

RISK MANAGEMENT GUIDE

For

PROJECT DEVELOPMENT



OFFICE OF DESIGN



NEW YORK STATE DEPARTMENT OF TRANSPORTATION

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CHAPTER 1 INTRODUCTION

1.0 INTRODUCTION

Developing Capital projects is a challenging, difficult and often lengthy process involving many interdisciplinary professionals who face a plethora of technical and process decisions. The expertise and involvement of decision makers and the processes that are employed can have significant influence on the final outcome of a project and its success. These are the risks and the judgments made on a daily basis as over one thousand currently active projects are being developed to produce the Capital Program.

This Capital Project Risk Management Guidance is intended to provide guidance and direction for practicing risk management for transportation project development. It serves to provide project managers, developers, consultants, team leaders, and team/squad member's guidance, policy and procedures specific to risk management. The guide will provide direction, outline appropriate methods and techniques used for risk management decision making and aid in the effective management of project risks, including threats and opportunities.

For the purposes of this document risk management is defined as: ***the intentional, systematic process of planning for, identifying, analyzing, responding to, monitoring of, and controlling Capital project related risks.*** Risk management involves people, processes, tools, and techniques that will contribute to the greatest extent possible to maximize the probability and results of positive events and minimize the probability and consequences of adverse events as indicated and appropriate within the context of risk to the *overall* project objectives of achieving the desired project outcomes within cost, schedule, scope and quality while meeting customer expectations. Project risk management is most effective when first performed early in the life of the project in the initial planning stages and practiced continually throughout the project's life cycle.



Figure 1
Source: FHWA

Effective risk management for project development begins in the planning stages, continues through design and culminates at the end of construction completion. The purpose of risk management is to effectively identify, quantify, mitigate and control risks so that they have a negligible effect on outcomes or, if necessary, are minimized to the greatest extent possible.

This guidance supersedes any other New York State Department of Transportation manuals on Risk Management (RM) for project development and delivery. Where risk management requirements of other manuals conflict with this manual, this Guide shall take precedence.

1.1 OVERVIEW, PURPOSE, AND USE

1.1.1 Overview

The Risk Management Guide covers the complete project development and delivery process, beginning from planning and environmental documentation through project execution and closeout. The procedures, format and content of this document has been developed based on “best practices” in the risk management industry to meet the specific needs and requirements of the Department and the State of New York, and to assure risk management is practiced in conformance with applicable Federal and State laws and regulations. Risks associated with project development are to be managed in accordance with this RMM.

An overarching perspective on risk management is highlighted in figures 1 and 2. The major steps involved with risk management relative to the fundamentals contained in this guidance, establishes a sound framework for which risk management is practiced during the development and delivery of projects.



Figure 2

The Capital Project Risk Management Process described in this guidance is intended to aid in the effective management of project risks, both threats and opportunities. To effectively manage risk, a concerted effort is necessary from all members involved with developing a project including the project manager, project sponsor, and project team members. Each should be involved in the joint development of a written risk management plan that will enable them to systematically identify, quantify, assess, prepare responses for, monitor, and control risks associated with project development.

Risk management is a practice that is conducted throughout the project development process. Risks must be identified, quantified, a response action planned and incorporated through a risk

management plan and effectively executed and monitored in order to best mitigate adverse effects. The project manager must conduct frequent reviews of project risks and the progress made in addressing them, indicating where risks are being effectively handled and where additional actions and resources may be needed.

Risk Management Fundamentals

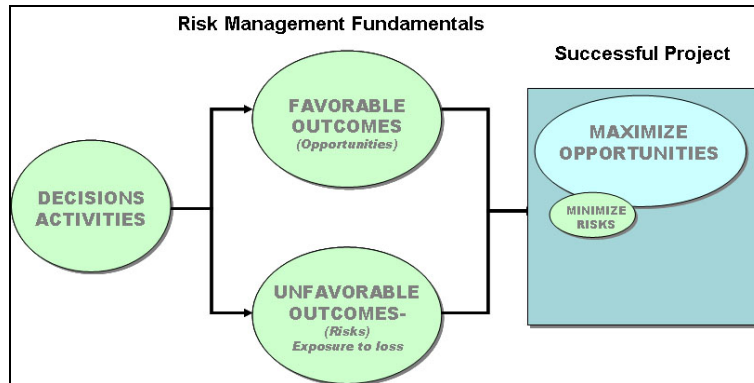


Figure 3

Identifying all project related risks is often an arduous and challenging task. There is little doubt about the fact that today's transportation projects are continuing to grow in their level of complexity. Complexity can be driven by several factors including a heightened awareness by stakeholders to participate and be part of the decision making process, increasing regulation at the Federal and State level, environmental and contextual sensitivities, and resource constraints. When these factors are combined the potential risks and how they are managed during project development including their scope, cost and schedule, can be and are very challenging tasks. The need for sound and effective methods to identify, quantify and manage potential risks is absolute.

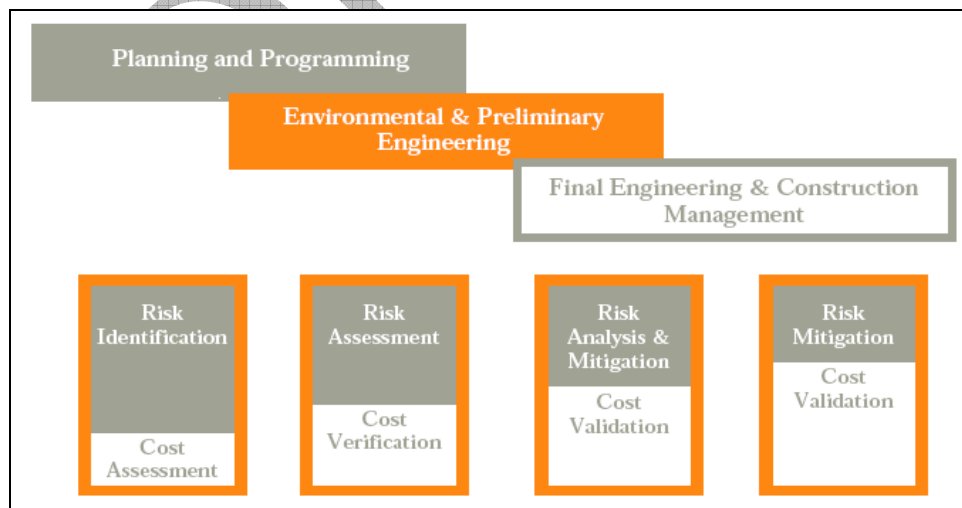


Figure 4

Source: Risk management and cost validation in the WSDOT CEVP process

The first and most important step in managing project risks is the able to identify and then quantify what the potential key risks are. Figure 2 is a conceptual illustration of the process and the types of risks that might be included.

Risk management is concerned with future events, whose outcome is unknown, and how to deal with uncertainties by identifying and examining a range of possible outcomes. The objective is to (a) understand risks and (b) mitigate or control risks. Understanding the risks inherent with each potential project alternative is important to controlling cost and developing estimates that reflect the cost of accepted risks and risks transferred to the contractor.

Risk management and an understanding of project uncertainty will assist project managers, developers, estimators and others involved in managing projects with the knowledge to address appropriately various contingencies for each individual project. This understanding is also important to managers of estimation processes. Cost estimation is one tool in a comprehensive risk management process. In the broader context of project development, a comprehensive risk management process includes:

- Risk identification
- Risk Assessment
- Risk analysis (qualitative and/or quantitative)
- Risk mitigation planning
- Risk management, monitoring and control

Analysis of Risk and Uncertainty

Analysis of risk and uncertainty involves the quantification of identified risks. In a comprehensive risk management process, risk analysis is used to prioritize the identified risks for mitigation, monitoring, and control purposes. In the context of cost estimation, risk analysis can be extremely helpful for understanding project uncertainty and setting appropriate contingencies. Risk analysis can be done through qualitative or quantitative methods.

Risk analysis can be done through qualitative or quantitative procedures. In a qualitative analysis process, the project team assesses each identified risk for its probability of occurrence and its relative magnitude of impact on project objectives. Quite often, experts or functional unit staff assess the risks in their respective fields and share these assessments with the project team. The risks are then sorted into high, moderate, and low risk categories (in terms of time, cost, and scope). The objective is to rank each risk by degree of probability and impact. The rationale for the decision should be documented for future updates, monitoring, and control.

Quantitative risk analysis procedures employ numeric estimates of the probability that a project will meet its cost and time objectives. It is common to simplify a risk analysis by calculating the expected value or average of a risk. The expected value provides a single quantity for each risk that is easier to use for comparisons. While this is helpful for comparisons and ranking of risks, estimators must take care when using the expected value to calculate project costs or contingencies. For example, if there is a 20% chance that a project will need a \$1 million storm water upgrade, the estimator will include \$200,000 in contingency using the expected value. If the storm water upgrade is required, this value will not be enough.

Unfortunately, a great deal of information is lost in this oversimplified contingency analysis. More comprehensive quantitative analysis is based on a simultaneous evaluation of the impact of all identified and quantified risks. The result is a probability distribution of the project's cost and completion date based on the risks in the project. Quantitative risk analysis involves statistical simulations and other techniques from the decision sciences. Tools commonly employed for these analyses include first-order second-moment (FOSM) methods, decision trees, and/or Monte Carlo simulations.

Highway project delivery is a complex task that is fraught with uncertainty. The Federal Transit Administration's 2004 *Risk Assessment Methodologies and Procedures* identifies several advantages of risk management:

- Better understanding of the project delivery process, including timelines and phasing, procedural requirements, and potential obstacles.
- More realistic estimates of individual component costs and durations, thereby allowing more reasonable expectations of total project cost and duration.
- Better understanding of what the project contingency is, whether it is sufficient, and for what it may need to be used.
- Information support to other project or agency activities, such as value engineering and strategic planning.
- Potential to improve the project budget and scheduling processes, possibly for the immediate project in development but certainly for future projects.

The intent of this guide is to provide a better understanding for managing the impacts of potential risks in terms of their consequences to project cost and schedules. It provides a systematic evaluation of project uncertainty. It assists estimators in setting appropriate contingencies and assists project managers in controlling project cost, schedule, and scope issues that can arise from uncertain or risky events.

Risk analysis can be used throughout the project development process. At the earliest stages of project development, risk analysis will be helpful in developing an understanding of project uncertainty and in developing an appropriate project contingency. As the project progresses through the development process, risk analysis can be used in a comprehensive risk management monitoring and control process to assist in managing cost escalation resulting from either scope growth or the realization of risk events.

1.1.2 Purpose

This document describes the basic concepts, processes and tools that guide risk management planning, implementation and management during project development.

The purpose of this manual is to describe the following:

- A) The RM process as it applies to planning, environmental process, Preliminary Engineering (PE), procurement, and project execution procedures to be followed;
- B) The roles and responsibilities of the participants in the RM process;
- C) The format and content of RM procedures and documents; and



- D) Any RM supplements and changes applicable to other Department policies and procedures.

1.2 Making a Business Case for Project Risk Management

One of the most compelling arguments for pursuing risk management as a standard practice is that the best agencies and organizations worldwide practice it, and with great success¹. Several reports from recent FHWA International Technology Scanning Program (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.

Findings of a scanning tour and identified in their reports recommended that the highway community:

- (1) Better align team goals to customer goals
- (2) Develop risk assessment, avoidance and mitigation techniques

As an example, the U.K. Highways Agency in its January 2001 report on a framework for business risk management makes a strong case for the necessity of practicing formal risk management.

It was determined from the findings of an international scan, that risk management be a core business practice. And, that the business practice drive decisions based on maximizing value for the investment (earned value management, EVM).

The reports collectively convey 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 decision making processes?

According to the Department of Energy, a risk management program should strive to accomplish the following:

- Be feasible, stable, and provide well-understood user requirements
- Foster a close relationship with user, industry, and other appropriate participants
- Be well planned and structured
- Be used to develop a preliminary acquisition strategy based on risk level and risk handling strategies
- Develop formal documentation

¹ Guide to Risk Assessment and Allocation for Highway Construction Management, Report #FHWA-PL-06-032, Federal Highway Administration, Washington, DC.

Risk Assessment: Timing, Issues, Objectives, and Outcomes Chart

PROJECT PHASE	STATUS	TYPICAL RISK ISSUE
LONG-RANGE PLANNING/ PROGRAMMING	<ul style="list-style-type: none"> ■ Focus is on general alignment and mode ■ Project details not defined; environmental reviews incomplete ■ Funding possibly not committed ■ Public support uncertain 	<ul style="list-style-type: none"> ■ Fatal or significant environmental economic impacts ■ Funding uncertainty ■ Uncertain political and public support ■ Competing interests and competing projects
PRELIMINARY ENGINEERING	<ul style="list-style-type: none"> ■ 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 	<ul style="list-style-type: none"> ■ 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	<ul style="list-style-type: none"> ■ 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 	<ul style="list-style-type: none"> ■ Changes to project scope and budget ■ Errors or omissions in quantities, inaccurate unit prices ■ Changes in design requirements ■ Market conditions, permit requirements
CONSTRUCTION	<ul style="list-style-type: none"> ■ Design complete; project defined ■ Commitments (funding, policy, etc.) in place ■ Construction in progress 	<ul style="list-style-type: none"> ■ Contractor performance, construction quality ■ Final permitting, right-of-way acquisition ■ Unanticipated site/working conditions ■ Field design changes ■ Construction safety

Figure 5
Source: FHWA

1.3. Use

This guidance is written primarily to assist Department staff directly involved in the development and delivery of capital projects. Other staff indirectly involved with project development may also use this guidance as necessary to help ensure a continuous and consistent risk management principled approach is used.

