and quantifying project risk using probabilistic techniques, and then choosing delivery and contracting strategies that can best control and mitigate these risks.

Risk management and risk planning are used interchangeably 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 and the U.S. Department of Energy use similar steps, but slightly different terms, to describe their risk management approach.[3,4] The most common set of processes would include risk *identification, assessment, analysis, mitigation, allocation, and monitoring and updating*. This document will use these processes or steps as the primary structure for an FHWA standard for project risk management. This document focuses on risk assessment and allocation techniques that will ultimately lead to alignment of the entire project team with customer-oriented performance goals.

While few State highway agencies use formalized risk assessment and management programs like HARM and PSC/PPC, awareness is developing in the U.S. highway community. In particular, the Washington State Department of Transportation (WSDOT) has developed the Cost Estimate Validation Process® (CEVP) and Cost Risk Assessment (CRA), and the California Department of Transportation (Caltrans) is employing a risk management program.[5,6] There are also a number of excellent examples in the United States of project-based risk management plans, many based on published standards from industry associations such as the Project Management Institute (PMI) and the Association for the Advancement of Cost Engineering International (AACEI).[3,7] This document relies heavily on these examples as well as examples from other infrastructure and major project areas to form the best risk management practices described.

1.2 Business Case for Project Risk Management

Perhaps the most compelling argument for pursuing risk assessment and allocation as a standard practice for highway programs is that the best agencies and organizations worldwide are doing it, and with great success. Several reports from recent FHWA International Technology Scanning Program

> ✔ The business case for including risk management as a standard project management component of major capital projects is unambiguous: The ability to better understand potential risks and how to manage them yields benefits far in excess of the costs of adopting risk management practices.

studies (e.g., *Contract Administration: Technology and Practice in Europe, Construction Management Practices in Canada and Europe, and Asphalt Pavement Warranties: Technology and Practice in Europe*) identified risk assessment and allocation as key components of professional practice.[8,9,10] These scanning reports recommended that the highway community (1) better align team goals to customer goals, (2) develop risk assessment and allocation techniques, and (3) strategically apply alternate project delivery methods.

The U.K. Highways Agency in its January 2001 report on a framework for business risk management makes an eloquent argument for the necessity of formal risk management.[1] Its business case is based on maximizing value for money (VFM).

> If Agency colleagues take decisions in ignorance of the associated risks, regardless of their possible impact on business, they are likely to reduce VFM rather than enhance it. This is exacerbated if the Agency is actively encouraging a more well thought approach towards risk taking, without defining the framework or criteria within which colleagues are expected to do so.

This report conveys a firm belief that active, thoughtful risk taking is just as important as risk mitigation. In the report, the agency poses three questions for itself:

1. Does the agency have adequate and dynamic processes in place to identify existing and new risks faced?
2. Does the agency have the right balance of arrangements in place to deal with these risks?
3. Does the agency have an adequate framework for risk analysis and evaluation to support decisionmaking processes?

Table 1. *Risk assessment: timing, issues, objectives, and outcomes.*

PROJECT PHASE	STATUS	TYPICAL RISK ISSUE
LONG-RANGE PLANNING/ PROGRAMMING	■ Focus is on general alignment and mode ■ Project details not defined; environmental reviews incomplete ■ Funding possibly not committed ■ Public support uncertain	■ Fatal or significant environmental economic impacts ■ Funding uncertainty ■ Uncertain political and public support ■ Competing interests and competing projects
PRELIMINARY ENGINEERING	■ Comprehensive definition of project goals ■ Environmental reviews approaching completion (Record of Decision) ■ Initial approvals received but long-term funding commitments still to be determined ■ High cost and schedule contingencies	■ Changes to project scope and budget ■ Costs of environmental compliance ■ Appropriate procurement methods ■ Changes in design requirements ■ Right-of-way acquisition ■ Technical uncertainties ■ Errors or omissions in quantities, inaccurate unit prices ■ Market conditions ■ Funding uncertainty
FINAL DESIGN	■ Project goals communicated to contracting partners ■ Project scope, cost, and schedule well defined ■ Minor open issues since all cost and design detail well advanced ■ Construction approvals, including permits and agreements, not yet final	■ Changes to project scope and budget ■ Errors or omissions in quantities, inaccurate unit prices ■ Changes in design requirements ■ Market conditions, permit requirements
CONSTRUCTION	■ Design complete; project defined ■ Commitments (funding, policy, etc.) in place ■ Construction in progress	■ Contractor performance, construction quality ■ Final permitting, right-of-way acquisition ■ Unanticipated site/working conditions ■ Field design changes ■ Construction safety

It is the taking of opportunities that will yield the greater gain, and to do so requires a rigorous analysis capability, as well as an understanding of the implications of associated management actions. The proposed framework is built on a foundation of organizational changes, modified behaviors, analytical tools, and an overall commitment to "living risk management" within the agency.

One can also look more locally for compelling arguments. The WSDOT CEVP and CRA processes, the Caltrans risk management handbook, the FHWA guidance on cost estimating, the Federal Transit Administration's (FTA) report on risk assessment methodologies, and the U.S. Department of Energy's (DOE) risk management practices all provide procedural outlines for the broad range of risk issues confronting major transportation projects.[5,6,9,11,4] Table 1 covers the time range from beginning alternatives analysis and conceptual design through construction completion and enumerates the many risk issues, objectives, and expected outcomes impacted by the project's risks.

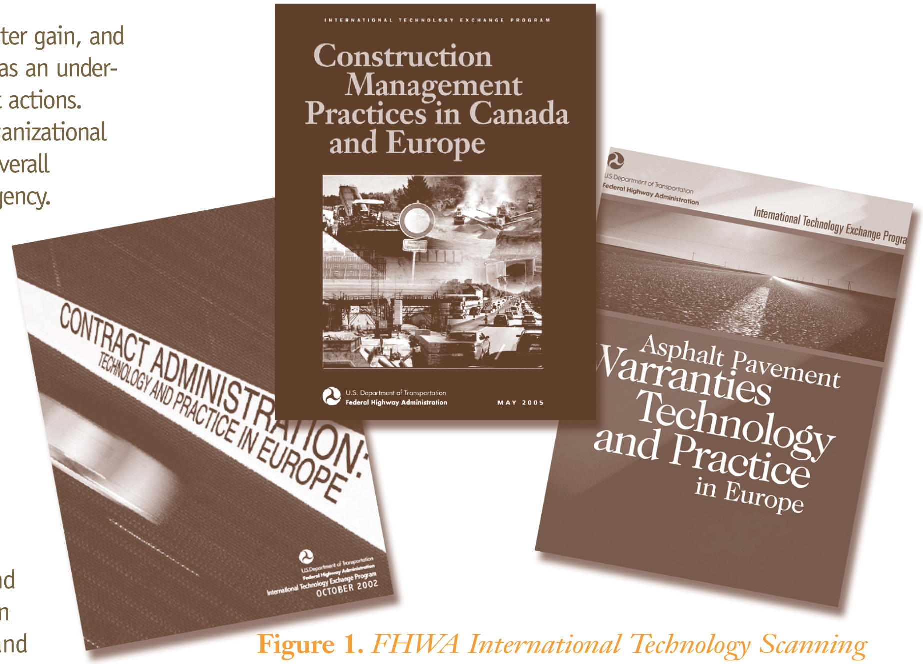


Figure 1. *FHWA International Technology Scanning Program scans citing risk assessment and allocation.*

OBJECTIVES FOR RISK ASSESSMENT	EXPECTED OUTCOMES
■ Identify implementation challenges— political, public acceptance, approvals ■ Establish order of magnitude costs by option ■ Identify major design and construction risks	■ 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
■ Identification, quantification, and likelihood of major scope, budget, and schedule risks for all major project components ■ General definition of and total probable project costs ■ Risks of alternative design concepts, procurement methods	■ 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
■ Identification, quantification, and likelihood of all identifiable scope, budget, and schedule risks for all project components ■ Detailed definition of base costs, risk costs, and total probable project costs ■ Validation of reasonableness of contingencies in project budget and schedule	■ List of major critical risks, prioritization of risks based on impacts to total project cost and duration ■ Estimate of risk costs and probable total project costs and duration ■ Costs/benefits of risk mitigation and risk allocation strategies ■ Risk management and allocation plan
■ Targeted assessment of construction problems, causes, and potential cost/ schedule impacts ■ Identification and systematic evaluation of possible corrective actions	■ Analysis of specific problems ■ Costs/benefits of possible corrective actions ■ Corrective action plan that will allow project sponsors/owners to maintain (or recover) schedule and avoid cost overruns

SOURCE: ADAPTED FROM RISK ASSESSMENT METHODOLOGIES AND PROCEDURES, FTA 2004.

It is the pervasiveness of these risks and their potential for changing the bottom-line value of the project that, in the end, demand attention.

The DOE's 2003 report on risk management practices further amplifies these considerations:[(4)]

> Risk management is a team function. This stems from the pervasive nature of risk and the impact that risk-handling plans may have on other project plans and actions. In the aggregate, risk planning, assessment, handling, and monitoring affect all project activities and organizations.

The DOE study emphasizes that risk management must be a formal, structured process if it is to have its full value.

> The need for a formal risk management process arises from the nature of risk and the complexity of acquisition projects. . . . A formal approach is the only effective method to sort through numerous risk events, to identify the risks and their interrelationships, to pinpoint the truly critical ones, and to identify cost-effective ways to reduce those risks, consistent with overall project objectives.

In addition, the DOE report emphasizes that risk management by its very nature must be forward looking. It must "identify potential problems...long before they occur and develop strategies that increase the probability/likelihood of a favorable outcome."[(4)]

The business case for including risk assessment and allocation as a standard project management component of major capital projects is unambiguous: The ability to better understand potential risks and how to manage them yields benefits far in excess of the costs of adopting risk management practices. A 1979 study by the Massachusetts Institute of Technology, *A Quantitative Method for Analyzing the Allocation of Risk in Transportation Construction,* found a high benefit-to-cost ratio in dealing with contractual risk through improving both contract clarity and contract management practices.[(12)] The Construction Industry Institute states that there is a realistic prospect of a 5 percent cost savings through better contracting practice, of which risk identification and allocation are major components.[(13)]

The importance to highway project development is especially high, from initial feasibility and conceptual planning through user availability. The long durations, environmental and community interactions, public contracting requirements, and physical dimensions all contribute to this importance and value. Guidance from the best practices globally and across other project domains implies that risk planning and management should start at the project's beginning and be applied continuously throughout the entire implementation period. It should be built into the organizational structure and become one of the critical project management practices applied to every major highway project and program.

1.3 Definition of Key Terms

A glossary in this document contains the most commonly used risk terms. The Project Management Institute's *A Guide to Project Management Body of Knowledge* is the primary reference for these definitions.[(3)] Some of the more critical concepts are worth explaining here. Among those are the two basic types of risk defined by Pennock and Haimes: "*technical risk* denotes the risk that a project will fail to meet its performance criteria" and "*programmatic risk* has the two major subcomponents of cost overrun and schedule delay."[(14)] By extension, other project execution metrics such as labor productivity would be classified as programmatic, while other outcome performance measures such as reliability would be technical. These distinctions are important because too often the focus of risk identification is on project features integral only to technical performance and misses features critical to overruns or delays such as external markets.

Another term often used to characterize risk is *contingency*. However, this term is often misunderstood and misused. For the purposes of this document, contingency is formally defined as "an amount of money or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization." Contingency is typically greatest in the beginning of a project and is gradually reduced as the project is designed, risks are resolved, or the contingency is spent. Figure 2 graphically depicts how a project range cost and its associated contingency is reduced as the project moves through the development process.

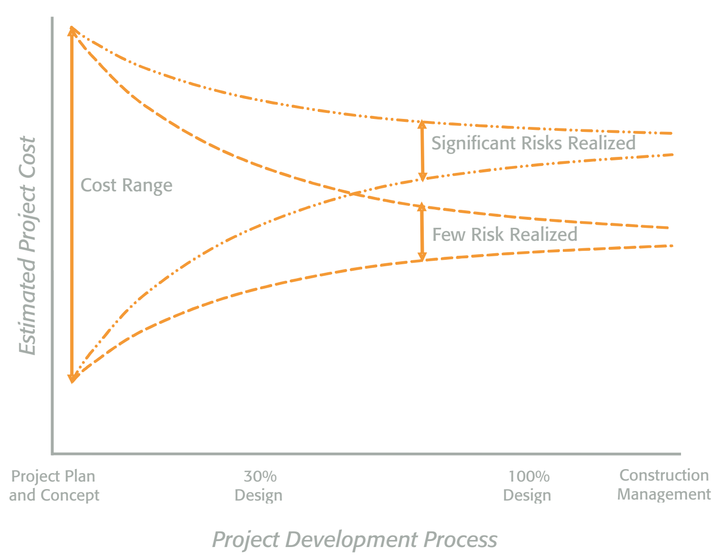


Figure 2. *Conceptual refinement of a cost estimate.*

1.4 Risk Management Process

The six primary steps in project risk management are the following:

- Identification
- Assessment
- Analysis
- Mitigation
- Allocation
- Tracking and updating

Each step will be described in this document. The focus here is on the linking of these steps and the repeated application of the processes. A good example of how these steps are related is captured in the overall process flowchart in figure 4 from the Caltrans *Project Risk Management Handbook,* which was derived from the Project Management Institute *Body of Knowledge.*[6,3] The flowchart shows the division of analysis into qualitative and quantitative analyses; these require considerably different tools and levels of effort, as explained in Chapters 3 and 4.

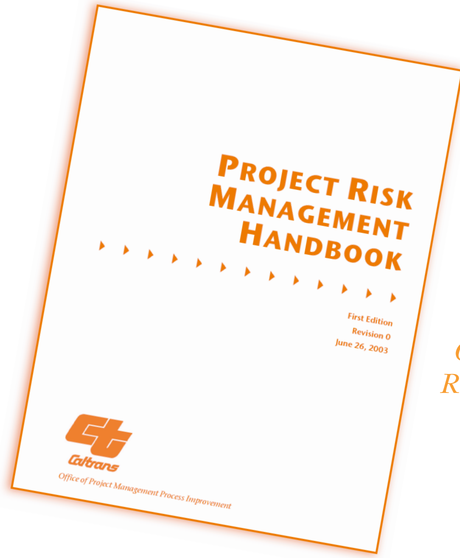


Figure 3. *Caltrans Project Risk Management Handbook.*

An important underlying concept of this approach is that the overall process is repetitive and cyclical (see figure 5 on page 6). As the project evolves, some risks will be resolved or diminished, while others may surface and thus be added. These steps are continually applied throughout the project implementation period.

A study performed for WSDOT provides an interesting graphical summary, shown in figure 6 (see page 6), of how the application of this process and its steps varies throughout the project development period. In particular, it demonstrates how the relative importance of the risk management activity corresponds to project cost verification and validation activities.

