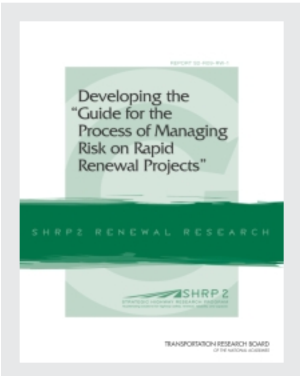

Developing the "Guide for the Process of Managing Risk on Rapid Renewal Projects"

DETAILS

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The Second
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP 2 REPORT S2-R09-RW-1

Developing the "Guide for the Process of Managing Risk on Rapid Renewal Projects"

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TRANSPORTATION RESEARCH BOARD

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Subject Areas

Construction
Highways

The Second Strategic Highway Research Program

America's highway system is critical to meeting the mobility and economic needs of local communities, regions, and the nation. Developments in research and technology—such as advanced materials, communications technology, new data collection technologies, and human factors science—offer a new opportunity to improve the safety and reliability of this important national resource. Breakthrough resolution of significant transportation problems, however, requires concentrated resources over a short time frame. Reflecting this need, the second Strategic Highway Research Program (SHRP 2) has an intense, large-scale focus, integrates multiple fields of research and technology, and is fundamentally different from the broad, mission-oriented, discipline-based research programs that have been the mainstay of the highway research industry for half a century.

The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life,* published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

SHRP 2 was authorized in August 2005 as part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is managed by the Transportation Research Board (TRB) on behalf of the National Research Council (NRC). SHRP 2 is conducted under a memorandum of understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Academy of Sciences, parent organization of TRB and NRC. The program provides for competitive, merit-based selection of research contractors; independent research project oversight; and dissemination of research results.

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Notice

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

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

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

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SHRP 2 STAFF

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The research team consisted of William Roberds and Travis McGrath of Golder Associates Inc. and Keith Molenaar of the University of Colorado at Boulder as co-principal investigators, supported by Michael Loulakis and Ted Ferragut. They thank all those transportation professionals who provided their expertise and time to this research. The team particularly thanks the following state departments of transportation personnel (listed in alphabetical order) for their participation in developing the guide and implementation materials: Brian Blanchard, Florida; Thomas Bohuslav, Texas; Dan D'Angelo, New York State; Steven DeWitt, North Carolina Turnpike Authority; Fred Doehring, Utah; Pat Friesen, Colorado; Mark Gabel, Washington State; Mike Ginnaty, Minnesota; Nabeel Khwaja, Texas; Thomas Pelnik, Virginia; and Ken Solak, California.

FOREWORD

James W. Bryant, Jr., PhD, PE, *SHRP 2 Senior Program Officer, Renewal*

In recent years, risk management has become an area of emphasis for transportation agencies. Project risks must be managed regardless of how they are allocated between the contractor and the transportation agency. Transportation agencies continue to seek a balanced approach to risk allocation because, generally speaking, increased risks to the contractor will be reflected in increased bid prices. The incorrect allocation of risks can also lead to project delays and increased costs.

Agencies are moving toward the use of innovative contracting approaches and accelerated construction techniques to complete projects more rapidly. Although guidance exists and is being developed for managing risks on transportation projects, this guidance has generally not included consideration of the unique features of rapid renewal projects, which are the ones that use accelerated project delivery.

Several state transportation agencies have been exposed to the formal risk management required by the Federal Highway Administration on infrastructure projects that exceed a total estimated cost of $500 million. Few transportation agencies use formalized risk assessment and management programs that are not associated with "major projects."

This report and the associated guide and supporting products provide information and tools that transportation agencies can use to apply risk management principles systematically to their projects. They are specifically useful for projects that are below the $500 million threshold for major projects.

The primary objectives of SHRP 2 Renewal Project R09 were to address the general lack of understanding of risk and risk management options associated with the unique aspects of rapid renewal projects and to develop practical guidance and materials for the application of risk management methods to the rapid renewal project development process in a manner consistent with state transportation agency business practices.