The roles and responsibilities of other participants in the RM process (such as project Stakeholders and Oversight and regulatory agencies) are defined and explained. The relationship of this RMM to other Department manuals is also provided.

This guide provides process, methodology and tool applications. It is intended to be a simple to use, yet effective method for identifying, quantifying and tracking project level risks. The tool / risk registry is discussed in chapter 6.

The processes described herein are intended to serve the following purposes:

- A) Provide knowledge, guidance and proper procedures on practicing risk management
- B) Provide technical information pertaining to risk management while offering explanations on risk management procedures and responsibilities;

- C) Provide risk management coordination and procedures with all pertinent Department policies and procedures;

Figure 7 illustrates an example of how risk mitigation can benefit project outcomes.

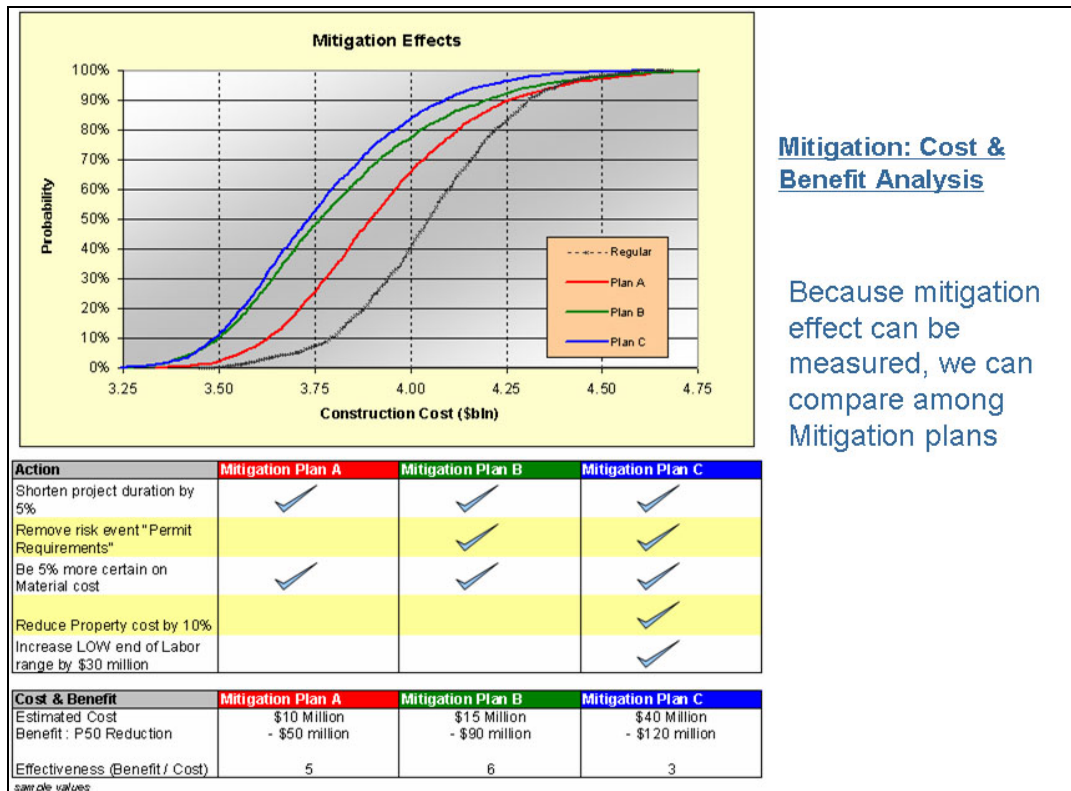


Figure 6

Source: DMJM Harris

1.4. Risk Management Process Overview

Successful Risk Management practices include the following major components: Awareness and Comprehension; Identification; Assessment and Analysis; Mitigation Planning; Allocation; Active Monitoring and Control. Each of these major components will be discussed in subsequent chapters to provide a thorough understanding and step by step methodology for practice.

Risk Assessment Methodologies and Procedures

OBJECTIVES FOR RISK ASSESSMENT	EXPECTED OUTCOMES
<ul style="list-style-type: none"> ■ Identify implementation challenges—political, public acceptance, approvals ■ Establish order of magnitude costs by option ■ Identify major design and construction risks 	<ul style="list-style-type: none"> ■ 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
<ul style="list-style-type: none"> ■ 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 	<ul style="list-style-type: none"> ■ 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
<ul style="list-style-type: none"> ■ 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 	<ul style="list-style-type: none"> ■ 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
<ul style="list-style-type: none"> ■ Targeted assessment of construction problems, causes, and potential cost/schedule impacts ■ Identification and systematic evaluation of possible corrective actions 	<ul style="list-style-type: none"> ■ 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

Figure 7
Source: FTA

Risk management practice must begin during the development stages of an Initial Project Proposal (IPP) and continues throughout the completion of construction close-out. During IPP, the transportation problem identification and definition process occurs within the context of potential environmental and social issues and possible constraints.

After all potential problems and issues have been adequately and satisfactorily explored, the proposed transportation project becomes defined as the IPP. At this time, the IPP should include all potential risk factors for further consideration and analysis. When the proposal is complete and approved, all potential risk factors are then included for further study as the Scoping phase of a project is conducted. Figure 8 illustrates the comprehensive overview of the risk management process.

Risk Management Process Overview (draft: in-development to be refined)

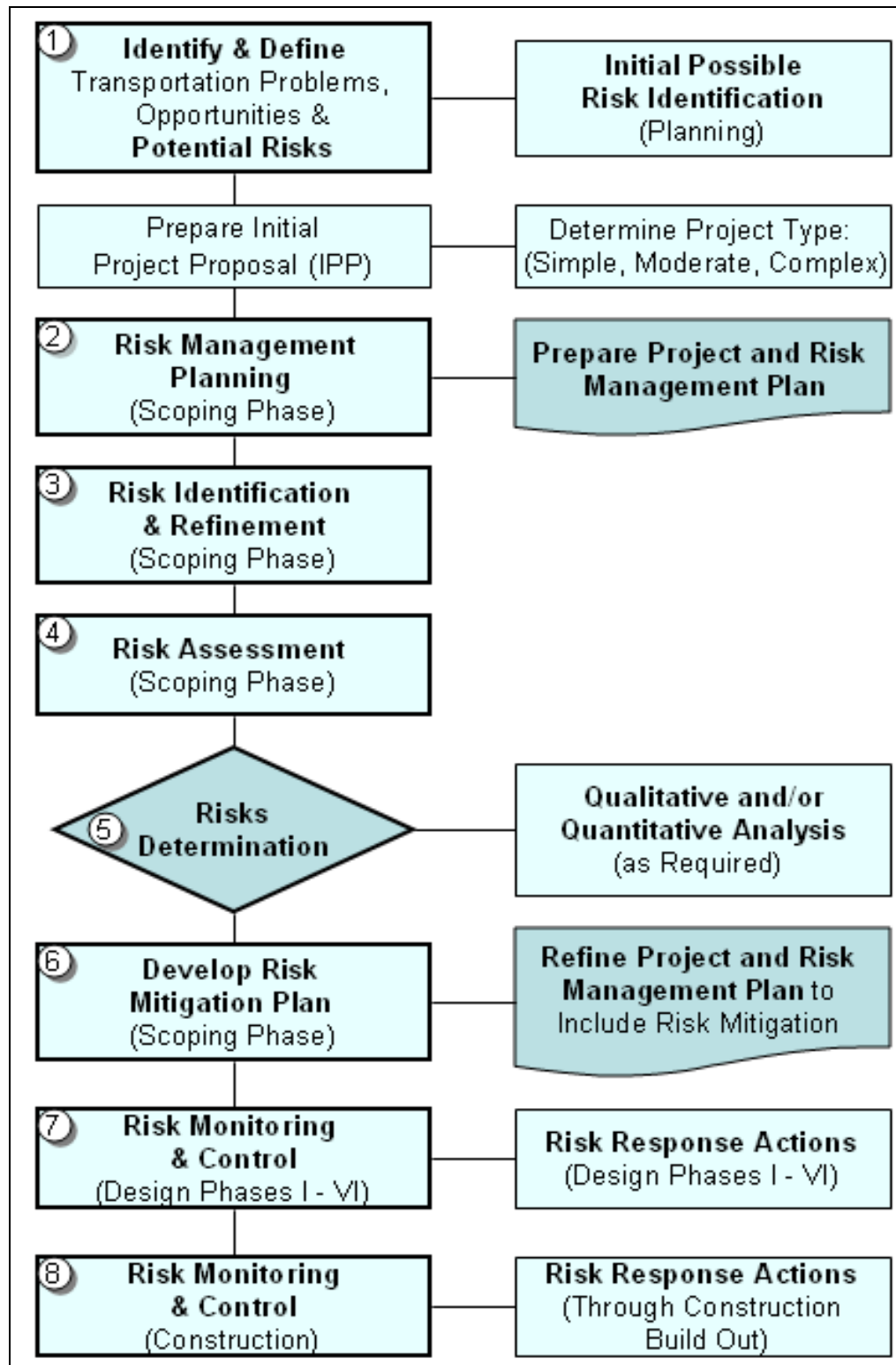


Figure 8
NYSDOT Office of Design

1.1.3 Roles and Responsibilities

Ultimately, the primary role and responsibility for identifying and managing project related risks lies with the Project Manager. The Project Manager has the authority to ensure project related risks are properly identified and mitigated. If certain risks are deemed beyond the authority of the Project Manager, the Regional Group director will have the ultimate responsibility to ensure the risk is managed effectively.

The project team also plays a central role in contributing to the development of a risk management plan for each project and that the risk tool (also described as a register, defined later in this guidance), be started at the beginning of the **Scoping** phase of project development. It is very important that the Project Manager and project team update the register on a regular basis for each subsequent project milestone to ensure all possible risks that can be avoided are avoided and all other identified risks continue to be monitored and controlled throughout the life of the project.

Roles and Responsibilities Table

Process Tasks	Role and Responsibility			
	Sponsor /Program Manager	Group Director	Project Manager	Project Team
Identify & Define Transportation Problems, Opportunities/Potential Risks	L	A		
Risk Management Planning	S	A	L	S
Risk Identification & Refinement		A	L	S
Qualitative / Quantitative Risk Analysis		A	L	S
Risks Determination and Mitigation Plan		A	L	S
Risk Monitoring & Control (Design)		A	L	S
Risk Monitoring & Control (Construction)		A	L (EIC)	S
Final Risk Performance Reporting		A	L (PM /EIC)	S

Legend:

L - lead role

S - support role

A - approval authority

2.0 RISK IDENTIFICATION

Caltrans describes the importance of risk identification in terms of careful and explicit planning that provides a foundation for risk mitigation and improves the likelihood of success. Risk Management Planning is the process of deciding how to approach and conduct the risk management activities for a project. Planning of risk management processes is important to ensure that the level, type, and visibility of risk management are suitable with both the risk and importance of the project to the organization, to provide sufficient resources and time for risk management activities, and to establish an agreed-upon basis for evaluating risks. The Risk Management Planning process should be completed early during project planning, since it is crucial to successfully performing the other processes.

The objectives of risk identification are to:

- (1) identify and categorize risks that could affect the project and
 - (2) document all identified 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.

A systematic approach to risk management can improve project development and outcomes while reducing the adverse effects such as costs, schedule and scope changes. As a result, risk management is a crucial part of the RM planning process, and should be one of the first steps taken when the Department starts to define candidate project for the Capital Program.

When risks are identified early and effectively analyzed to determine their applicability and magnitude, project managers are in a much better position to evaluate and determine possible measures to mitigate the potential impacts of a risk, determine how to best manage them, take appropriate steps to avoid adverse impacts to manage the effects of the risk and ultimately reduce that such risks may have on a given project. The risk factor evaluation lists help ensure project teams are aware of the range of risks that may exist in order to begin to address them. Implementation of risk mitigation strategies and risk allocation decisions are covered within this guidance. In addition, risk-related decision-making practices which serve to focus mitigation efforts will ultimately reduce the risks to the Department.

The result of Risk Management Planning is a Risk Management Plan. The risk management plan identifies and establishes the activities of risk management for the project in a project management plan.

Figures 8 and 9 provide more detailed illustration of many associated steps involved that are necessary to effectively manage risks during the project development process.

