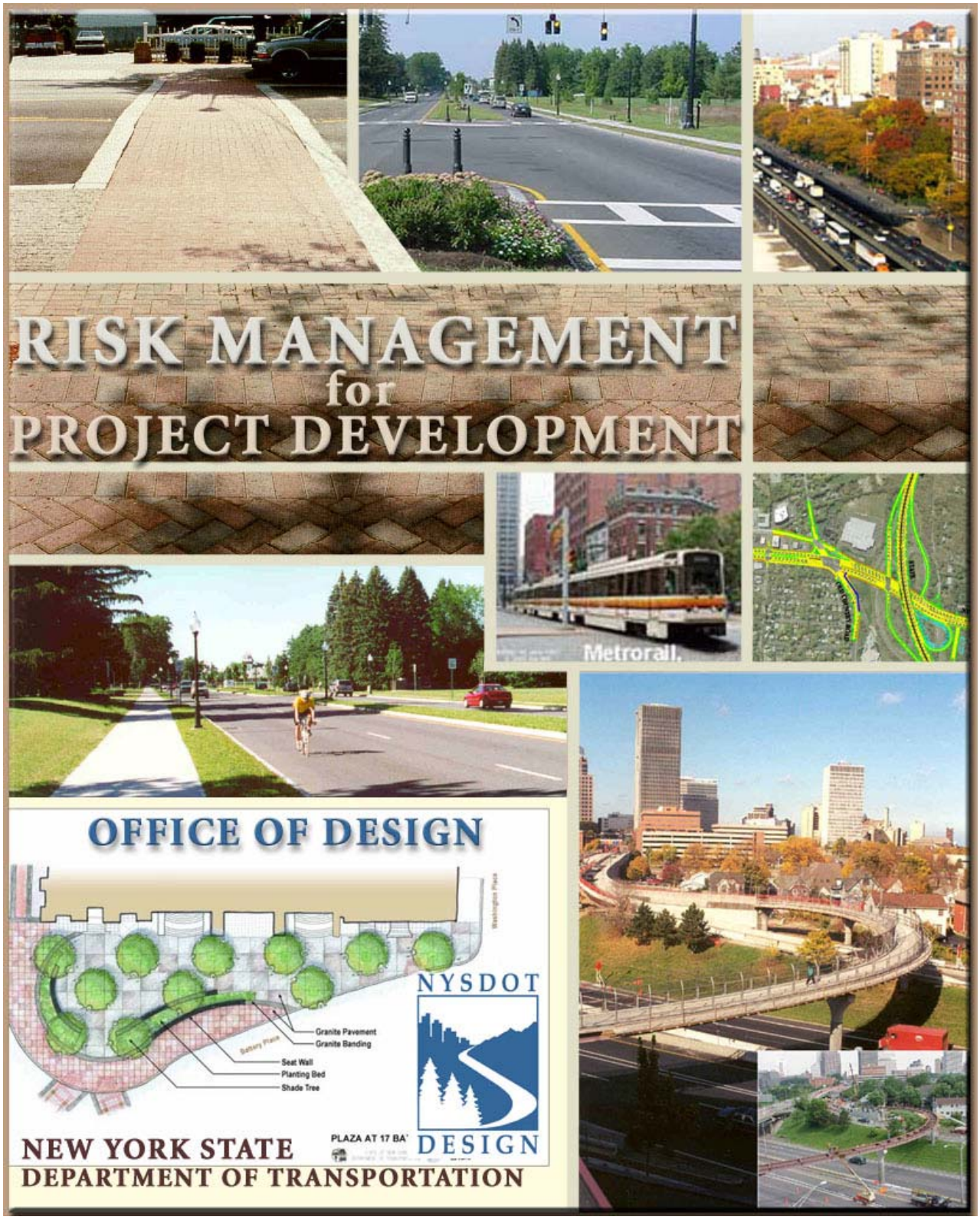
Appendix 15 –

Risk Management

for

Project Development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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 potentially significant risks. Engineering and other interdisciplinary design professionals face a plethora of technical, operational and process decisions that they are held accountable for. Their level of expertise, ability to understand and manage risk and decision making processes can have significant influence on the final outcome of a project and its success. Risk management decisions made on a daily basis, compounded by over one thousand active projects currently being developed to produce the Capital Program, brings this important practice into perspective.

This guide for Capital project risk management is intended to provide guidance and direction for practicing risk management for Capital transportation project development. It serves to provide project managers, developers, consultants, team leaders, and team/squad members with 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 and controlling Capital project related risks.*** Risk management involves people, processes, tools, and techniques that will contribute, to the greatest extent possible, to maximizing the probability of successful results. Risk management will also, to the greatest extent possible, help minimize the likelihood, probability and consequence of adverse effects within the context of the *overall* project objectives. It is a valuable tool for better ensuring desired project outcomes are achieved within cost, schedule, scope and quality while meeting customer expectations.

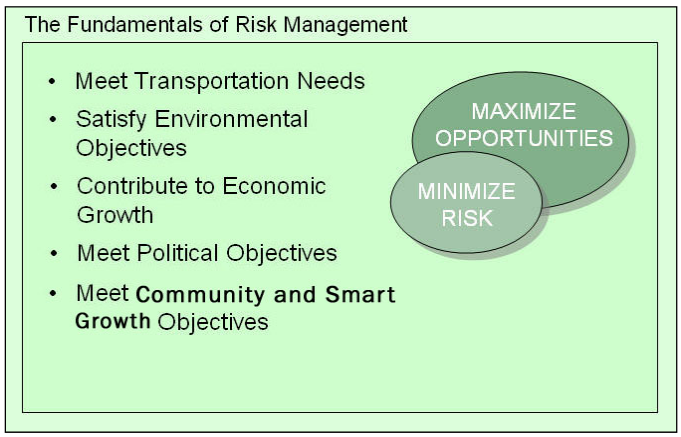


Figure 1
Source: FHWA

Risk management is the intentional, systematic process of planning for, identifying, analyzing, responding to, monitoring and controlling Capital project related risks.

Not adequately attending to risk is a leading cause of project failure.

It has been demonstrated that the most effective risk management practices for project development begin in the planning stages, continues through design and culminates at the completion of construction[1]. The primary purpose of risk management is to effectively identify, quantify, mitigate and control risks so that they have a negligible effect on project outcomes or, at a minimum, are reduced 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 identified in other manuals conflict with this manual, this guide shall take precedence.

1.1 OVERVIEW, PURPOSE, AND USE

1.1.1 Overview: The Complex Nature of Risk in Highway Project Delivery

Transportation projects are complex endeavors. Risk assessment for these 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 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 have 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 guide.

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, establish a sound framework for how risk management is to be practiced during the development and delivery of projects.

[1] A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Project Management Institute, 2004

Figure 2
Source: FHWA

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. Figure 2 shows a conceptual illustration of the process. A more detailed illustration of the process is shown in figure 8.

Risk management is a practice that is conducted throughout the project development process. Identified potential risks are quantified and a response action incorporated within a risk management plan. The risk management plan must be effectively executed and monitored in order to best mitigate adverse effects while promoting opportunities and favorable outcomes. The project manager and risk management team must conduct a frequent, comprehensive review of all potential project risks, progress made in addressing them, indicating where risks are being effectively handled and where additional actions and resources may be needed.

Risk Management Fundamentals

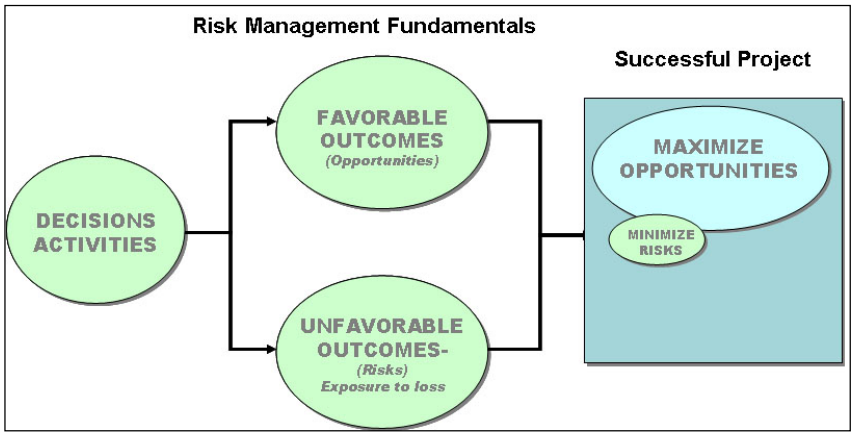


Figure 3
Source: DMJM Harris

Identifying all possible project related risks is an arduous and challenging task. There is little doubt that today's transportation projects continue to grow in their level of complexity. Complexity can be driven by several factors such as: heightened stakeholder awareness and desire to participate in the decision making process; increasing regulation at the Federal and State levels; sensitive environmental and contextual factors; challenging constructability issues; scheduling and coordination issues; and resource constraints. When these project development factors are combined with scope, cost, schedule, quality and safety considerations, risk management efforts can be, and are often very challenging tasks. The need for sound, effective and accountable methods to identify, quantify and manage potential risks is very clear.

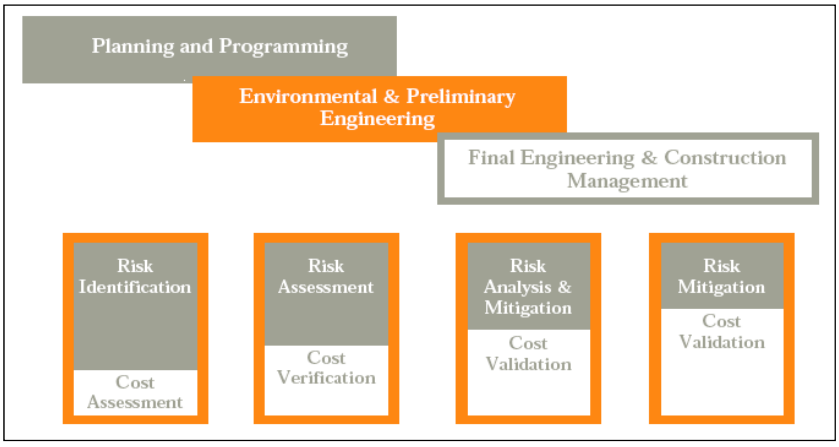


Figure 4
Source: *Risk management and cost validation in the WSDOT CEVP process*

Risk management is concerned with today's impacts, either potential or projected, on future events, often whose outcome is unknown, and how to best deal with these uncertainties by identifying, examining and determining a ***range*** of possible outcomes. The objective is to (a) best understand risks and (b) mitigate or control risks as best as possible. Understanding the risks inherent with each potential project condition and alternative is important for controlling schedules and developing estimates that reflect the cost of accepted risks or risks that may be transferred to the contractor.

Risk management addresses potential impacts on future events and how to best deal with uncertainties by identifying and determining a range of possible outcomes.

Practicing risk management and having a working understanding of project uncertainty will assist project managers, developers, estimators and others involved in managing projects. Risk management knowledge and procedures will help them to address various contingencies for each individual project more effectively. Understanding risk management principles and practices is also important to managers of estimation processes. Cost estimation is one of the primary factors in a comprehensive risk management process.

Qualitative and Quantitative Analysis of Risk and Uncertainty

In a comprehensive risk management process, risk analysis is used to prioritize 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 an appropriate range of contingencies.

Project Complexity

Project complexity will dictate the level of and scope of the risk management efforts necessary and the type of risk analysis that should be performed.

Project complexity will often dictate the level of and scope of the risk management efforts necessary and the type of risk analysis that will be performed. Simple projects will most often use only qualitative methods of risk analysis. Complex projects will most likely use quantitative methods of risk analysis. However, there will be exceptions to this general rule.

In a ***qualitative risk 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 utilize numeric values, simulation models and estimates of probability that a project will meet its cost, schedule and other objectives. It is often common to simplify a risk analysis by calculating the expected value or average range of a risk. The expected value provides a single quantity for each risk which is easier to use for comparison purposes. While this is helpful for comparisons and ranking of risks, estimators must use caution when using the expected value to calculate project costs or contingencies. As an example, if there is a 20% chance that a project may need a $1 million dollar full storm water upgrade, and the estimator includes only a $200,000 value in contingency using the expected value method, if the full storm water upgrade is required, this value will be much too low.

Occasionally, a great deal of important information may be lost in an oversimplified contingency analysis. More comprehensive quantitative analysis may be necessary based on a simultaneous evaluation of the impact of all identified and quantified risks. The result is a probability and frequency distribution of the project's cost and completion date based on the risks identified on the project. *Quantitative risk analysis* involves statistical analysis, simulations and other advanced techniques drawn from the decision sciences. Tools commonly employed for these analyses include first-order second-moment (FOSM) methods, decision trees, tornado diagrams and/or Monte Carlo simulations. Specialized software such as Crystal Ball©, is involved when performing these analysis.

As mentioned earlier developing and delivering transportation projects is a complex task that is fraught with uncertainty. Risk management is an effective and valuable tool for managing uncertainty. The Federal Transit Administration's 2004 *Risk Assessment Methodologies and Procedures* identifies several advantages of risk management:

- To better understand project development process impacts, including timelines, 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 contingencies are, whether they are sufficient, and for what they may need to be used.
- Improved information for supporting other project or agency activities, such as value engineering and *strategic planning*.
- Improving project estimating, budgeting and scheduling processes, either for projects currently in development and for future projects.

1.1.2 Purpose

This document describes the basic concepts, processes and tools necessary to perform risk management throughout project development and delivery.
This guide covers the following:

A) Risk management principles and concepts
B) Risk management processes as they apply to initial project planning, scoping, environmental process, preliminary and final design and project build out;
B) Recommended roles and responsibilities of participants in the risk management processes;
C) The format and content of risk management procedures and documents;
D) Supplemental risk management information for outlier situations.

Another purpose for 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 also provides a means to systematically evaluate project uncertainty. Further, 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 is to be practiced 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 appropriate project contingencies. 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.

1.2 Project Risk Management Business Case

One of the most compelling arguments for practicing risk management as a standardized, systematic and formal process is that the best agencies and organizations worldwide practice it with great success[2]. 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*

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

and Practice in Europe) identified risk assessment and allocation as key components of professional practice.

Findings from a recent scanning tour recommended that Transportation organizations:

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

The US Department of Energy (DOE) also stresses the importance of practicing risk management. The DOE states that the need for a formal risk management process arises from the growing complexity of Capital projects.

Professional organizations such as the Construction Industry Institute (CII), Earned Value Management Institute (EVMI) and the Project Management Institute (PMI) stress the important of risk management as a vital means to increase the likelihood and probability of favorable outcomes. They also stress that it is necessary for risk management and planning to start at the beginning of a project in order to be effective.

The DOE posed three questions for its risk management practices to be most effective:

1. Does the agency have adequate skills, tools and experience to identify existing or potential new risks?
2. Does the agency have an adequate framework for risk analysis and evaluation to support decision making processes?
3. Does the agency have the right processes in place to effectively manage risks?

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

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

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 will also find this guidance useful to better ensure a systematic and well thought out risk management approach is used in the work they perform.

Roles and responsibilities of the primary participants involved in the risk management process are defined and explained. Stakeholders and their involvement are identified also. Where appropriate, the relationship of this guidance with other Department manuals is also provided.