The products developed as part of this project include (1) a comprehensive guide, with checklists and an example application, and (2) associated implementation materials for conducting risk management on nonmajor rapid renewal projects, including a presentation introducing the risk management process and a Microsoft Excel template (with user's guide) for both documenting the process and conducting the necessary analyses.

The report, guide, and training materials provide the state of the practice for risk management on rapid renewal projects, as well as a detailed process of risk identification and mitigation strategies. The materials will be useful to state departments of transportation, municipal agencies, and consultants working on projects that involve accelerated project delivery and will make the risk management process more accessible for use as a standard project solution.

CONTENTS

Executive Summary

This report documents the development of the *Guide for the Process of Managing Risk on Rapid Renewal Projects* (referred to as the guide) and the associated materials needed for successful implementation of that guide (Golder Associates et al. 2014), which are available at http://www.trb.org/Main/Blurbs/168369.aspx.

The guide and materials are intended to help departments of transportation (DOTs) manage risk during the development process for rapid renewal projects, thus optimizing project performance (with respect to cost, schedule, disruption, and longevity). The guide and materials address methods for risk identification, assessment, analysis, and management (both planning and subsequent implementation, and consideration of proactive individual risk reduction, contingency to cover remaining risks collectively, and monitoring–updating). This includes methods for objectively prioritizing risks, evaluating the cost-effectiveness of potential individual risk reduction actions, and estimating project performance. As part of developing the guide and materials, various entities successfully applied the process to two projects and demonstrated it in two training workshops for DOT staff.

These efforts resulted in the following products:

- A comprehensive guide, which includes extensive checklists and a comprehensive example of a rapid renewal project application (for illustration of concepts and for training purposes).
- Associated implementation materials for conducting risk management on relatively simple rapid renewal projects, including (a) annotated Microsoft (MS) PowerPoint training presentations (with practical exercises and discussions) for each section of the guide, (b) a PowerPoint presentation for introducing the risk management process at the beginning of future risk management workshops, (c) forms for documenting the process, and (d) an MS Excel workbook template (with user's guide) for both documenting the process (similar to the forms) and automatically conducting the necessary analyses.

The primary objectives of this study were to address the general lack of understanding of risk and risk management associated with the unique aspects of rapid renewal projects and to develop practical guidance and materials for the application of risk management methods to the process of developing rapid renewal projects in a manner consistent with the business practices of DOTs. Although some guidance exists and more is being developed for managing risks on transportation projects, that guidance has generally not included consideration of the unique features of rapid renewal projects. Renewal Project R09 was designed to fill the definitive need for guidance and materials for managing risks on rapid renewal projects.

The guide and materials will enable DOTs to facilitate risk workshops for relatively simple rapid renewal projects (as well as other design and construction projects) and thus develop and subsequently implement comprehensive risk management plans to improve project performance.

The research team anticipates that through the implementation of the principles and practices described in the guide, DOTs can develop a culture of risk management and more successfully complete rapid renewal projects, as well as non–rapid renewal projects (to which the guide and materials also apply).

To develop the guide and materials, the research team performed the following technical tasks:

- Task 1: Identify gaps in the current processes available for managing risks on rapid renewal projects and develop an appropriate plan to fill them.
- Task 2: In accordance with the approved plan, fill the gaps in current processes available for managing risks on rapid renewal projects and develop a draft guide and implementation materials for managing risks on rapid renewal projects.
- Task 3: Apply the draft guide and materials to at least two rapid renewal projects and conduct at least two training workshops.
- Task 4: Finalize the guide and materials on the basis of workshop feedback.

CHAPTER 1

Background

Problem Statement from Request for Proposal

The overall goal of the SHRP 2 Renewal program is to develop a consistent, systematic approach to performing highway renewal that works rapidly, minimizes disruption, and produces long-lived facilities. The scope of renewal applies to all classes of roads.

As such, the focus of SHRP 2 rapid renewal research is to develop a systematic approach to renewing the aging highway infrastructure through rapid design and construction methods that cause minimal disruption and produce long-lived facilities. Fulfilling the objectives of rapid renewal requires the use of innovative contracting processes and a departure from "business as usual." Many of these innovative techniques involve shifts in the burden of risk from the state to the contractor. Renewal Project R09 addresses the general lack of understanding of risk and risk-transfer decisions associated with some contracting approaches.