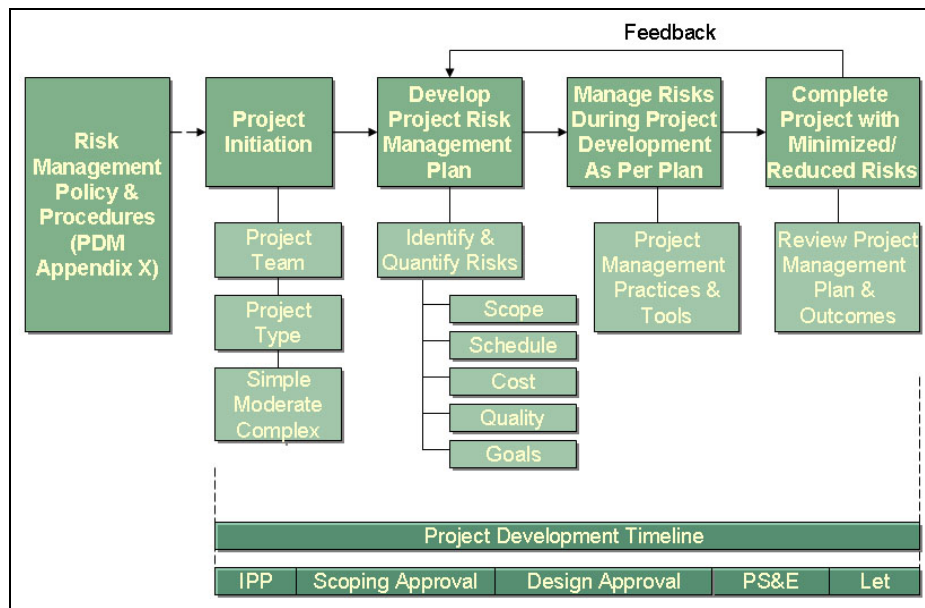


Figure 9
Source: Office of Design

Risk identification involves identifying and documenting potential project risks. The risk identification deliverable becomes part of the project risk model registry. Risk identification also documents risks their characteristics that might affect the project. The risk model registry is a living document that may at times be amended with updates and results from qualitative risk analysis and risk response planning, which can and should be reviewed and updated throughout the project.

The Department's project manager and his/her team will be the primary identifiers of and analyzers of project related risks. Several types of risks will often emerge that will require input or direction from group directors or executive management. Other participants such as project stakeholders should be actively involved as they offer important balance to social and physical characteristics of a project.

2.1 Risk Categorization

For more complex projects, participation by other Department specialists is advisable. There are many ways to assess and allocate risk. The procedure outlined here is relatively straightforward and easily documented and can be used on projects of any size or complexity. The process consists of 8 primary steps as described below and summarized in Figure 4. The rating process for risk probability, severity and overall risk rating is discussed and described in subsequent chapters.

On noncomplex, lower-cost projects with less uncertainty (and fewer risks) the risks may be kept simply as a list of red flag items to be monitored. 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.

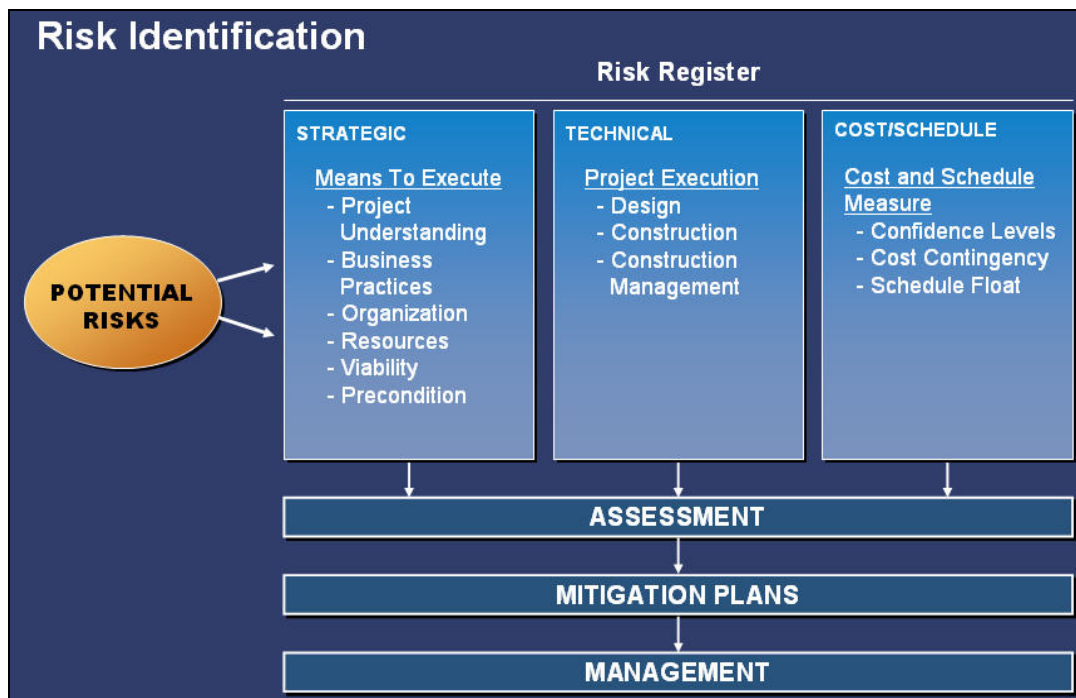


Figure 10
Source: DMJM Harris

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 C contains 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.

2.3 Risk Characterization

Risk characteristics can be defined in a number of ways. Wideman² provides one example that has transcended risk management in a number of technical fields:

- *Known;*
- *known-unknowns;*
- *unknown-unknowns;*

This classification is used to describe project costs and potential contingencies. 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. Applying these characteristics to the elements of a conceptual cost estimate provides a good illustration. See Appendix C - Case Study, for more information and how it can be applied.

RISK CHARACTERISTICS	POSSIBLE CONDITIONS	MAGNITUDE
Knowns		Low -Moderate
Known-unknowns		High
Unknown-unknowns		High
Risk triggers		High
Risk versus opportunity events		Low -Moderate

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). Risk characteristics provide a means to better categorize types of risk making it possible to plan for contingencies and their potential effect on a project.

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

² *Project and Program Risk Management: A Guide to Managing Project Risks and Opportunities*, Wideman, R.M., Project Management Institute, Newton Square, PA. 1992.

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.

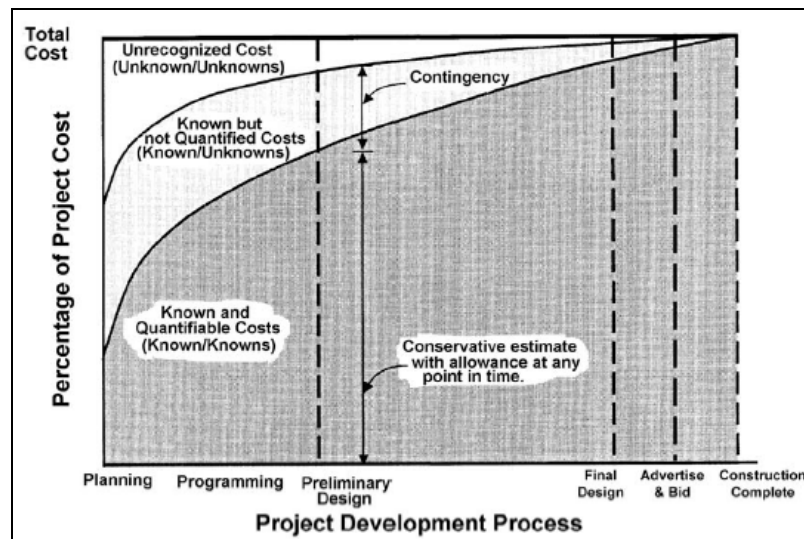


Figure 11
Source: TRB

It is also helpful to think of risk in its broader terms of uncertainty. Uncertainty involves both *positive* and *negative* events. This document builds from the Project Management Institute's definition of risk. It is stated here as: ***an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives, results and outcomes.*** However, it is often useful to separate uncertain events into two types, those that may have a negative effect (risks) and, those that may have a positive effect (opportunities). Some examples contained in this document, and the case study (Appendix D) are taken from the FTA, WSDOT, FHWA and DOE which use the concepts of risk to characterize uncertainty in their risk management programs. The terminology used has become common place in the state-of-the practice.

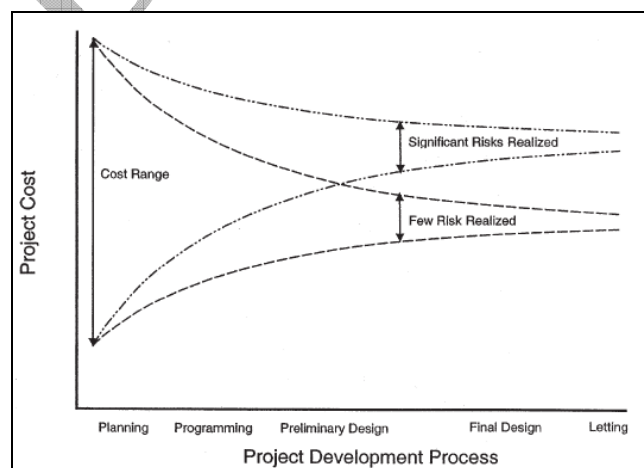


Figure 12
Source: TRB

However, it should be noted that project teams must be cautious not to overlook risk or focus on solving problems using the risk/opportunity characterization during the risk identification process. Project managers and team members may sometimes have an optimistic bias when thinking about uncertain items or situations because they are, by nature, problem-solvers. It is recommended that practitioners focus on exploring 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 2 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 2.

Numerous techniques are available to facilitate risk identification after these documents have been reviewed. Brainstorming, scenario planning, and expert interviews are some of the methods project developers commonly use in routine project development 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 a 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 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 judgment required for a comprehensive risk identification process.

Using the comprehensive Potential Risk Factors identification lists provided in Appendix B the project team shall identify and record all potential applicable project risks within each category. The list is intended to be comprehensive and a point of beginning. However, if and when additional risks are identified depending on project circumstances and context, they need to also be incorporated. The list includes risks that may affect successful implementation of the project, regardless of when such risks may occur.

The Potential Risk Factors list includes the following major categories:

- A) Project Development Risks
- B) External Risks
- C) Environmental Risks
- D) Project Management Risks
- E) Right of Way Risks;
- D) Construction Risks;



While many projects will have similar risk categories, the risks may vary from project to project.

Using the Potential Risk Factors list found in Appendix B the project team should review and discuss in relationship to the draft Initial Project Proposal, the project circumstances, needs, opportunities, challenges and context to identify and record potential project risks. The Potential Risk Factors list is provided to assist project teams with potential risk identification. They serve as a reference. It is important to note that other factors may be identified that are not on the list. In such cases they too shall be incorporated into the risk management plan. After the potential project risks have been identified during the IPP stage they must be recorded within the Risk Management Tool. All identified project risks shall be recorded and tracked using the Risk Management Tool.

It is important to note that all risks that have been identified be continued to be tracked during each successive stage. If any new risks emerge that were not initially identified during a prior project milestone phase they shall be added to the registry within the Tool. As each identified risk factor is addressed appropriately, it is imperative that they be tracked using the Risk Management Tool.

2.5 Conclusions

The risk identification process explores, distinguishes and categorizes any 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 while any new risks should continually be accounted for and included into the process. The tools and techniques outlined in this chapter provide a sound methodology for completing the activities that support the risk identification process. However, it will be the people involved in risk identification who are most critical to the success of the process.

3.0 RISK ASSESSMENT

After all potential project risks have been identified and recorded within the model registry in the Risk Management Tool it is necessary to determine and quantify the degree of risk that each risk factor has on the successful outcome of the project. To determine the risk quantification, qualification methods should be used.

Assess the likelihood (probability) a risk event of the nature listed and defined will occur over the course of the project. The probability should be rated on a scale of 1 to 3, with 3 representing the highest probability.

3.1. Risk Quantification Process

Risk Quantification is the process of evaluating the probability that a risk event will occur, and assessing the range of possible outcomes. Assess the degree of impact (severity) the occurrence of an identified risk event would have on the Project. The impact should be rated using a scale of 1 to 3, with 3 representing the highest severity and impact.

3.1.1. Understanding Risks 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 project developer, changes in the scope of a project (i.e., resulting from program changes) are a cost risk because the consequences of the change were unanticipated. The later changes occur the greater the potential risk. From the vantage point of the agency, everything must be in its scope. Whether it maintains the risk itself or allocates it to the others via a contract, it ultimately bears the risk and must understand and manage it. This essential concept - whose risk is being assessed - is central to an accurate and effective risk assessment. The allocation of risks through the design or construction contract is discussed further in Chapter 6.

3.1.2. Potential Sources of Risks

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

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

The potential projects risk checklists (Appendix B) have been developed in order to help assist in the classification and management of different types of risks according to their source. The lists are provided as a point of beginning. Other risks may be identified over the course of a project depending on its type, complexity and its context.

3.2. Risk Assessment and Analysis

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.

3.3. 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. A 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.

3.4. 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.

3.4.1. 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)

3.4.2. 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.