The scope of this guide is to provide useful information and guidance necessary for practicing risk management including processes, methodology and tool applications, during the development of Capital projects. It is intended to be simple to use and effective for identifying, quantifying and tracking project level risks. A spreadsheet tool, also provided in Access format, for creating the *Risk Registry* is provided and 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 consistent with all pertinent and appropriate Department policies and procedures.

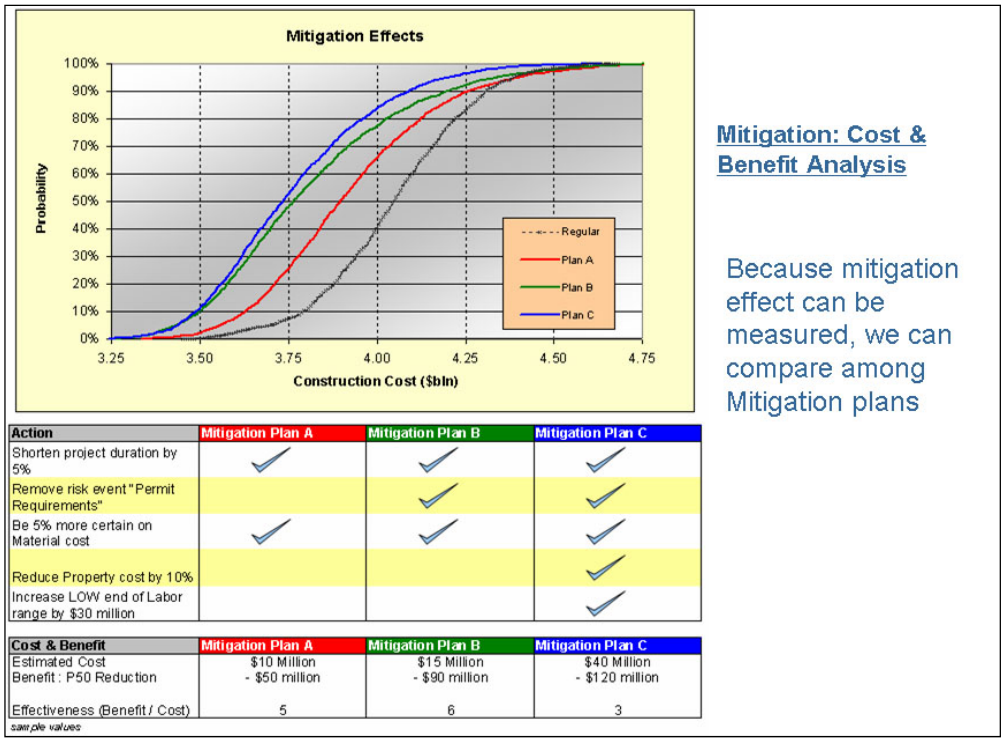


Figure 6
Source: DMJM Harris

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.

Successful Risk Management practices include the following major components: Awareness and Comprehension; Identification; Assessment and Analysis; Mitigation Planning; Allocation; Active Monitoring and Control.

Three key elements that are considered essential for a successful risk management program in today's transportation system are:

(1) A strong commitment in the organization, beginning with senior management, for developing and maintaining a risk management program and culture;
(2) Open communication and teaming among project development and industry partners in order to promote successful implementation;
(3) Being proactive in implementation to improve performance and outcomes.

Risk management can no longer mean public agencies overstressing administrative procedures, regulatory controls, and action avoidance, but should mean being able to systematically assess circumstances, being prepared to make informed judgments about policy, operations, financial, and political situations, and being willing to act. Figure 7 illustrates an example of how risk mitigation can benefit project outcomes.

Risk Assessment Methodologies and Procedures

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

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 a comprehensive overview of the risk management process.

Detailed Risk Management Process Overview

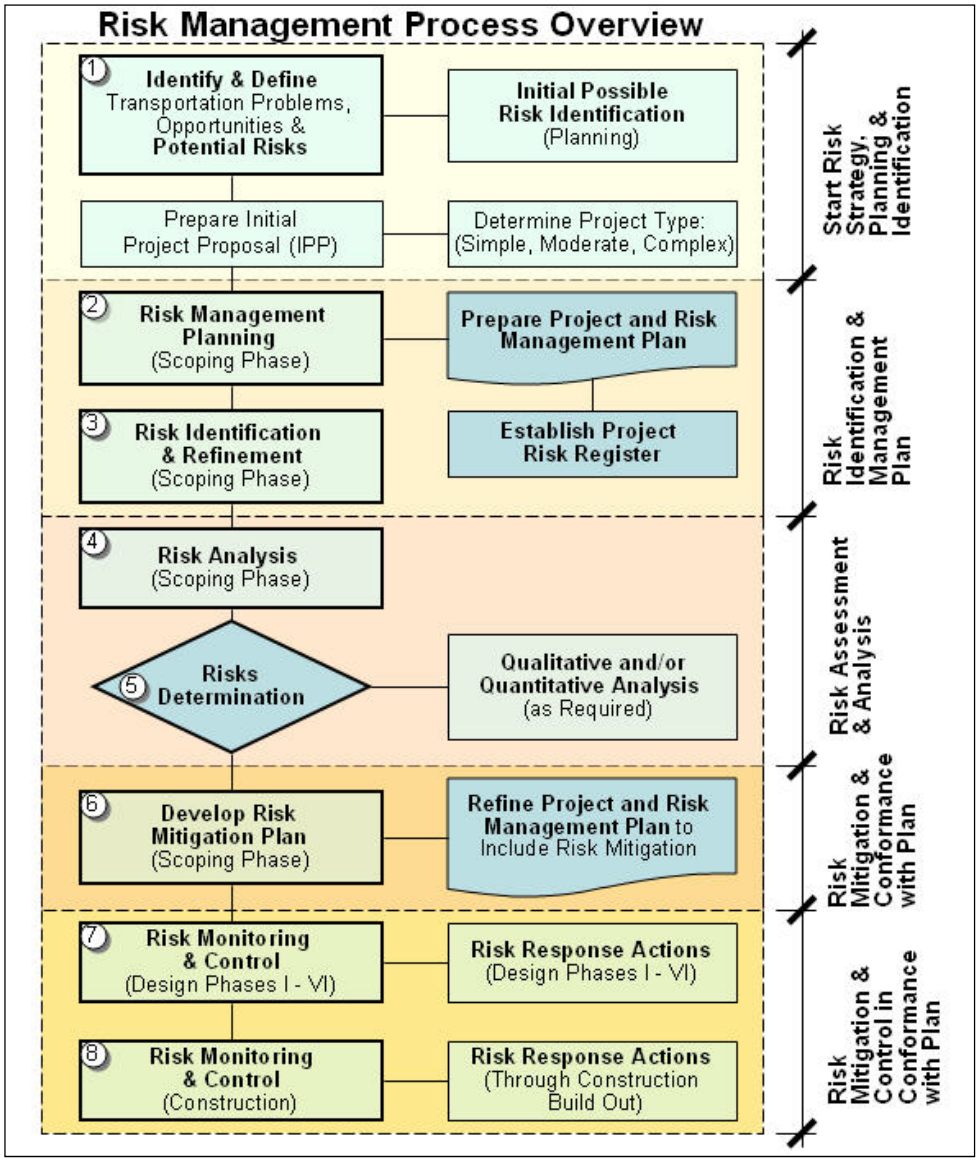


Figure 8
NYSDOT Office of Design

Risk Management Process: When to Start

As Figure 8 illustrates, risk management starts at the initial phase of project development – during the formulation of Initial Project Proposals (IPPs). When risk management is formally started during the formulation of IPPs, it provides the most value, return on effort, is most effective and provides the greatest potential to ensure projects will get developed within an acceptable range of scope, schedule and budget. This is possible because potential factors that may affect the scope, schedule and budget are identified early in the process when they can be most effectively managed at the least cost and impact to the project.

The IPP is the initial definition of the transportation problem(s), needs, potential environmental issues and community issues within which the proposed transportation needs exist, e.g., the project area context, and as described within this guide, potential risk issues that may pertain to the project. All potential risk issues will be managed and tracked as the project continues into scoping, preliminary design, final design, and as warranted, through construction build out.

1.5. 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, avoided, and/or mitigated. If certain risks are deemed beyond the authority of the Project Manager, the Regional Group director (either the Regional Design Engineer or Regional Planning and Program Manager) will have the ultimate responsibility to ensure the risk is managed satisfactorily and effectively.

The project team plays a central role in contributing to the development of the risk management plan.

The project team plays a central role in contributing to the development of a risk management plan for each project, and ensuring that all risks are identified and either avoided or mitigated. The project team shall assist the project manager to ensure the necessary actions for avoiding and or mitigating risks are proposed, approved and implemented. The risk management tool, also described as the *risk register*, defined later in this guidance, started during the development of the ***Initial Project Proposal*** (IPP) phase shall be used to ensure all necessary risk management actions continue throughout the remaining project development process through the ***Scoping, Design Approval and Final Design*** phases.

It is very important that the Project Manager and project team update the risk register on a regular basis. At a minimum the risk register shall be updated at each subsequent project milestone to ensure all possible risks are identified and avoided and or mitigated. Any other newly emerging risks must be identified. All potential risks shall 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*- see Construction guidance)		A	**L (EIC)**	S
Final Risk Performance Reporting		A	**L** (PM /EIC)	S

Table 1
Source: FHWA

Legend:
L - lead role
S - support role
A - approval authority

1.6. Risk Management Strategy

The Risk Management Strategy defines how risks will be managed most effectively during the lifecycle of the project. The Risk Strategy and supporting plan acknowledge actual and potential threats to the successful delivery of a project and determine the activities required to minimize or eliminate them. The risk plan needs to be capable of integration into or co-ordination with the project plan.

1.6.1. Risk Strategy Outputs

The result of risk strategy development is the ***Risk Management Plan***. The plan (see outline Appendix B) prepared by the project manager in collaboration with the project development team and stakeholders, provides a strategic overview of the risk approach, what actions will be undertaken for the project and details a process for addressing the important risk factors that the project will likely need to address.

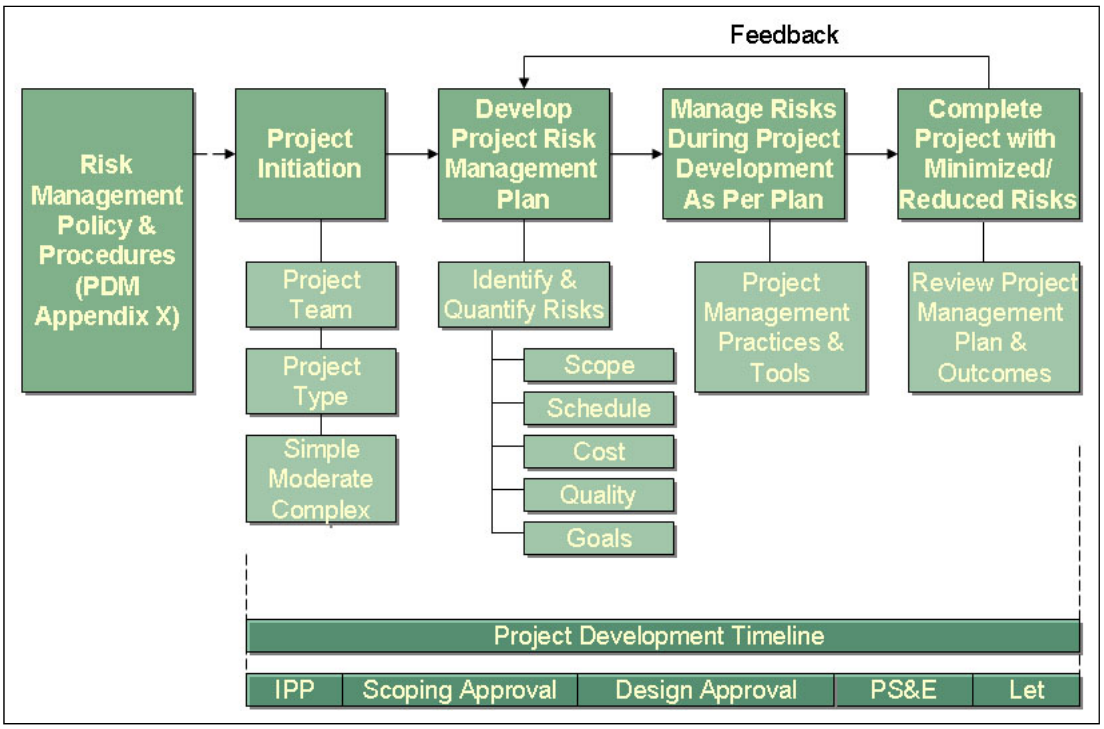


Figure 9
Source: Office of Design

Risk Management Planning is defined as the process of deciding how to best prepare for and conduct the risk management activities for a project to ensure its most successful completion. 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.

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

The resulting output of risk management planning is a Risk Management Plan. The risk management plan identifies and establishes the preliminary activities necessary to discuss, conduct, coordinate and manage all potential risks, determine their likelihood given the project's level of complexity (Maintenance, Simple, Moderate or Complex type), and be incorporated as necessary into the ***Project Management Plan***.

1.8. 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. Planning should also address evaluation of the capabilities of potential sources of risk mitigation as well as early industry involvement.

1.9. Process and Procedures Overview

Figure 8 illustrates the overarching steps involved and necessary to effectively manage risks during the project development process. Figure 9 illustrates in greater detail the steps necessary for the development of the risk management planning process for a project. It should be noted however that planning, especially at the early stages of project identification and definition is an iterative process.

It is important that at the Initial Project Planning (***IPP***) stage, risks be considered and a sound risk management strategy be discussed, formulated and included for each potential proposed project. In this way, the true work to develop a potential project is realized early, can be managed either through avoidance or mitigation, more effectively and therefore risks will not come as a surprise later with as great of an impact especially to costs and schedule. Once an IPP is approved, the initial risk management plan shall be finalized and recorded as part of the overall project management plan.

> ***Risk Management Planning is the process of deciding how to approach and conduct the risk management activities for a project.***

The output of the initial stage of risk management is the development of the ***risk strategy and the management plan.*** The risk strategy and the management plan evolves from the strategy used. The plan should also include: technical risks, programmatic risks and any possible contingencies as necessary.

A important component for consideration at the early stages of risk management is planning for ***contingencies***. Contingencies are usually described in terms of monetary and schedule needs above the original estimate to reduce the risk of overruns of project objectives within an acceptable level[3]. Contingency planning is especially useful and valuable at the initial stages of project development (IPP and Scoping Phases) when the greatest numbers of unknowns exist. Contingencies planning should continue throughout the project development process as warranted and required.

Risk management planning begins by developing and documenting a clear risk management strategy.

SUMMARY

1) Risk management is an important component of managing and developing Capital projects.
2) Risk management including a risk management plan should be incorporated into every project. The extent of the plan should be consistent with the complexity of the project, e.g. a simple project may only require a strategy to be developed and a list of red flag items, whereas a complex project will most likely warrant an in-depth plan using the format found in Appendix B.
3) During the development of an Initial Project Proposal (IPP) potential risk issues should be fully explored as transportation needs are formulated and refined. As potential risk issues are identified, considered and deemed appropriate, they are to be incorporated into the IPP.
4) As and when initial potential risk issues are identified during the development of an IPP and continued within the Scoping phase, they shall be included with the risk registry.
5) The risk registry shall be part of the official project documents and records throughout the project development process concluding at the completion of construction build out.