The type of expertise necessary to support risk management, especially for identification and assessment, varies over time. The earliest stages of project development may depend heavily on expertise in environmental planning, funding, and operations. As engineering evolves and design nears completion, there will be more reliance on specialists in such areas as scheduling, cost estimating, and budgeting/controls. Table 2 (see page 7) from the 2004 FTA report *Risk Assessment Methodologies and Procedures* provides an excellent summary of key expertise needed for risk identification and risk assessments by project phase. This amplifies the value

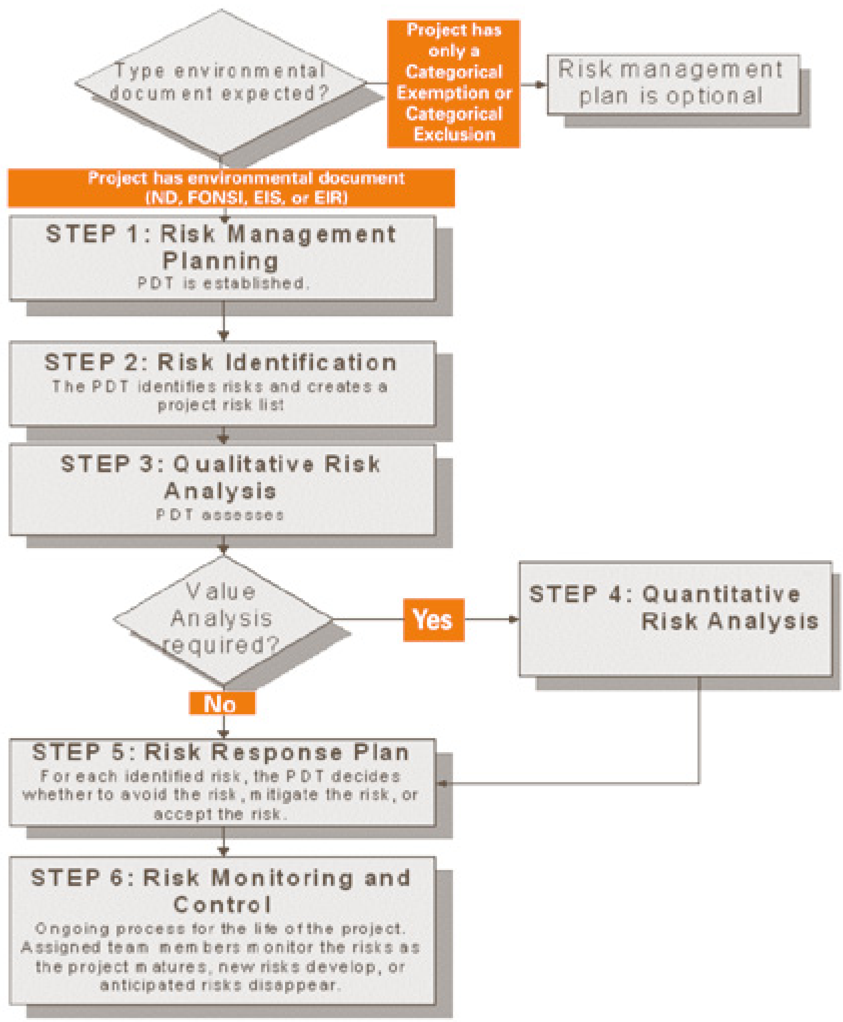


Figure 4. *Caltrans risk management process.*

Figure 5. *Cyclical nature of the risk management process.*

of considering risk management as a core project management process with broad-based team support.

The *Caltrans Project Risk Management Handbook* offers an additional framework for considering the proper role of expertise over the project lifetime.[(6)] It presents a matrix of key responsibilities by process step and key stakeholder, shown in table 3. It distinguishes roles by the categories of "responsible," "support," and "approve." These responsibility assignments could be a valuable mechanism for insuring broad team participation.

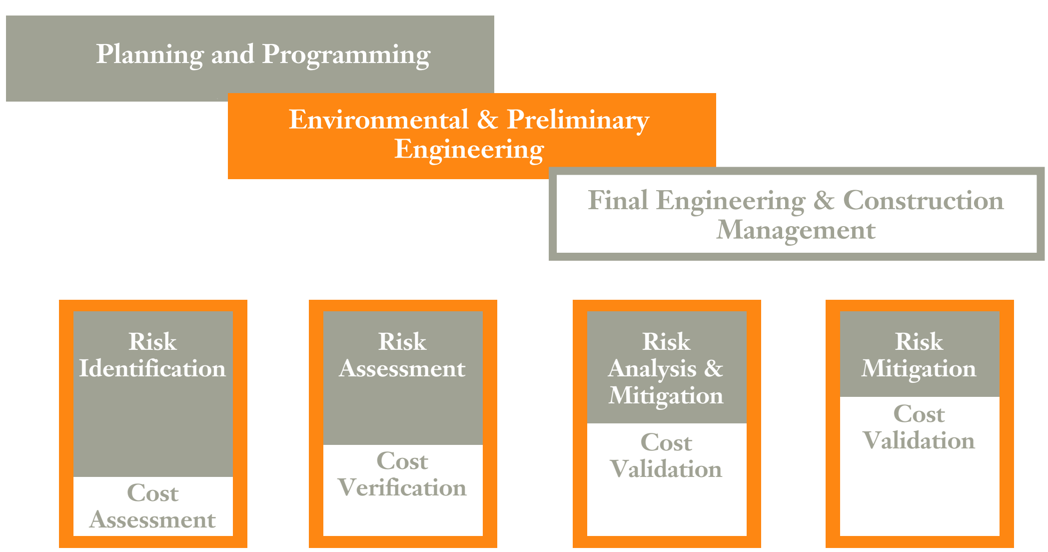
1.5 Outputs from Risk Assessment and Allocation Process

Depending on the nature of the project, several outputs from the process are possible. Among the most common are the following:

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

> ✔ The simplest representations often work best.
>
> ✔ While the analysis may be supported by a complex, rigorous, and probabilistically sophisticated model, it is of little value if its outputs are obscured in jargon or overly complicated in their representation.

These outputs will be explained later in this document, including examples of best practices from throughout the transportation community and elsewhere. There are indeed some excellent examples from WSDOT, Caltrans, FTA, and DOE. Effectiveness of the process as a management decision aid is most often linked to the clarity



SOURCE: WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Figure 6. *Risk management and cost validation in the WSDOT CEVP process.*

Table 2. *Key expertise for risk analysis by project phase.*

DISCIPLINE	CONCEPTUAL DESIGN*	PRELIMINARY ENGINEERING	FINAL DESIGN	CONSTRUCTION
Implementation planning	●	●	○	
Environmental planning	●	●	○	○
Funding approvals	●	●	○	
Project management	●	●	●	●
Engineering	●	●	●	●
Civil, structural, systems		○	●	●
Architectural design		●	●	○
Cost estimating	○	●	●	●
Scheduling	○	●	●	●
Budgeting controls		○	●	○
Real estate	○	●	●	○
Construction management/oversight			●	●
Constructability/contractor			○	●
Operations	●	●	●	●
Other technical (e.g., legal, permitting, procurement)	○	●	●	●
Risk facilitation	●	●	●	○

** Includes FTA systems planning and alternatives analysis.*

● **Highly desirable** ○ **Desirable but optional depending on circumstances**

SOURCE: *RISK ASSESSMENT METHODOLOGIES AND PROCEDURES*, FTA 2004

of its communication. The simplest representations often work best. While the analysis may be supported by a complex, rigorous, and probabilistically sophisticated model, it is of little value if its outputs are obscured in jargon or overly complicated in their representation. Similarly, simple qualitative analyses that are easily understood by the decisionmakers can have a powerful influence on the risk measures taken. Communication is very much a key in using these outputs to their full potential.

1.6 Successful Use of Project Risk Management

A May 2001 survey conducted by DOE identified several characteristics of successful risk management programs:[15]

- Feasible, stable, and well-understood user requirements.
- A close relationship with user, industry, and other appropriate participants.
- A planned and structured risk management process integral to the acquisition process.
- An acquisition strategy consistent with risk level and risk-handling strategies.
- Continual reassessment of project and associated risks.
- A defined set of success criteria for all cost, schedule, and performance elements (e.g., performance baseline thresholds).
- Metrics to monitor effectiveness of risk-handling strategies.
- Effective test and evaluation program.
- Formal documentation.

These findings are directly transferable to the planning, design, and construction of highway facilities, and thus serve as an excellent starting point for launching a standardized process for highway project risk management.

1.7 Conclusions

The rigorous process of risk *identification, assessment, analysis, mitigation, allocation, and monitoring and updating* described in this document 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.

Table 3. *Key responsibilities for risk process tasks.*

PROCESS TASKS	ROLE					
	Sponsor	District division chief for program and project management	Project manager	Assistant project manager/ project management support unit	Functional manager	Task manager
Risk management planning	S	S	R	S	S	S
Risk identification	S	S	A	S	R	R
Qualitative risk analysis			R	S	S	S
Quantitative risk analysis (performed only as part of value analysis)			A	S	R	R
Risk response planning	S	S	R, A	S		
Risk monitoring and control	R	R	R, A	S	R	R
Legend: R=responsible S=support A=approve						

SOURCE: *PROJECT RISK MANAGEMENT HANDBOOK*, CALTRANS 2003

1.8 Illustration: Strategic Approach

At the end of each chapter, this document provides an illustration that applies the concepts covered in the chapter. A fictitious State highway agency, QDOT, and project example, US 555–SH 111 interchange, have been created for the illustrations. The objective is to simulate an agency developing a risk assessment and allocation program and applying it to a project. Where possible, the illustrations draw from actual experiences of public sector agencies in the highway, infrastructure, and building industries.

OVERVIEW OF QDOT'S ISSUES AND OPPORTUNITIES

QDOT has been facing growing capital project needs as well as a backlog of maintenance. The agency is operating an aging infrastructure under tight funding constraints and increasing environmental challenges, all with leaner staffing resources. The agency and its industry partners have become more aware of customers' needs because of some high-profile issues that have played out recently in the public forum. Among the most pressing issues are the following:

- Severe cost escalation from planning through final design and construction.
- Legal actions from stakeholders adversely affected by new projects.
- Construction management problems, including environmental violations.
- Project management mistakes because of the large number of complex projects.

QDOT also has a number of opportunities that offer hope for addressing the significant challenges it faces. Among the most significant opportunities are the following:

- Legislation at the State and Federal levels that allows for innovative project delivery and procurement options.
- Private sector partners who are making unsolicited proposals to help finance and operate QDOT's facilities.
- Recent successes in partnering that have helped make QDOT an owner of choice for small- to medium-sized contractors.

QDOT's New Strategic Approach to Risk Management

The QDOT executive management has decided to create an agencywide risk management program to address the challenges and capitalize on the opportunities the agency faces. It believes that a better awareness of risk analysis and allocation techniques can assist it in improved planning, engineering, and construction management. The executive management has decided to dedicate resources for the following critical tasks:

- Creation of a strategic risk management oversight committee with representatives from planning, engineering, environmental, construction, and all other major groups.
- Investment in full-time staff and a commitment to on-call consultant agreements for facilitating risk identification workshops, performing risk assessments, and monitoring and updating project risk management plans.
- Development of a training program to create an awareness of risk identification, allocation, and management for planners, designers, estimators, and others.
- Development of a risk-based estimating approach for creating range estimates and supporting the risk assessment and allocation processes.
- Pilot (or test) of the risk management process on the US 555–SH 111 project.
- Monitoring and continuous improvement of the risk management process at periodic intervals.

CHAPTER 2

Risk Identification

2.1 Objectives of Risk Identification

The objectives of risk identification are to (1) identify and categorize risks that could affect the project and (2) document these risks. The outcome of risk identification is a list of risks. What is done with the list of risks depends on the nature of the risks and the project. On noncomplex, low-cost projects with little uncertainty (few risks), the risks may be kept simply as a list of red flag items. The 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 complex, high-cost projects that are by nature uncertain, 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 that it does not inhibit the identification of "minor" risks. The process should promote creative thinking and leverage team experience and knowledge. In practice, however, risk identification and risk assessment are often completed in a single step, a process that can be called risk assessment. For example, if a risk is identified in the process of interviewing an expert, it is logical to pursue information on the probability that it will occur, its consequences/impacts, the time associated with the risk (i.e., when it might occur), and possible ways of dealing with it. The latter actions are part of risk assessment, but they often begin during risk identification. This document, however, will treat the two activities of risk identification and assessment discretely for clarity.

2.2 Risk Identification Process

The risk identification process begins with the team compiling the project's risk events. The identification process will vary, depending on 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. Appendix B contains four examples of risk checklists and table 4 provides a summary of two of these checklists. Checklists and databases can be created for recurring risks, but project team experience and subjective analysis almost always will 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, (i.e., risk drivers). This is a practical way of addressing the large and diverse numbers of potential risks that often occur on highway design and construction projects. Risks are those events that team members determine would adversely affect the project.

After the risks are identified, they should be classified into groups of like risks. Classification of risks helps reduce redundancy and provides for easier management of the risks in later phases of the risk analysis process. Classifying risks also provides for the creation of risk checklists, risk registers, and databases for future projects. Table 4 is the highest level

Table 4. *Sample DOT risk identification checklists.*

CALTRANS SAMPLE RISK LIST	WSDOT 2002 URBAN CORRIDORS COMMON RISKS
☐ Technical	☐ Economic
☐ External	☐ Environmental
☐ Environmental	☐ Third party
☐ Organizational	☐ Right-of-way
☐ Project management	☐ Management
☐ Right-of-way	☐ Geotechnical
☐ Construction	☐ Design process
☐ Regulatory	☐ Construction
SOURCE: *PROJECT RISK MANAGEMENT HANDBOOK,* CALTRANS 2003.	SOURCE: *PROGRAMMATIC COST RISK ANALYSIS FOR HIGHWAY MEGA-PROJECTS,* MOLENAAR 2005.

NOTE: *See Appendix B for complete lists.*

classification for the checklist, which is provided in detail in Appendix B. Figure 8 in the "Foundations of Risk" section of Chapter 3 provides a different classification suggested by the Project Management Institute.

2.3 Risk Characteristics

Risk characteristics can be defined in a number of ways. Wideman provides one example that has transcended risk management in a number of technical fields: *knowns, known-unknowns,* and *unknown-unknowns*. This classification was used to describe project costs and contingency in figure 2. A known is an item or situation containing no uncertainty. Unknowns are things we know but we do not know how they will affect us. A known-unknown is an identifiable uncertainty. An unknown-unknown is simply an item or situation whose existence has yet to be encountered or imagined.

RISK CHARACTERISTICS

- ✔ Knowns, known-unknowns, and unknown-unknowns
- ✔ Risk triggers
- ✔ Risk versus opportunity events

Applying these characteristics to the elements of a conceptual cost estimate provides a good illustration. A known cost element is one that we can identify and quantify on the plans. A known-unknown is an item that is known to be required on the project, but at the conceptual stage it is not yet drawn on the plans and not yet quantifiable. An unknown-unknown is a project requirement that is not yet apparent or contemplated and therefore unknown. These characterizations can also be applied to the life cycle of a pavement. It is known that the pavement will fail. A known-unknown is that it will require maintenance (but it is not known when this will be needed). An unknown-unknown might be a new technology that will be invented to extend the life of the pavement.

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.

Finally, it is often helpful to think of risk in broader terms of uncertainty. Uncertainty involves both positive and negative events. This document follows the Project Management Institute's definition of risk: an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives.(3) 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). Examples discussed in this document from the FTA, WSDOT, FHWA's Federal Lands Highway Division, and 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 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.

2.4 Risk Identification Tools and Techniques

A number of documents and tools are available to support the risk identification process. Table 5 provides an example of project-specific documents, programmatic documents, and techniques available for risk identification.

Project risk can be identified multiple ways. At a minimum, the team should start by examining the project-specific and programmatic documents listed in table 5. Numerous techniques are available to facilitate risk identification after these documents have been reviewed. Brainstorming, scenario planning, and expert interviews are tools highway engineers commonly use in routine engineering and construction management tasks. The nominal group method allows each team member to create a list individually. The Delphi method is a process in which each team member individually and anonymously lists potential risks and their inputs. The Crawford slip method allows the team to individually list up to 10 risks. Afterward these risks are divided by the team into various categories and logged by category. Influence or risk diagramming is explained in the "Probability or Decision

Table 5. *Risk identification tools and techniques.*

PROJECT-SPECIFIC DOCUMENTS	PROGRAMMATIC DOCUMENTS	TECHNIQUES
■ Project description	■ Historic data	■ Brainstorming
■ Work breakdown structure	■ Checklists	■ Scenario planning
■ Cost estimate	■ Final project reports	■ Expert interviews
■ Design and construction schedule	■ Risk response plans	■ Nominal group methods
■ Procurement plan	■ Organized lessons learned	■ Delphi methods
■ Listing of team's issues and concerns	■ Published commercial databases	■ Crawford slip methods
	■ Academic studies	■ Influence or risk diagramming

Trees and Influence Diagrams" section of Chapter 4. Nominal group, Delphi, Crawford slip, and influence diagramming also serve as good tools for risk assessment, which is often blurred with risk identification.