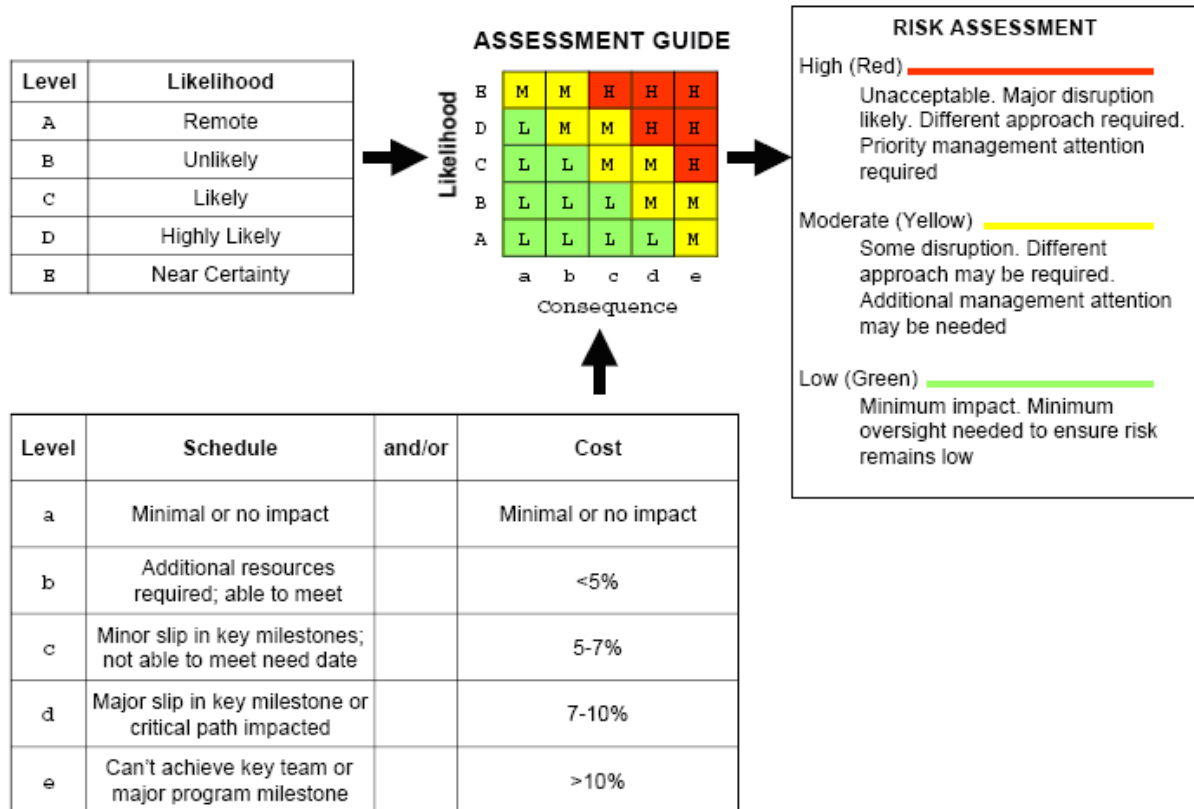
3.4.3. Model Risk and Data Risks

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

3.4.4. 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-dimensional 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).



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



Figure 13
Source: DOE

3.4.4.1. 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.

3.4.4.2. 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. Frequently, 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.

3.4.4.3. 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.

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 any given project and initiate an appropriate management response to their effective management and mitigation. A more complete discussion of risk mitigation and planning is provided in Chapter 5.

4.0 RISK ANALYSIS

Typically, a project's qualitative risk assessment will recognize risks where their occurrence is so likely or whose consequences are so serious that further quantitative analysis is warranted. Risk analysis can be done through qualitative or quantitative procedures. This guide discusses both qualitative and quantitative risk analysis methods. However, it will focus on and address primarily *qualitative* methods techniques and procedures. *Quantitative* procedures are briefly discussed to orient the reader and provide a better understanding of how it differs from qualitative methods. More information on quantitative procedures is provided in appendix E.

In a qualitative analysis process, the project team assesses each identified risk for its probability of occurrence and its relative magnitude of impact on project objectives. Quite often, experts or functional unit staff assess the risks in their respective fields and share these assessments with the project team. The risks are then sorted into high, moderate, and low risk categories (in terms of time, cost, and scope). The objective is to rank each risk by degree of probability and impact. The rationale for the decision should be documented for future updates, monitoring, and control.

Quantitative risk analysis procedures employ numeric estimates of the probability that a project will meet its cost and time objectives. It is common to simplify a risk analysis by calculating the expected value or average of a risk. The expected value provides a single quantity for each risk that is easier to use for comparisons. While this is helpful for comparisons and ranking of risks, estimators must take care when using the expected value to calculate project costs or contingencies. For example, if there is a 20% chance that a project will need a \$1 million storm water upgrade, the estimator will include \$200,000 in contingency using the expected value. If the storm water upgrade is required, this value will not be enough.

Unfortunately, a great deal of information may be missed or lost in this oversimplified contingency analysis. More comprehensive quantitative analysis is based on a simultaneous evaluation of the impact of all identified and quantified risks. The result is a probability distribution of the project's cost and completion date based on the risks in the project. Quantitative risk analysis involves statistical simulations and other techniques from the decision sciences. Tools commonly employed for these analyses include first-order second-moment (FOSM) methods, decision trees, and/or Monte Carlo simulations.

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.

Cost Risk Assessment Diagram

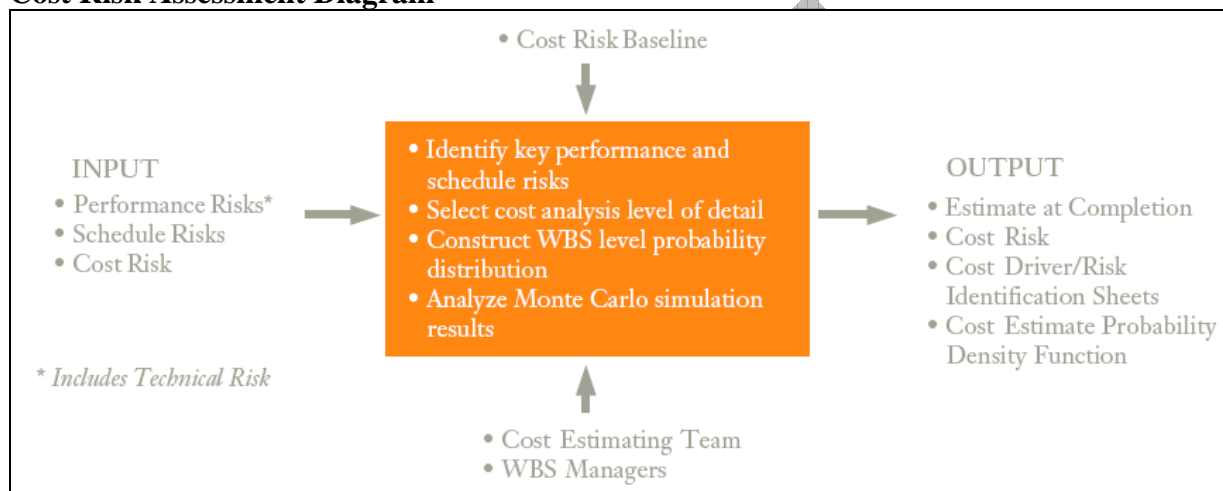


Figure 14
Source: DOE

Three basic risk analyses can be conducted during a project risk analysis:

- Technical performance analysis (will the project work; will it provide the planned benefits?)
- Schedule risk analysis (when will the project be completed?)
- Cost risk analysis (what will the project cost?)

4.1. Risk Parameter Inputs

		Risk Level				
Probability of Risk Materializing	Very Likely	Low	Moderate	High	High	High
	Likely	Low	Moderate	High	High	High
	Unlikely	Low	Low	Moderate	Moderate	High
	Very Unlikely	Low	Low	Low	Low	High
		Negligible	Marginal	Significant	Critical	Crisis
Severity of Consequence						

Figure 15
Source: DOE

4.2. Risk Analysis Methodology

To be developed

4.3. 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.

Tornado Diagram

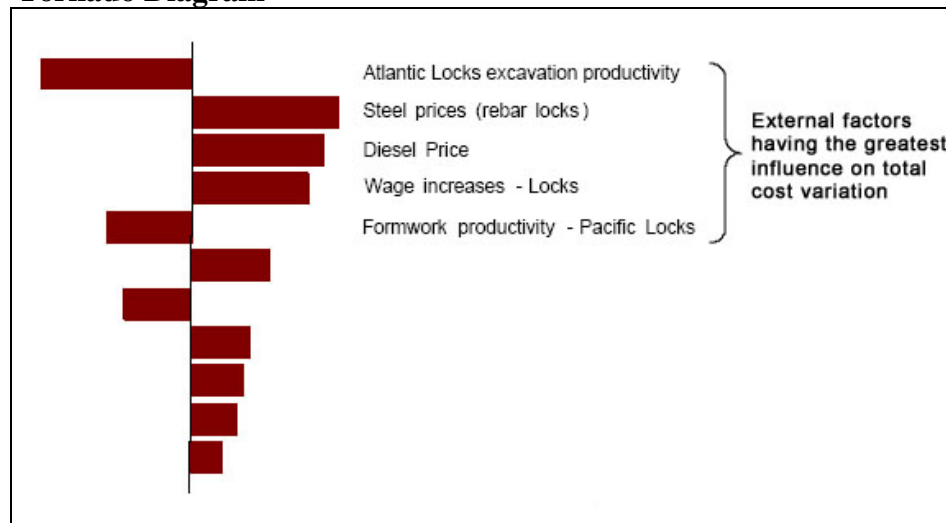


Figure 16
Source: FHWA

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 Analysis 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 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.

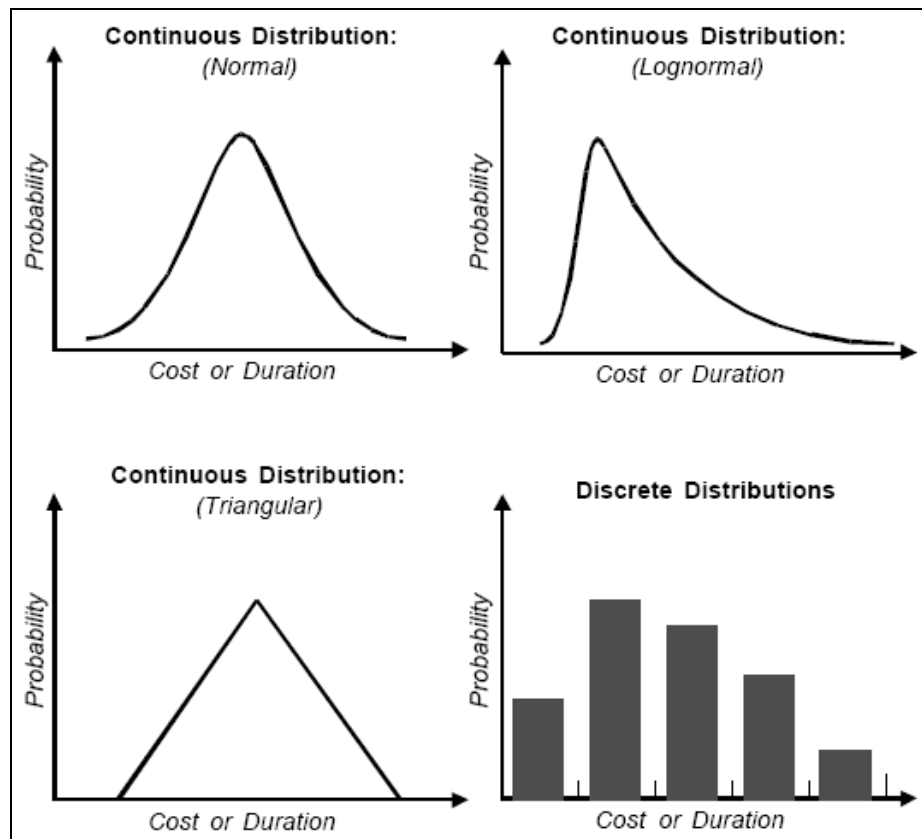


Figure 17
Source: FHWA

4.5. Risk Allocation

This guidance provides only a brief discussion on risk allocation. The purpose of providing this information is to assist project planners, developers and managers with a better, more complete understanding of risk allocation so as to apply this knowledge as necessary in the project development process.

The contract is the vehicle for risk allocation. Whether the contract is for development, construction, construction engineering and inspection, design, design-build, or some other aspect of transportation development, it is important to define the roles and responsibilities for managing identify risks and who is responsible for what actions and controls. Risk allocation in any contract affects cost, time, quality, and the potential for disputes, delays, and claims. Contractual misallocation of risk has been found to be one of the leading causes of construction disputes in the United States (CIS, 1990)

In a 1990 study, the Construction Industry Institute, 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.

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.

The rigorous process of risk identification, assessment, analysis, and mitigation described in this document provides for a more transparent and informed determination and allocation of project risks. When risks are well understood and their potential consequences measured and better understood, more effective decisions can be made to best allocate risks in a manner that minimizes impacts while maximizing project goals.

(*ADD PROCESS OVERVIEW DISCUSSION AND DETAILS FOR PRACTICIONERS and MANAGERS)

5.0. RISK MITIGATION PLANNING

Risk mitigation planning involves establishing priorities for addressing identified risks, determining risk mitigation measures, and managing the risk between appropriate project parties. The general rule is to allocate or delegate the risk to those with the ability and authority to best manage and deal with such risks in a positive, effective, proactive manner. Further guidance is provided in Chapters 5 and 6.

The objectives of risk mitigation 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, project manager, engineer, landscape architect, environmental specialist 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.

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:

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 identifies 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.

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 also uses this approach. Likewise, this guidance has provided a ‘*Potential Risk Factors List*’ developed as a sample list of risks (see Appendix B). 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)

NYSDOT's Risk Model serves as the risk charter or registry. It is described in more detail and illustrated in Chapter 6.