Different contracting approaches, such as design–build–operate–maintain–transfer (D–B–O–M–T), build–operate–transfer, warranties, design–bid–build, and design–build, generate different levels of risk for all parties involved. No standardized systematic process exists to quantify the risks for the parties involved (e.g., the transfer of risk from DOT to the contractor). Objective guidance on the level and management of risk is needed to ensure industry acceptance of the concept and to assist states and industry in assessing the level of risk associated with various contracting approaches.

This research project is based on the work recorded in the Federal Highway Administration (FHWA) document *Guide to Risk Assessment and Allocation for Highway Construction Management* (*Risk Guide*) (Molenaar et al. 2006). The *Risk Guide* notes that few U.S. state departments of transportation (DOTs) use formalized risk assessment and management programs, although awareness is growing. For those DOTs that have adopted formal risk-based programs, the benefits have been substantial and multifaceted. However, risks can be magnified in rapid renewal projects, which involve accelerated environmental–permitting processes and construction methods in conjunction with innovative contracting methods (possibly including project financing). DOTs are even less experienced with rapid-renewal types of risks and how they can be evaluated and effectively managed. However, the stakes can be quite large and can include significant project delays and budget overruns, as well as significant disruption during construction and poor longevity.

Project R09 developed a guide for implementing processes for risk management on rapid renewal projects. The *Guide for the Process of Managing Risk on Rapid Renewal Projects* (the guide) is intended for use by transportation agencies to manage risk during the process of project development (Golder Associates et al. 2014). The guide illustrates methods that can be used to identify, assess, analyze, mitigate, allocate, and monitor risk. It includes methods to determine the economic consequences of risk transfer to the various parties involved in a project.

Background

Cost and schedule overruns, especially relative to initial estimates, are relatively common on DOT projects and often lead to many other issues (e.g., those related to funding, politics). Poor estimates can lead to poor choices among project alternatives. Overruns generally result from underestimates (e.g., in quantities or in unit costs), problems (e.g., change in scope, permit delays, errors), or both when they were not adequately taken into account in either project plans or estimates, either specifically or collectively through contingency. Such underestimates and incomplete consideration of problems could be either intentional (e.g., project advocacy) or unintentional (e.g., optimism, errors, ignorance).

For most problems, the cost and schedule effects are often a function of when they occur or when they are discovered. In many cases, if they are discovered early in a project, the cost or schedule impact is smaller than if discovered late because they are generally easier to fix earlier in the project (e.g., through avoidance). Most problems are highly uncertain beforehand; if they were certain, they should have already been incorporated into the project plans and the associated cost and schedule estimates. For potential (rather than certain) problems, once they are recognized as a possibility, the question becomes what to do about them beforehand: (1) fix them immediately, typically at some cost, often incompletely, and perhaps unnecessarily, because they might not occur if left alone; or (2) do not fix them and take a chance that they will not occur with associated cost and schedule impacts. Of course, for potential problems that have not been recognized, DOTs are unaware that they may occur and cause cost and schedule impacts. If they do occur, one or more parties generally own the problem and are responsible for the cost and schedule impacts. The contractor is responsible for some problems and will have included the cost of those problems in the price; the owner is responsible for the remainder of the problems. In contracting, to preclude legal battles, decisions should be made beforehand about who owns various problems.

Contingency has traditionally been used to account for all potential unfixed problems collectively (through recognition that some potential problems will occur and some will not), more so for problems related to cost and than for those related to schedule, primarily on the bases of experience and judgment. However, such empirically based contingency has generally been inadequate, as evidenced by frequent overruns.

Formal risk assessment and risk management can be used to deal more effectively with such potential problems by

- Identifying and evaluating potential problems (risks) as early as possible in project development (i.e., the diagnosis);
- Identifying, evaluating, selecting, and ultimately implementing ways to deal with those risks, eventually including their allocation, focusing on the more significant risks (i.e., the treatment); and
- Evaluating the remaining risks (on the bases of the diagnosis and the treatment) to determine the appropriate contingency for each party (i.e., the prognosis).