The key to success with any risk identification tool or technique is to assist the experts in identifying risks. People and the agency's risk culture are the keys to continuous risk identification and risk management. The documents and techniques should only support the people in the risk assessment process and never inhibit or replace the engineering judgment required for a comprehensive risk identification process.

2.5 Conclusions

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 new risks should continually be invited into the process. The tools and techniques outlined in this chapter 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.

2.6 Illustration: Identification of Major Risks

The following continues the illustration described at the end of Chapter 1. In the previous illustration, QDOT had embarked on the creation of an agencywide risk assessment and allocation program. The following illustrates how QDOT applied the process on a pilot project. The first section describes the pilot project and the second section describes the risk identification process, which follows the tools and techniques outlined in Chapter 2.

US 555–SH 111 INTERCHANGE PROJECT

QDOT is planning to design and build an overpass and interchange on the existing at-grade intersections shown below. The project is of average complexity and size, which is appropriate for the agency's first project. The project is at the preliminary engineering stage and has the following characteristics and scope:

- Convert US 555 into a limited access four-lane freeway.
- Convert the intersection of US 555 and SH 111 into a grade-separated interchange.
- Reroute the arterials (Main and 12th Streets) that intersect SH 111 and eliminate the signalized intersections.
- US 555 consists of four 3.3-meter (m) (11-foot (ft)) lanes with no shoulders.
- SH 111 is two 3.3-m (11-ft) lanes with 1.2-m (4-ft) shoulders.
- Right-of-way is available to expand US 555 on the north side only.
- Right-of-way is also available at the US 555–SH 111 junction.

Figure 7. *Map of US 555–SH 111 interchange.*

RISK IDENTIFICATION

QDOT decided to conduct a facilitated risk identification workshop for this project. A consulting firm was selected based on its qualifications to help identify, categorize, and document the risks for the project. The project team gathered preliminary data for the workshop, including the project description, cost estimate, and the design and construction schedule. The facilitator brought a series of standard risk checklists and risk templates to be sure the team did not miss any common risks. All major QDOT disciplines were represented in the workshop, from planning to construction and environmental to right-of-way. The risk workshop began with all team members brainstorming about their issues and concerns on this

continued on next page

RISK IDENTIFICATION

continued from previous page
project. They also brainstormed about risks they had encountered on similar projects.

The outcome of the risk identification workshop was a categorized list of more than 100 risks that could affect the project's success. The following are examples of the categories and risks:

Technical risks

- Right-of-way analysis is in error at US 555 on the north side.
- The bridge piers have unexpected geotechnical issues.

External risks

- Landowners are unwilling to sell land at the US 555–SH 111 junction.
- Local communities pose objections.

Project management risks

- Project purpose and need are poorly defined.
- The QDOT staff has too many projects in the region.

CHAPTER 3

Risk Assessment

3.1 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 costs or schedules. 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, their likelihood of occurrence, and the consequences of such occurrences.

> - ✔ Risk determines the likelihood of a risk occurring (risk frequency) and judges the impact of the risk should it occur (consequence severity).
> - ✔ The risk assessment phase has as its primary objective the systematic consideration of risk events, their likelihood of occurrence, and the consequences of such occurrences.

3.2 Conducting Risk Assessment

Risk assessment is fundamentally a management activity supported by persons 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 on their worst-case effects and their relative likelihood of occurrence. Managers also 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 of the risks on project scope, cost, and schedule.

A comprehensive risk assessment combines both qualitative and quantitative assessments. The qualitative assessment is useful for screening and prioritizing risks and for developing appropriate risk mitigation and allocation strategies. The quantitative assessment is best for estimating the numerical and statistical nature of the project's risk exposure. This chapter will discuss qualitative risk assessments and Chapter 4 will cover quantitative risk assessment.

3.3 Complex Nature of Risk in Highway Project Delivery

Transportation projects are complex endeavors, and risk assessment for transportation projects is likewise a complex process. Risk events are often interrelated. Occurrence of a technical risk usually carries cost and schedule consequences. Schedule risks typically impact cost escalation and project overhead. One must carefully consider the likelihood of a risk's occurrence and its impact in the context of a specific set of project conditions and circumstances. A project's goals, organization, and environment influence every aspect of a given risk assessment. Some projects are primarily schedule driven; other projects are primarily cost or quality driven. Whether a specific risk event is perceived fundamentally as a cost risk or a schedule risk is governed by the project-specific context. The next several paragraphs discuss some risk characteristics that are salient to their assessment.

> - ✔ Risk assessment for transportation projects is a complex process.
> - ✔ Risk events are often interrelated.
> - ✔ A project's goals, organization, and environment influence every aspect of a given risk assessment.

3.3.1 Risk to Whom

A fundamental concept for any risk assessment is "risk to whom," or whose risk is being assessed and measured. A typical transportation project has many participants, most of whom carry some share of the risk. Some risks are carried by the construction contractor, others by the agency or its design consultants. Some risks are allocated between parties by contract or through insurance. From the vantage point of a performing contractor, changes in the scope of a project (i.e., differing site conditions) are not traditionally a cost risk because the cost consequences of the site condition fall to the transportation agency. From the vantage point of the agency, everything must be in its scope. Whether it maintains the risk itself or allocates it to the contractor via a contract, it ultimately bears the risk and must understand it. This essential concept—whose risk is being assessed—is central to an accurate and effective risk assessment. The allocation of these risks through the design or construction contract is discussed in Chapter 6.

3.3.2 Sources of Risks

Although project risks are interrelated and interdependent, most risks spring from a definite origin. The customary origins for project risks are the following:

- Performance, scope, quality, or technology issues
- Environment, safety, and health concerns
- Scope, cost, and schedule uncertainty
- Political concerns

Many risk checklists (see Chapter 2 and Appendix B) have been developed that classify different types of risks according to their source.

3.3.3 Foundations of Risk

It is useful to consider the source of the risk when conducting a risk assessment. Risks can be classified as either internal or external. Internal risks are those that arise within the scope and control of the project team. Most internal risks can be referenced to a specific project document such as a cost estimate or a schedule. Internal risks usually refer to items that are inherently variable (i.e., what is the cost of concrete or how long will it take to require the right-of-way?). External risks are items that are generally imposed on the project from establishments beyond the limits of the project. Interactions with citizens groups or regulators are typical external risks. Funding constraints and restrictions are other common external risks. External risks tend to refer to items that are inherently unpredictable but generally foreseeable. The Project Management Institute uses this classification of risk, shown in figure 8.[16]

3.3.4 Incremental and Discrete Risks

One can think of measuring risks two different ways. Some risks are measured incrementally and continuously. That is, occurrence of the risk evidences itself in a series of small changes over the life of the project. For example, the cost of one item may be 5 percent higher, the cost of another 10 percent. Most internal risk (costs, durations, quantities) are of this type. On the other hand, external risks are usually incident-oriented or discrete risks. In other words, the risk either occurs or it does not.

Many frequent, small changes characterize incremental risks. They are high-frequency but low-consequence risks. Discrete risks are characterized by a single large change. They are low-frequency but high-consequence events.

3.3.5 Model Risk and Data Risks

One risk distinction that is especially important in quantitative risk assessment is whether risks are epistemic or aleatory. Aleatory (data) risks refer to uncertainty associated with the data used in risk calculations. An example of an aleatory risk is the uncertainty surrounding the cost of a material (i.e., steel or asphalt). Epistemic (model) risks refer to risks that arise from the inability to accurately calculate a value. For example, one may know precisely the soils characteristics and

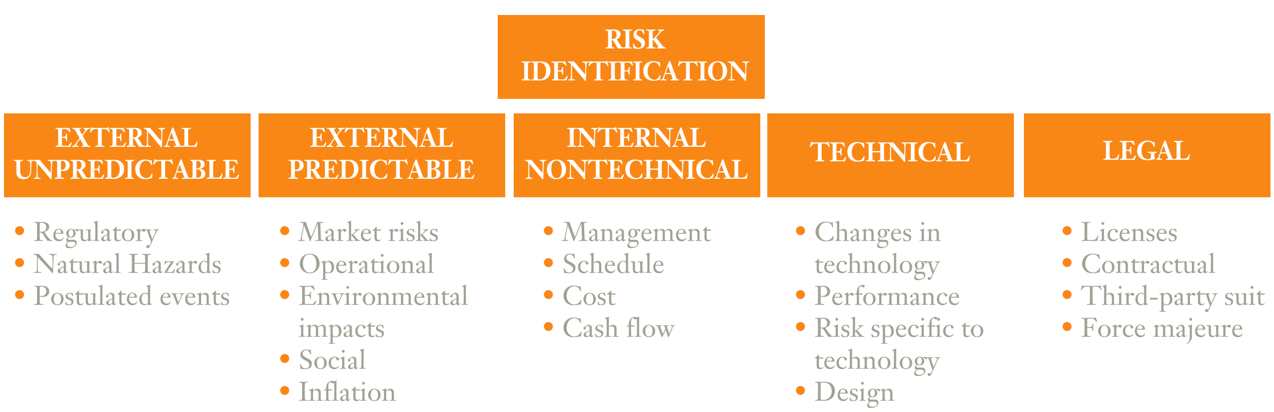


Figure 8. *Risk identification classification (adapted from* Project and Program Risk Management: A Guide to Managing Project Risks, *Wideman 1992).*

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

ASSESSMENT GUIDE

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

Consequence

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

RISK ASSESSMENT

High (Red)
Unacceptable. Major disruption likely. Different approach required. Priority management attention required

Moderate (Yellow)
Some disruption. Different approach may be required. Additional management attention may be needed

Low (Green)
Minimum impact. Minimum oversight needed to ensure risk remains low

Figure 9. *Risk assessment process (adapted from* Project Management Practices: Risk Management, *DOE 2003).*

still be unable to precisely calculate the number of compactor passes needed to attain a certain compacted soil density.

3.4 Risk Screening: Risk Severity and Frequency

Following the risk identification and qualitative risk assessment phases, one has developed a set of risks characterized by their frequency of occurrence and the severity of their consequences. Frequency and severity are the two primary characteristics used to screen risks and separate them into minor risks that do not require further management attention and significant risks that require management attention and possibly quantitative analysis. Various methods have been developed to help classify risks according to their seriousness. One common method is to develop a two-dimensioned matrix that classifies risks into three categories based on the combined effects of their frequency and severity. Figure 9 requires classifying risks into one of five states of likelihood (remote through near certain) and into five states of consequence (minimal through unacceptable). These assessments yield a five-by-five matrix that classifies a risk as either "high" (red), "moderate" (yellow), or "low" (green).

3.4.1 Low-Risk Events

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

3.4.2 Moderate-Risk Events

Moderate-risk events are either high-likelihood, low-consequence events or 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 either in their probability of occurrence or in their potential impacts. The subject of risk registers or risk watch lists is discussed in more detail in Chapter 5. Some events with very large, albeit unlikely, impacts may be actively managed to mitigate the negative consequences should the unlikely event occur.

3.4.3 High-Risk Events

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 the risk's negative impact.

3.5 Application of Risk Assessment

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 small highway reconstruction project can yield a prioritized list of red flag items to monitor over the course of a project's development, design, and construction. Red flag item lists are discussed in Chapter 5.

Risk assessment can also be conducted on a program of many projects. Figure 10 shows the results of a risk assessment used to identify areas of risk in the project and program delivery of the FHWA Federal Lands Highway Division. The agency was able to identify areas (the red cells in figures 10 and 11) that it needed to put more effort into for stewardship and oversight of the program. The intent in implementing this matrix was to use it as a framework to further refine the risk assessment of projects and program areas. It provides an excellent example of risk assessment at the programmatic level for highway project delivery.

3.6 Conclusions

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. A more complete discussion of risk mitigation and planning is in Chapter 5.

3.7 Illustration: Assessment of Risks

The following continues the illustration of QDOT's US 555–SH 111 interchange project. The risk assessment process has progressed from the risk identification phase to the risk assessment phase.