Other examples are available such as Caltrans spreadsheet. The spreadsheet forms the basis of the agency's risk management plan. The spreadsheet contains columns for identification, analysis, response strategy, and monitoring and control. Another example can be found in the FTA report on risk assessment, which uses the term risk register synonymously with risk charter. The FTA risk register contains more quantitative risk assessment information than the Caltrans example, but the goal of the documentation is similar. The FTA also 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. See Appendix B for a more complete outline.

1. Introduction
2. Summary
3. Definitions
4. Project Description
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 management plan should be documented, but the level of detail will vary with the type and unique attributes of each project. Red flag item lists, risk charters, and formal risk management plans provide flexibility in risk management documentation. Appendix B provides a sample format for use by NYSDOT.

5.5 Conclusions

Risk mitigation and planning uses information derived from the risk identification, assessment, and analysis processes to formulate appropriate 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

DRAFT

CHAPTER 6 RISK MANAGEMENT MODEL REGISTRY

6.0. RISK MANAGEMNT MODEL REGISTRY

Excel Format View (screen capture)

Microsoft Excel - RMDesignTool.xls

File Edit View Insert Format Tools Data Window Help Adobe PDF PDF Create! Type a question for help

A10 Funding Availability

RISK ASSESSMENT & MANAGEMENT WORKSHEET									
PIN	2123.45	DESCRIPTION	Route 66, Here to There - 3R		LETTING	05/22/12	LAST RISK ASSESSMENT UPDATE	02/22/08	
PM	John Smith	PROJECT DEVELOPMENT START DATE	01/22/08		CURRENT PROJECT PHASE	Scoping Phase - IFP completed 06/2007			
RISK FACTOR	Severity (H,M,L)	Probability (L,M,H)	SCHEDULE RISK Severity (H,M,L)	Probability (L,M,H)	QUALITY RISK (H,M,L)	ASSUMPTIONS	JEOPARDY	RISK MANAGEMENT PLAN [ACTIONS]	RESPONSIBLE PARTY
Business Risks									
Consistent with Asset Mgmt Goals									
Funding Availability			High	Med		Based on 9/2007 program update	STP Files funding over allocated	Monitor program, may need to delay to future SFY if funding not available. May need to substitute other project to meet letting target.	John Smith - PM
Process Risks									
Utility relocations							Ownership of water utility being transferred from village to county, transfer may not occur in time for betterment funding agreements to be finalized, jeopardizing design and construction.	Include waterline design in PS&E but be ready to pull at the last minute, set up PS&E to facilitate this	Joe Smith - DJM
Betterment agreement			Med	Med					Joe Smith - DJM
a			High	High		Work not fundable as a project cost	Village is bankrupt and may be unable to fund sewer replacement.	Continue dialog with village, be prepared to delete work	Joe Smith - DJM
Water Quality Cert			Med	Low			May not complete analysis in time for timely submission to DEC	Monitor situation, work with Survey Unit to assign resources to obtain nec. data, request QT if nec.	Joe Smith - DJM
Technical Risks									
Bridge type	High	Med				Extra design time for truss is minimal. SHPO is non-committal at this point	SHPO may require truss structure, cost is \$3.8 M more than multi-girder bridge. Steel costs also volatile.	Progress 106 process ASAP, communicate with SHPO, keep cost estimates up to date, follow cost trends	Joe Smith - DJM
TEST									
Project Risks									
Public involvement					Med		Difficult to engage transportation users or stakeholders due to highway type and location	Work with elected officials to identify possible stakeholder groups, update PI plan regularly	John Smith - PM
Political influence	Med	Med				Dept. is not in support of adding work at this time.	Assemblyman has expressed desire to add streetscape features	Request is beyond scope of project. Say no, get agreement or compromise. Check funding availability with RPPM.	John Smith - PM
Project scope certainty									
Right-of-way	Low	Low	High	Low		No ROW needed	Not fully certain of existing ROW. Addition of ROW acquisition phase will require project delay.	Define needs ASAP	Bill Smith - Designer

INSTRUCTIONS / POTENTIAL RISKS / JPP / SCOPING / IV (DAD) / V (ADP) / VI (PS&E) / Risk Revisions / LESSONS LEARNED /

Figure 18
NYS DOT

Access Format Views (screen captures)

Project Information

The screenshot shows the 'Enter Project Information' window of the Risk Management Tool Application. The window has a menu bar (File, Edit, View, Insert, Format, Records, Tools, Window, Help) and a status bar (Form View, NUM). The main area contains the following fields and controls:

- Enter the following information to get started:**
- STEP 1. Enter Project Information**
- PIN:** [Text Field] (add PIN without decimal)
- DNumber:** [Text Field] (add without 'D')
- Current Project Stage:** [Dropdown Menu]
- Project Description:** [Text Field]
- Project Manager:** [Text Field]
- Letting Date:** [Text Field]
- Save Record >** [Button]
- Date of Risk Assessment:** [Text Field]
- Go Back to Main SwitchBoard** [Button]

Figure 19
Source: NYSDOT

Risk Identification

The screenshot shows the 'Identify Risks' window of the Risk Management Tool Application. The window has a menu bar (File, Edit, View, Insert, Format, Records, Tools, Window, Help) and a status bar (Form View, NUM). The main area contains the following fields and controls:

- Activity 2. Identify Risks**
- PIN:** 566666 **DNumber:** 260890 **Return to Project Summary** [Button]
- Project Description:** State Route I-190
- Project Manager:** Billtiber **Let Date:** 6/6/2006 **Current Project Stage:** Design Phase I **Date of Risk Assessment:** 10/23/2008
- Select Risk Class:** [Radio Buttons]
 - Design
 - External
 - Environmental
 - Project Management
 - Right-of-Way
 - Construction
- [Active Risk Class]**
 - Design
 - External
 - Environmental
 - Project Management
 - Right-of-Way
 - Construction
- [Determine the Risk Class at the Left, then select the specific Risk Factor by navigating each single Risk Factor. Next, identify the impact by checking Cost, Schedule, Scope or Quality associated with the Risk Factor. Insert any Remarks and then click Add Risk Factor. When finished identifying all Risks and determining the impacts, go to the next step.]**
- RISK FACTOR:** 59 - Additional Information required for permits
- [Select Impact] POTENTIAL FOR IMPACT ON**

COST	SCHEDULE	SCOPE	QUALITY
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- REMARKS:** USACE requested additional wetland information **Reset** [Button]
- Does Risk Factor Apply?** Yes [Dropdown Menu]
- [Navigate Single Risk Factors]** [Navigation Buttons]
- Add Risk Factor** [Button]
- Next Step >>** [Button]

Figure 20
Source: NYSDOT

Risk Assessment

Risk Management Tool Application - [frmStep3_EvaluateRisk : Form]

File Edit View Insert Format Records Tools Window Help

Type a question for help

Activity 3. Evaluate Risk Tolerances [Return to Project Summary](#)

Project Description: State Route I-190
 Project Manager: Blittler Let Date: 6/6/2006 Current Project Stage: Design Phase I Date of Risk Assessment: 10/23/2008

RISK FACTOR:	COST RISK		SCHEDULE RISK		SCOPE RISK	QUALITY RISK	COMMENTS
Design incomplete at PS&E	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	Test
RiskClass: Design	[Select Measures]		[Select Measures]				
	Risk Effect	Inherent Risk	Risk Effect	Inherent Risk	Risk Effect	Risk Effect	
	Severity	Probability	Severity	Probability	Severity	Severity	
	Hed						

[Record Navigation]
[Save & GO TO NEXT](#)
[PREVIOUS RECORD](#)
 Undo Data Entry
[Next Step >>](#)

Form View NUM

Figure 21
Source: NYSDOT

Risk Management Plan

Risk Management Tool Application - [frmStep4_RiskManagementPlan : Form]

File Edit View Insert Format Records Tools Window Help

Type a question for help

Activity 4. Develop Risk Management Plan

PM: Blittler PIN: 566666 Contract DNumber: 260890 Letting Date: 6/6/2006 Last Risk Assessment Update: 10/23/2008

Project Description: State Route I-190

RISK FACTOR:	COST RISK	SCHEDULE RISK	SCOPE RISK	QUALITY RISK
Assumptions:	Jeopardy:	Risk Management Plan:		Responsible Party:

Save Record and GO TO THE NEXT RECORD GO TO PREVIOUS RECORD Complete View Reports Undo Data Entry Go Back to Main Switch Board

Form View NUM

Figure 22
Source: NYSDOT

6.1. Risk Management Model / Registry

The risk management model provides a structured approach in identifying, analyzing, ranking, mitigating, tracking and documenting project risks. The model provides a systematic methodology to organize, and track all identified risks, including their description, cause, probability of occurrence, impact(s) control, responsible owners, and current status. Figure 20 illustrates the model and the information it contains.

6.2. Risk Management Model Processes

Use of the risk management model should be and is intended to be used beginning in the pre-IPP stage. In this way project teams and managers can be better assured that project risks can be identified appropriately during the beginning of a project as this policy requires.

6.3. Risk Management Model, Applications and Use

The risk management model should continue to be used throughout the project life-cycle concluding with construction completion. In this way project teams and managers can be better assured that project risks can be monitored and managed appropriately through out the project.

7.0. RISK MANAGEMENT and MONITORING

The objectives of risk management and monitoring 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. An example has been adapted by the DOE’s Office of Engineering and Construction Management and populated with risks from the example risk lists (See Case Study Appendix D).

WSDOT has developed a top-level risk status report, shown in figure 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.

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.

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.

The risk monitoring and updating process must address the management and resolution of any project contingencies. This process involves a system for identifying, tracking and managing contingencies and their expense.

DRAFT

Appendix A Glossary of Terms

Risk - A defined uncertainty that can impact the outcome of a project including cost, schedule, scope or quality.

Risk Management - The systematic process of planning for, identifying, analyzing, responding to, and monitoring project risk. Risk management involves people, processes, tools, and techniques that will help the project manager maximize the probability and consequences of positive events and minimize the probability and consequences of adverse events. Project risk management is most effective when first performed early in the life of the project and is a continuing responsibility throughout the project.

Risk Assessment - A component of risk management that bridges risk identification and risk analysis in support of risk allocation.

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 a project in either a positive or negative way.

Probability - Likelihood of the occurrence of any event.

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.

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 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)

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

Contingency Plan - A set of predefined actions to be taken when a negative risk occurs.

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.

Decision Tree - A diagram used to select the best course of action in uncertain situations.

Environmental Document - The National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) require certain environmental documentation for transportation projects. Types of documents include a negative declaration (ND) finding of no significant impact (FONSI), or an environmental impact study (EIS)/environmental impact report (EIR).

Impact - Effect or consequence of an action or the failure to take action.

Milestone - A significant event in the project, usually completion of a major deliverable.

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.

Opportunity - A risk that will have a positive impact on a project objective if it occurs.

Probability - Likelihood of the occurrence of any event.

Program Change Request - Any significant changes to the scope, cost, or schedule of a programmed project (STIP, SHOPP, or TCRP) or special program project (toll seismic retrofit, soundwall) require a revision to the delivery commitment.

Project Development Team - An interdisciplinary team composed of key members of the project team as well as external stakeholders, that acts as a steering committee in directing the course of studies required to evaluate the various project alternatives during the early components of the project lifecycle.

Project Objective - A particular goal of a project. All projects have these four objectives:

- Scope
- Schedule
- Cost
- Quality



Project Risk - An uncertain event or condition that, if it occurs, has a positive or negative impact on at least one project objective. A risk has a cause and, if it occurs, a consequence.

Residual Risk - Risks that remain even after developing responses to the project's original risks.

Risk Interaction - The combined effect of two or more risks occurring simultaneously greater than the sum of the individual effects of each free standing risk.

Risk Owner - A person assigned to monitor the risk(s) and inform the project manager of any changes in the status of the risk.

Secondary Risks - Secondary risks are caused by responses to the project's original risks.

Scope - Encompasses the work that must be done to deliver a product with the specified features and functions.

Threat - A risk that will have a negative impact on a project objective if it occurs.

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 Trigger - Symptoms and warning signs that indicate whether a risk is becoming a near-certain event and a contingency plan/response plan should be implemented.

Value Analysis -

A multi-disciplined team systematically applies recognized techniques to:

- Identify the function of a product or service
- Establish a worth for that function
- Generate alternatives through the use of creative thinking
- Reliably provide the needed functions at the lowest overall cost

The term is often interchanged with Value Engineering.

Value Analysis Team - A team that performs value engineering.

Workplan - A resourced schedule. The workplan identifies the project-specific WBS elements and defines the cost, timeline, and requirements for each. The current workplan guides the day-to-day operations of project execution and project control.