[3] A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Project Management Institute, 2004

CHAPTER 2 RISK IDENTIFICATION

2.0 RISK IDENTIFICATION

California Department of Transportation (Caltrans) describes the importance of risk identification in terms of careful and explicit planning which provides a foundation for risk avoidance and mitigation thereby greatly improving the likelihood of a projects overall success.

Risk Identification is defined as the process of identifying any and all potential risks that might affect a project and documenting their characteristics. The outcome of risk identification is a listing of all possible ***potential*** risks. What is done with this list of potential risks depends on the nature of the risks, their potential impact and the scope of project.

The objectives of risk identification are to:

(1) Identify and categorize risks that could affect the project;
(2) Document all identified risks.

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.

During risk identification every possible potential risk of the project is added to the risk registry. The risk identification process also includes documenting the risk characteristics that might affect the project. The risk registry becomes a 'living' document that may at times be amended with updates and results from qualitative risk analysis and risk response planning, which should be reviewed and updated throughout the project.

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

Identified risks become a part of the project risk registry.

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 less-complex, lower-cost projects with less uncertainty (and fewer risks), identified 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 more uncertain, identified risks will undergo a rigorous process of assessment, analysis, mitigation and planning, allocation, and monitoring and updating described in this document.

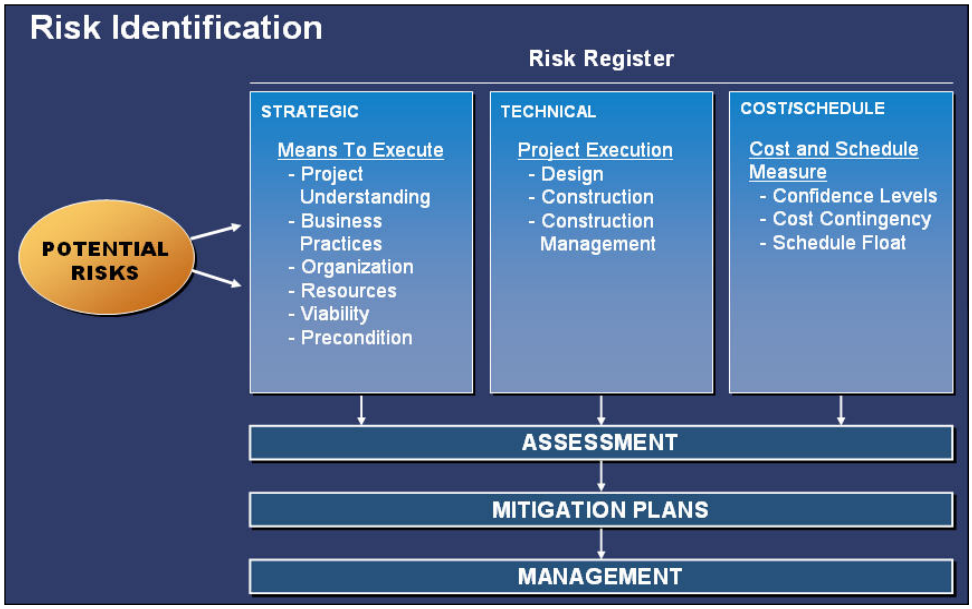


Figure 10
Source: DMJM Harris

It is important to note that 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.

***Risk identification* should stop short of assessing or analyzing risks so that it does not inhibit the identification of "minor" risks.**

2.3. Potential Sources of Risks

Although potential project risks are interrelated and interdependent, most risks originate from specific areas. 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
- Economic factors
- Epistemic or aleatory data factors (e.g. escalating costs or limited site or subsurface data)

The potential project risk checklists (Appendix C) 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.

2.4 Risk Characterization

Risk characteristics can be defined in a number of ways. An example provided by Wideman[4] classifies risk characteristics by:

- *Knowns;*
- *known-unknowns;*
- *unknown-unknowns;*

These classifications can be used to describe project costs and potential contingencies. A known is an item or situation containing no uncertainty. Known-unknowns are known potential risks but 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 these risk terms 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

Table 2
Source: FHWA

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 it 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 called risk symptoms or warning signs, are indications that a risk or is about to or has occurred. 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.

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

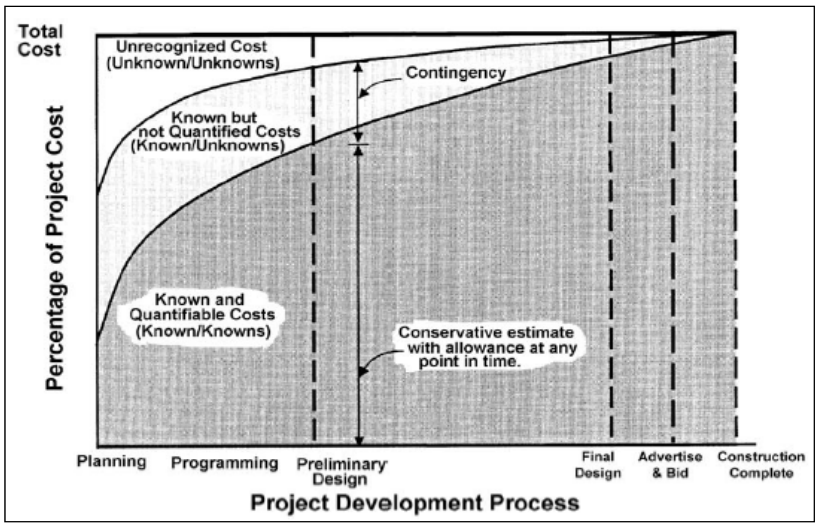


Figure 11
Source: TRB

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 more common place in the state-of-the practice.

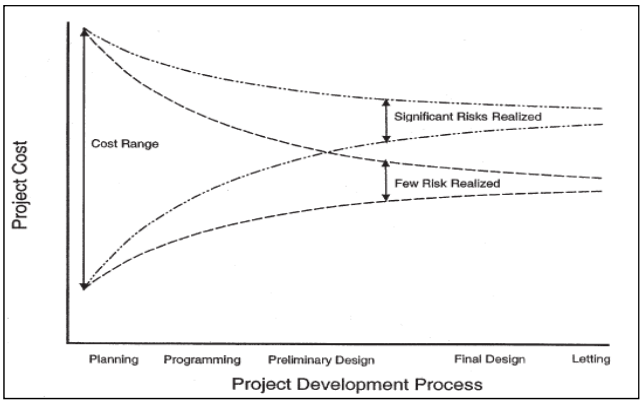


Figure 12
Source: TRB

It should be noted however, that project teams must take precautions not to overlook risks 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 fully during the identification stage and explore opportunities during the mitigation process.

2.5 Risk Identification Tools and Techniques

A number of documents and tools are available to support the risk identification process. The ***Initial Project Proposal*** (IPP) is the primary starting point for becoming familiar with the project. Potential project risks should begin to be considered and documented as necessary at this time. Identifying potential project risks continues vigorously throughout Scoping, Preliminary Design and Final Design and concluding at the completion of construction.

All project-specific documents, programmatic documents, supportive information available should be reviewed prior to commencing risk identification interviews, meetings and investigations. Project risk can be identified multiple ways. ***A site visit is also highly recommended****. Interviewing residents, officials, and other key people familiar with the project, its context and historical issues is also recommended. Staff performing the risk assessments should record all information using the risk registry using either the excel format for simple projects or the Access Tool for moderate and complex projects. A Risk Identification, Assessment, and Allocation Worksheet can be found in Appendix D, page 57.*

Other methods used by project developers for identifying risks include brainstorming, scenario planning, and interviews. Interviews should include a wide range of stakeholders. Techniques such as the nominal group method, allows each team member to create a list individually. Individual list should be shared with the project manager and all team members after they are developed. 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.

Using the comprehensive ***Potential Risk Factors identification lists*** *provided in Appendix B the project team should 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.*

After risks have begun to be identified, they are to be classified by the team into various categories and entered into the **Risk Registry** by category. The Risk Registry is the formal documentation used to record all identified potential project related risks.

Staff performing the risk assessments should record all information using the risk registry either using the Excel format for simple projects, or the Access Tool for moderate and complex projects.

The key to success with any risk identification tool or technique is the value it provides to assist in identifying risks for further analysis and action. Having an effective process in place and staff who are knowledgeable of and proficient in the agency's risk processes are essential to effectively perform risk identification and risk management. This Risk Registry and its prescribed techniques provide the necessary means to effectively and efficiently manage and control project development risks.

As listed in the **Risk Registry Potential Risk Factors** include 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;

Risks identification tools add value while providing support to the people involved in the process.

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 discusses 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 should continue to be tracked during each successive stage of project development. If any new risks emerge that were not initially identified during a prior project milestone phase, they should be added to the registry and addressed appropriately.

2.6. Risk Identification Procedures, Outputs and Conclusions

The risk identification process explores, distinguishes and categorizes potential risks that could affect the project. Identified potential risks are recorded in the ***Risk Registry*** and tracked throughout the project development process. Risk identification is an ongoing process. Potential risks identified later in the project development process should continue to be tracked during each successive stage of the project.

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.

Risk Identification Outputs will be a list of all potential risks entered into the ***Risk Registry***. Each potential risk will be analyzed as described and discussed in Chapter 3.

Potential risks identified later in the project development process should continue to be tracked during each successive stage of the project.

Risk Identification Gathering Techniques

Technique	Purpose	Advantages	Steps
Brainstorming	Probe individuals for ideas about risks, in a group setting, by enabling individuals to explore and build on each others' ideas.	Participants springboard off each others' ideas, resulting in a more creative and comprehensive list. Brainstorming fosters inclusiveness. Participants enjoy the process. Process is inexpensive and fast.	Facilitator leads a group of individuals in identifying specific risks. Individuals are encouraged to build upon each others' ideas. No criticism of anyone else's ideas is allowed. Often, brainstorming is fast and furious, with people shouting out their ideas as quickly as they occur.
Delphi Technique	Solicit information on risks from experts who are not co-located	Anonymity eliminates possibility of strong individual dominating the group or exerting undue influence on results. Can be conducted via e-mail. Every individual must participate.	Facilitator solicits experts--individually--via questionnaire for their thinking, experience, and opinions about risks. The facilitator analyzes, coordinates, combines, and edits the experts' input and redistributes the questionnaire The process is repeated until consensus is reached.
Interviewing	Obtain opinions, thoughts, and experiences with project risks directly by holding structured conversations with interviewees.	It's often easier to discuss experiences and obtain information face-to-face. It's not always appropriate for certain stakeholders (e.g., managers, clients, managers on past projects) to participate in group meetings.	The interviewer determines whom to interview and what kinds of information to obtain from each interviewee, creates questions, schedules and conducts the interview, and documents the discussion. The interviewer may send a copy of the interview to the interviewee.
Root Cause Identification	Identify the root causes--rather than or in addition to the symptoms--of risks in order to develop more effective risk responses.	Identifying root causes sharpens the definitions of risk.	Facilitator can use diagrams in conjunction with brainstorming sessions to identify root causes. Commercial software and trademarked processes are also available to assist with root cause identification.
SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis	Examine a project from the perspectives of its strengths, weaknesses, opportunities, and threats (SWOT) in order to increase the breadth of the risks considered.	Helps the team to look at the big picture by expanding their perspectives.	Brainstorm the strengths, weaknesses, opportunities, and threats to the project and to the organization as a result of the product or service being created.

Table 3
Source: PMBOK®

SUMMARY

1) During the identification of potential risk issues process, it is vital that the project development team conduct discussions with project area stakeholders to ensure a thorough review is conducted. Discussions should include internal and external stakeholders very familiar with the project area context such as community issues, understanding and integration with comprehensive planning, coordination of other services, and others as necessary to ensure a thorough review is conducted.
2) The potential risk issues identification process should use the various techniques discussed in chapter 2.
3) All identified potential risks shall be included and entered into the risk registry for further analysis and management.

CHAPTER 3 RISK ANALYSIS

RISK ANALYSIS

Risk Analysis for the purposes and scope of this guide will focus primarily on ***Qualitative Analysis*** methods and techniques. More advanced ***Quantitative*** methods and techniques are discussed in Appendix E. For practical purposes the majority of risk analysis will be performed for simple and moderate type projects. Complex projects will typically use quantitative methods. Users may however find it necessary to use some quantitative methods depending on the circumstances of the project and therefore knowledge of quantitative methods is needed.

After all potential project risks have been identified and recorded within the registry model / 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. ***Risk Analysis*** is the process of quantifying all identified risks in terms of likelihood or frequency on a range from very unlikely to very probable, and impact or consequence severity should the risk occur.

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. The Risk Rating Matrix (below) can be used to assist in the rating process.

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 Item 3				
Risk Item *n*				

Final ratings should be recorded in the risk registry.

Table 4
Source: FHWA

3.1. Risk Quantification Process

Risk Quantification *is the process of prioritizing potential risks for subsequent further analysis, evaluating the probability that a potential risk event may occur, and assessing the range of possible outcomes*. Risk quantification assesses the possible 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***. The table below provides a simple framework for recording an initial range of risks.

3.1.1. Understanding Risks to Whom

> ***Risk Quantification** is the process of prioritizing potential risks for subsequent further analysis, evaluating the probability that a potential risk event may occur, and assessing the range of possible outcomes.*

A fundamental concept for any risk assessment is "risk to whom," or whose risk is being assessed 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 a change occurs, 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.

3.2. 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 using a range 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 Analysis

As potential risks are identified as described and discussed in Chapter 2, analysis and assessment is to be performed on each identified risk. Project managers, project team members and other analysts should conduct the analysis jointly. Each brings important perspectives to the assessment process. Managers may tend toward qualitative assessment of risks - evaluating risks on their worst-case effects and their relative likelihood of occurrence. Managers may also tend to focus on strategies and tactics for avoiding risks or reducing a risk's negative impacts. Analysts, on the other hand, may tend toward quantitative assessment of risks. They may evaluate risk impacts in terms of a range of tangible results and they evaluate risk of

occurrence in terms of probabilities. Team members may tend to focus 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 discusses qualitative risk assessment. Chapter 4 covers quantitative risk assessment.

Any potential risk identified in later project development stages should be tracked through the completion of the project.

3.4. Foundations of Risk Analysis

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 acquire 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.

3.4.1. Incremental and Discrete Risks

Risks are measured by two fundamental and different ways, incrementally or discrete. 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, typically large change. They are often low-frequency but may be high-consequence events.

3.4.2. 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.

3.4.3. Risk Screening: Risk Severity and Frequency

After the risk identification and qualitative risk assessment process has been completed, the next risk activity to take place is to develop a set of risks characterized by their frequency of occurrence and the severity of their consequences.

> Frequency and severity are the two primary characteristics used to screen risks and separate them into minor risks that do not require further management attention and significant risks that require management attention and possibly quantitative analysis. Various methods have been developed to help classify risks according to their seriousness. One common method is to develop a two-dimensioned matrix that classifies risks into three categories based on the combined effects of their frequency and severity. Figure 9 requires classifying risks into one of five states of likelihood (remote through near certain) and into five states of consequence (minimal through unacceptable). These assessments yield a five-by five matrix that classifies a risk as either "high" (red), "moderate" (yellow), or "low" (green) refer to figure 13 on the following page. Record potential risk frequency and severity using the Risk Model Registry (see Chapter 6).

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

ASSESSMENT GUIDE

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

Consequence

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

RISK ASSESSMENT

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

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

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

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

Figure 13
Source: Department of Energy (DOE)

3.4.3.1. 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.