The FHWA *Risk Guide* briefly summarizes risk assessment and risk management with respect to cost and schedule. Under a previous contract, the authors of this R09 report developed tools and a training course to apply those risk guidelines to relatively simple traditional projects; that work included successful testing on several actual projects (Golder Associates 2008).

Fundamentally, risk management has two major objectives:

- To understand uncertainty in project performance, including cost, schedule, safety, environmental impacts, and level of service (traffic). Understanding project performance uncertainty enables more effective project decisions, such as establishment of funding levels and decisions among project alternatives.
- To optimize project performance through cost-effective management of potential problems and opportunities (risks)—for example, through design, choice of construction methods, contract provisions, and the like. Optimizing project performance increases the likelihood of desirable outcomes, such as meeting an established budget and schedule and minimizing the likelihood of undesirable outcomes.

At present, most DOTs do not have formal risk assessment and risk management programs, although FHWA has mandated that risk be analyzed on all major projects (i.e., those costing more than $500 million) (FHWA 2007). However, several state risk programs may be cited here. The Washington State Department of Transportation (WSDOT) has established a policy that risk be analyzed on all projects costing more than $100 million (WSDOT 2005). The Florida Department of Transportation (FDOT) has also recently established a risk assessment policy requiring qualitative risk assessment along with value engineering for all projects costing less than $100 million, quantitative risk assessment by internal resources for projects from $100 million to $500 million, and quantitative risk assessment by external resources for projects over $500 million. Other state DOTs (including California, Colorado, Iowa, Kentucky, Nevada, North Carolina, Pennsylvania, Texas, Utah, Virginia, and Wisconsin) have successfully applied risk assessment and management on various projects.

Nonetheless, risk management to date has generally considered only project cost and schedule; the FHWA *Risk Guide* and implementation materials are one example of this approach. Rapid renewal projects and their risks are generally even less understood than traditional DOT projects because they are typically innovative (meaning, in general, that DOTs have less experience with them) and complex. Rapid renewal projects can also have extremely large potential cost and schedule impacts in some cases, like innovative project delivery of megaprojects; and practitioners need to consider both disruption and longevity in addition to cost and schedule.

Thus, additional guidance (including tools and training) is needed to manage risk to improve performance of rapid renewal projects, as well as traditional projects.

Research Objectives

The primary objectives of this study were (a) to address the general lack of understanding of risk and risk-transfer decisions associated with the differing contracting approaches that can be used for rapid renewal, and (b) to develop practical guidance for the application of risk management methods to the project development process in a manner consistent with the business practices of transportation agencies.

Research Approach

The chosen research approach was developed by leveraging team members' theoretical knowledge and practical expertise in implementing formal project risk management on a large number of infrastructure projects. The approach provided a synergy of theoretical principles, practical tools for implementation, and guidance for using the results in project risk decision making. The key features of the proposed approach for developing and conducting this research are described below.

The research team reviewed the FHWA *Risk Guide* and other relevant documents (especially those related to the unique characteristics of rapid renewal projects) to determine where gaps exist in those guidelines in applying them to rapid renewal projects. The researchers then planned how to fill those gaps. They conducted research—based on a literature review, surveys of FHWA and DOT staff, and theoretical analysis—to identify the unique risks associated with rapid renewal projects and possible ways to mitigate them. The team then developed a significantly expanded and enhanced *Guide for the Process of Managing Risk on Rapid Renewal Projects* and related practical materials that DOTs can apply. Development included testing the guide and implementation materials with two DOTs that had rapid renewal projects.