Appendix B Sample Risk Management Plan (in –development)

Risk Management Plan Outline

1. Introduction
2. Summary
3. Definitions
4. Project Description
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

1. Introduction

Background Information
Project Name
Location

2. Summary

Brief discussion of the project purpose and need, context, public issues (if any), possible risk issues and considerations for solutions

3. Definitions

4. Project Description

5. Risk management strategy and approach

6. Risk Identification (Reference Risk Model)

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

APPENDIX C POTENTIAL RISK FACTORS LISTING

POTENTIAL RISKS LIST

Key: When multiple checkmarks apply, red ✓ indicates highest priority

PROJECT DEVELOPMENT RISKS				
RISK FACTOR	POTENTIAL FOR IMPACT ON			
	COST	SCHEDULE	SCOPE	QUALITY
Design incomplete at PS&E				✓
Unexpected geotechnical or groundwater issues	✓	✓		
Changes to materials/geotechnical/foundation		✓		
Foundation and geotechnical tasks (foundation drilling and material testing) not identified and included in project workplan		✓		
Inaccurate assumptions on technical issues in planning stage			✓	
Additional survey required		✓		
Bridge site data incomplete to DES		✓		
Existing structures planned for modification not evaluated for seismic retrofit, scour potential and structural capacity	✓	✓		
Condition of the bridge deck unknown	✓			
For projects involving bridge replacement, bridge carries traffic during staging causing traffic delay				✓
Design changes to alignment, profile, typical cross section, stage construction between Advance Planning Study and the Bridge Site Submittal		✓		
Unforeseen design exceptions required		✓		
Consultant design not up to Department standards				✓
Unresolved constructability review items	✓			
Complex hydraulic features				✓
Incomplete quantity estimates	✓			
New or revised design standard	✓			
RR Agreements not obtained on time		✓		
Special railroad requirements not identified during preliminary design		✓		
Utility Agreements not obtained on time		✓		
Construction staging more complex than anticipated	✓	✓		
Unforeseen aesthetic requirements	✓			
Contextual Assessment incomplete			✓	
Unresolved Public Involvement Issues		✓	✓	
Other Design Risks				

EXTERNAL RISKS



RISK FACTOR	POTENTIAL FOR IMPACT ON			
	COST	SCHEDULE	SCOPE	QUALITY
Local communities pose objections			√	
Unreasonably high expectations from stakeholders			√	
Political factors or support for project changes		√	√	
Stakeholders request late changes			√	
New stakeholders emerge and request changes			√	
Threat of lawsuits		√		
Increase in material cost due to market forces	√			
Reviewing agency requires longer than expected review time		√		
Pressure to deliver project on an accelerated schedule		√		√
Limited Number of Bidders expected	√	√		
Changes in funding availability		√		
Other External Risks				

ENVIRONMENTAL RISKS				
RISK FACTOR	POTENTIAL FOR IMPACT ON			
	COST	SCHEDULE	SCOPE	QUALITY
Environmental analysis incomplete				√
Environmental regulations change	√	√		
Additional Information required for permits		√		
Hazardous waste site analysis incomplete	√			
TE or PE in a DEC hazardous waste remediation site	√	√		
TE or PE in a DEC hazardous waste remediation site	√	√		
Hazardous materials in existing structure or surrounding soil; lead paint, contaminated soil, asbestos pipe, asbestos bearings and shims	√			
Potential for lowering water table that is a public water source		√		
Water quality regulations or requirements change	√			
Available project data and mapping at the beginning of the environmental study is insufficient			√	
New information after Environmental Document is completed may require re-evaluation or a new document (i.e. utility relocation beyond document coverage)		√		
New alternatives required to avoid, mitigate or minimize impact		√		
Acquisition, creation or restoration of on or off-site mitigation	√	√		
Environmental clearance for staging or borrow sites required		√		
Historic site, endangered species, riparian areas, wetlands and/or public park present, flood plain		√		
Design changes require additional Environmental analysis		√		
Controversy on environmental grounds expected		√		
Unforeseen formal NEPA/404 consultation is required		√		
Unforeseen formal Section 7 (Endangered Species Act)		√		

consultation or specialized staff required				
Unexpected Section 106 issues (Historic Preservation)		√		
Unexpected Native American concerns		√		
Unforeseen Section 4(f) resources affected			√	
Project within area with Local Waterfront Revitalization Plan (LWRP) and/or Greenway Plan			√	
Project may encroach onto a Scenic Highway			√	
Project may encroach to a Wild and Scenic River		√		
Unanticipated noise impacts	√			
Construction or pile driving noise and vibration impacting adjacent businesses or residents		√		
Project causes an unanticipated barrier to wildlife	√			
Bridge is a habitat to bats or other species requiring mitigation or seasonal construction				
Project may encroach into a floodplain or a regulatory floodway		√		
Project does not conform to the state implementation plan for air quality at the program and plan level			√	
Unanticipated secondary or cumulative impact issues		√		
Environmental justice issue		√		
Other Environmental Risks				

PROJECT MANAGEMENT RISKS				
RISK FACTOR	POTENTIAL FOR IMPACT ON			
	COST	SCHEDULE	SCOPE	QUALITY
Project scope and objectives are not clearly defined or understood			√	
Project cost estimate or constraints are not clearly defined	√			
Project schedule and deliverables are not clearly defined or understood		√		
No control over staff priorities		√		
Inexperienced staff assigned				√
Losing critical staff at crucial point of the project		√		
Insufficient time to plan			√	
Internal “red tape” causes delay getting approvals, decisions		√		
Consultant or contractor delays		√		
Potential cost estimating errors	√			
Potential scheduling errors		√		
Unplanned work that must be accommodated		√		
Lack of coordination/communication				√
Underestimated support resources or overly optimistic delivery schedule		√		
Scope creep	√			
Overlapping of one or more project limits, scope of work or			√	

schedule				
Lack of specialized staff (biology, anthropology, geotechnical, archeology, etc.)				√
Unresolved project conflicts not elevated in a timely manner		√		
Delay in earlier project phases jeopardizes ability to meet programmed delivery commitment		√		
Added workload or time requirements because of new direction, policy, or statute		√		
Public awareness/campaign not planned or inadequate			√	
Risk Management Plan incomplete	√	√	√	√
Public Involvement Plan incomplete		√	√	√
Other Project Management Risks				

RIGHT-OF-WAY RISKS				
RISK FACTOR	POTENTIAL FOR IMPACT ON			
	COST	SCHEDULE	SCOPE	QUALITY
Insufficient ROW available for all operations		√		
ROW Clearance not received in time for advertising				
Unanticipated need for public hearing due to ROW acquisition not deemed "di minimus"				
Unforeseen railroad involvement	√	√		
Resolving objections to Right of Way appraisal takes more time and/or money	√	√		
Unanticipated escalation in right of way values or construction cost	√			
Need for "Permits to Enter" not considered in project schedule development		√		
Condemnation process takes longer than anticipated		√		
Access to adjacent properties is necessary to resolve constructability requirements	√	√	√	√
Acquisition of parcels controlled by a State or Federal Agency may take longer than anticipated		√		
Discovery of hazardous waste in the right of way phase	√	√		
Inadequate pool of qualified appraisers		√		
Landowners unwilling to sell	√	√	√	
Other Right-of-Way Risks				

CONSTRUCTION RISKS				
RISK FACTOR	POTENTIAL FOR IMPACT ON			
	COST	SCHEDULE	SCOPE	QUALITY
Unreasonable contract time requirements, constraints or incentive provisions		√		
Permit work window time is insufficient		√		
Change orders due to differing site conditions	√			

Temporary excavation and shoring system design is not adequate	√			
Unidentified utilities encountered	√	√		
Utility relocation not completed within the time specified in utility agreements	√	√		
Utility company workload, financial condition or timeline		√		
Buried unidentified hazardous waste discovered	√			
Overhead electrical power lines in conflict with construction	√			
Street or ramp closures not coordinated with local community				√
Insufficient or limited construction or staging areas	√			√
Unanticipated weather delays		√		
Changes during construction require additional coordination with resource agencies/possible permit modification		√		
Unexpected archeological findings		√		
Delay due to unanticipated sensitive habitat requirements or other reasons		√		
Construction or pile driving noise and vibration impacting adjacent businesses or residents		√		
Extensive shop drawing review/approval time requirements		√		
Railroad agreements not in place		√		
Other Construction Risks		√		

APPENDIX D CASE STUDY

The following is a case study developed to best understand the information, concepts and techniques described in this guidance. In this example QDOT has embarked on the creation of a risk management policy and guidance for application during project development.

The case study walks through the process of how QDOT applied risk management 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 each chapter.

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.

Project Information and Description

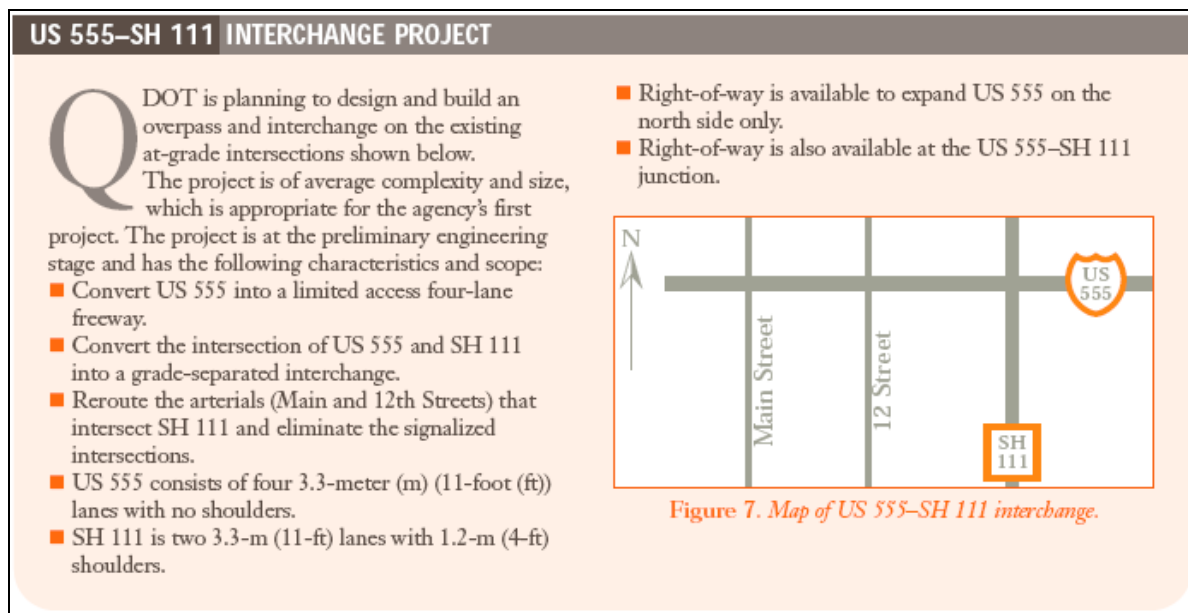
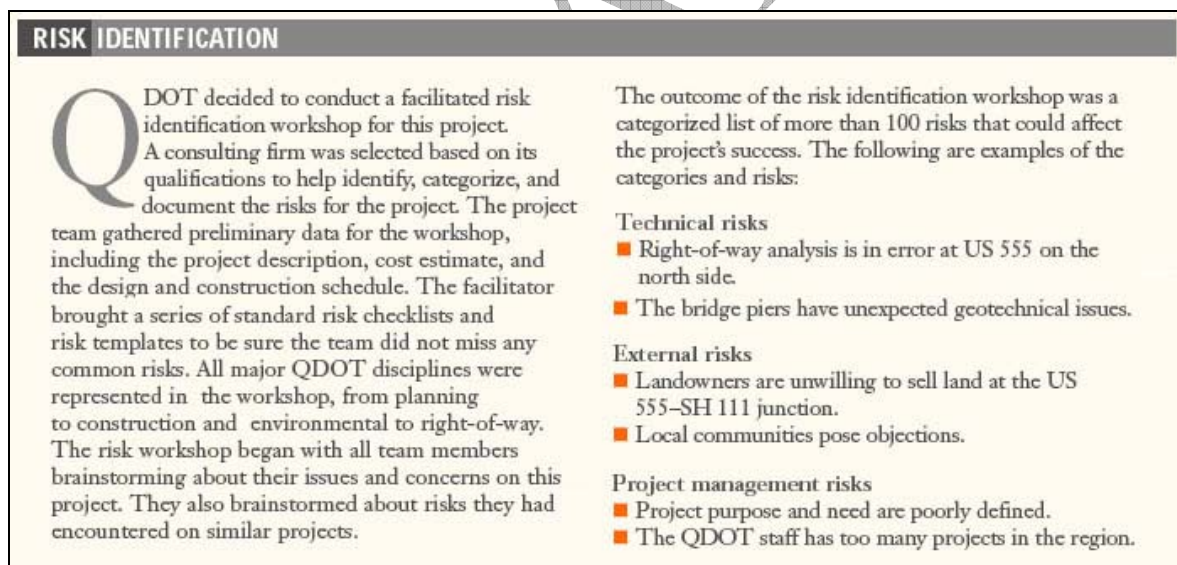


Figure 1

Risk Identification



RISK CHARACTERISTICS	POSSIBLE CONDITIONS	MAGNITUDE
Knowns		Moderate
known-unknowns		High
unknown-unknowns		High
Risk triggers		High
Risk versus opportunity events		Low

Risk Identification

PROJECT-SPECIFIC DOCUMENTS	PROGRAMMATIC DOCUMENTS	TECHNIQUES
<ul style="list-style-type: none"> ■ Project description ■ Work breakdown structure ■ Cost estimate ■ Design and construction schedule ■ Procurement plan ■ Listing of team's issues and concerns 	<ul style="list-style-type: none"> ■ Historic data ■ Checklists ■ Final project reports ■ Risk response plans ■ Organized lessons learned ■ Published commercial databases ■ Academic studies 	<ul style="list-style-type: none"> ■ Brainstorming ■ Scenario planning ■ Expert interviews ■ Nominal group methods ■ Delphi methods ■ Crawford slip methods ■ Influence or risk diagramming