Typically minor risks do not require further management attention while significant risks do require management attention.

3.4.3.2. 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 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.

Typically, Low-likelihood, high-consequence events usually warrant individualized attention and management.

3.4.3.3. 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 items are discussed in more detail in Chapter 5.

Risk assessment can also be conducted on a program of many projects. Figure 14 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) 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 effective example of risk assessment at the programmatic level for highway project delivery.

Likelihood-Impact Matrix

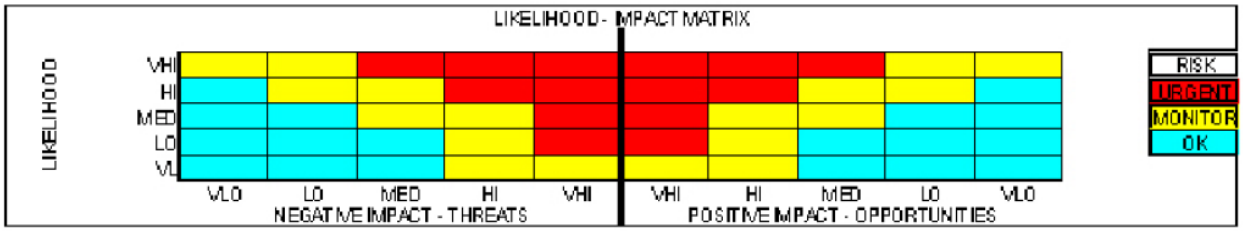


Figure 14
Source: FHWA

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.

Risk assessment techniques are scalable. They are as effective on small highway reconstruction projects as they are on large projects or even corridor programs.

3.6. Advanced Risk Analysis Methods

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 familiarize the reader to the terminology 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.

In a qualitative analysis process each identified risk is assessed for its probability of occurrence and its relative magnitude of impact on project objectives.

3.6.1. Cost Risk Assessment Diagram

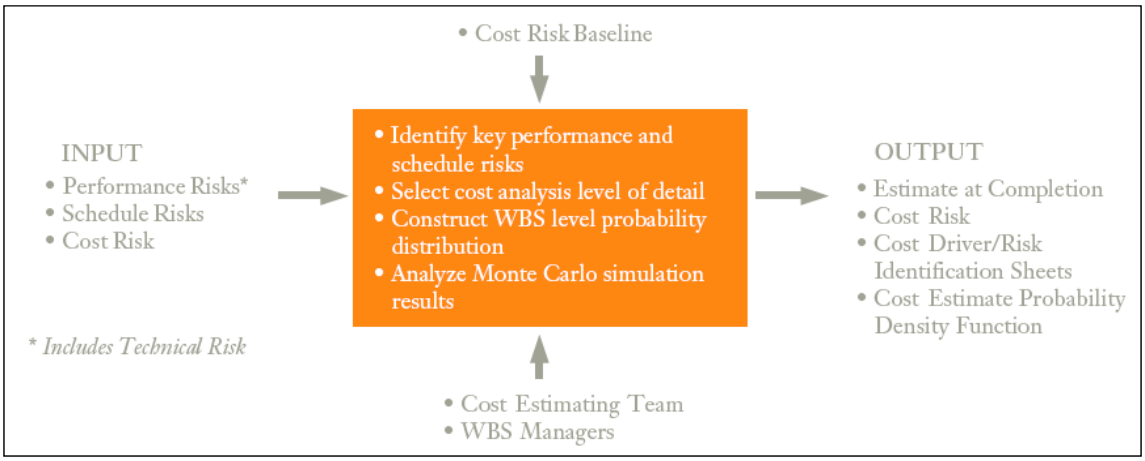


Figure 15
Source: DOE

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?)

3.7. Risk Probability

Risk Probability Matrix

Risk probability *is the determination of the likelihood that a specific risk may occur*[5]. It is one of the key assessments and determinations to make. Risk impact assessment is the potential ***effect*** the risk has on the project and its objectives which often drive other important decisions regarding the project. Combined, the probability and impact of a potential risk on time, cost, scope, quality, and customer satisfaction, including negative effects for threats and positive effects for opportunities, are the primary outcomes of risk management.

A probability/impact matrix can be used to associate identified potential risks with their probability and severity levels. Each identified potential risk can be assigned a possible range based on past trends or other references and supporting details. Acceptable tolerance levels can be established to help manage possible risks. The emerging risk position is defined by the acceptable tolerances established for the project. Risk tolerances can be outlined using a matrix which illustrates the desired acceptable risk levels for the project. The position of the risk tolerance line would depend on the project and the degree of acceptable risk (see figure 16). The risk probability matrix is another tool to help analyze and determine possible risk tolerances.

[5] A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Project Management Institute, 2004

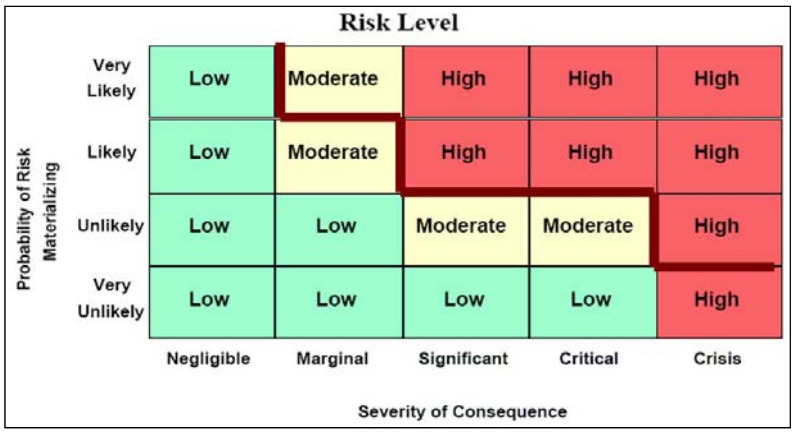


Figure 16
Source: DOE

Quantitative risk analysis is the process of numerically analyzing the effects of each identified risk on overall project objectives. These 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.

See **Appendix E** for more information regarding ***Quantitative risk analysis.***

3.8. Risk Analysis Procedures, Outputs and Conclusions

The primary outputs of risk analysis are the weighted ratings for each identified risk, including potential severity, probability and impact affect. Weighted ratings of either: high; moderate; or low; are recorded and included within the risk register for further mitigation or avoidance action. Appropriate actions and avoidance will depend on the assessment of the risks identified. Chapter four addresses avoidance and mitigation actions and methods.

SUMMARY

1) The analysis and assessment of all identified potential risk factors shall be undertaken in accordance with the guidance and practices described in chapter 3 using the format provided in the risk registry.
2) Analysis and assessment will be relative to the project type, e.g. maintenance and simple projects will, as a general rule, require qualitative assessment relative the needs and risks identified, moderate and complex project will require more exhaustive analysis and assessment that may require qualitative ***and*** quantitative analysis given project circumstances.
3) All analysis and assessment results are to be included with the risk registry and project documentation.

CHAPTER 4 RISK MITIGATION

4.0. RISK MITIGATION

Risk mitigation involves addressing identified risks, determining risk mitigation measures, and managing the risk between the appropriate project parties responsible. A 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.

4.1 Risk Response Options

Risk mitigation response planning is conducted once project risks, including their frequency and severity, have been identified and analyzed.

Risk identification, assessment, and analysis exercises form the basis for sound risk response options. A series of risk response actions can help agencies and their industry partners avoid or mitigate the identified risks.

Wideman, in the *Project Management Institute Standard Project and Program Risk Management: A Guide to Managing Risks and Opportunities*, states that a risk may be the following:

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

> Risk mitigation explores 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 and accountability for each risk response. The project manager, project team and all necessary stakeholders should participate in risk mitigation response planning and actions.

4.2. Risk Mitigation Documentation

Each risk management plan should provide appropriate documentation with the understanding that the level of detail will vary with the unique aspects associated with each project. Large projects or projects with high levels of uncertainty will benefit from greater detail and formal risk management plans that record all aspects of risk identification, risk assessment, risk analysis, risk planning, risk allocation, documentation and risk reporting. Simple projects that likely contain minimal uncertainties may require only limited documentation such as red flag item list that can be updated at critical milestones throughout the project development and construction.

4.3. 'Red Flag' Item Lists

Red flag items are unique or unusual risks that may have high negative or 'fatal flaw' potential which warrant special management attention. A red flag item list should be created at the earliest stages of project development and maintained as a checklist through out 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 objectives, cost and schedule. Issues and items that can potentially impact project objectives, cost or schedule in a significant way are identified in a list, or in other words 'red flagged', and the list is kept current as the project progresses through development and construction build out. By listing items that can potentially impact a project's objectives, 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, designers and construction managers about these items. By maintaining a running list, red flag items will be less likely to disappear from consideration only to cause problems later on.

Caltrans also uses this approach. Likewise, this document includes a '*Potential Risk Factors List*' developed as a sample list of risks (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.

The risk charter is used as a management tool to identify, communicate, monitor, and control risks.

4.4. Risk Registry

The risk charter is synonymous with the risk register, which is updated regularly as part of the risk management process and report capable at each successive project major milestone. The risk charter provides project managers with the list of all significant risks identified and includes information about the cost, schedule and quality impacts of these risks and their likeliness to occur or probability. It is used as a tool to record and continuously track changes in the magnitude of potential risk and their impacts as the project progresses through the development process and as 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.

The 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 includes relevant information such as the following:

- Risk type and description
- Status
- Date identified
- Project phase
- Functional assignment
- Risk trigger
- Probability of occurrence
- Impact affect
- Response actions
- Responsibility (allocation)

The Risk Registry serves as the risk charter and is described in more detail in the following pages.

4.5. Risk Registry Table

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

Arial 10

A10 Funding Availability

RISK ASSESSMENT & MANAGEMENT WORKSHEET

PIN Z123.45 **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 - IPP completed 06/2007

RISK FACTOR	COST RISK Severity (High, Med)	COST RISK Probability (L, M, H)	SCHEDULE RISK Severity (High, Med)	SCHEDULE RISK Probability (L, M, H)	QUALITY RISK (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 Flex 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									
Betterment agreement			Med	Med			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
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 OT if nec.	Joe Smith - DJM
Technical Risks									
Bridge type	High	Med				Extra design time for truss is minmal. SHPO is non-commital 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 ot 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 / IPP / SCOPING / IV (DAD) / V (ADP) / VI (PS&E) / Risk Revisions / LESSONS LEARNED

Figure 17

NYSDOT

Access Format Views (screen captures)