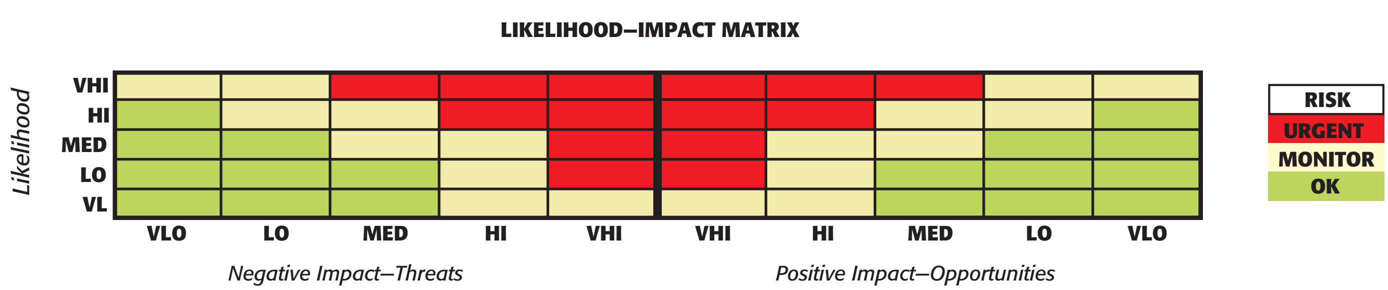


Figure 10. *Likelihood-impact matrix for the Federal Lands Highway Division.*

Program Components	Risk Factors	FLH Unit with Primary Responsibility	Frequency of Exposure (High, Medium or Low)	Likelihood of Risk Event/ Occurrence (High, Medium, Low)	Impact (High, Medium or Low)	Tolerance	Risk Prior to Control (High, Medium, or Low)	Stewardship and Oversight Controls	Post Control Risk (High, Medium, or Low)
Program Management									
Program Funding Allocations	Accuracy, Timeliness, Interception, Many players. Loss of ability to timely obligate funds. FHWA Integrity with Federal and State Partners	HQ	L	L	L	M	L	Reviewed by 3rd party. Separation of duties. Reconciliation. Project cost tracking.	L
IRR Program Oversight	Misuse of funds, Breakout of activities pending	HQ	H	H	H	L	H	Stewardship agreements, BIA controls	H
Delegations of Authority	Recent Audit issues have brought attention to this	HQ, FLHD	L	L	L	H	L		L
Planning & Programming									
Management Systems, Bridge BMS	Congressionally mandated. SMS, PMS under development. Bridge Mngmt Sys in place, poor data collection/data mining	HQ, P&P, TS PMS	M	M	L	M	M	Many under development	L
Selection of Projects	Not much political fallout with FWS and NPS but some with FS. FHWA sometimes involved in Project Selection with FWS and NPS	P&P	M	M	L	H	M	Under development via mgmt systems	L
Roadway Inventory Program	Cost, Data Integrity, Data Access, Schedule Delays	Tech Serv	H	M	L	H	M	FHWA Collects Data (NPS), QC/QA of digital data	L
Bridge Inspection Program	Tort Claims, Safety Issues, Loss of service which can be an adverse event if structural failure results in loss of life>>hence low tolerance	Bridge	H	L	H	L	M	FHWA Collects Data (NPS) biennially and evaluates bridge condition when critical. Projects added/revised to Program at annual Program Meetings. Bridge Inspections are conduted every 2-years, except for structures that are new or have low risk of deterioration, e.g. concrete which are then visited every 2- yrs & inspection reports developed every 4th yr. Struc. experiencing distress are monitored frequently, e.g. ever yr until rehabilitation or replacement occurs.	L
Reimbursable Agreements	Misunderstanding on how RAs are to be used. Focus of the Auditors. Signatory Auth. CO vs. DE.	P&P, Finance	H	H	H	L	H	FMFIA? 31 USC Section 1535?. EFLHD Legal Reviews	H
Project Delivery									
Bridge Design Standards (i.e. AASHTO LRFD)	Structural Failures impact Public Safety (i.e. loss of life & emergency access); Tort Claims; General Safety	Bridge	H	L	H	L	M	All bridge designs are independantly checked by an experienced checker.	L
A/E Outsourcing	Core competency, higher PE, poor quality, longer time, succession planning	P&P and Proj. Develop.	H	M	H	M	M	COTR certification, Evaluation Process, IDIQCs. FAR A/E Selection process, phased SOW with Notice to Proceed required between phases, Progress Meetings, Quality Control checklists, Performance Evaluations, Business Focused Measurements	M
R/W Acquisition (Uniform Act)	Larger issue for WFL/ CFL with counties., transferring to agencies	Proj. Develop.	H	H	H	L	H	Scheduling activities in PRMS, Timeline controlled by Partner Agency	H
Procurement and Acquisition									
Bidding Methodology	Increased usage of letter contracts	P&A	H	M	H/M	L	H	FAR, TAR, CO Review, Separation of Duties.	M
8(a) Procurement, Hub Zone	Not meeting targets, higher costs, less experience, brokering/suit case contracting. Potential Claims and loss of control in program (SBA). Little emphasis from DOT-FHWA	P&A	M	L	M	M	M/H	SBA. FDL, Annual Procurement Plan and Division goals established and monitored	M
Small Business Utilization	Not meeting targets, higher costs, less experience, brokering/suit case contracting. Little or no ability to control who gets contracts	P&A	L/H	L	M	L	L/M	SBA. FDL, Annual Procurement Plan and Division goals established and monitored	L
Small Purchases	Fraud, abuse, mismanagement	P&A	H	M	M	L	L		
Fiscal Management									
Accounting System	Cash flow, Cost Accounting System, Integrity with vendors, Inability to track project costs, loss of funds	Finance	H	H	H	L	H	FMFIA Review	H
Overhead Cost	Loss of program, dissatisfied partner, outsourcing?	Finance	H	H	M	M	M	FMFIA Review	M
Reimbursable Authority	Loss or limitations of Reimbursable Authority. Misuse. Consistency among Divisions. Tied with flexibility and capabilities of Accounting System.	P&P and Finance	H	H	H	L	H	15R Budget Tracking for Projects and Overhead	L

Figure 11. *Example of a Federal Lands Highway Division critical elements risk assessment.*

US 555–SH 111 INTERCHANGE PROJECT RISK ASSESSMENT

QDOT has retained the services of the consultant who facilitated the risk identification workshop to conduct the risk assessment because of the facilitator's skills and experience in risk elicitation, which is the process of drawing out judgments about uncertain events from the project team. The facilitator conducted meetings with a smaller group of the most experienced QDOT staff to elicit qualitative assessments of the major risks for the project. With each team member, the facilitator elicited the likelihood and consequences of each risk event. Whenever possible, the facilitator used caution in the assessment of these risks to compensate for individual biases. The facilitator also used caution in assessing risks that have differing consequences, such as time, cost, or political implications. QDOT has decided that it would like to standardize risk assessment in its process and use a variation of PMI's risk assessment method. An example of the outcome for two of the more severe assessments is provided here.

With the risks quantified in terms of their likelihood and impact, a ranked list of risks can be generated. QDOT management will use this knowledge to formulate a risk management plan. It will also determine if a rigorous quantitative risk analysis is required.

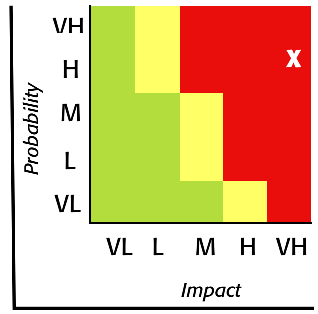
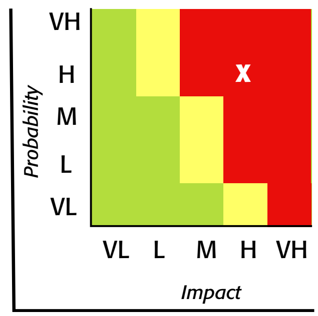
RISK	ASSESSMENT
Unexpected geotechnical issues at bridge piers	
Landowners unwilling to sell at US 555–SH 111 junction	

Figure 12. *Assessment outcome.*

CHAPTER 4

Risk Analysis

4.1 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 view projects from the contractor's perspective through a better understanding of the contractor's 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. The ultimate purpose of quantitative analysis, however, is not only to compute numerical risk values but also to provide a basis for evaluating the effectiveness of risk management or risk allocation strategies.

Many methods and tools are available for quantitatively combining and assessing risks. The selected method will involve a tradeoff between sophistication of the analysis and its ease of use. There are at least five criteria to help select a suitable quantitative risk technique:

1. The methodology should be able to include the explicit knowledge of the project team members about the site, design, political conditions, and project approach.
2. The methodology should allow quick response to changing market factors, price levels, and contractual risk allocation.
3. The methodology should help determine project cost and schedule contingency.
4. The methodology should help foster clear communication among the project team members and between the team and higher management about project uncertainties and their impacts.
5. The methodology should be easy to use and understand.

4.2 Characterizing Risk

Three basic risk analyses can be conducted during a project risk analysis: technical performance analysis (will the project work?), schedule risk analysis (when will the project be completed?), and cost risk analysis (what will the project

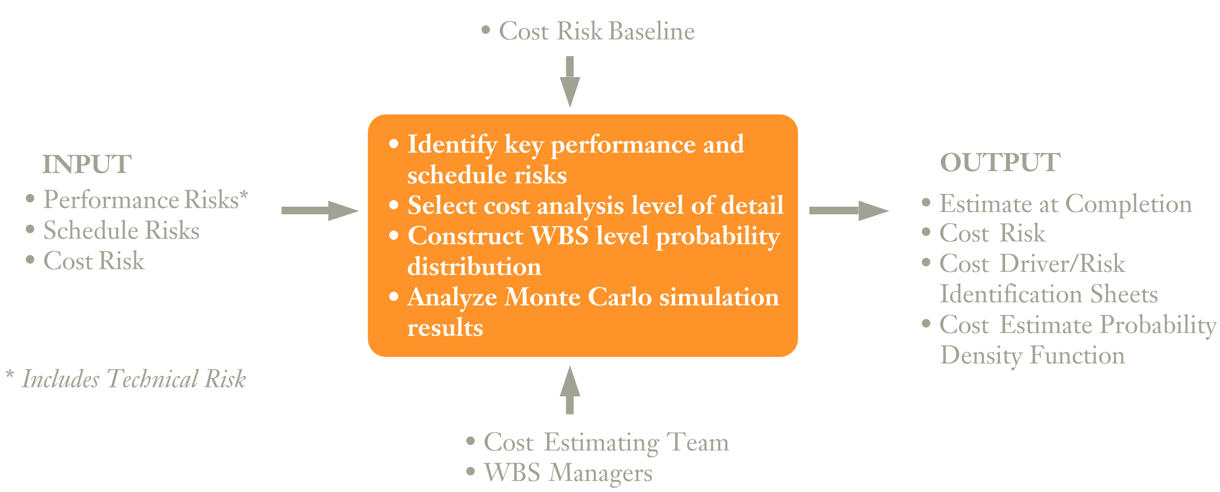


Figure 13. *Cost risk assessment top-level diagram (adapted from* Project Management Practices: Risk Management, *DOE 2003).*

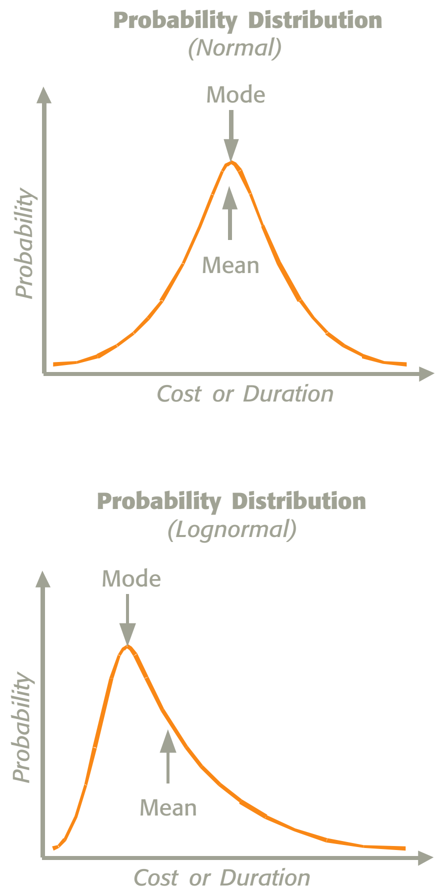


Figure 14. *Mean and mode in normal and lognormal distributions.*

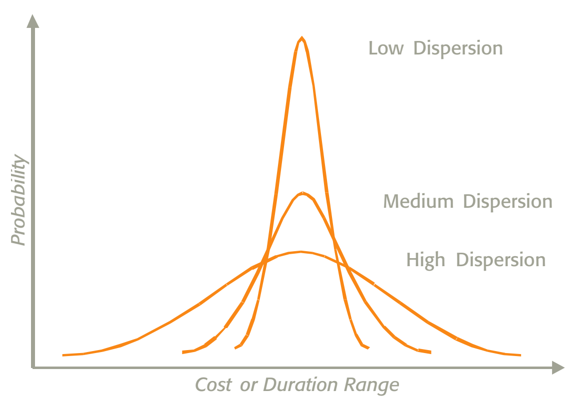


Figure 15. *Probability distributions for high, medium, and low dispersions.*

cost?). Technical performance risk analysis can provide important insights into technology-driven cost and schedule growth for projects that incorporate new and unproven technology. Reliability analysis, failure modes and effects analysis (FMEA), and fault tree analysis are just a few of the technical performance analysis methods commonly used. However, this discussion of quantitative risk analysis will concentrate on cost and schedule risk analysis only. 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 are required to perform the risk analysis? Second, what kinds of data, outputs, and insights does the method provide to the user? Figure 13, adapted from DOE's *Project Management Practices: Risk Management*, illustrates the relationship between the computational method (the model) and its required inputs and available outputs.

4.3 Input Risk Parameters

The most stringent methods are those that require as inputs probability distributions 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 alternative measures of central tendency; the mode is the most likely value across the variable's range. The mean is the value when 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 examples of continuous distributions are illustrated in figure 14.

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 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 15.

Finally, its shape or the type of distribution may distinguish a probability variable. Distribution shapes that are commonly continuous distributions used in project risk analysis are the normal distribution, the lognormal distribution, and the triangular distribution. These three distributions and a typical discrete distribution are shown in figure 16.

All four distributions have a single high point (the mode) and a mean value that may or may not equal the mode. 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.

4.4 Outputs of Risk Analyses

The type of outputs a technique produces is an important consideration when selecting a risk analysis method. Generally speaking, techniques that require greater 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:

1. Single parameter output measures
2. Multiple parameter output measures
3. 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 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 contingency 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 identification and subsequent management of the key risk drivers are the goals 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 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; in other words, they highlight the greatest contributors to the overall risk. Figure 17 (see page 24) is a tornado diagram for a portion of the Panama Canal Third-Lane Locks expansion project. The length of the bars on the tornado diagram corresponds to the influence of the items on the overall risk. Figure 17 depicts only a portion of the tornado diagram from one analysis of technical risks on the project.

4.5 Risk Analysis Methods

The selection of a risk analysis method requires an analysis of what input risk measures are available and what 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.

4.5.1 Traditional Methods

Traditional methods for risk analysis are empirically developed procedures that concentrate primarily on developing cost contingencies for projects. The method assigns a risk factor to various project elements based on historical knowledge of 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 its respective risk

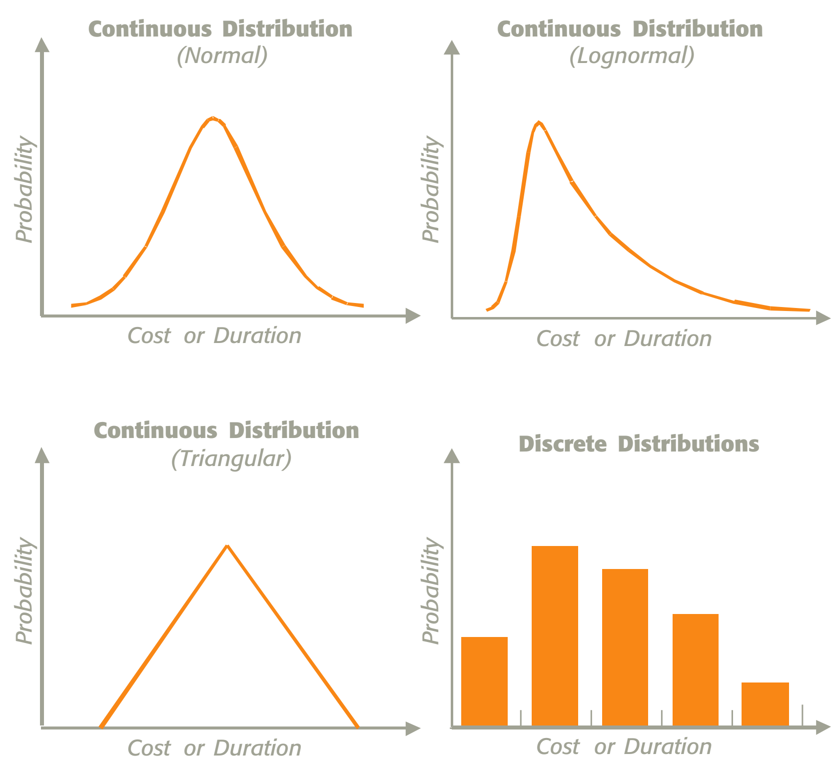


Figure 16. *Distributions for risk analysis.*

factors. This method profits from its simplicity and does produce an estimate of cost contingency. However, the project team's knowledge of risk is only implicitly incorporated in the various risk factors. Because of 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.

4.5.2 Analytical Methods

Analytical methods, sometimes called second-moment methods, rely on the calculus of probability to determine the mean and standard deviation of the output (i.e., project cost). These methods use formulas that relate the mean value of individual input variables to the mean value of the variables' output. Likewise, there are formulas that relate the variance (standard deviation squared) to the variance of the variables' output. These methods are most appropriate when the output is a simple sum or product of the various input values. The formulas below show how to calculate the mean and variance of a simple sum.

For sums of risky variables, $Y = x_1 + x_2$;

The mean value is $E(Y) = [E(x_1) + E(x_2)]$ and the variance is $\sigma_Y^2 = \sigma_{x_1}^2 + \sigma_{x_2}^2$

For products of risky variables, $Y = x_1 * x_2$;

The mean value is $E(Y) = [E(x_1) * E(x_2)]$ and the variance is $\sigma_Y^2 =$
$(E(x_1)^2 * \sigma_{x_2}^2) + (E(x_2)^2 * \sigma_{x_1}^2) + (\sigma_{x_1}^2 * \sigma_{x_2}^2)$

Analytical methods are relatively simple to understand. They require only an estimate of the individual variable's mean and standard deviation. They do not require precise knowledge of the shape of a variable's distribution. They allow specific knowledge of risk to be incorporated into the standard deviation values. They provide for a practical estimate of cost contingency. Analytical methods are not particularly useful for communicating risks; they are difficult to apply and are rarely appropriate for scheduled risk analysis.