Risk Assessment

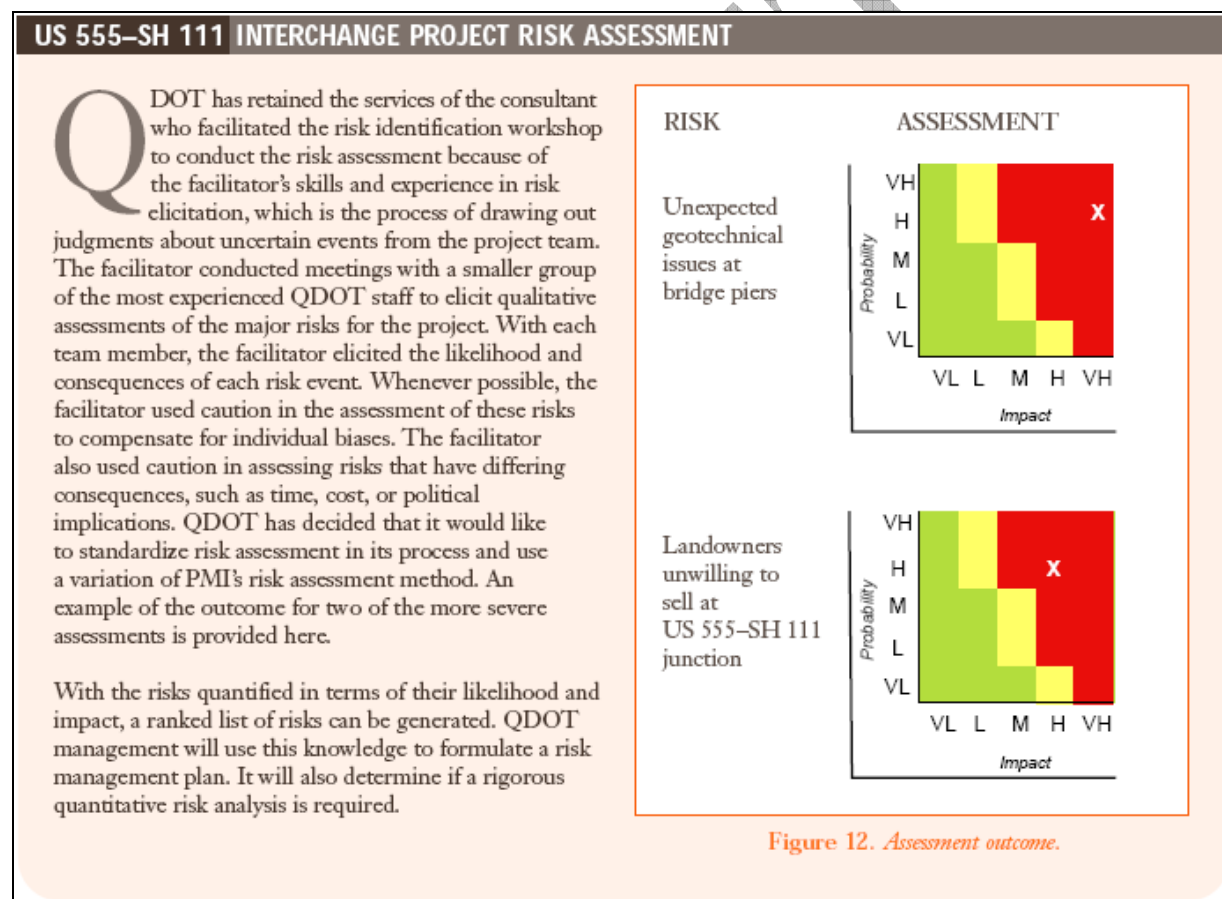


Figure 2

Sample Risk Matrix

1	2	3	4	5
Risk Identification	Probability Rating (1)	Impact Rating (2)	Overall Risk Rating (1)x(2)	Mitigation/Allocation
Risk Item 1				
Risk Item 2				

RISK ANALYSIS MATRIX

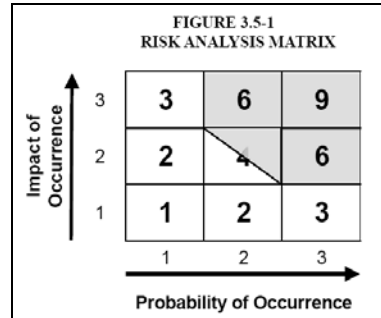


Figure 3

Use of the Risk Management Model, detailed in Chapter 6, provides a structured approach for identifying and categorizing project risks early in the process and documenting their mitigation.

The following matrix provides an intermediate step to better assist the determination of, quantifying and assessing identified project related risks.

RISK IDENTIFICATION, ASSESSMENT, AND ALLOCATION WORKSHEET		
Risk area and definition	Discussion	Applies (Y/N)
Issue(s)		
Options (Department, Design-Builder, or Sharing)		
How can risk be shared?		
Who can best manage the risk?		
Resources		
Challenges		
Recommended allocation		
Steps for mitigation		
Other recommendations		

Likelihood-Impact Matrix (FHWA)

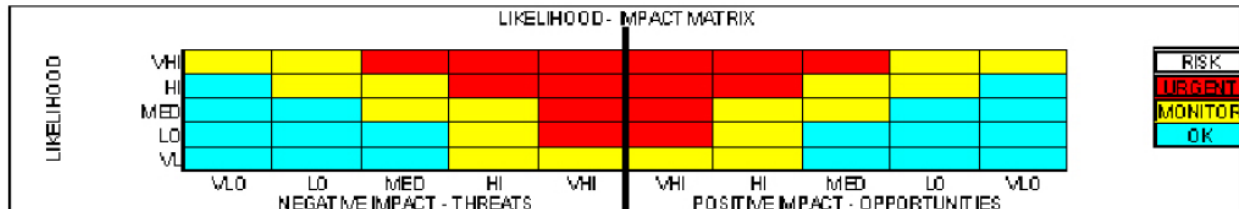


Figure 4

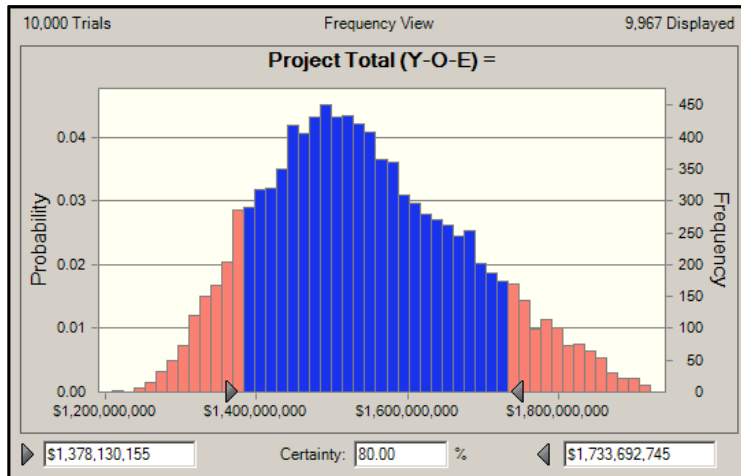


Figure 5

Sample Distribution of Year-of-Expenditure Costs, with an 80% Probability Range

Monte Carlo Simulation

Figure 5 shows the result of the simulation for the Project. This simulation iteratively combined the occurrence of various project threats and opportunities, as discussed above, and depicts the Total Project Cost in year-of-expenditure dollars. The blue shaded area in the figure represents an 80% likelihood that the total cost for the Project will be between \$1.38-1.73 billion, which is considerably higher than the 2005/2006 estimate of \$739 million. As such, it should be noted that risks such as extreme inflation, the impact of world events, or other unforeseen circumstances, were not considered.

Sensitivity Analysis

The sensitivity chart in Figure 6 shows how the variation in the cost estimate components impact the variation of the total cost estimate for the Project. Those components at the top of the chart have greater impact on the variation in total project costs while those at the bottom have less impact. As shown, the escalation threat is the significant driver in the variation of total year-of-expenditure costs. This one item accounted for almost 90% of the total project variability.

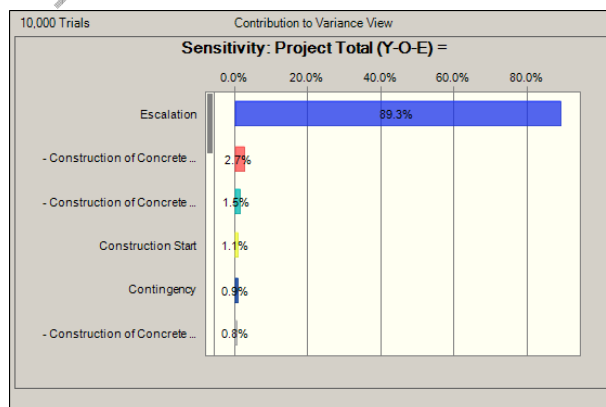


Figure 6 - Sensitivity Chart for Year-of-Expenditure Costs

Risk Registry Model (screen capture)

Microsoft Excel - RMDesignTool.xls

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Type a question for help

A10 Funding Availability

RISK ASSESSMENT & MANAGEMENT WORKSHEET										
PIN	DESCRIPTION	ROUTE	START DATE	END DATE	LETTING	LAST RISK ASSESSMENT UPDATE				
212345	Route 66, Here to There - 3R		01/22/08		05/22/12	02/22/08				
PM	John Smith				Scoping Phase - IPP completed 08/2007					
RISK FACTOR	COST RISK Severity (High, Med)	SCHEDULE RISK Severity (L, M, H)	QUALITY RISK Severity (High, Med)	ASSUMPTIONS	JEOPARDY	RISK MANAGEMENT PLAN [ACTIONS]	RESPONSIBLE PARTY			
Business Risks										
Consistent with Asset Mgmt Goals										
Funding Availability		High	Med	Based on 9/2007 program update	STP Files funding over allocated	Monitor program, may need to delay to future SFY if funding not available. May need to substitute other project to meet letting target.	John Smith - PM			
Process Risks										
Utility relocations					Ownership of water utility being transferred from village to county, transfer may not occur in time for betterment funding agreements to be finalized, jeopardizing design and construction.	Include waterline design in PS&E but be ready to pull at the last minute, set up PS&E to facilitate this	Joe Smith - DJM			
Betterment agreement		Med	Med				Joe Smith - DJM			
a		High	High	Work not fundable as a project cost	Village is bankrupt and may be unable to fund sewer replacement	Continue dialog with village, be prepared to delete work	Joe Smith - DJM			
Water Quality Cert		Med	Low		May not complete analysis in time for timely submission to DEC	Monitor situation, work with Survey Unit to assign resources to obtain nec. data, request DT if nec.	Joe Smith - DJM			
Technical Risks										
Bridge type	High	Med		Extra design time for truss is minimal. SHPO is non-committal at this point	SHPO may require truss structure, cost is \$3.8 M more than multi-girder bridge. Steel costs also volatile.	Progress 106 process ASAP, communicate with SHPO, keep cost estimates up to date, follow cost trends	Joe Smith - DJM			
TEST										
Project Risks										
Public involvement					Difficult to engage transportation users or stakeholders due to highway type and location	Work with elected officials to identify possible stakeholder groups, update PI plan regularly	John Smith - PM			
Political influence	Med	Med		Dept. is not in support of adding work at this time.	Assemblyman has expressed desire to add streetscape features	Request is beyond scope of project. Sag no, get agreement or compromise. Check funding availability with RPPM.	John Smith - PM			
Project scope certainty										
Right-of-way	Low	Low	High	No ROW needed	Not fully certain of existing ROW. Addition of ROW acquisition phase will require project delay.	Define needs ASAP	Bill Smith - Designer			

INSTRUCTIONS / POTENTIAL RISKS / IPP / SCOPING / IV (DAD) / V (ADP) / VI (PS&E) / Risk Revisions / LESSONS LEARNED /

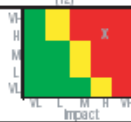


Figure 7

Risk Registry Model - Caltrans Example

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

PROJECT RISK MANAGEMENT PLAN											
Identification						Qualitative Analysis					
Status	ID #	Date Identified	Functional	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 sound wall than needed to mitigate noise.	The height of the proposed sound wall is 2 meters. Residents who live next to the freeway have expressed a desire for a 5 meter high wall.	Risk is occurring if the Revised Noise Study indicates the additional wall height is warranted.	Schedule Cost	High	High	

Caltrans Risk Management Plan Worksheet (Part 2).

PROJECT RISK MANAGEMENT PLAN												
Qualitative Analysis				OPTIONAL Quantitative Analysis			Response Strategy			Monitoring and Control		
Type (1)	Probability (2)	Impact (3)	Risk Matrix (4)	Probability (%) (5)	Impact (\$ or days) (6)	Effect or (days) @ (100=100000) (7)	Strategy (8)	Response Actions including advantages and disadvantages (9)	Affected WBS Tasks (10)	Responsibility (Task Manager) (11)	Status Interval or Milestone Check (12)	Date, Status and Review Comments (13)
Schedule Cost	High	High		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	
												
												

NOTE: Risk Management Plan Worksheet available at <http://www.dot.ca.gov/bq/projmgmt/guidance.htm>.