Main Screen

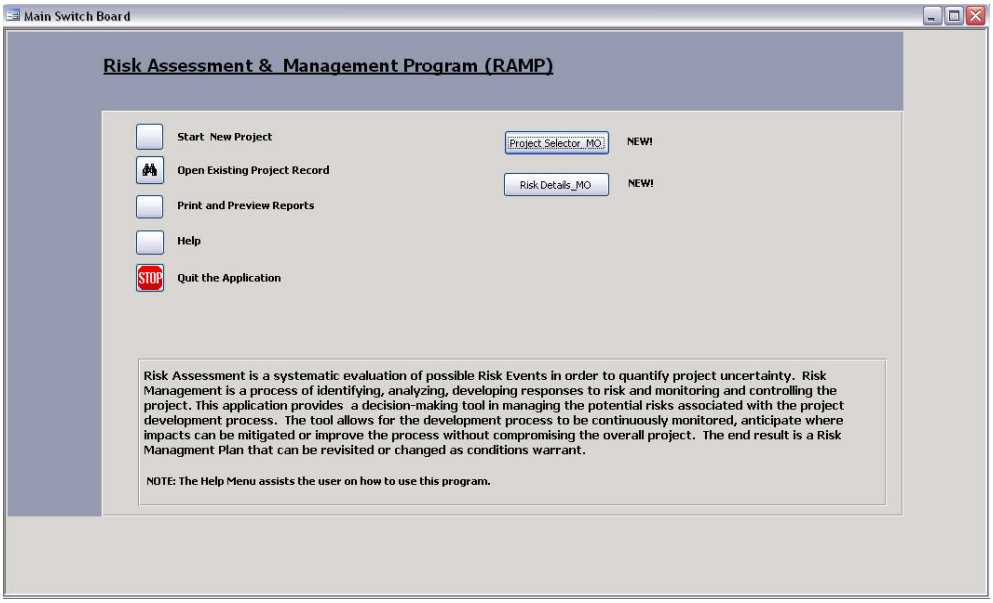


Figure 18
Source: NYSDOT

Project Selector

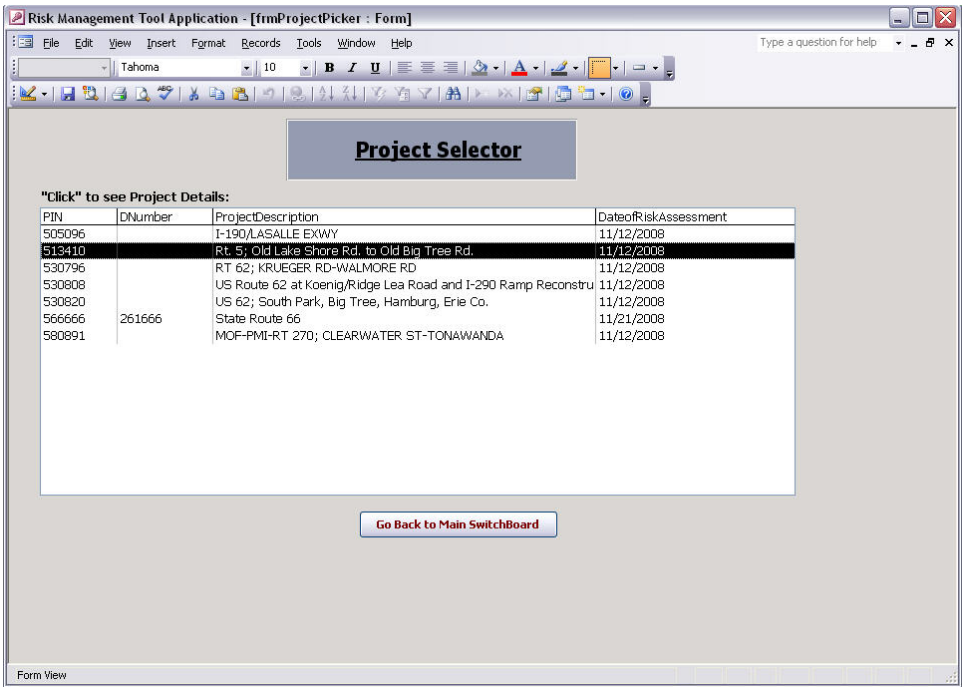


Figure 19
Source: NYSDOT

Project Information

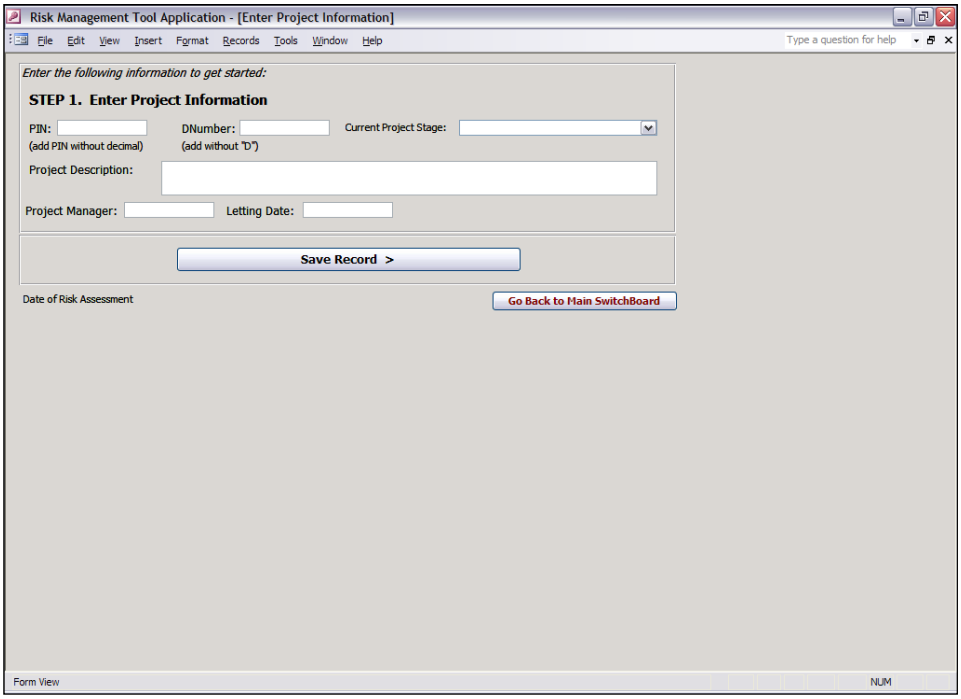


Figure 20
Source: NYSDOT

Risk Identification

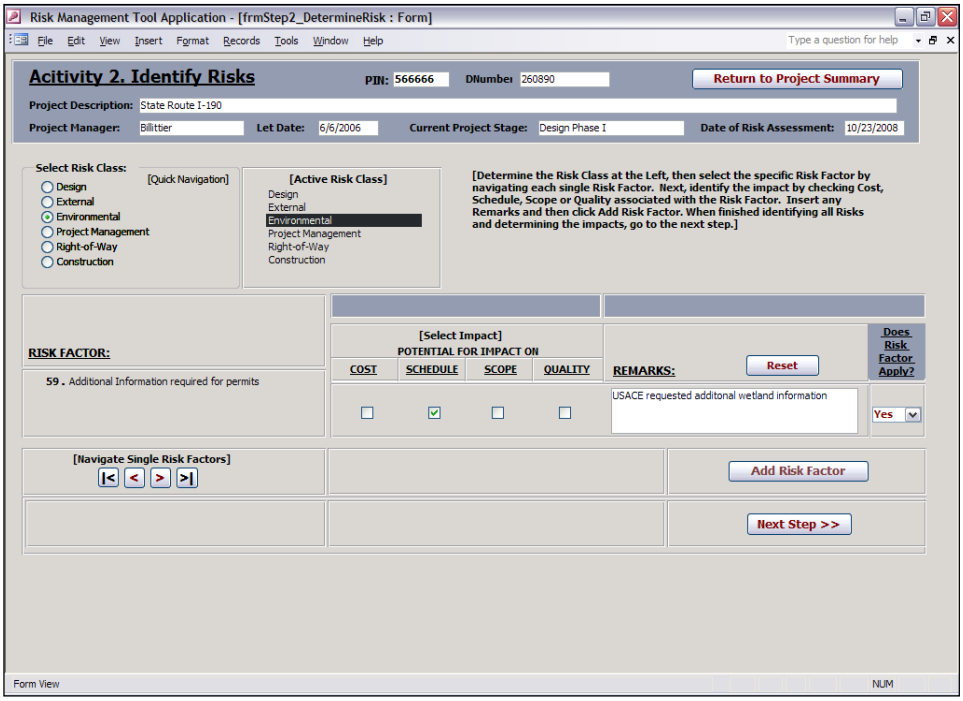


Figure 21
Source: NYSDOT

Risk Selection

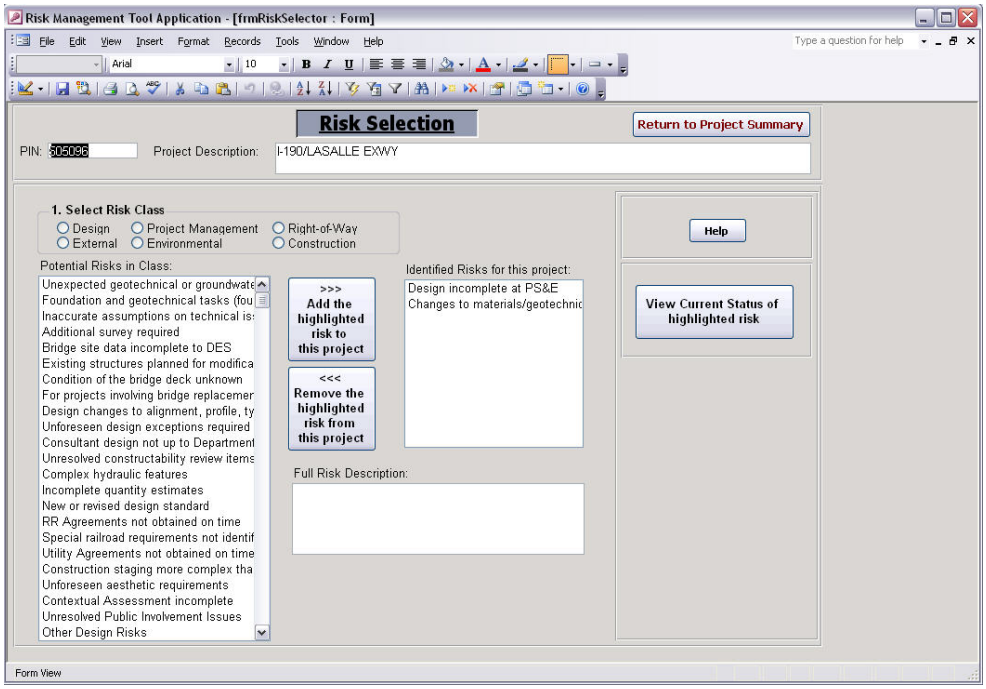


Figure 22
Source: NYSDOT

Risk Assessment

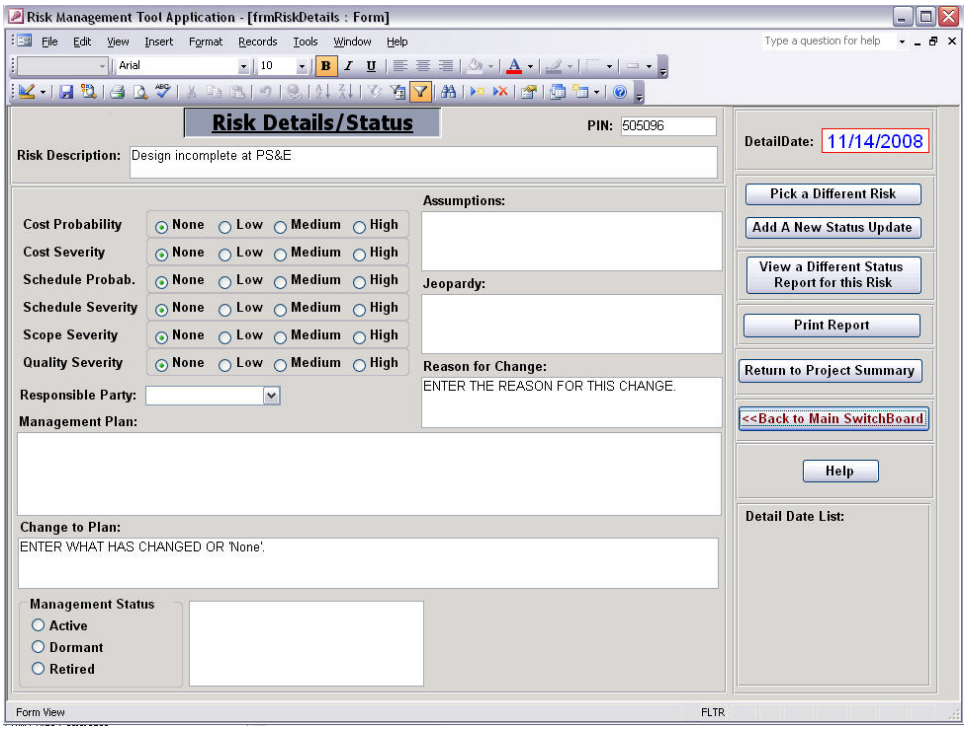


Figure 23
Source: NYSDOT

Risk Tolerances

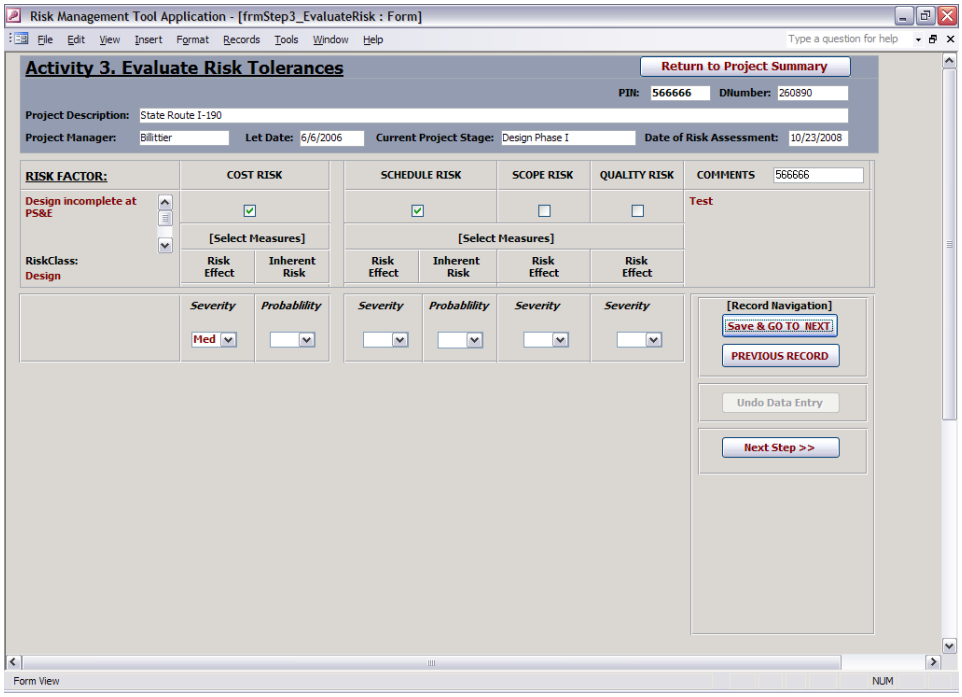


Figure 24
Source: NYSDOT

Risk Management Plan

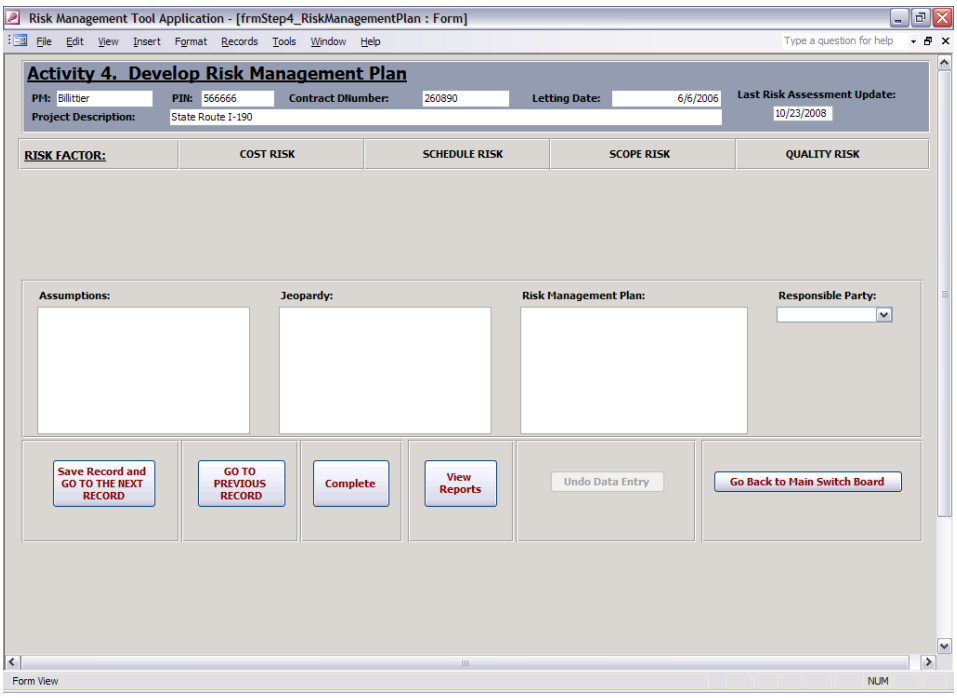


Figure 25
Source: NYSDOT

Risk Reporting Formats

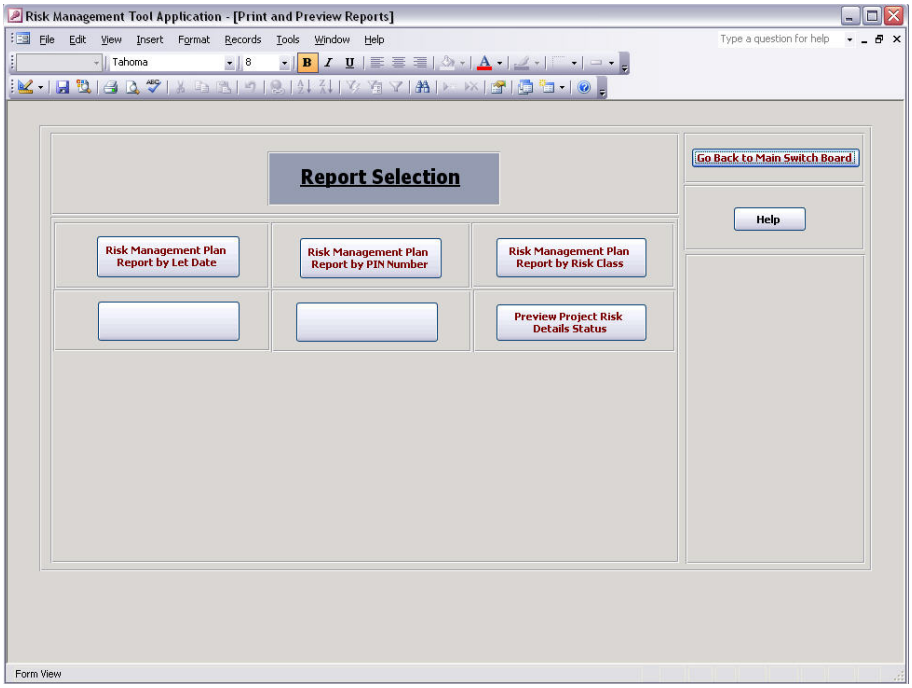


Figure 26
Source: NYSDOT

The risk registry 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. Figures 17- 26 illustrate the risk registry and the information it may contain.

Use of the risk management registry should be continuous from the beginning of the pre-IPP Phase through to Construction completion. In this way, project teams and managers can be better assured that project risks that have been identified throughout the project will be managed appropriately.

Risk Registry Model, Applications and Use

The risk registry 'model' is the term given to the Excel spreadsheet or Access data base. It is the tool used to capture and document risks. The risk registry model should 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 throughout the project.

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.