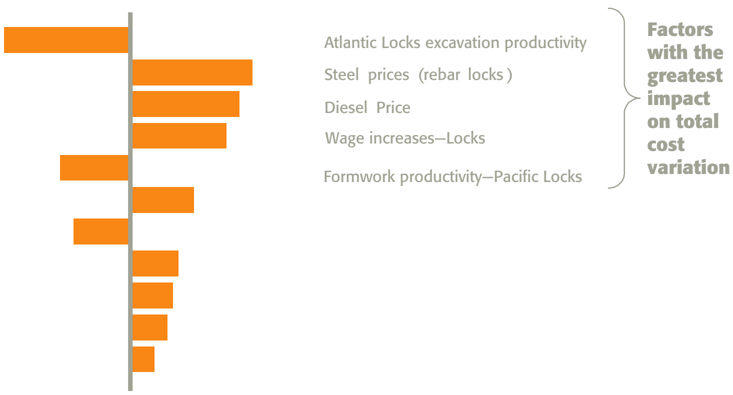


Figure 17. *Example of sensitivity analysis with tornado diagram.*

PROJECT COST ELEMENT	ESTIMATED COST	RISK FACTOR	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**

Table 6. *Traditional risk analysis method example.*

4.5.3 Simulation Models

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). Monte Carlo methods have many advantages. 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 their successful implementation. Input to Monte Carlo methods also requires the user to know and specify exact probability distribution information, mean, standard deviation, and distribution shape. Nonetheless, Monte Carlo methods are the most common for project risk analysis because they provide detailed, illustrative information about risk impacts on the project cost and schedule.

Figure 18 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

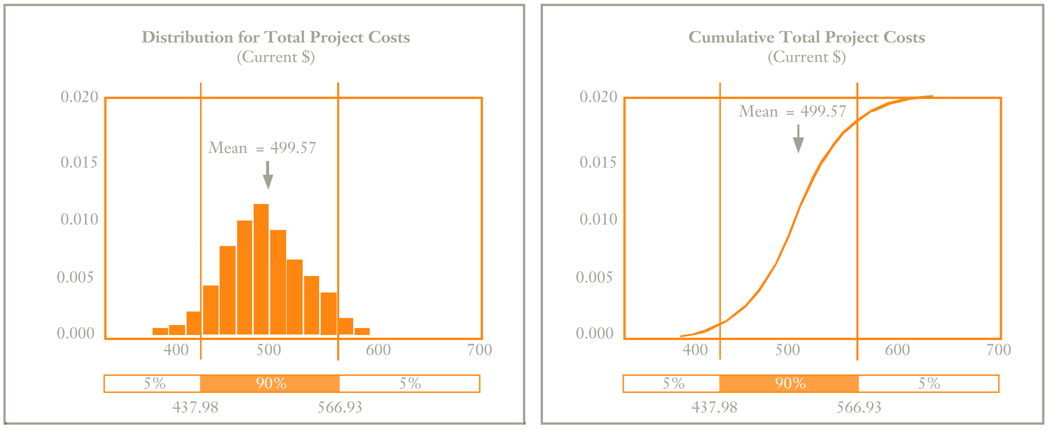


Figure 18. *Typical Monte Carlo output for total costs.*

Carlo methods produce numerical values for common statistical parameters, such as the mean, standard deviation, distribution range, and skewness.

4.5.4 Probability or Decision Trees and Influence Diagrams

Probability trees are simple diagrams showing the effect of a sequence of multiple events. Probability trees can also be used to evaluate specific courses of action (i.e., decisions), in which case they are known as decision trees. Probability trees are especially useful for modeling the interrelationships between related variables by explicitly modeling conditional probability conditions among project variables. Historically, probability trees have been used in reliability studies and technical performance risk assessments. However, they can be adapted to cost and schedule risk analysis quite easily. Probability trees have rigorous requirements for input data. They are powerful methods that allow the examination of both data (aleatory) and model (epistemic) risks. Their implementation requires a significant amount of expertise; therefore, they are used only on the most difficult and complex projects. Figure 19 presents a typical probability tree analysis.

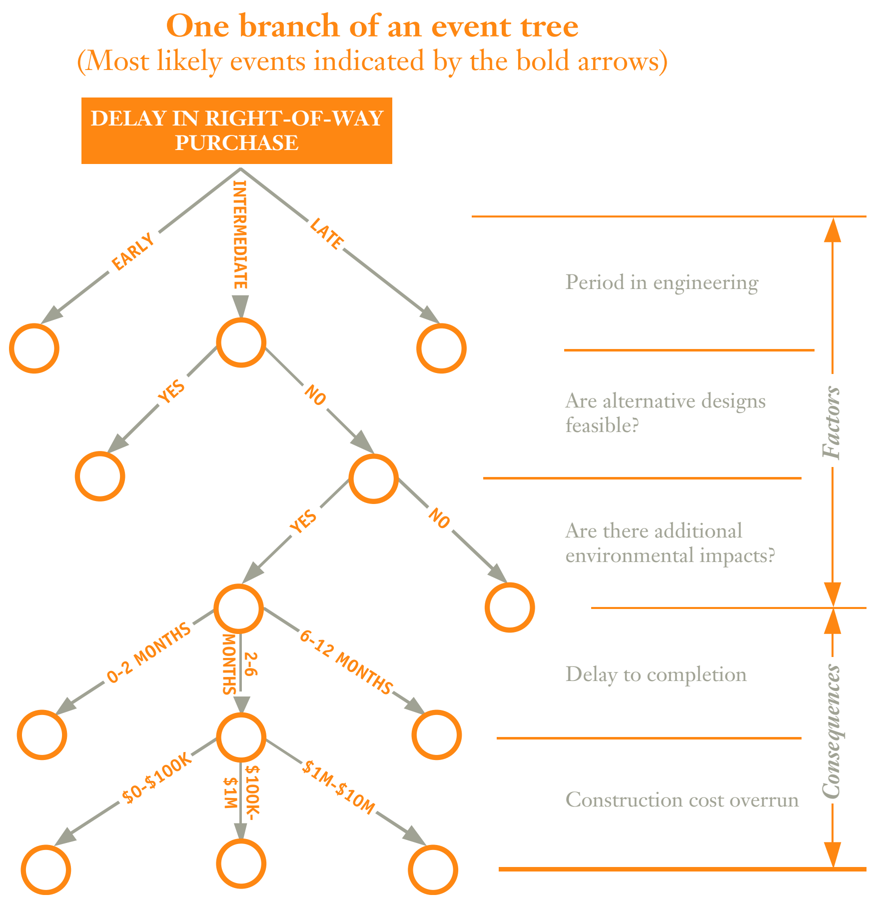


Figure 19. *Example of decision tree or event tree.*

4.6 Conclusions

The risk analysis process can be complex because of the complexity of the modeling required and the often subjective nature of the data available to conduct the analysis. However, the complexity of the process is not overwhelming and the benefits of the outcome can be extremely valuable. Many methods and tools are available for quantitatively combining and assessing risks. The selected method will involve a tradeoff between sophistication of the analysis and its ease of use. Adherence to sound risk analysis techniques will lead to more informed decisionmaking and a more transparent allocation of project risk.

4.7 Illustration: Risk Analysis and Range Cost Estimate

The following describes how the risks assessed in the Chapter 3 illustration were quantitatively assessed for inclusion in a risk-based cost estimate for the US 555–SH 111 interchange project. It also provides a range output for the project cost.

US 555–SH 111 INTERCHANGE PROJECT RISK ANALYSIS

QDOT management has determined that it will conduct a rigorous risk analysis for the project. It will use this information to develop a comprehensive risk management plan and generate a range cost estimate to communicate the uncertainty in the project to the internal and external stakeholders. The team determined that the most appropriate method to generate a range estimate is a Monte Carlo simulation. The team also wanted to use the sensitivity analysis and other output from the simulation model to support the risk management plan.

The consultant continued the elicitation process to gather more detailed information from the team members on quantitative measurements for cost and schedule risks. Two examples are shown here. This information was integrated with the project estimate to generate a range estimate.

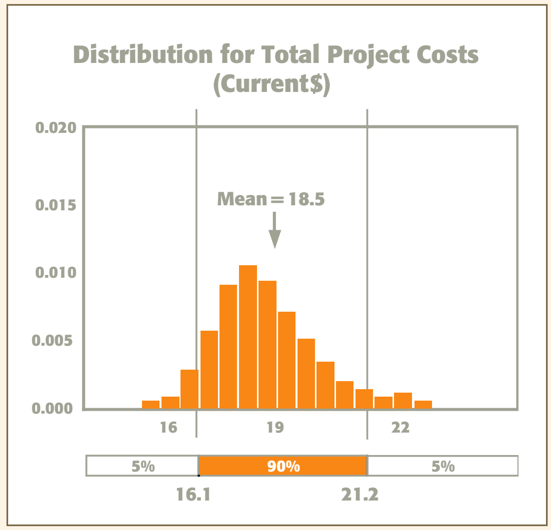


Figure 20. *Range estimate for project costs.*

Table 7. *Cost and schedule risks.*

RISK	COST		SCHEDULE	
	Probability	Impact	Probability	Impact
Unexpected geotechnical issues at bridge piers	20%	$1.5 mil	25%	2 months
Landowners unwilling to sell at US 555–SH 111 junction	15%	$0.5 mil	30%	4 months

CHAPTER 5

Risk Mitigation and Planning

5.1 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 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 on the point in project development, or it could be a private sector contractor or partner, depending on the contracting method and risk allocation.

> ✔ Formalizing risk mitigation and planning throughout a highway agency will help establish a risk culture that should result in two benefits:
> 1. Better cost management from planning through construction
> 2. Better allocation of project risks that align teams with customer-oriented performance goals.

Risk mitigation and planning efforts may require that agencies set policies, procedures, goals, and responsibility standards. Formalizing risk mitigation and planning throughout a highway agency will help establish a risk culture that should result in better cost management from planning through construction and better allocation of project risks that align teams with customer-oriented performance goals.

Once the agency planner, engineers, and construction managers have thoroughly analyzed the critical set of risks, they are in a better position to determine the best course of action to mitigate those risks. Pennock and Haimes of the Center for Risk Management of Engineering Systems state that three key questions can be posed for risk mitigation:[14]

1. What can be done and what options are available?
2. What are the tradeoffs in terms of all costs, benefits, and risks among the available options?
3. What are the impacts of current decisions on future options?

An understanding of these three questions is critical to risk mitigation and risk management planning. Question 1 addresses the available risk response options, which are presented in the following section. An understanding of questions 2 and 3 is necessary for risk planning because they determine the impact of both the immediate mitigation decisions and the flexibility of risk mitigation and planning on future events.

5.2 Risk Response Options

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

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

The above categorization of risk response options helps formalize risk management planning. The Caltrans *Project Risk Management Handbook* suggests a subset of strategies from the categorization defined by Wideman above.[6] 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 strategies and actions in the handbook include the following:

- **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. Transference reduces the risk only if the contractor is more

capable of taking steps to reduce the risk and does so. (This strategy is discussed in depth in Chapter 6).

- **Mitigation—**The team seeks to reduce the probability or consequences of a risk event to an acceptable threshold. It accomplishes this 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 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 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.

5.3 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 defines risk planning as the detailed formulation of a plan of action for the management of risk.(4) It is the process to do the following:

- Develop and document an organized, comprehensive, and interactive risk management strategy.
- Determine the methods to be used to execute a risk management strategy.
- 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 large projects or 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 also address evaluation of the capabilities of potential sources as well as early industry involvement.

5.4 Risk Planning Documentation

Each risk plan should be documented, but the level of detail will vary with the unique attributes of each project. Large projects or projects with high levels of uncertainty will benefit from 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. Projects that are smaller or contain minimal uncertainties may require only the documentation of a red flag item list that can be updated at critical milestones throughout the project development and construction.

5.4.1 Red Flag Item Lists

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.

> ✔ By listing items that can potentially 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 risk.

A red flag item list is a technique to identify risks and focus attention on critical items that can impact the project's cost and schedule. 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 and construction management. By listing items that can potentially 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 risk. Occasionally, items considered risky are mentioned in planning but soon forgotten. The red flag item list facilitates communication among planners, engineers, and construction managers about these items. By maintaining a running list, these items will not disappear from consideration and then later cause problems.

Caltrans has developed a sample list of risks (see Appendix B) in its *Project Risk Management Handbook.*(6) While this sample list can be used to create a list of red flag items for a project, it is quite comprehensive and any single project's list of red flag items should not include all of these elements. The next section discusses risk charters, which is a more formalized and typically more quantitative extension of a red flag list.

5.4.2 Risk Charters

The creation of a risk charter is a more formal identification of risks than the listing of red flag items. Typically, it is completed as part of a formal and rigorous risk management plan. The risk charter provides project managers with a list of significant risks and includes information about the cost and schedule impacts of these risks. It also supports the contingency resolution process described in Chapter 6 by tracking changes in the magnitude of potential cost and schedule risk impacts as the project progresses through the development process and the risks are resolved.

A risk charter is a document containing the results of a qualitative or quantitative risk analysis. It is similar to a list of red flag items, but typically contains more detailed information about the potential impact of the risks and the mitigation planning. The risk charter contains a list of identified risks, including description, category, and cause. It may contain measurements of magnitude such as the probability and impact of occurrence. It may also include proposed mitigation responses, "owners" of the risk, and current status. This method may be more effective than simply listing potential problem areas through red flagging because it integrates with the risk monitoring and control processes. The terms "risk charter" and "risk register" are synonymous in the highway industry.

A risk charter 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 charter can help control cost escalation. It is appropriate for large or complex projects that have significant uncertainty.

The charter organizes risks that can impact cost estimates and project delivery. A risk charter is typically based on either a qualitative or quantitative assessment of risk, rather than simple engineering judgment. The identified risks are listed with relevant information for quantifying, controlling, and monitoring. The risk charter may include relevant information such as the following:

- Risk description
- Status
- Date identified
- Project phase
- Functional assignment
- Risk trigger
- Probability of occurrence (percent)
- Impact ($ or days)
- Response actions
- Responsibility (task manager)

Two examples of risk charters are in Appendix D. The first example, from Caltrans, is a spreadsheet that forms the basis of the agency's risk management plan.[6] The spreadsheet contains columns for identification, analysis, response strategy, and monitoring and control. The second example is from an FTA report on risk assessment, which uses the term risk register synonymously with risk charter.[11] The FTA risk register contains more quantitative risk assessment information than the Caltrans example, but the goal of the documentation is similar. FTA adds issues such as correlation among dependent components, type of distribution used to model the risk, and expected value of the risks.

5.4.3 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 scoping process and updated at subsequent project development phases. Since the agency and contractor team's ability 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 road map that tells the agency and contractor team how to get from where the project is today to where the public wants it to be in the future. 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. The following is a sample risk management plan outline:

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 charter and risk monitoring
11. Risk management information system, documentation, and reports

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 charters, and formal risk management plans provide flexibility in risk management documentation.

5.5 Conclusions

Risk mitigation and planning use 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 charters, 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 help establish a risk culture that should result in better cost management from planning through construction and better allocation of project risks that align teams with customer-oriented performance goals.

5.6 Illustration: Risk Mitigation and Planning

The following provides an example of the risk mitigation and planning strategies for the illustrative project. It shows the portion of the overall risk charter used to manage the risks on the project. It also shows a sample of the risks and their associated mitigation strategy and mitigation actions. The columns for responsibility and interval or milestone check enable monitoring and control, as described in Chapter 7.