The team synthesized a set of work tasks that supported the overall research approach. To accomplish the study objectives efficiently, the research team used ongoing research and development work on risk assessment and risk management (including work by team members) and applied it to rapid renewal. The team defined and conducted the following research tasks, which are discussed in more detail in Chapter 2:

- Task 1: Develop a work plan. First the team evaluated gaps in current risk assessment practice and guidelines with respect to rapid renewal projects. On the basis of those gaps, the team developed a plan to fill the gaps and develop a complete guide for rapid renewal projects.
- Task 2: Develop a draft guide and related implementation materials. Using the gaps identified in Task 1, the team conducted research on several parallel paths, including an additional literature review, interviews with DOT personnel experienced with rapid renewal projects, and internal team brainstorming on potential problems associated with various aspects of rapid renewal projects. The team then consolidated the results from these various research paths to develop a substantial checklist of rapid renewal risks and potential mitigation strategies. From this research, the team developed the draft guide and associated implementation materials in preparation for the pilot workshops.
- Task 3: Conduct pilot workshops. The draft guide and associated implementation materials were applied to actual rapid renewal projects. The team conducted training workshops with multiple transportation agencies.
- Task 4: Finalize the guide and related implementation materials. Using information gathered during the two pilot workshops and related feedback, the team finalized the guide and related implementation materials (including an MS Excel template to model rapid renewal risks and report mean-value results). The final guide and materials were submitted on February 15, 2011.
- Task 5: Manage the study. This task included coordination among research team members and the project officer, as well as completing required status reports.

CHAPTER 2

Findings and Applications

Overview

Many transportation projects experience budget and schedule overruns and other types of undesirable performance issues (e.g., excessive disruption of traffic, short life span), which often result in other unfavorable outcomes (e.g., public dissatisfaction, funding difficulties). These performance issues typically result from the occurrence of unexpected problems—risks; yet it is possible for some risks to be anticipated, managed, and effectively mitigated.

Through literature search, interviews, and personal experience, the R09 research team found that few state DOTs have formal risk management programs to anticipate and proactively manage risks. The team also found no comprehensive inventories (checklists) of rapid renewal elements, risks associated with those elements, or actions for reducing those risks.

This chapter describes the research approach introduced in Chapter 1 and details the methodology. This chapter also explains the findings of the research and how those findings were developed into the *Guide for the Process of Managing Risk on Rapid Renewal Projects* (the guide) and associated implementation materials. The research comprised five tasks. Each task is described in the subsections that follow.

- Task 1: Develop a work plan.
- Task 2: Develop a draft guide and related implementation materials.
- Task 3: Conduct pilot workshops.
- Task 4: Finalize the guide and related implementation materials.
- Task 5: Manage the study.

Task 1: Develop a Work Plan

The first task was to develop an initial detailed work plan for the entire project consistent with the proposal. On the basis of this initial plan (submitted January 13, 2008, and approved with revisions June 4, 2008), sufficient research was conducted to determine where significant gaps exist in the current risk guidelines and associated implementation materials with respect to application to rapid renewal projects. This research included a literature review, interviews with select DOTs, drawing on research team experience, and review of other related research projects. The gaps were documented and a more-detailed plan developed to fill the gaps for rapid renewal projects. The Task 1 report, with input from the Technical Expert Task Group and staff, was finalized on January 14, 2009. The Task 1 report is unpublished, but its various subtasks are described in more detail below.

Subtask 1.1: Conduct Team Kick-Off Meeting

At project initiation, the team conducted an internal project kick-off meeting. The primary objectives were to (a) clarify project scope and approach, as well as establish communication methods and expectations; (b) share information; and (c) coordinate related activities of the team members. The primary outcome of this meeting was a preliminary detailed work plan.

Subtask 1.2: Review the FHWA *Risk Guide* and Other Background Documents

After the kick-off meeting, all team members reviewed the FHWA *Risk Guide* and considered other ongoing developments in their evolution. The team also reviewed other documents that address various innovative contracting methods and specifications (e.g., *NCHRP Report 451: Guidelines for Warranty, Multi-Parameter, and Best Value Contracting*) and cost estimating (e.g., *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*) (Anderson and Russell 2001; Anderson et al. 2006). This review inventoried and examined the distinct variables of the available construction and contracting methods (e.g., insurance, finance, and safety).