4.6. Risk Avoidance and Mitigation Plans

The project development team's strategy to manage risk provides the project team with direction and a basis for planning and action. A formal risk management plan should be developed during the initial planning (IPP) and carried, as mentioned earlier, into the scoping process. The risk management plan must be 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 risk management 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
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

The Risk Avoidance and Mitigation Plan must provide sufficient information on what actions will be taken in what time frame to address each identified risk and who is responsible for what.

Appendix B provides a sample format for use by NYSDOT.

4.7. 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 identified 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, state 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 identified risks and their potential consequences are measured and fully understood, more effective decisions can be made to best address the risk in a manner that minimizes impacts while maximizing project goals.

4.9. Risk Mitigation Procedures, Outputs and Conclusions

Risk mitigation, planning and allocation uses information derived from the risk identification, assessment, and analysis processes to formulate appropriate response strategies for all identified, appropriate and necessary risks. Common strategies include avoidance, transference, mitigation, or acceptance. Mitigation and planning must be documented in an organized and comprehensive fashion that clearly assigns responsibilities and delineates procedures for appropriate mitigation and allocation of identified potential project 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 management culture that should result in better cost management from planning through construction and better allocation of project risks.

Formalizing risk planning, management and mitigation throughout project development will improve performance while establishing a risk management culture

SUMMARY

1) Determining the most appropriate response to all identified risks will depend on the analysis and conclusions made for each potential risk factor, the complexity of the project, the circumstances involved and the options available.
2) Risk response strategies include: avoidance; transference; mitigation; and acceptance. Each response has various options and actions necessary for successful management to be achieved.
3) Risk response strategies, range of options and determinations of specific actions shall identify the appropriate owner and their role and responsibility in managing the assigned risk.
4) When identified risks and their potential consequences are measured and fully understood, more effective decisions can be made to best address the risk in a manner that minimizes impacts while maximizing project goals.
5) Each response strategy has specific actionable tasks which shall be determined and included with the risk registry.

CHAPTER 5 RISK MONITORING and CONTROL

5.0. RISK MONITORING AND CONTROL

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.

5.1. Risk Reporting

Risk reporting involves recording, maintaining, and reporting assessments. Monitoring results and assessing the adequacy of existing plans are critical. The Department of Energy's Office of Engineering and Construction Management, states that the primary criterion for successful management is formally documenting the ongoing risk management process. 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 Appendix D, figure 12, on page 64. 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.

5.2. Risk Management Metrics

The development of performance metrics for risk management is essential to risk monitoring success. The establishment of performance indicators that provides accurate, timely, and relevant risk information in a clear, easily understood manner will be an important tool for effective risk management. Early in the planning phase of the process, the team should identify potential 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 utilizes performance measures for its risk management program. Caltrans measures: (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 (demonstrating project quality). 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.
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.

The primary criterion for successful management is formally documenting the ongoing risk management process. 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.***

5.3. Risk Monitoring and Control Procedures, Outputs and Conclusions

Monitoring and controlling risks are the final stages of effective risk management. 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.

SUMMARY

1) Appropriately managing risk requires: (1) systematically tracking all identified risks, (2) identification of any new or emerging risks throughout project development, (3) effectively managing contingencies, and (4) capturing lessons learned for future risk assessment and allocation performance improvement.
2) Determining the most appropriate response to all identified risks will depend on the analysis (and rigor) required and conclusions made for each potential risk factor, the complexity of the project, the circumstances involved and the range of options available.
3) Monitoring and control decisions should be made collaboratively.
4) Performance measures for risk provide numbers of, types of, and magnitude of risks being experienced on projects statewide. What risks are being successfully mitigated? What trends and patterns can be identified?

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.

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

Empirical data - data that are produced and verifiable by experiment or observation.

Appendix B Sample Risk Management Plan Outline

1. Introduction

Project Background Information
Project Name
Project Location

2. Project Description

Provide a brief summary overview discussion of the project purpose and need, context, public issues (if any), potential macro-level risk issues and any considerations for mitigation/minimization. Any detailed information will be included within the Project Report.

3. Risk Management Strategy and Approach

Provide a brief summary overview of the strategy that will be used to manage, mitigate and minimize potential macro and micro-level risk issues (if any), involved with the particular project macro-level risk issues and any considerations for.

4. Risk Identification (Reference Risk Model/Register)

Using the guide, procedures and risk register model, identify all potential risks

5. Risk Assessment and Analysis

7A. Qualitative (used for simple and moderate project types)

Use the techniques outlined in the guide to perform and determine. Techniques include: (list)

7B. Quantitative (complex project types)

When necessary, use the techniques outlined in the guide to perform and determine. Techniques include: (list)

6. Risk Response Planning (Reference Risk Model/Register)

7. Risk Allocation

Determining who, what group or groups will have responsibility for avoiding or mitigating identified risks.

8. Risk Charter and Risk Monitoring

9. Risk Management Information System, Documentation, and Reporting

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		√	√	√
Lack of clear roles and responsibilities and authority		√		
Scheduling changes made to critical path		√		

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.

Figure 1
Source: FHWA

Project Information and Description

US 555–SH 111 INTERCHANGE PROJECT

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

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

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

Figure 2
Source: FHWA

Risk Identification

RISK IDENTIFICATION

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

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

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

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

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

Figure 3
Source: FHWA

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

Figure 4
Source: FHWA

Risk Assessment

US 555–SH 111 INTERCHANGE PROJECT RISK ASSESSMENT

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

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

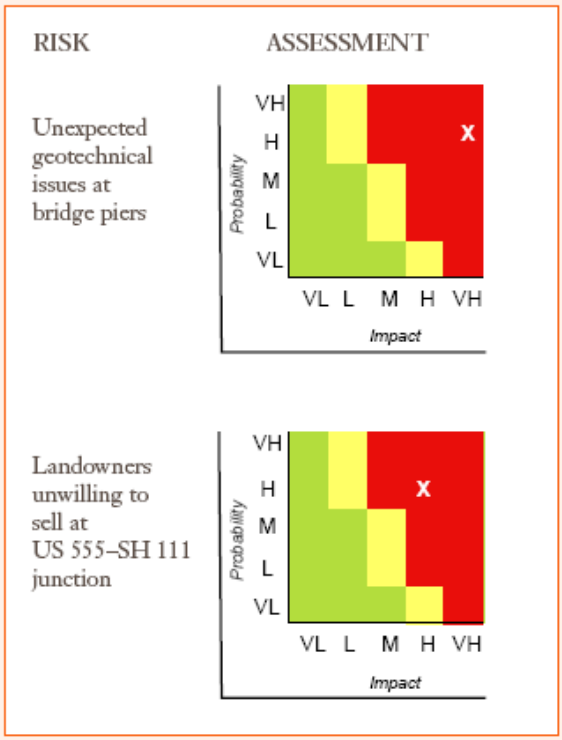


Figure 12. *Assessment outcome.*

Figure 5
Source: FHWA

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

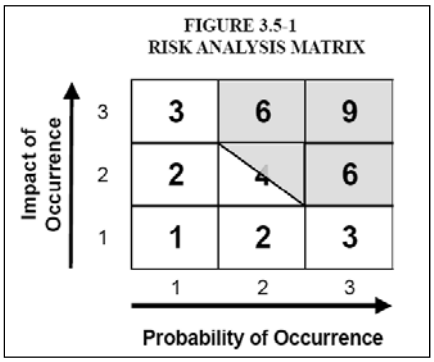


Figure 6
Source: FHWA

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		

Likelihood-Impact Matrix (FHWA)

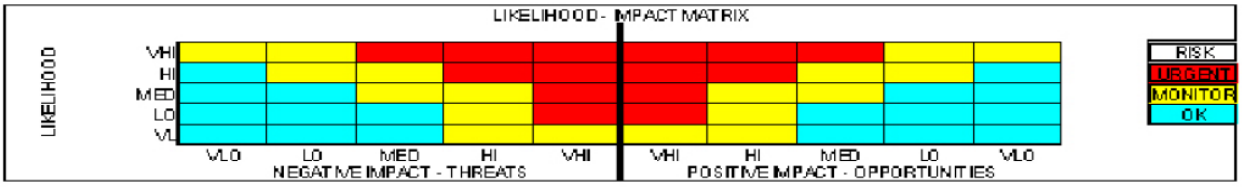


Figure 7
Source: FHWA

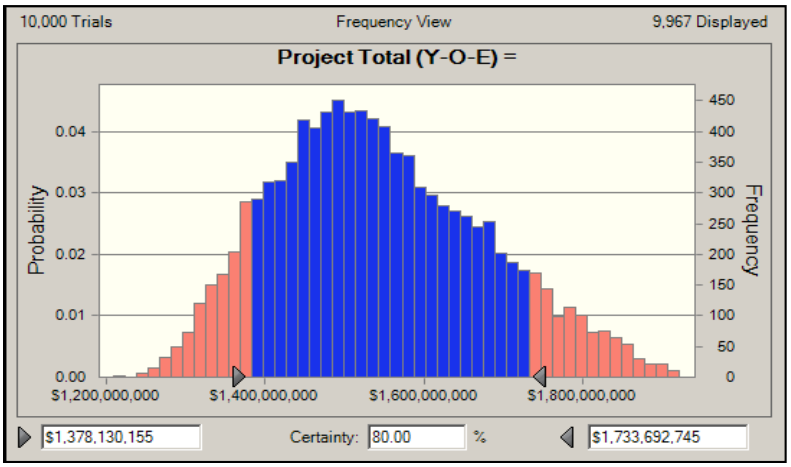


Figure 8
Source: FHWA
Note: Sample Distribution of Year-of-Expenditure Costs, with an 80% Probability Range.

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.

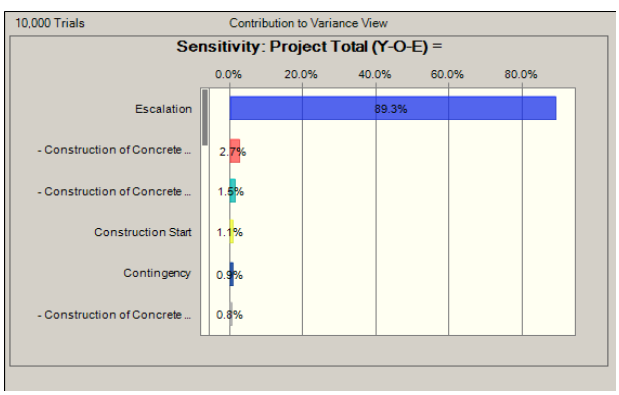


Figure 9
Source: FHWA
Figure 6 - Sensitivity Chart for Year-of-Expenditure Costs

Risk Registry Model (screen capture)

Microsoft Excel - RMDesignTool.xls

File Edit View Insert Format Tools Data Window Help Adobe PDF PDF Create!

A10 Funding Availability

RISK ASSESSMENT & MANAGEMENT WORKSHEET

PIN Z123.45	**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 - IPP completed 06/2007			

RISK FACTOR	COST RISK Severity (High, Med)	COST RISK Probability (L, M, H)	SCHEDULE RISK Severity (High, Med)	SCHEDULE RISK Probability (L, M, H)	QUALITY RISK (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 Flex 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									
Betterment agreement			Med	Med			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
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 OT if nec.	Joe Smith - DJM
Technical Risks									
Bridge type	High	Med				Extra design time for truss is minmal. SHPO is non-commital 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 ot 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

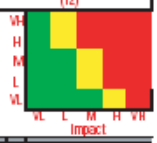
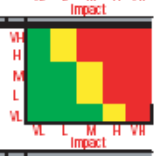
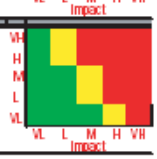
INSTRUCTIONS / POTENTIAL RISKS / IPP / SCOPING / IV (DAD) / V (ADP) / VI (PS&E) / Risk Revisions / LESSONS LEARNED

Figure 10
Source: NYSDOT

Risk Registry Model - Caltrans Example

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

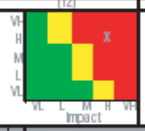
PROJECT RISK MANAGEMENT PLAN

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

EXAMPLE

Caltrans Risk Management Plan Worksheet (Part 2).

PROJECT RISK MANAGEMENT PLAN

Qualitative Analysis				OPTIONAL Quantitative Analysis			Response Strategy			Monitoring and Control		
Type (9)	Probability (10)	Impact (11)	Risk Matrix (12)	Probability (%) (13)	Impact ($ or days) (14)	Effect ($ or days) (15) = (13)x(14)	Strategy (16)	Response Actions Including advantages and disadvantages (17)	Affected WBS Tasks (18)	Responsibility (Task Manager) (19)	Status Interval or Milestone Check (20)	Date, Status and Review Comments (21)
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/hq/projmgmt/guidance.htm.*

Figure 11
Source: FHWA

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.

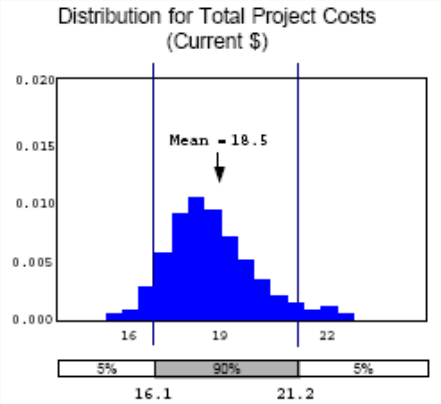


Figure 20. *Range estimate for project costs.*

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 12
Source: FHWA

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

Figure 13
Source: FHWA

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.

Figure 14
Source: FHWA

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			CLOSED	Land acquired
Unexpected utilities discovered on SH 111				Utilities identified; design-builder will move
Right-of-way outside of basic configuration at US 555–SH 111 junction				Small construction right-of-way still pending
Local communities pose objections				Continued concerns with business
Successful public information plan				Design-builder plan is working well
Too many projects in the region for QDOT staff				Key staff could be lost to other projects

Figure 15
Source: FHWA

WSDOT Risk Status Report

I-405 Congestion Relief and Bus Rapid Transit Projects

Revised July 2003

Scenario

Tukwila to Bothell
(Option C)

Project Descriptions:

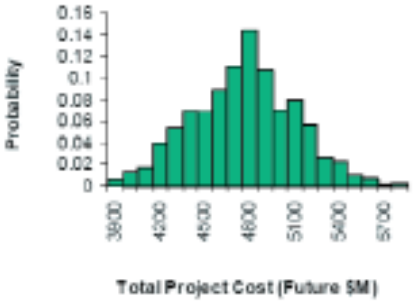
- Continuous multi-modal corridor improvement projects from I-5 in Tukwila to SR 522 in Bothell.
- Adds one lane each direction from I-5 to SR 181 in Tukwila.
- Adds two lanes each direction from SR 181 in Tukwila to I-90 in Bellevue.
- Adds one lane each direction from I-90 in Bellevue to SR 522 in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

Schedule:

Begin Construction
Range: 2006-2007

End Construction
Range: 2013-2014

CEVP Result:



Project Benefits:

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

Project Cost Range:

10% chance the cost < $ 4.2 Billion

50% chance the cost < $ 4.7 Billion

90% chance the cost < $ 5.1 Billion

Project Risks:

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

What's Changed Since 2002:

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

Financial Fine Print (Key Assumptions):

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

Level of Project Design: Low | Medium | High

July 16, 2003

Washington State Department of Transportation

Figure 16
Source: FHWA

Note: The "What's Changed" section also acts as a high-level monitoring report.