US 555-SH 111 INTERCHANGE RISK MITIGATION

The QDOT project team examined all of the risks for the project that would have a high impact if they were realized. The team also focused on those risks with a high probability of occurrence. This information was valuable for the team's understanding of the critical issues and helped them determine where they should expend their design effort. The team created a risk charter based on the initial risk identification and the detailed risk assessment and analysis. A number of the risks from this charter are illustrated below to show how the team proceeded with risk mitigation and planning. This charter formed the basis for the monitoring and control process described in Chapter 7.

Table 8. *Highlights from the US 555–SH 111 interchange risk charter.*

RISK	RESPONSE STRATEGY	RESPONSE ACTIONS	RESPONSIBILITY	INTERVAL OR MILESTONE CHECK
Unexpected geotechnical issues at bridge piers *Assessment—high*	Mitigation	The team will conduct further soils exploration and consider alternative pier designs.	Project team lead	Soil exploration complete Initial pier design complete
Landowners unwilling to sell at US 555–SH 111 junction *Assessment—high*	Avoidance	The team will attempt to design around areas where right-of-way may be an issue.	Right-of-way lead	Alignment complete
Local communities pose objections *Assessment—medium*	Mitigation	The team will conduct an aggressive public information campaign and inform the public about the safety and efficiency benefits of the project.	Public information lead	Monthly
Too many projects in the region for QDOT staff *Assessment—medium*	Acceptance	The team will attempt to design the project with agency staff and accept a longer design schedule.	Region executive management	Monthly

CHAPTER 6

Risk Allocation

6.1 Objectives of Risk Allocation

The contract is the vehicle for risk allocation. Whether the contract is for construction, construction engineering and inspection, design, design-build, or some other aspect of highway construction management, it defines the roles and responsibilities for 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.[17]

In a 1990 study, the Construction Industry Institute® (CII), a group of construction industry owners, contractors, and academics who study the industry and create best practices, states the following:

> 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.

Highway agencies have arrived at a somewhat standard set of risk allocation principles for highway projects in the traditional design-bid-build process. Most highway agencies follow the risk allocation principles suggested in the AASHTO *Guide Specifications for Highway Construction*. For example, highway agencies have discovered over time that maintaining the risk of differing site conditions (*Guide Specifications for Highway Construction*, Section 104.02) with the agency will result in lower bid prices and lower costs to the public in the long term. While this practice for the allocation of differing site conditions in the industry has undoubtedly resulted in an optimal risk allocation strategy, other traditional risk allocation principles have resulted in adversarial relationships between agencies and the contracting community.

- ✔ Risk allocation principles embedded in the industry can promote a one-size-fits-all process of risk allocation.
- ✔ The rigorous process of risk identification, assessment, analysis, and mitigation allows for a more transparent and informed understanding of project risk.

The risk allocation principles embedded in the industry's guide specifications are tested and well established in case law. However, their use can promote a one-size-fits-all process of risk allocation. The rigorous process of risk identification, assessment, analysis, and mitigation described in this document allows for a more transparent and informed understanding 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.

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

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

6.1.1 Allocate Risks to Party Best Able to Manage Them

A fundamental tenet of risk management is to allocate the risks to the party best able to manage them. The party assuming the risk should be able to best evaluate, control, bear the cost of, and benefit from its assumption.[18] For example, the risk of an inadequate labor force, a breakdown in equipment, or a specific construction technique 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 best able to manage them will ultimately result in the lowest overall price because contractors will not be forced to include contingencies 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 discusses the concept of allocating risks to the party best able to accept them:[20]

> 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.

6.1.2 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 it 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 a clear communication of these objectives to the contracting, consulting, or design community.

Allocating risks in alignment with project objectives begins with a clear understanding of the project objectives by the agency and a clear communication of these objectives to the contracting, consulting, or design community. While this idea seems simple, in practice it is often difficult to identify and prioritize concise objectives because of the complex nature of highway construction projects. A sample of project objectives is listed in table 9.

The project objectives in table 9 vary in style and emphasis because of unique project needs, but they all help define the agencies' requirements in terms of schedule, cost, quality, aesthetics, and end-user requirements. Ranking of the project objectives is important. Every project has tradeoffs among schedule, cost, and quality. It is to the project's benefit if both the agency and industry are in alignment with these project objectives.

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. In addition, project objectives can affect the procurement methods and contracting strategies. The objectives should be understood early in the project process and referred to for any important design, procurement, contracting, or construction management decision.

Table 9. *Example of project objectives to promote risk allocation.*

AGENCY	PROJECT	PROJECT OBJECTIVES (in descending order of importance)
Colorado DOT	Colorado Springs Metro Interstate Expansion Project	1. Maximize capacity and mobility improvements in the corridor within the program budget of about $150 million. 2. Minimize inconvenience to the public during construction. 3. Provide a quality project. 4. Complete by the end of calendar year 2008. 5. Provide a visually pleasing final product.
New Mexico DOT	US 70 Hondo Valley	1. Cost not to exceed budget. 2. High quality, safe, aesthetic, environmentally responsible, durable and maintainable project. 3. Contract awarded and signed by June 2002. 4. Project complete no later than September 25, 2004. 5. Valid basis for evaluation of design-build delivery system.
South Dakota DOT	Interstate 229	1. Timely completion. 2. Quality design and construction. 3. Reasonable cost.
Washington State DOT	I-405 Kirkland Stage I	1. Quality of design and construction (on time within budget). 2. Environmental compliance and innovation. 3. Maintenance of traffic. 4. Public information and community involvement.

6.1.3 Risk Sharing

The concepts of risk sharing and risk allocation are often used synonymously. 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."[18]

However, the term "risk sharing" can be somewhat misleading. In reality, no risk is truly shared; instead, exposure to the risk is split among 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 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 WSDOT. Traditionally, the agency maintained the risk for differing site conditions on drilled shafts for bridge piers. On a number of projects, it experienced substantial cost growth for differing site condition claims from contractors using equipment that was insufficient to remove small boulders in the drilled shafts. The agency determined it 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 it would choose the appropriate method for removing the rocks. Unfortunately, neither option was aligned with standard agency policy. Because the agency foresaw too much risk in prescribing the means and methods of construction, it chose the second solution of allocating the risk of the differing site conditions to the contractor.

Communication among 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 project objectives as described above. All nontraditional allocation of risk should be clearly pointed out to the contractors.

6.1.4 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 construction management scan was that the European highway community allocates more risk to the private sector, which has resulted in better alignment of team goals with customer goals.[10] 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. The agency has 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 (time plus cost) procurement is used on selected projects in the majority of highway agencies in the United States. In essence, A+B procurement passes the risk for early completion to the contractor to achieve a customer goal of satisfaction with the service. 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.

6.1.5 Risk Allocation Matrix

Perhaps the most widely used tool for risk allocation is a simple risk allocation table or matrix. Agencies and consultants often find it useful to compile the list of project risks (see Chapters 2, 3, and 4) in the form of a project risk allocation matrix. The matrix is intended to be a template for risk allocation in the contract provisions and a communication tool for all team members throughout the design and construction management process. The matrix can be a great benefit in keeping all team members aligned as they write individual provisions in the contract documents or sections of relevant procedural manuals. It provides clear direction when determining how far to carry design or when writing contract provisions. Table 10 provides a simple example of a risk allocation matrix as presented by the American Consulting Engineers Council and the Associated General Contractors of America in their 1992 *Owner's Guide to Saving Money by Risk Allocation*.[19]

Although table 10 is an example of a simple risk allocation table, the concepts can be expanded to cover all significant risks on the project. It intentionally does not contain a category for shared risks, but every attempt should be made to clearly assign the responsibility to one party.

Table 10. *Example of risk allocation matrix.*

RISK	PARTY RECOMMENDED TO ASSUME RISK	HOW RISK IS ASSIGNED OR MANAGED
Site access	Owner	Advanced planning or acquisition
Means and methods of construction	Contractor	Specific contract clause
Site conditions	Owner	Geotechnical investigation and contract clause
Weather, acts of God	Shared (owner assumes delay risk, contractor assumes dollar risk)	Contract clause

Allocation matrices are a fundamental tool in the development of design-build contracts. Appendix C provides an example design-build risk allocation matrix adapted from WSDOT's "Design-Build Responsibility/Risk Allocation Matrix" and Colorado DOT's "Southeast Multi-Modal Corridor Project's Contractual Responsibility Allocation Charts." It provides a detailed framework to make risk allocation decisions for each design-build project. The matrix is also applicable to traditional design-bid-build projects or projects that employ some type of innovative contracting.

6.2 Innovative Contracting Tools and Techniques

The contract is the vehicle for risk allocation. The contract provisions determine risk allocation, which in turn affects cost, time, quality, and the potential for disputes, delays, and claims. Most highway agencies follow the risk allocation principles suggested in the AASHTO Guide Specifications for Highway Construction. In December 1991, however, the Transportation Research Board published the final recommendations of Task Force A2T51 in a benchmark document titled Transportation Research Circular Number 386: Innovative Contracting Practices. In 1990, FHWA implemented Special Experimental Projects 14 (SEP 14) to provide a means for evaluating some of the task force's more project-specific recommendations. While SEP 14 is still in use today to monitor innovative contracting methods, many innovative methods—such as A+B (time plus cost) bidding, lane rental, and warranties—have become mainstream and do not require SEP 14 approval on projects with Federal-aid financing.

Innovative contracting techniques provide a means to allocate risks in alignment with project and customer goals. A+B bidding provides a means to allocate the risk for early completion to the contractor to achieve a customer goal of satisfaction with the service. Lane rental provides a means to allocate the risk for creating congestion during construction to the contractor. Likewise, warranties provide a means for passing long-term performance of the facility to the contractor. All of these techniques provide a means for aligning the construction partner's goals with the customer goals, and they can be effective when used on the right project.

Figure 21 provides a list of innovative project delivery, procurement, and contracting methods that can be used for risk allocation. Agencies can develop these nontraditional techniques and consider them on a project-by-project basis. As these techniques are considered, agencies should follow the fundamental tenets of sound risk allocation, including allocating risks to the party that is best able manage them, allocating the risk in alignment with project goals, sharing risk when appropriate to accomplish project goals, and ultimately seeking to allocate risks to promote team alignment with customer-oriented performance goals.

6.3 Contingency Considerations

Any party assuming a risk must be prepared for the financial burden associated with that risk. Prudent contractors and agencies use the quantitative risk assessment techniques described in Chapters 3 and 4 to estimate the contingency necessary to complete a project. Proper risk allocation will allow for the minimization of this contingency for both parties.

When an agency requires a contractor to assume a risk in a lump-sum contract, that contractor must include a contingency. This will obviously cost the owner money, but it may achieve a required project goal. An option that is not often exercised in the public highway industry but that has been successful in the private sector is establishment of a shared contingency pool, a sum of money set aside by the agency for an uncertainty in the project. The contractor can spend the contingency pool at its standard unit rates, but if the contractor can avoid spending the contingency pool, it can receive an incentive payment of 50 percent of the

Project Delivery Approaches

- Indefinite quantity/indefinite delivery construction manager at risk
- Design-build
- Design-build-warranty
- Design-build-operate-maintain (DBOM)
- Design-build-operate-maintain-finance (DBOM-F)
- Performance-based total asset management contracts

Procurement Approaches

- Bid-averaging method (BAM)
- Alternative bids/designs
- Request for proposals
- Cost plus time (A + B)
- Multiparameter bidding (A + B + Q)
- Best-value

Contract Payment Approaches

- Disincentive or penalty contracts
- Incentive contracts
- Incentive/disincentive contracts
- Lane rental contracts
- Active management payment mechanism
- No-excuse bonus contracts
- Lump-sum contracts

Figure 21. *Innovative contracting approaches for risk allocation.*

remaining money in the contingency pool. In the WSDOT example, the agency could have set $500,000 aside for removal of boulders encountered in drilled shafts. If the contractor used appropriate construction methods and requested only $300,000 of the pool to complete the work, it could receive a $100,000 incentive (50 percent of the money remaining in the pool). This incentive would be more profit than if the contractor had used the entire contingency pool at its standard unit rates. In this fashion, the agency and the contractor truly share the risk and rewards for managing the project uncertainty in construction.

6.4 Conclusions

The rigorous process of risk identification, assessment, analysis, and mitigation described in this document 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.

The 2005 construction management scan found that the European highway agencies have a more mature risk culture than found in the United States. The following statement of fair risk allocation is from England's Highway Agency *Procurement Strategy*).[21]

> **Fair Allocation of Risks**
>
> The HA has sought to improve the certainty of final construction project costs on certain contracts by the transfer of most risks to the contractor. This has been successful in improving cost and time certainty but it may not necessarily deliver best value as it comes at the price of a risk premium. A fair allocation of risks requires that risks are identified prior to the establishment of a contract. In addition, offerors need to be able to assess the potential consequence of a risk and to be able to include an appropriate risk allowance in the price bid. It is unlikely that a client will get best value if offerors have had to rely on guesswork if they have had inadequate information or if they will not be in a position to manage the risk. The outcome will be that the offerors will either guess too high or too low, neither of which scenarios will result in best value. The client will either pay too much or the quality of the product or service may be threatened by commercial pressure.
>
> In theory, best value is achieved by the owner paying for appropriate risk management measures together with the costs of dealing with the consequences of only those risks that actually occur. However, the contractor and the supply chain are more likely to contribute to the effective and efficient management of risks if they have fair and reasonable incentives. The judgment required by a client is how much to pay for the transfer of a risk, and at what level it is judged better value to retain the risk and to pay any consequential costs. The HA will accept risks where suppliers are prepared to work in partnership to manage the risks and control the consequences.

✔ In theory, best value is achieved by the owner paying for appropriate risk management measures together with the costs of dealing with the consequences of only those risks that actually occur.

6.5 Illustration: Risk Allocation

The following is an example risk allocation for the US 555–SH 111 interchange project. As described below, the executive management and the project team decided to pursue a design-build delivery for the project because of time and staffing constraints.

US 555–SH 111 INTERCHANGE RISK ALLOCATION

One of the risks that the project team described in the risk charter in the Chapter 5 illustration was "too many projects in the region for the QDOT staff." During the course of preliminary engineering, full funding for design and construction was allocated to the project earlier than expected and political pressure was put on the project team from the State level to complete the project early. Given the staffing issues and the need for early completion, the regional executive management and the project team determined that the project should be delivered using a design-build delivery method.

The team created a design-build risk allocation matrix to be certain that it was allocating the project risks equitably and in line with the project goals. A sample of the design-build risk allocation matrix is shown on page 36. Note that the allocation for the right-of-way risk concerning landowners at the US 555–SH 111 junction has been subdivided. QDOT has retained the risk for securing right-of-way within the basic configuration in the request for proposals, but left the door open for the design-builder to procure right-of-way outside the basic configuration at its own risk. Likewise, the team allocated the risk for a successful project information plan to the design-builder. In this manner, the State has retained some risk, but left the project open for design-builder innovation.

Table 11. *Highlights from the US 555–SH 111 risk allocation matrix.*

RISK	DESIGN-BID-BUILD ALLOCATION		DESIGN-BUILD ALLOCATION	
	Owner	Contractor	Owner	Design-Builder
Unexpected geotechnical issues at bridge piers	✔		✔	
Landowners unwilling to sell land at US 555–SH 111 junction	✔		✔	
Right-of-way outside of basic configuration at US 555-SH 111 junction	✔			✔
Local communities pose objections	✔		✔	
Successful public information plan	✔			✔
Too many projects in the region for QDOT staff	✔		✔	

CHAPTER 7

Risk Monitoring and Updating

7.1 Objectives of Monitoring and Updating

The objectives of risk monitoring and updating 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 risk monitoring and updating process occurs after the risk mitigation, planning, and allocation processes. It must continue for the life of the project because 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 can vary depending on 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.
3. Provide feedback of analysis and mitigation for future risk assessment and allocation.