Figure 8

Risk Analysis

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.

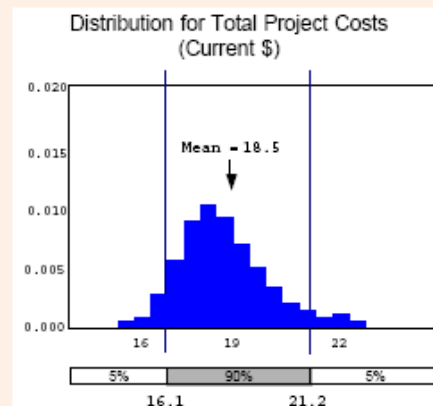


Figure 20. Range estimate for project costs.

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

Figure 9

Risk Mitigation Planning

The following is 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 <i>Assessment—high</i>	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 <i>Assessment—high</i>	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 <i>Assessment—medium</i>	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 <i>Assessment—medium</i>	Acceptance	The team will attempt to design the project with agency staff and accept a longer design schedule.	Region executive management	Monthly

Figure 10

Risk Allocation

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 consultant to assist with specialty design features.

The team created a design 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 consultant to determine the appropriate right-of-way needs outside the basic configuration.

Likewise, the team retained the risk for the successful project information plan. In this manner, the State has retained some risk, but left the project open for design innovation.

Risk Monitoring and Control

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				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

Figure 11

WSDOT Risk Status Report

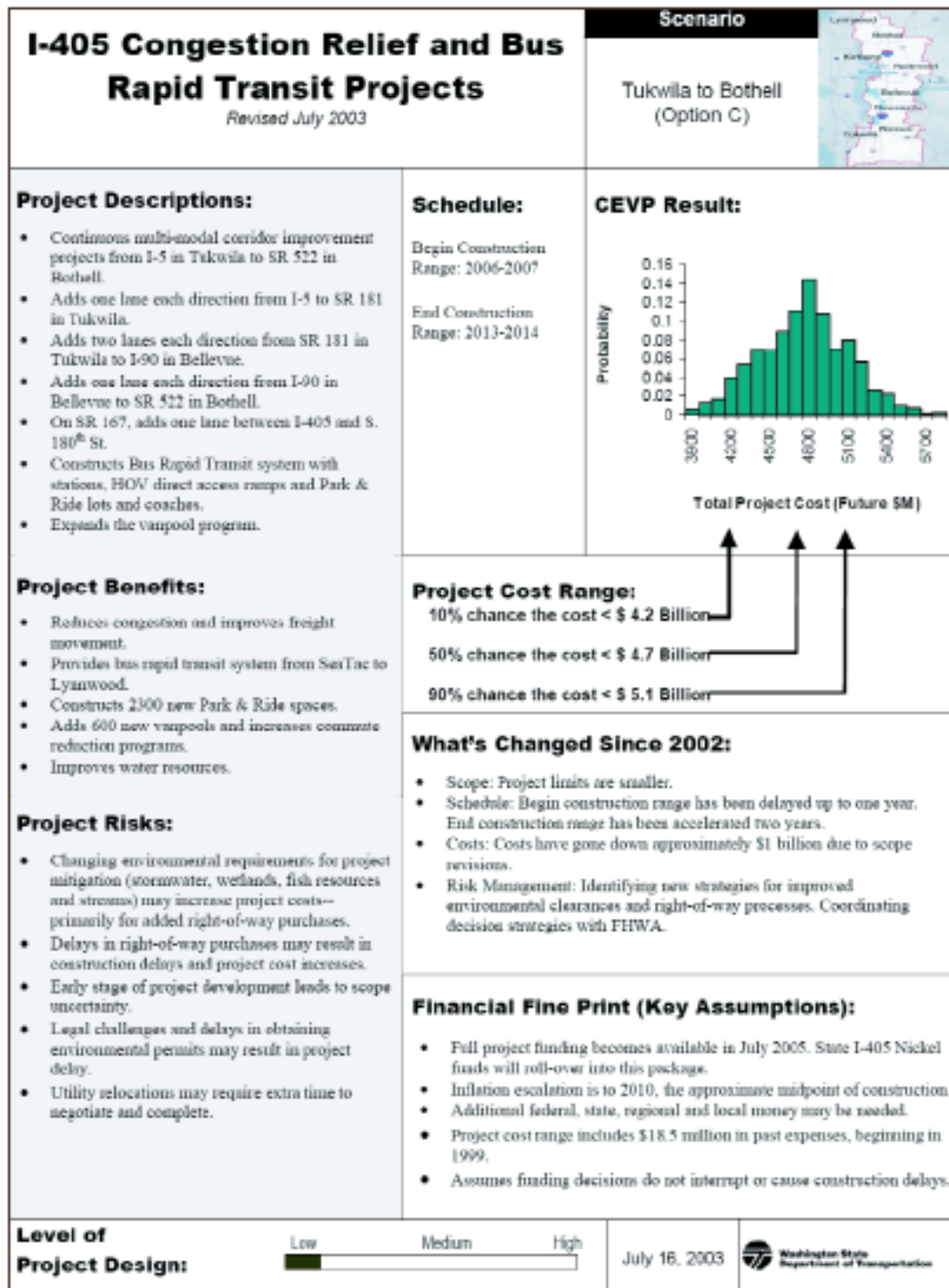


Figure 12

Note: The “What’s Changed” section also acts as a high-level monitoring report.

APPENDIX E QUANTITATIVE ASSESSMENT

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 for Risk Management*, illustrates the relationship between the computational method (the model) and its required inputs and available outputs.

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 primary 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 13.

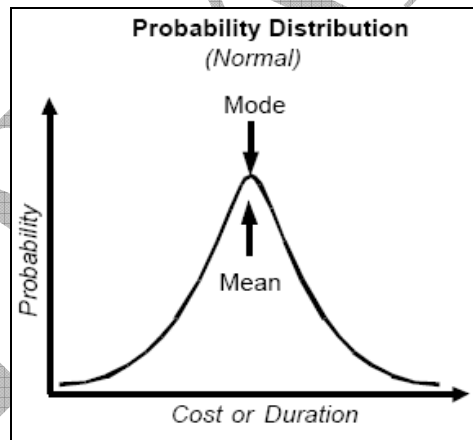


Figure 1

Source: FHWA

Mean and mode in normal and lognormal distributions

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 14.

Technical elements and performance 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.

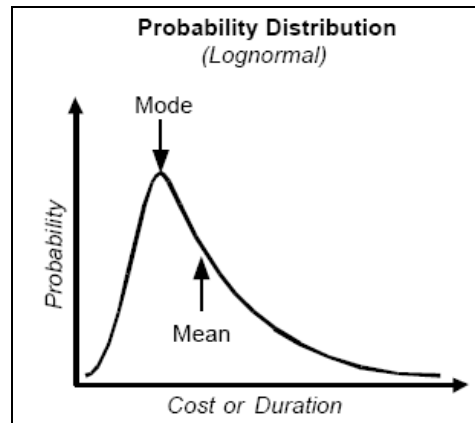


Figure 2

Source: FHWA

Mean and mode in normal and lognormal distributions

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 15.

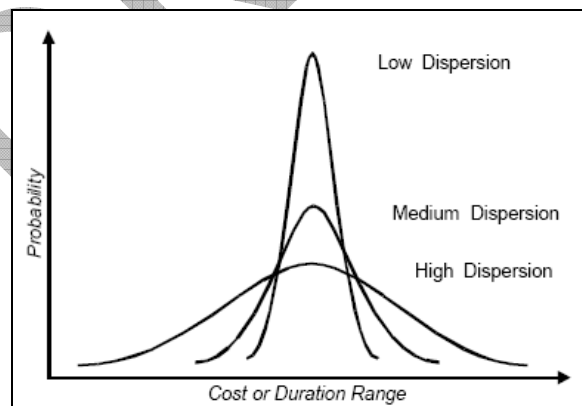


Figure 3

Source: FHWA

Probability distributions for high, medium, and low dispersions

4.2. Risk Analysis Methodology

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.

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” as shown in figure 16 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 distribution of the outcomes; in other words, they highlight the greatest contributors to the overall risk and may include technical or other risk categories. The length of the bars on the tornado diagram corresponds to the influence each item contributes to the overall 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.

These analytical methods are typical but may be challenging to understand. They require an estimate of the individual variable’s mean and standard deviation. They do not however 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.

4.5.3. Analytical Modeling

A simulation model 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.

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

Figure 4
Source: FHWA

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 14 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 provides information for determining project budgets and contingency values at specific levels of certainty or confidence.

Example probability outputs from a Monte Carlo analysis

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

Figure 5
Source: FHWA

In addition to graphically conveying information, Monte Carlo methods produce numerical values for common statistical parameters, such as the mean, standard deviation, distribution range, and amount of skew.

Typical Monte Carlo output for total costs.

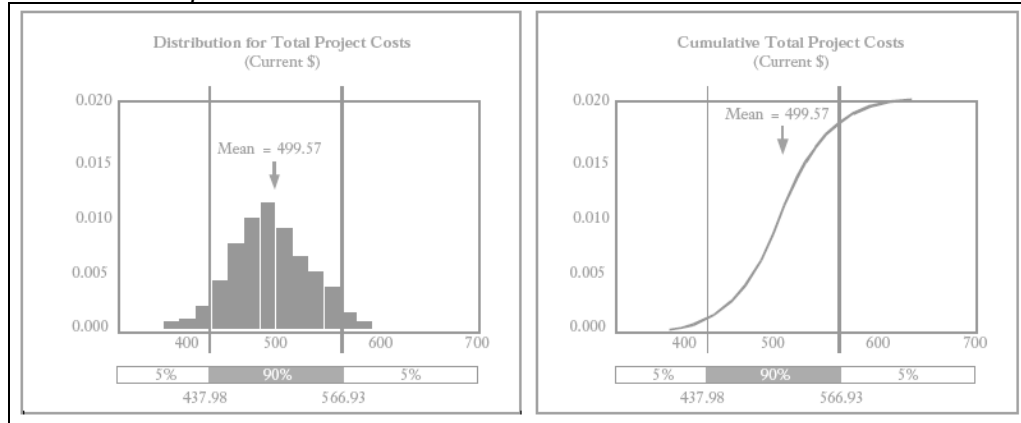


Figure 6

Source: FHWA

Other analysis techniques include ‘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.

Probability trees can be adapted to cost and schedule risk analysis quite easily. However, they do require rigorous standards for input data. Yet, 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 15 illustrates a typical probability tree analysis.

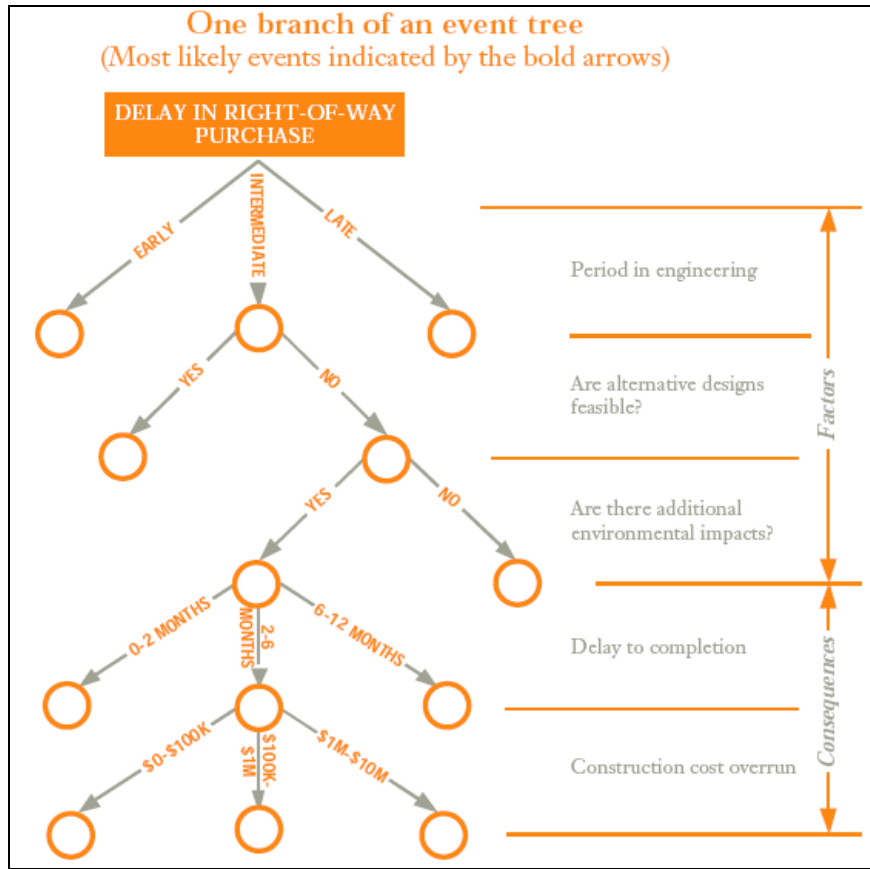


Figure 7
Source: FHWA

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 decision making and a more transparent allocation of project risk.

APPENDIX F REFERENCES

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