APPENDIX E QUANTITATIVE ASSESSMENT

As mentioned in Chapter 3, ***Quantitative risk analysis*** is the process of numerically analyzing the effects of each identified risk on overall project objectives. These 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. The Department's, and FHWA's, de-facto standard tool for performing Monte Carlo simulations is Chrystal Ball.

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 understand and use.

Cost Risk Assessment Diagram

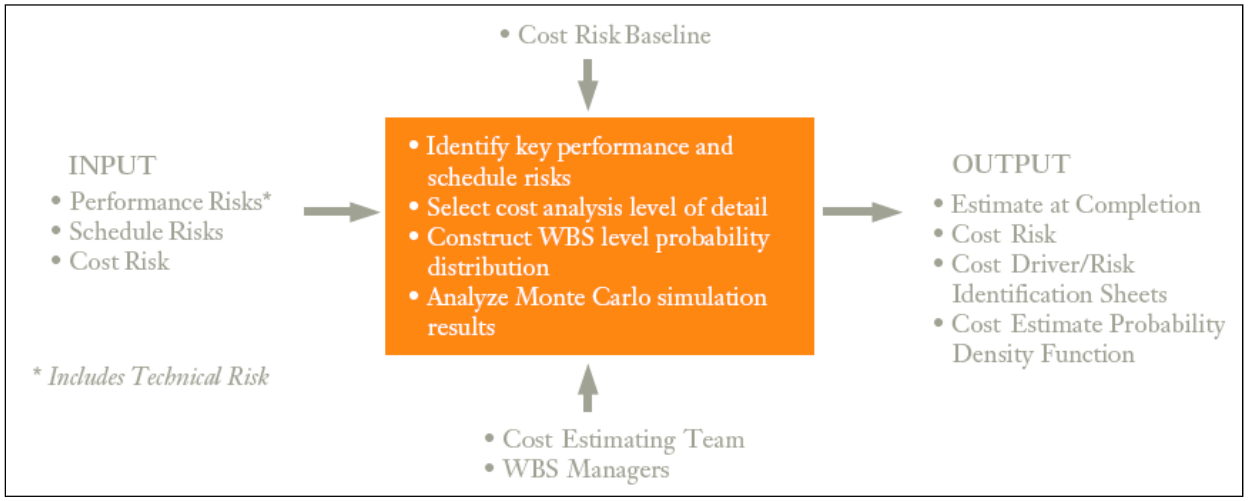


Figure 1
Source: DOE

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?)

Risk Parameter Inputs

Risk Probability Matrix

A probability/impact matrix can be used to associate identified potential risks with their probability and severity levels. Each identified potential risk can be assigned a possible range based on past trends or other references and supporting details. Acceptable tolerance levels can be established to help manage possible risks. The emerging risk position is defined by the acceptable tolerances established for the project. Risk tolerances can be outlined using a matrix which illustrates the desired acceptable risk levels for the project. The position of the risk tolerance line would depend on the project and the degree of acceptable risk (see figure 2). The risk probability matrix is another tool to help analyze and determine possible risk tolerances.

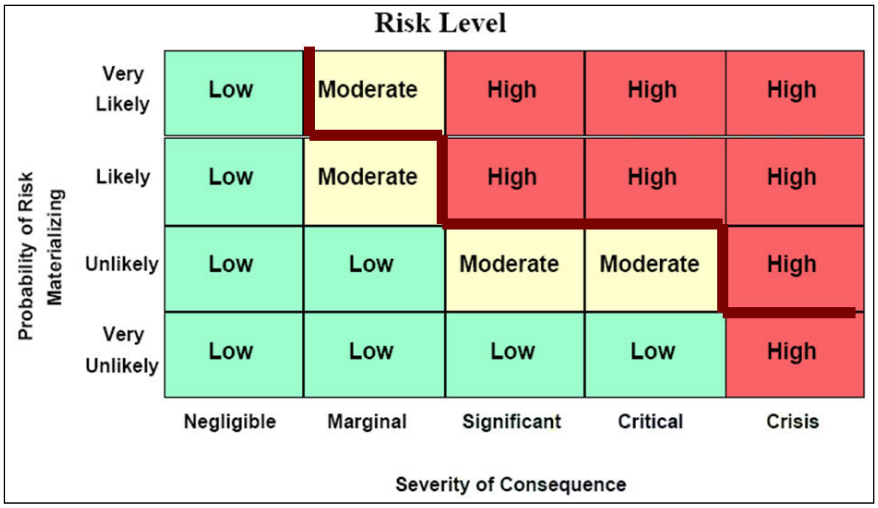


Figure 2
Source: DOE

Risk Analysis Methodology

The intent of this guide is to provide an overview of risk analysis methodologies, not an in-depth explanation or step-by-step procedural account. For an in-depth explanation and step-by-step procedural accounting refer to the specific references listed in the glossary including the Chrystal Ball handbook.

Typically, ***quantitative*** risk analysis requires the development of a risk model (see Appendix E). Once the model is developed, quantitative risk analysis can be performed to the extent necessary to achieve a certain confidence level and degree of certainty based on the data and the parameters around the assumptions made. Scenario analysis can be performed to help further improve the probability and degree of confidence in the analysis. The degree of certainty will depend primarily on the data available, the range of distribution and its statistical significance. Software programs such as Chrystal Ball are used to calculate

Outputs of Quantified Risk Analyses

The type of output various techniques produce is an important consideration when selecting a risk analysis method. Generally speaking, techniques that require greater rigor, demand stricter assumptions and need greater and more refined input data. *Reliable, accurate and relevant data is necessary for performing extensive quantitative analysis with a high degree of certainty*.

Reliable, accurate and relevant data is necessary for performing extensive quantitative analysis with a high degree of certainty.

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 model, assumptions used and distribution or the cumulative distribution is needed (complete distribution measures). *These are advanced techniques*. Finally, when identification and subsequent management of the key risk drivers are the goals of the analysis, the techniques used, such as sensitivity analyses, become very important selection criterion.

Tornado Diagram

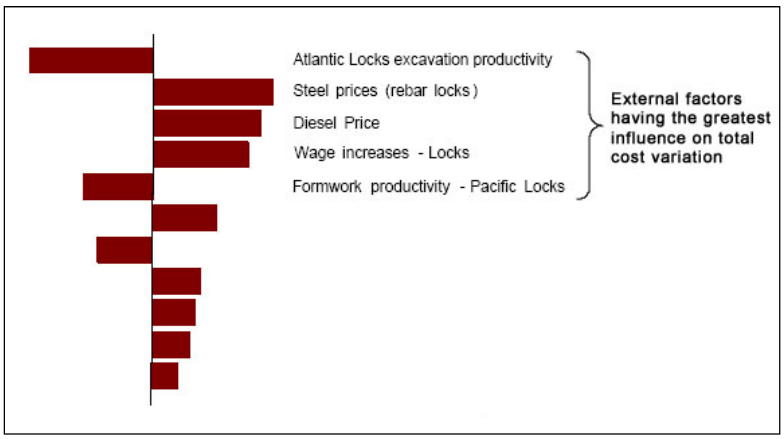


Figure 3
Source: FHWA

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 sections describe some of the more frequently used quantitative risk analysis methods and an explanation of the input requirement and output capabilities. These methods range from simple, empirical methods to computationally complex, statistically based methods.

Traditional Analysis Methods

Traditional methods for risk analysis often focus on empirical procedures that concentrate primarily on developing a range of cost contingencies for projects. Risk factors for various project elements are based on historical knowledge of past trends. For example, pavement material costs may have remained constant over an extended period of time exhibiting a low degree of cost risk, whereas acquisition of rights-of-way may have shown continuous or even erratic increases in cost over time which would indicate a higher degree of cost risk. Project contingencies are determined by multiplying the estimated cost of each element by its respective risk factor.

One of the benefits of this method is its degree of simplicity. Project staff will need to possess an ability and skill to effectively track and analyze data in order for this method to be successful. However, one of the risks in using this methodology is the potential difficulty in being able to accurately project trends to determine future possible cost scenarios. One of the drawbacks from this method is the degree of difficulty in directly associating potential project risk drivers and their possible range, or distribution, of their effects on cost or schedules.

Analytical Methods

Analytical methods, sometimes called second-moment methods, use statistical calculation of probability to determine mean values and standard deviation of outputs and project costs. Analytical methods are relatively easy to understand and apply. They use mean values of the input variables to plug into formulas for calculating standard deviation which then is used to determine projected project costs. This method is most appropriate when the output is a simple sum or is the product of the various input values being analyzed (FHWA). They provide basic capability for estimating cost contingencies, but are not as effective for determining schedules.

Analytical Modeling

Simulation models, also called Monte Carlo methods, are based on computerized, probabilistic calculations using random number generators to draw samples from probability distributions. The objective of the simulation is to determine the effect multiple complex uncertainties of a particular indicator of interest will potentially have on the outcome. More details on Quantitative Analysis are provided in Appendix E.

Qualitative analysis range from simple, empirical methods to computationally complex, statistically based, methods.

Figure 4 illustrates examples of simulation models of probability distributions.

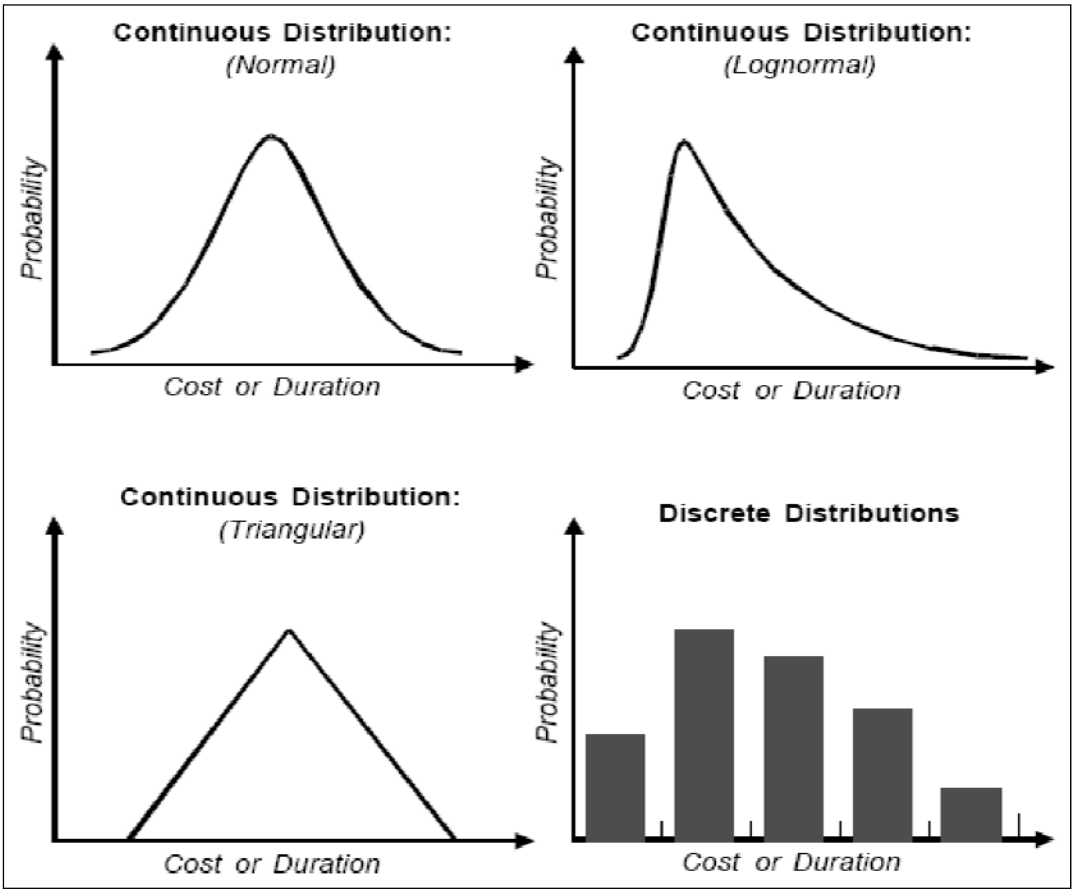


Figure 4
Source: FHWA

The appropriate risk analysis technique to use for a project will depend on the complexity of the project, its context, proposed cost and expected schedule.

If a quantitative risk analysis is deemed necessary, it will require specialized skills and software. Contact Phil Bell in the Office of Design for further information.

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 1, adapted from the Department of Energy's (DOE) *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 5-7.

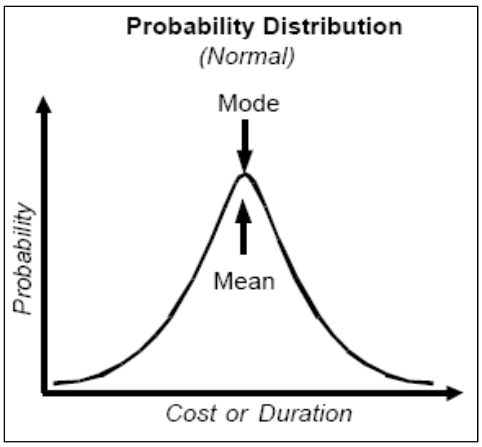


Figure 5
Source: FHWA
Mean and mode in normal and lognormal distributions

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 2.

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.

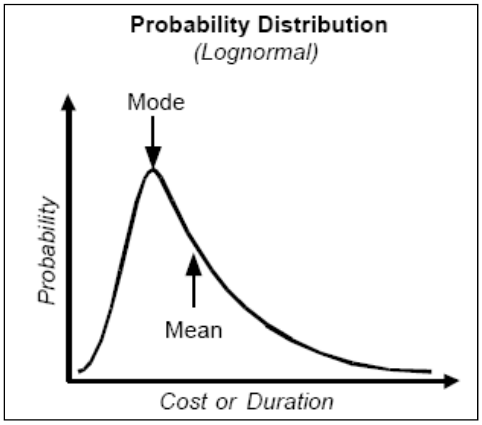


Figure 6
Source: FHWA
Mean and mode in normal and lognormal distributions

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 3.

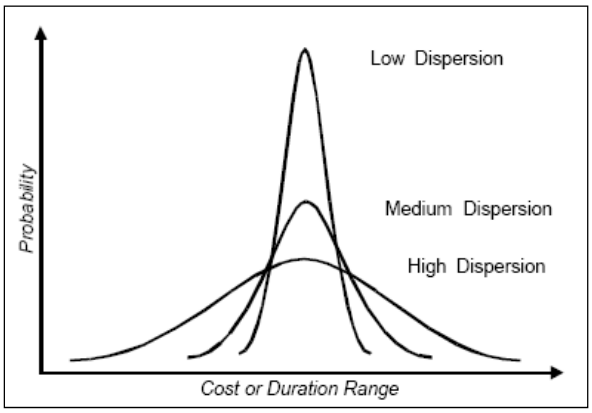


Figure 7
Source: FHWA
Probability distributions for high, medium, and low dispersions

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.

Analytical Modeling

A simulation model, called Monte Carlo methods, is a set of 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 8
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 9
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.