7.2 Reporting

Risk reporting involves recording, maintaining, and reporting assessments. Monitoring results and assessing the adequacy of existing plans are critical. DOE's Office of Engineering and Construction Management states that the primary criterion for successful management is formally documenting the ongoing risk management process.(4) This is important for the following reasons:

- 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.
- It provides the rationale for project decisions.

A comprehensive risk charter can form the basis of documentation for risk monitoring and updating. The Caltrans risk charter/risk management plan in Appendix D provides documentation for risk monitoring and updating. Table 12 (see page 38) provides a summary of the risk monitoring items in the Caltrans risk charter.

Table 12 provides a communication tool for managers. The first two columns communicate if the risk is active and who "owns" the risk. The risk trigger helps management know when to implement a response strategy. The assessment quantifies the magnitude of the risk. The final column for monitoring and control summarizes the ongoing risk management activities.

Status reports can also be more graphically oriented. Table 13 (see page 38) 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 by DOE's Office of Engineering and Construction Management and populated with risks from the example risk lists in Appendix B.(4)

WSDOT has developed an exceptional top-level risk status report, shown in figure 22.(5) The "What's Changed" section 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 agency personnel and external stakeholders. It communicates key project information, benefits, and 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 done annually and updates information from the previous report. While the example shown is for a large corridor-level program, this format can be implemented successfully on smaller projects as well.

Table 12. *Selected monitoring items from Caltrans risk charter.*

CATEGORY	STATUS	FUNCTIONAL ASSIGNMENT	RISK TRIGGER	ASSESSMENT (Qualitative or Quantitative)	MONITOR AND CONTROL
Options or Definition	**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.

SOURCE: CALTRANS

Table 13. *Example of risk status report.*

RISK PLAN #	RISK ISSUE	HIGH	MEDIUM	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

SOURCE: ADAPTED FROM *PROJECT MANAGEMENT PRACTICES; RISK MANAGEMENT*, DOE 2003

7.3 Risk Management Metrics

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. It is considering (1) percentage of projects with risk management plans during the project initiation document (PID) phase (is it happening?), and (2) percentage of project change requests (PCRs) due to unidentified risks (builds into the quality of the PCRs). These measures will be tracked and reported by division headquarters of project management (for the measure on PCRs) and planning (for the measure on PIDs)

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

7.4 Contingency Management and Contingency Resolution

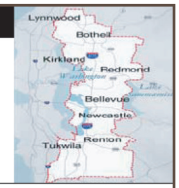
Contingency is a reserve amount of money or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization. Not all risks can be avoided or fully mitigated. If an agency accepts a risk, it is prudent to maintain a contingency in case the risk

I-405 Congestion Relief and Bus Rapid Transit Projects

Revised July 2003

Scenario

Tukwila to Bothell (Option C)



Project Descriptions:

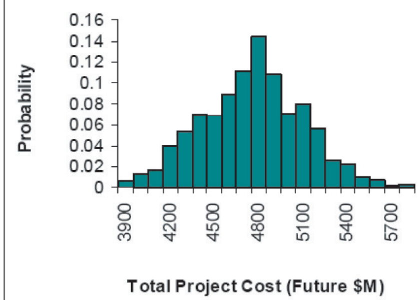
- Continuous multi-modal corridor improvement projects from I-5 in Tukwila to SR 522 in Bothell.
- Adds one lane each direction from I-5 to SR 181 in Tukwila.
- Adds two lanes each direction from SR 181 in Tukwila to I-90 in Bellevue.
- Adds one lane each direction from I-90 in Bellevue to SR 522 in 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

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.

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.

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 22. *WSDOT cost and risk status report.*

occurs. Likewise, the contractor maintains a contingency for risks that have been allocated to its organization in the contract. In the case of a shared contingency pool described in Chapter 6, the contingency is transparent to both parties and there are incentives for completing the project without spending the entire contingency.

The risk monitoring and updating process must address the management and resolution of the project contingency. The process involves a system for tracking and managing the contingency funds. In its simplest form, the estimated contingency reserve is allocated over time to match the exposure to the underlying risks. For example, the contingency derived from uncertainty in a right-of-way acquisition would be allocated before final design and continue until the acquisition is complete. Once the acquisition is complete, any remaining contingency for that item would be removed to avoid the temptation of spending it elsewhere in the project. Projects that have employed this approach often successfully limit the total contingency expended.

Traditional construction management tools, such as variance reports or earned-value methods, can be applied to the management of contingency. The key is tying risk resolution to the contingency pool. As risks are mitigated or resolved over time, the contingency pool should be reduced and reallocated. Likewise, if new risks are identified, the contingency funds should be revisited to ensure that they are adequate for successful completion of the project objectives.

7.5 Conclusions

A successful risk monitoring and updating process will systematically track risks, invite the identification of new risks, and effectively manage the contingency reserve. The system will help 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.

7.6 Illustration: Risk Monitoring and Reporting

The following illustrates how the QDOT project management team monitored and reported on the risks during construction. It is a highlight from the final step in the risk management process.

US 555–SH 111 INTERCHANGE RISK MONITORING

The QDOT team integrated the risk identification, assessment, analysis, planning, and allocation processes into the risk management process during design, procurement, and construction. The team used table 14 as a summary-level status report for the major project risks. The table provided the team with a periodic update of the risks so that the team could bring the risks to resolution. Notice that a new risk, unexpected utilities discovered on SH 111, was identified during construction and has been added to the monitoring system. The full monitoring system included a component for contingency management. The reporting information was also used to generate lessons learned and feedback for the overall risk management program at QDOT.

Table 14. *Highlights from the US 555–SH 111 risk status report.*

RISK	HIGH	MEDIUM	LOW	STATUS/COMMENT
Unexpected geotechnical issues at bridge piers	○ →	○ →	●	85% of piers complete
Landowners unwilling to sell US 555–SH 111 junction	○ →	○ →	CLOSED	Land acquired
Unexpected utilities discovered on SH 111	○	●	○	Utilities identified; design-builder will move
Right-of-way outside of basic configuration at US 555–SH 111 junction	○	●	○	Small construction right-of-way still pending
Local communities pose objections	○	○ →	●	Continued concerns with business
Successful public information plan	○	○	●	Design-builder plan is working well
Too many projects in the region for QDOT staff	○	●	○	Key staff could be lost to other projects

CHAPTER 8

Conclusions: What's Next?

8.1 Vision of Risk Assessment and Allocation in the Highway Sector

The construction management scan provided insights into the advanced awareness of risk assessment and allocation techniques in other countries. The case studies conducted in the development of this document revealed that these techniques are just now evolving in some U.S. highway agencies, but are not yet standard practice. It is hoped that this guidance document, which was developed as part of the scan implementation plan, will help raise awareness of risk management techniques and begin the process of incorporating elements of risk management into the institutional structures of State highway agencies.

It is the taking of opportunities that will yield the greater gain, and to do so requires rigorous analysis capability, as well as an understanding of the implications of associated management actions. The proposed framework outlined in this guidance document is built on a foundation of organizational changes, modified behaviors, analytical tools, and an overall commitment to "living risk management" within State highway agencies. Through the use of formalized risk assessment and allocation techniques, the team members from the construction management scan believe that State highway agencies will allocate risks in a more appropriate and transparent manner and thereby better align team goals to customer goals.

8.2 Next Steps

The FHWA/AASHTO Construction Management Expert Technical Group (CM ETG) plans to facilitate a series of workshops to assist in implementing risk management. The hands-on workshops will use local case studies and include both DOT and construction industry participation. The CM ETG will use this guidance document as the outline for the workshops. The intent of the workshop is to establish risk management in three to five States and then to adopt a lead State approach to spread the technique to other States.

The ETG will work with three to five States to conduct risk analysis in each State as a followup to the course. These States will commit resources in the form of personnel to develop and implement the risk management process in their States. Each State will conduct a minimum of three pilot studies, and it is hoped that an overlap of subject matter will allow States to compare results.

The first pilot study will focus on program topics, such as inspection levels or innovative contracting, using a qualitative assessment similar to the example from the Federal Lands Highway Division provided in Chapter 3. The second study will focus on a qualitative assessment for an appropriate construction project. This study will use the tools and techniques described in Chapter 3. The third and final study will involve a rigorous risk analysis using the analytical tools and techniques described in Chapter 4.

All three case studies will employ the mitigation and planning techniques described in Chapter 5 and the monitoring and updating tools and techniques used in Chapter 7. Finally, the project pilot studies will employ the risk allocation concepts and techniques in Chapter 6.

The CM ETG plans to provide instructors who can conduct the workshops and be available to help manage and oversee the case studies. The instructors will capture each case study, written by the host State, and compile them in a report to complement this guide. At that point, the CM ETG will revise this guide or create a risk manual that includes the case studies as appendixes.

The CM ETG encourages all States to begin development of a risk management process, with or without participation in the workshops. This guide has been written as a standalone document. The bibliography, case study information, checklists, and example charters can be used as reference materials to get started. The CM ETG hopes that this guidance document will help raise awareness of risk management techniques and begin the process of incorporating elements of risk management into the institutional structures of State highway agencies.

APPENDIX A

Case Studies

A number of U.S. and international agencies were employed as case studies for the development of this document. In some cases, the authors visited the agencies or interviewed staff via phone and e-mail. In other cases, they reviewed agency documents and incorporated them into this document.

Publication of this document does not necessarily indicate acceptance by the agencies participating in the case study, either inferred or expressed herein.

The CM ETG and the authors of this document wish to convey their sincere appreciation for the volunteer participation of these agencies and their dedicated staff. Without their participation, the development of this document would not have been possible.

Caltrans Risk Management Program

The case study for the Caltrans Risk Management Program was developed primarily through a review of Caltrans risk management documents and procedures. Additional information was collected by the authors as part of a cost estimating and risk management review of the Skyway Extension Span for the San Francisco–Oakland Bay Bridge.

For documents and procedures relating to the Caltrans Risk Management Program, see the Caltrans Office of Project Management Process Improvement Web site at:
http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

For documents on the San Francisco–Oakland Bay Bridge, visit:
http://www.dot.ca.gov/baybridge/
http://www.dot.ca.gov/baybridge/archive.

Highways Agency Risk Management (HARM)

The case study for the Highways Agency Risk Management (HARM) was developed through the international construction management scan. To view a report on the scan, visit:
http://international.fhwa.dot.gov/
http://international.fhwa.dot.gov/construction_mgmt/index.htm.

Information on the Highways Agency in England is at:
http://www.highways.gov.uk/.

Ministry of Transport, Public Works, and Water Management Public Sector Comparator

The case study for the Public Sector Comparator was developed through the international construction management scan. To view a report on the scan, visit:
http://international.fhwa.dot.gov/
http://international.fhwa.dot.gov/construction_mgmt/index.htm.

Information on the Ministry of Transport, Public Works, and Water Management (Rijkswaterstaat) in the Netherlands is at:
http://www.verkeerenwaterstaat.nl and www.rijkswaterstaat.nl

Additional information on the Public-Private Comparator and the Public Sector Comparator is on the PPP Knowledge Centre Web site at:
http://kenniscentrumppps.econom-i.com/uk/pps/otherpub.html.

FHWA Federal Lands Highway Division

The case study for the Federal Lands Highway Division was developed through correspondence with Dennis C. Quarto, technical services engineer for the Western Federal Lands Highway Division. For more information on the Western Federal Lands Highway Division or to contact Mr. Quarto, visit:
http://www.wfl.fhwa.dot.gov.

Virginia DOT Route 58 Project

The case study for the Virginia DOT Route 58 project was developed through an interview with Thomas W. Pelnik, director of the Innovative Project Delivery Division for the Virginia DOT. The case study was derived from a June/July 2003 preliminary risk assessment for the Route 58 Public-Private Transportation Act project from Hillsville to Stuart, VA. For more information on the Virginia DOT and the Innovative Project Delivery Division or to contact Mr. Pelnik, visit: *http://www.virginiadot.org/*
http://www.virginiadot.org/business/bu-ipd.asp.

Washington State DOT CEVP and CRA Programs

The case study for the WSDOT Cost Estimate Validation Process (CEVP) and Cost Risk Assessment (CRA) process was developed through an interview with Mark Gabel, design engineer for cost risk estimating and management, the CRA staff, and project managers using the processes. For more information on WSDOT and the CEVP and CRA processes or to contact Mr. Gabel, visit:
http://www.wsdot.wa.gov/
http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/

APPENDIX B

Risk Identification Checklists

1. DOE Office of Engineering and Construction Management Risk Document Checklist[4]

Risk management reports vary depending on the size, nature, and phase of the project. The following are examples of risk management documents and reports that may be useful:

- Risk management plan
- Risk information form
- Risk assessment report
- Risk handling priority list
- Risk handling plan of action
- Aggregated risk list
- Risk monitoring documentation:
  - Project metrics
  - Technical reports
  - Earned value reports
  - Watch list
  - Schedule performance report
  - Critical risk processes reports

2. Caltrans Sample Risk List[6]

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, or wetlands present
- ❑ Environmental impact statement (EIS) required
- ❑ Controversy on environmental grounds expected
- ❑ Environmental analysis on new alignments required
- ❑ Formal National Environmental Policy Act (NEPA) 404 consultation required
- ❑ Formal Section 7 consultation 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 manager workload
- ❑ Internal red tape causes delay getting approvals, decisions
- ❑ Functional units not available or 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 are 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 take more time and/or money

Construction Risks

- ❑ Inaccurate contract time estimates
- ❑ Permit work windows
- ❑ Utility
- ❑ Surveys
- ❑ Buried manmade objects/unidentified hazardous waste

Regulatory Risks

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

3. American Consulting Engineers Council and Associated General Contractors of America Checklist[19]

- ❑ Adequacy of project funding
- ❑ Subsurface conditions—rock, soils, water levels, hazardous wastes, archaeological encounters, existing utilities
- ❑ Adequacy of labor force
- ❑ Political climate and interference, community activism
- ❑ Adequacy and availability of owner representation
- ❑ Permits and licenses
- ❑ Site access
- ❑ Sufficiency of plans and specifications
- ❑ Innovative designs
- ❑ Owner involvement in design
- ❑ Appropriate designer involvement in construction
- ❑ Late or unsuitable owner-furnished material and equipment
- ❑ Delayed deliveries
- ❑ Delay in presenting problems
- ❑ Delay in addressing and solving problems
- ❑ Labor productivity
- ❑ Subcontractor capability
- ❑ Delays and disruptions
- ❑ Worker and site safety
- ❑ Adequacy of performance time
- ❑ Changes in needs or requirements of finished project
- ❑ Governmental acts
- ❑ Acts of God
- ❑ Union strife and work rules
- ❑ Cost escalation
- ❑ Overlapping insurance coverage
- ❑ Unreasonable systems performance guarantees

4. Washington State DOT 2002 Urban Corridors Study Common Risks (See Molenaar 2005 for Complete Definition)

Economic

- ❑ Market conditions
- ❑ Labor disruptions

Environmental

- ❑ Storm water treatment and/or quantities
- ❑ Changes in permitting
- ❑ Offsite and onsite wetlands
- ❑ Environmental impact statement (EIS)
- ❑ National Environmental Policy Act (NEPA) 404 merger process

Third Party

- ❑ Utility issues
- ❑ Rail lines (regular and light)