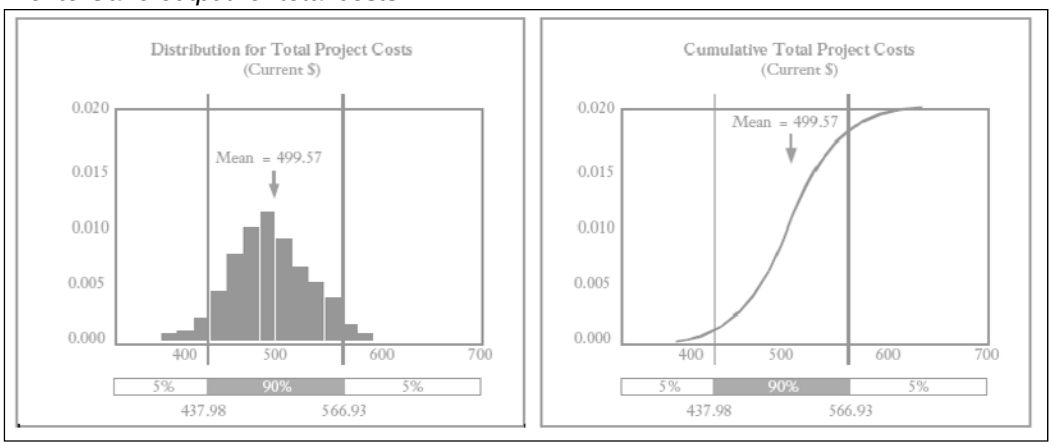


Figure 10
Source: FHWA

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.

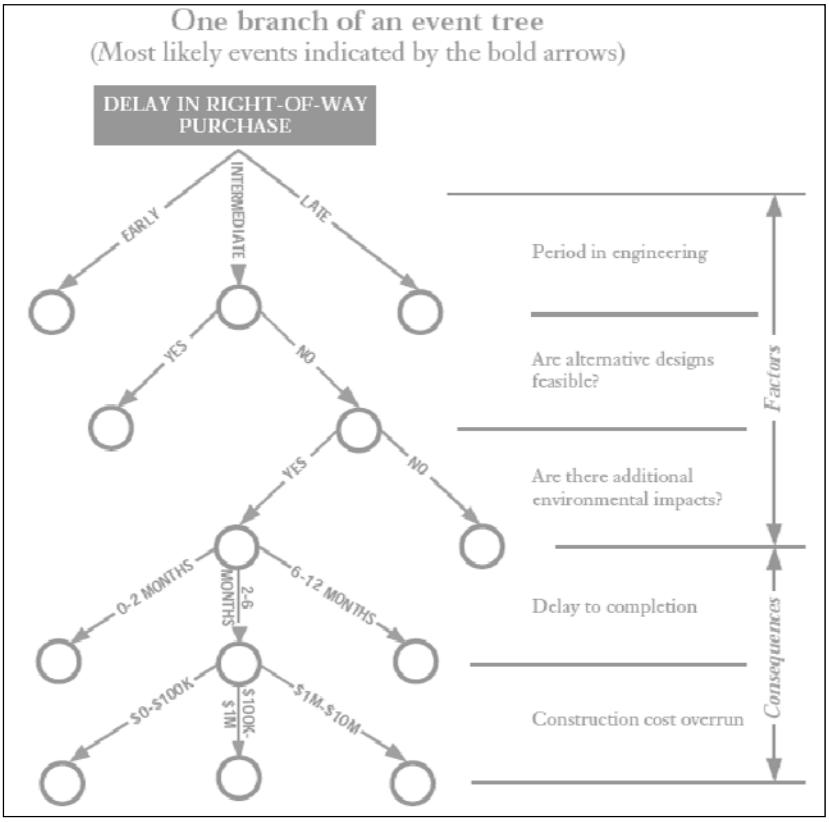


Figure 11
Source: FHWA

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.

Other State Departments of Transportation Project Examples

The following cost risk analysis examples illustrated below are from projects the other State Departments of transportation have prepared. Cost risk analysis a key factor for determining accurate and reliable cost estimates which is an important component of risk management.

FHWA Cost Estimate Quantitative Risk Review

TOTAL PROJECT All Segments	Prior	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
PA&ED	$3,382	$0	$0	$0	$0	$0	$0	$0	$0	$3,382
PS&E	$40,015	$0	$0	$0	$0	$0	$0	$0	$0	$40,015
R/W and UT	$0	$0	$53,765	$0	$0	$27,991	$0	$0	$0	$81,756
R/W Support	$8,112	$0	$0	$0	$0	$0	$0	$0	$0	$8,112
Construction	$0	$0	$0	$114,795	$0	$278,483	$0	$0	$0	$393,278
Construction Support	$39,944	$0	$0	$0	$0	$0	$0	$0	$0	$39,944
TOTAL	$91,453	$0	$53,765	$114,795	$0	$306,474	$0	$0	$0	$566,486,849

Assumption:
Segment 3 Temp K Rail Quantity
Triangular distribution with parameters:

Minimum	24,000
Likeliest	30,000
Maximum	35,000

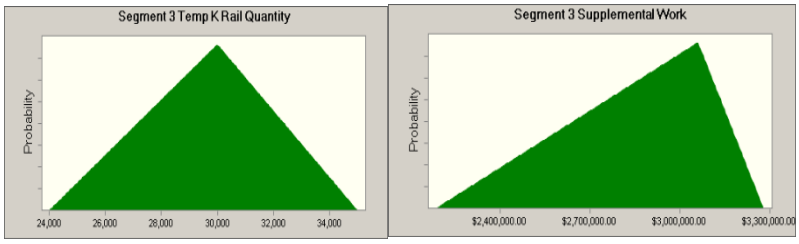


Figure 12
Source: FHWA

The example above is taken from CalTrans I-10 Corridor analysis. The information illustrates Monte Carlo analysis performed using Chrystal Ball. Probability ranges shown are based on the triangular distribution method.

The type of distribution method selected depends on the conditions surrounding the variables. Analysis is performed on each risk factor and the sum total of costs, schedules or other factors are then determined.

Monte Carlo analysis using Chrystal Ball depends on spreadsheet models. A spreadsheet model incorporates combinations of data, variables, formulas and functions. The more accurate and reliable the data will determine the level of ***certainty*** of the model. When the certainty of the data is not absolute, which is often the case, the use of ranges is appropriate.

Certainty levels are based upon the probability of any particular value being used in a risk assessment. The certainty is the percent chance that a particular forecast value will fall within a specified range[6].

[6] Chrystal Ball® User Manual, 2000

Contingency Profiling *(Draft)*

Another analysis and management control technique used to for risks associated with certain activities is the contingency profile. The contingency profile identifies risks associated with various project activities and requirements and assigns potential risk contingency factors.

Assumptions

- Project Contingency is the sum of individual estimates for each category
- Total Project Budget is the sum of estimated Baseline Project Cost plus estimated Contingency Budget.
- Baseline Project Cost is defined as the estimated cost of completing the project on time and within budget.
- Contingency is calculated using Risk Factors that reflect project various unknowns and unanticipated expense.

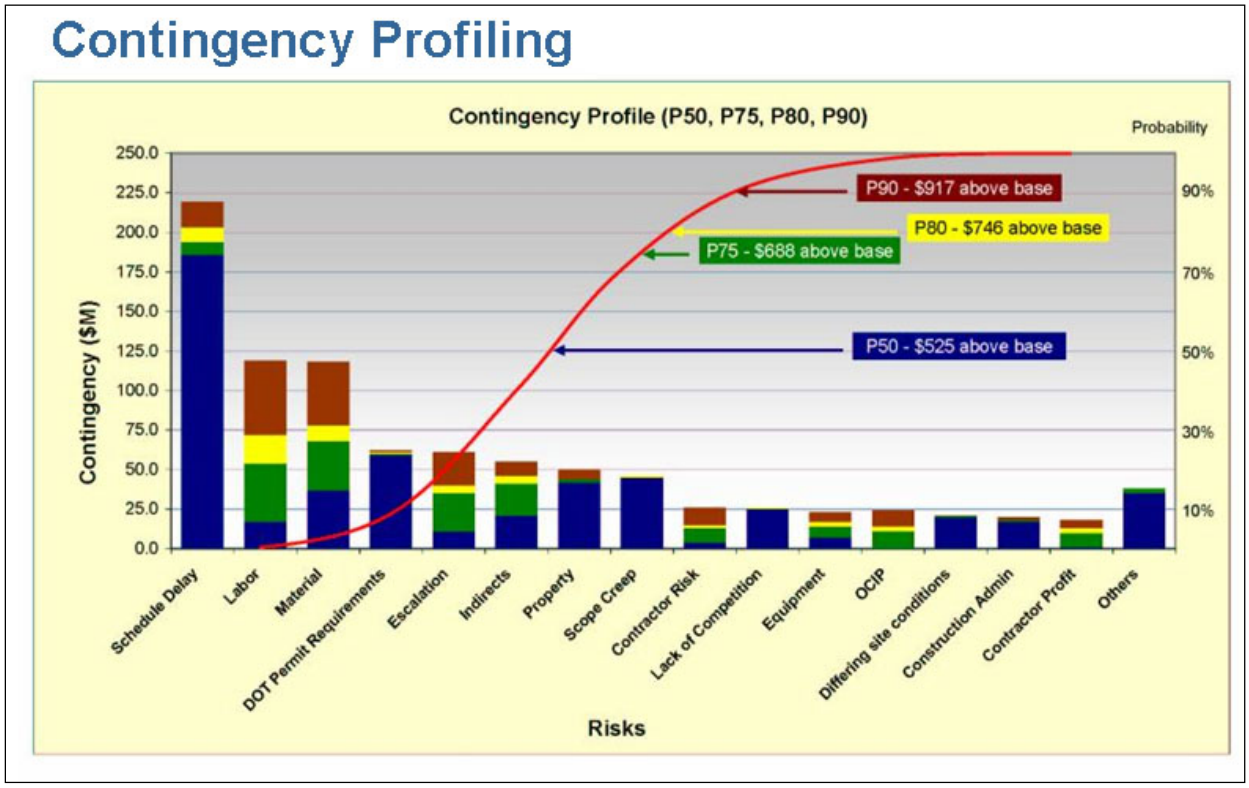


Figure 13
Source: FHWA

NYSDOT Risk Status Report

APPENDIX F COST RISK ANALYSIS

CONTINGENCY FACTORS FOR PROJECT DEVELOPMENT ESTIMATES

Cost escalation of a project from the conceptual stage to the final project acceptance has a severe detrimental effect on the Department's ability to efficiently deliver the capital program. There are several factors that contribute to cost escalation including project complexity, scope changes and scheduling changes.

Proper estimating requires risk management techniques to minimize the effects that risks may have on a project. Risk Management has long been a requirement of our project Management process[7] and the basic steps in any risk management process should be followed when generating estimates throughout project development. Risk Management is the continuing process of planning, qualifying, handling, and controlling future events that may have an impact on the project success. Each time a new estimate is generated throughout project development, the potential risks to the project need to be reevaluated and the risk management strategy should be updated.

Contingency is included in the estimate to account for substantial uncertainties in quantities and unit costs and the possibility of currently unforeseen risk events related to quantities, work elements, or other project requirements. Contingency is recognized as a risk cost[8].

The purpose of this guidance is to establish contingency factor ranges to be considered by the estimator when estimates are developed at IPP, Scoping, Design Phase I to Design Approval and at ADP. The following table includes the suggested ranges:

PROJECT PHASE	CONTINGENCY FACTOR RANGE % of Estimate
IPP	25-40
SCOPING	20-25
Design Phase 1 to Design Approval	15-20
ADP	5-10

These ranges are provided as suggestions. It is important that the estimator be cognizant of the definition of estimate in determining the contingency factor for a particular project. An estimate is the most probable cost for a project, consisting of normal costs, contingencies, and the probable cost of risk events[2]. Thus, an estimator will be justified in using a higher contingency in the estimate if the risk potential to the project can warrant the higher contingency.

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[7] Procedure for Managing Projects, Third Working Draft, pp. 81, 82, September 3, 1991

[8] NCHRP Report 574 Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction, p A-155, A-156, and C-2

Regardless of the phase of project development, the estimator needs to first perform a risk analysis in order to establish the contingency. Estimators need to be familiar with preparing estimates of the project type and complexity and they should draw on experience needed to sufficiently qualify the risks. Understanding project complexity will allow for the determination of appropriate risk and contingency factors. The contingency should not account for items that should be known and detailed at the given project phase. Known miscellaneous items that may reasonably be estimated should not be included in the contingency. The estimator's focus needs to be on arriving at the most probable cost of the project. It is imperative that the estimator recognize the importance of the estimate at the time of its development, appropriately detail the estimate and establish a reasonable contingency commensurate with the risk to the project.

This guidance is not applicable to projects with an estimated total cost of $100M or more (cost in "year of expenditure" dollars). Such projects require an annual Financial Plan and all contingencies should be sufficiently detailed and managed[9].

Estimating Risks:
When preparing initial cost estimates during the NEPA process, all potential risks should be identified, analyzed, and quantified in the estimate. However, if this is not possible, because sufficient information is unavailable, a "worst-case" analysis may be appropriate to estimate costs. Existing facilities thought to be adequate may become inadequate because of changes to standards, new data, further deterioration prior to construction, etc. For example, full reconstruction of existing features, including structures, should be considered, as well as rehabilitation. Consider structure lengths that span entire floodplains and wetlands. It may be appropriate to assume worst-case geotechnical conditions as a basis for design if there is limited information available. A worst-case scenario should only be used after analyzing the project and the available information carefully. Again, if there is considerable unknown information regarding the project, it may be suitable to attach a range to the cost estimate at this stage.

For specific project cost risk information or assistance, contact the Design Quality Assurance Bureau, Office of Design.

Projects From $100 million up to $500 million
SAFETEA-LU required that Projects in this dollar range have Financial Plans and Annual Updates prepared by the Project Owner. It is expected that these projects will be less complex than Major Projects and will be completed in a shorter timeframe. There will often only be one main construction contract associated with this category of projects. The estimated total cost will be based on the full scope of the project for the limits defined by the environmental process or for the limits that are considered operationally independent. The financial plan content should address the same five sections as those for Major Projects (see **Content of the Financial Plan**). It is anticipated that the level of detail will be more straightforward for these plans. Also, optional reporting formats for these projects that present multiple projects within

[9] FHWA, Fed Aid Program Adm., Major Projects Guidance, Financial Plans, Contingency Fund Mgmt. http://www.fhwa.dot.gov/ipd/project_delivery/resources/financial_plans/contingency_fund.aspx

the Project Owners' geographical area will be considered on a case-by-case basis. FHWA will not approve these financial plans but they will be subject to review. As part of its ongoing stewardship and oversight responsibilities, FHWA will need to assure that they were completed in accordance with Title 23 requirements for content and timeliness.

Cost Estimate Review of Financial Plans (as per SAFETEA-LU)

- Threshold Costs include all costs, (preliminary engineering, construction, right-of-way, utilities, construction engineering, etc.)
- Greater than $500 Million - Major Project - Required concurrence from Headquarters prior to Construction or Right-of-Way authorization
- $100 to $500 Million – authorization is required, however review is at each Division's discretion
- Costs to complete estimates must be based on reasonable assumptions as determined by the Secretary (of FHWA).
- Reasonable assumptions are dependent upon Risk Based Analysis and procedures

APPENDIX G REFERENCES

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

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

4. *Project Risk Management Handbook,* California Department of Transportation, Office of Project Management Process Improvement, Sacramento, CA., 2007.

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6. *NCHRP Report 574 Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction,* S. Anderson, K. Molenaar, C. Schexnayder, Transportation Research Board, Washington, D.C. 2007.

7. *Principles and Guidelines for Project Risk Management*, M. Pennock, Y. Haimes, *Systems Engineering,* Center for Risk Management of Engineering Systems, 2001.