Right-of-Way

- ❑ Acquisition problems
- ❑ Value and impact

WSDOT Management
- ❑ WSDOT program management

Geotechnical
- ❑ Geotechnical conditions

Design Process
- ❑ Change in seismic criteria
- ❑ Bridge foundations
- ❑ Local arterial improvements and access
- ❑ Inadequate design/design uncertainty for interchanges
- ❑ Traffic demand

Construction
- ❑ Contaminated soil
- ❑ Natural hazards
- ❑ Work window
- ❑ Auxiliary lanes
- ❑ Staging areas

Other Risks
- ❑ Minor risks

APPENDIX C

Design-Build Responsibility and Risk Allocation Matrix

DESIGN-BUILD RISKS	OWNER	DESIGN-BUILDER
DESIGN		
Definition of scope		
Project definition		
Establishing performance requirement		
Preliminary survey/base map		
Geotechnical investigation—based on preliminary design in RFP		
Geotechnical investigation—based on proposal		
Establish/define initial subsurface conditions		
Initial project geotechnical analysis/report—based on preliminary design		
Proposal-specific geotechnical analysis/report		
Plan conformance with regulations/guidelines/RFP/proposal		
Plan accuracy		
Design criteria		
Conformance to design criteria		
Design review process		
Owner review time		
Design quality control		
Design quality assurance		
Changes in scope		
Constructability of design		
Efficacy of design		
Contaminated materials		
RIGHT-OF-WAY		
Establishing ROW limits		
Access hearings/findings and order		
ROW plan approval		
Appraisal/review		
Establish just compensation		
Acquire right-of-way		

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DESIGN-BUILD RISKS	OWNER	DESIGN-BUILDER
Construction easements		
Permanent easements		
Condemnation		
Complete relocation		
Take possession		
Certification		
Additional ROW purchase due to alignment change		
ENVIRONMENTAL		
Define initial project environmental impacts		
Define parameters for impacts		
Environmental investigation		
Environmental permits		
Environmental mitigation		
Environmental compliance		
Known hazardous waste—mitigation		
Unknown/undefined hazardous waste—mitigation		
Obtain environmental approvals—construction related		
UTILITY RELOCATION, LOCAL AGENCY PERMIT, THIRD PARTY, PUBLIC		
Identification of initial local agency impacts		
Obtaining initial local agency permits		
Establishing initial local agency requirements		
Establishing final/actual local agency impacts		
Modifications to existing local agency permits		
Identification of initial utility impacts from preliminary design		
Establish initial utility locations/conditions		
Defining required utility relocations from preliminary design		
Relocation of utilities before contract		
Relocation of utilities under agreement during contract		
Modified agreement with private utility		
Modified agreement with public utility		
Damage to utilities under construction		
Payment to utility owners		
Verification of utility locations/conditions		
Coordination with utility relocation efforts during contract		
Unforeseen delays due to utility owner and third party		
Utility/third-party delays resulting from proposal/modified design		
Betterment to utility		
Other work/coordination		
Third-party agreements (Federal, local, private, etc.)		
Coordinating with third parties under agreement		

DESIGN-BUILD RISKS	OWNER	DESIGN-BUILDER
Coordination/collection for third-party betterments		
Coordination with other projects		
Coordination with adjacent property owners		
Performance of utility work		
Coordinating with other government agencies (FHWA, etc.)		
Community relations		
Public safety		
CONSTRUCTION		
Disadvantaged business enterprise compliance		
Safety/safety QA		
Construction quality/workmanship		
Schedule		
Materials quality		
Materials documentation		
Material availability		
Initial performance requirements of QA plan		
Final construction/materials QC/QA plan		
Construction/materials QA		
Construction QC		
Construction QA procedural compliance auditing		
Construction independent assurance (IA) testing/inspection		
Construction staking		
Erosion control		
Spill prevention		
Accidents within work zone/liability		
Third-party damages		
Operations and maintenance during construction		
Maintenance under construction—new features		
Maintenance under construction—existing features		
Extraordinary maintenance		
Maintenance of traffic		
Damage to utilities under construction		
Falsework		
Shop drawings		
Equipment failure/breakdown		
Work methods		
Early construction/at-risk construction		
Community relations		
Performance of defined mitigation measures		
Warranty		

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DESIGN-BUILD RISKS	OWNER	DESIGN-BUILDER
FORCE MAJEURE/ACTS OF GOD		
Strikes/labor disputes—onsite labor		
Ordinary weather condition		
Extraordinary weather condition		
Tornado/earthquake		
Epidemic, terrorism, rebellion, war, riot, sabotage		
Archaeological, paleontological discovery		
Suspension of any environmental approval		
Changes in law		
Lawsuit against project		
Storm/flooding		
Fire or other physical damage		
DIFFERING SITE CONDITIONS/CHANGED CONDITIONS		
Changed conditions		
Differing site conditions		
COMPLETION AND WARRANTY		
Establishment/definition of any risk pool		
Long-term ownership/final responsibility		
Insurance		

NOTE: *Adapted from Washington State DOT's "Design-Build Responsibility/Risk Allocation Matrix" and Colorado DOT's "Southeast Multi-Modal Corridor Project's Contractual Responsibility Allocation Charts" for Recommended AASHTO Design-Build Procurement Guide (NCHRP 20-7/172).*

A P P E N D I X   D

Risk Charters

1. Caltrans Risk Management Plan Worksheet (Part 1).

PROJECT RISK MANAGEMENT PLAN											
	Identification							Qualitative Analysis			
	Status	ID #	Date Identified Project Phase	Functional Assignment	Threat/Opportunity Event	SMART Column	Risk Trigger	Type	Probability	Impact	Risk Matrix
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Active	3c	8/7/2002 PID	Environmental Analysis	Residents will want a higher soundwall than needed to mitigate noise.	The height of the proposed soundwall is 2 meters. Residents who live next to the freeway have expressed a desire for a 5 meter high wall.	Risk is occuring if the Revised Noise Study indicates the additional wall height is warranted.	Schedule Cost	High	High	Probability: VH H M L VL; Impact: VL L M H VH; X
											Probability: VH H M L VL; Impact: VL L M H VH
											Probability: VH H M L VL; Impact: VL L M H VH

EXAMPLE

Caltrans Risk Management Plan Worksheet (Part 2).

PROJECT RISK MANAGEMENT PLAN												
Qualitative Analysis				OPTIONAL Quantitative Analysis Impact			Response Strategy			Monitoring and Control		
Type	Probability	Impact	Risk Matrix	Probability (%)	($ or days)	Effect ($ or days)	Strategy	Response Actions including advantages and disadvantages	Affected WBS Tasks	Responsibilty (Task Manager)	Status Interval or Milestone Check	Date, Status and Review Comments
(9)	(10)	(11)	(12)	(13)	(14)	(15)=(13)x(14)	(16)	(17)	(18)	(19)	(20)	(21)
Schedule Cost	High	High	Probability: VH H M L VL; Impact: VL L M H VH; X	70%	100,000	70,000	Mitigation	Earmark $70,000 in the 6-page estimate for this risk. Add in an additional 250 hours in WBS 165 for an additional noise study to analyze 5 meter high wall at this location.	WBS 165 Perform Environmental Studies and Prepare Draft Environmental Document (DED)	Joe Envr. Manager	Two Months	
			Probability: VH H M L VL; Impact: VL L M H VH									
			Probability: VH H M L VL; Impact: VL L M H VH									

NOTE: *Risk Management Plan Worksheet available at http://www.dot.ca.gov/hq/projmgmt/guidance.htm.*

2. Example of Risk Register Detail (For Hypothetical Eight-Component Light Rail Project)

ID	Risk/Opportunity	Description of Issue	Affected Project Component	Correlation Among Dependent Components	Probability of Risk Occurring	Risk Cost: Distribution	Risk Cost: Expected Value[1]	Risk Duration: Distribution	Risk Duration: Expected Value of Delay[1]
Risk 1.	**Permitting and Interagency Agreements:**	Permits required from approval agencies could be delayed; intergovernmental agreements between grantee and other agencies might not be concluded on schedule.	**A. Design & Permitting** **D. Transit Construction**	Positive between Cost and Schedule (i.e., Duration) of Both Components A & D	25% (0.25)	Triangular *(see Fig 4-7 "C")*	A. $ 2.2 m D. $21.6 m	Triangular *(see Fig. 4-7 "C")*	A. 7 mos. D. 4 mos.
Risk 2.	**FFGA Approval:**	Grantee documentation of readiness to enter into full funding grant agreement negotiations with FTA might require further revisions, thereby delaying the anticipated FFGA approval date.	**B. FFGA Approval**		10%	No Significant Effect	No Significant Effect	Discrete *(see Fig. 4-6 "B")* 1 mos.= 50% 2 mos.= 30% 4 mos.= 20%	2 mos.
Risk 3.	**Station Design:**	Changes in stations features could occur late in final design and/or during early construction due to community concerns, requiring additional design effort and delaying start of certain construction activities.	**C. Station Construction**	Positive between Cost and Schedule (Delay=Higher Costs	30%	Exponential *(Fig. 4-7 "F")*	$10.0 m	Lognormal *(Fig. 4-7 "E")*	5 mos.
Risk 4.	**Right-of-Way Cost and Availability:**	Property costs are uncertain and possibly higher than anticipated; the acquisition schedule, including obtaining of construction easements, could be extended.	**D. Transit Construction**	Positive between Cost and Schedule	50%	Lognormal *(Fig. 4-7 "E")*	$30.0 m	Lognormal *(Fig. 4-7 "E")*	6 mos.
Risk 5.	**Utility Relocations:**	Locations of certain utilities are unknown and their relocation could be required.	**D. Transit Construction**		20%	Lognormal *(Fig. 4-7 "E")*	$5.0 m	Uniform *(Fig. 4-7 "A")*	6 mos.
Risk 6.	**Changing Market Conditions:**	The construction market is changing, with bid prices on similar work components on other projects varying considerably. Procurement costs for major project components could be higher than estimated.	**C. Station Construction** **D. Transit Construction** **E. Vehicle Design** **F. Systems Installation** **G. Vehicle Manufacture**	Positive among Costs of Components C-G	100%	Normal *(Figure 4-7 "D")*	C. $4.5 m D. $5.9 m E. $0.7 m F. $4.5 m G. $4.5 m	No Significant Effect	No Significant Effect
Risk 7.	**Light Rail Vehicles Price:**	With vehicles likely to be supplied by firms based outside the U.S., prices could fluctuate significantly in response to changing dollar exchange rates.	**E. Vehicle Design** **G. Vehicle Manufacture**	Positive between Cost and Schedule of Both Components E & G	10%	Lognormal *(Fig. 4-7 "E")*	E. $ 2.0 m G. $20.0 m	Lognormal *(Fig. 4-7 "E")*	E. 4 mos. G. 4 mos.
Risk 8.	**Systems Equipment Integration:**	Problems installing and testing of complex systems equipment and controls (signals, communications, tractions power, fare collection, etc.) could add to costs and delay the revenue operations date.	**H. Testing**	Positive between Cost and Schedule	50%	Lognormal *(Fig. 4-7 "E")*	$5.0 m	Lognormal *(Fig. 4-7 "E")*	6 mos.
Risk 9.	**Contractor Incentive Payment:**	Construction contract for primary general contractor includes an incentive payment of $10 million if work is completed ahead of grantee's base schedule.	**H. Testing**[2]		50%	Single Value	$10.0 m	No Significant Effect	No Significant Effect
Risk 10.	**Grantee Administrative Costs:**	Should project construction be extended, grantee administrative costs, including costs for construction management and design support during construction, will increase proportionately.	**H. Testing**[2]	Directly Proportional to Delay if Project Duration Over 72 Months	100%	Multiplicative[3]	Months of Delay X $0.5 m per Month	No Significant Effect	No Significant Effect

[1] Calculated or simulated expected value for individual risk event; does not account for possible effects of correlations with other components/risks, escalation effects, etc.
[2] Impacts assigned to final project component although the risk does not only apply to Testing component.
[3] Estimated project duration is 80 months. Total Admin. Cost Calculated as (80+Months Delay)/80 X Base Administrative Cost

SOURCE: RISK ASSESSMENT METHODOLOGIES AND PROCEDURES, FTA 2004.

Glossary*

brainstorming A general creativity technique that can be used to identify risks using a group of team members or subject-matter experts. Typically, a brainstorming session is structured so that each participant's ideas are recorded for later analysis. A tool of the risk identification process. (PMI)

checklist A list of many risks that might occur on a project. It is used as a tool in the risk identification process. Checklists are comprehensive, listing several types of risk that have been encountered on prior projects. (PMI)

contingency (or contingency reserve) The amount of money or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization. (PMI, Caltrans)

decision tree A diagram used to select the best course of action in uncertain situations. (Caltrans)

mitigation The act of alleviating a harmful circumstance. Risk mitigation seeks to reduce the probability and/or impact of a risk to below an acceptable threshold. (Caltrans)

monitoring The capture, analysis, and reporting of project performance, usually as compared to plan. (PMI)

Monte Carlo analysis A technique that performs a project simulation many times to calculate a distribution of likely results. See simulation. (PMI)

probability Likelihood of the occurrence of any event. (Caltrans)

probability and impact matrix A common way to determine whether a risk is considered low, moderate, or high by combining the two dimensions of a risk: its probability of occurrence and its impact on objectives if it occurs. (PMI)

project objective A particular goal of a project. All projects have four objectives: scope, schedule, cost, and quality. (Caltrans)

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. (PMI)

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 positive or negative effect on a project's objectives. (PMI)

risk acceptance A technique of the risk response planning process that indicates 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. (PMI)

risk allocation Placing responsibility for a risk to a party through a contract. The fundamental tenets of risk allocation include allocating risks to the party best able manage them, allocating risks in alignment with project goals, and allocating risks to promote team alignment with customer-oriented performance goals.

risk assessment A component of risk management that bridges risk identification and risk analysis in support of risk allocation.

risk avoidance Changing the project plan to eliminate the risk or to protect the project objectives from its impact. It is a tool of the risk response planning process. (PMI)

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. (DOE)

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. Tools used include brainstorming and checklists.

risk management plan Documents how the risk processes will be carried out during the project. This is the output of risk management planning. (PMI)

risk mitigation Seeks to reduce the probability and/or impact of a risk to below an acceptable threshold. (PMI)

risk register A document detailing all identified risks, including description, cause, probability of occurrence, impact(s) on objectives, proposed responses, owners, and current status. (PMI)

risk transference Seeking to shift the impact of a risk to a third party together with ownership of the response. (PMI)

scope Encompasses the work that must be done to deliver a product with the specified features and functions. (Caltrans, PMI)

simulation Uses a project model that translates the uncertainties specified at a detailed level into their potential impact on objectives 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. (PMI)

triggers Indications that a risk has occurred or is about to occur. Sometimes called risk symptoms or warning signs, triggers may be discovered in the risk identification process and watched in the risk monitoring and control process. (PMI)

**NOTE: This glossary relies heavily on the standards listed below. Many of the terms are defined directly from these references as noted at the end of the definitions.*

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The International Technology Exchange Program assesses and evaluates innovative foreign technologies and practices that could significantly benefit U.S. highway transportation systems. This approach allows for advanced technology to be adapted and put into practice much more efficiently without spending scarce research funds to recreate advances already developed by other countries.

The main channel for accessing foreign innovations is the International Technology Scanning Program. The program is undertaken jointly with the American Association of State Highway and Transportation Officials and its Special Committee on International Activity Coordination in cooperation with the Transportation Research Board's National Cooperative Highway Research Program Project 20-36 on "Highway Research and Technology—International Information Sharing," the private sector, and academia. For a complete list of International Technology Scanning Program topics and to order free copies of the reports, visit *www.international.fhwa.dot.gov* or e-mail *international@fhwa.dot.gov*.

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