The team also reviewed the reports of the Accelerated Construction Technology Transfer program, which is discussed further in the subsection below, Review of Accelerated Construction Technology Transfer Program. Ultimately this preliminary literature review was used to identify potential problems (risks) with various elements and possible ways to mitigate them (lessons learned)—the topic of Task 2. The content of these documents is briefly summarized in an annotated bibliography included in Appendix A.

Furthermore, the team proposed to survey and interview FHWA and DOTs about their experience with risks in rapid renewal activities and their interest in being involved in this study; these topics are discussed further in the subsection below, Agency Surveys and Interviews. Similarly, team members' experience with rapid renewal projects is summarized in the subsection below, Summary of Industry Experience, and in Appendix C (see also Table C.9).

Literature Review

The research team reviewed available literature to identify information on risks related to rapid renewal projects. The search included TRB resources, academic engineering databases, academic business databases, American Society of Civil Engineers (ASCE) and Project Management Institute (PMI) publications, and selected transportation agency websites. The resulting annotated bibliography of that literature search appears in Appendix A and is largely taken from the results of NCHRP Project 8-60 (Molenaar et al. 2010) on the same subject, which was conducted by R09 research team member Keith Molenaar concurrently with this research project.

Review of Accelerated Construction Technology Transfer Program

The methodology for developing the inventory of rapid renewal strategies and methods included a review of 25 case studies from the Accelerated Construction Technology Transfer (ACTT) program; these cases represent the state of the art in rapid renewal construction. The area of rapid renewal has been evolving in the highway industry for more than 10 years. FHWA and American Association of State Highway and Transportation Officials (AASHTO) have been at the forefront of the effort through their work on the ACTT program. In 1996, TRB released Special Report 249, which called for formation of a strategic forum to accelerate innovation in the highway industry. In response, the TRB Task Force A5T60 (now AFH35T) was formed in 1999 to facilitate removal of barriers to innovation, advocate continuous quality improvement and positive change, encourage development of strategies that generate beneficial change, and create a framework for informed consideration of innovation (FHWA 2004). In 2002, the task force conducted the first two pilots of ACTT; since then FHWA and AASHTO have carried forward the effort as managers of the ACTT program.

Although *construction* is in the ACTT title, the program addresses all phases of project delivery. As the FHWA described in its interim report on the ACTT program, "the goals of the program include minimizing the impact of ongoing highway construction on motorists and adjacent communities by streamlining project schedules and containing costs while enhancing safety and improving quality." Under the ACTT program a corridor or project is selected because of its need for accelerated delivery; each one is reviewed in a 2-day workshop by experts from local, state, and federal agencies and private industries with a variety of skill sets relating to project acceleration. The multidisciplinary team of 20 to 30 transportation experts works with local transportation agency professionals to evaluate all aspects of the project. Workshop participants present feasible recommendations for reducing roadway construction time, enhancing safety, and delivering quality. The whole ACTT process is ultimately aimed at enabling agencies to save time and money while reducing construction-related congestion and improving work zone safety (FHWA 2004).

The findings of these project reviews were documented in project reports, annual reports, training materials, and additional records (available on the ACTT website at http://www.fhwa.dot.gov/construction/accelerated/). The costs of projects examined ranged from $1 million to $3.5 billion. A rigorous review of these reports by the R09 research team yielded a significant number of case studies that were later used to develop a preliminary inventory of rapid renewal methods, as well as some common recommendations for accelerating the projects. The ACTT project analysis and resulting recommendations were organized by skill sets that offered a logical framework for the inventory of rapid renewal methods. The skill sets were the following:

- Innovative contracting and financing;
- Roadway geometric design;
- Structures;
- Traffic engineering, safety, and intelligent transportation systems (ITS);
- Environment;
- Construction;
- Coordination of rights-of-way (ROWs), utilities, and railroads;
- Geotechnical aspects, materials, and accelerated testing;
- Long-life pavements and maintenance; and
- Public relations.

Figure 2.1 summarizes the skill sets that were applied to the 25 ACTT projects. The construction skill set was represented in all 25 ACTT workshops, which was not surprising given

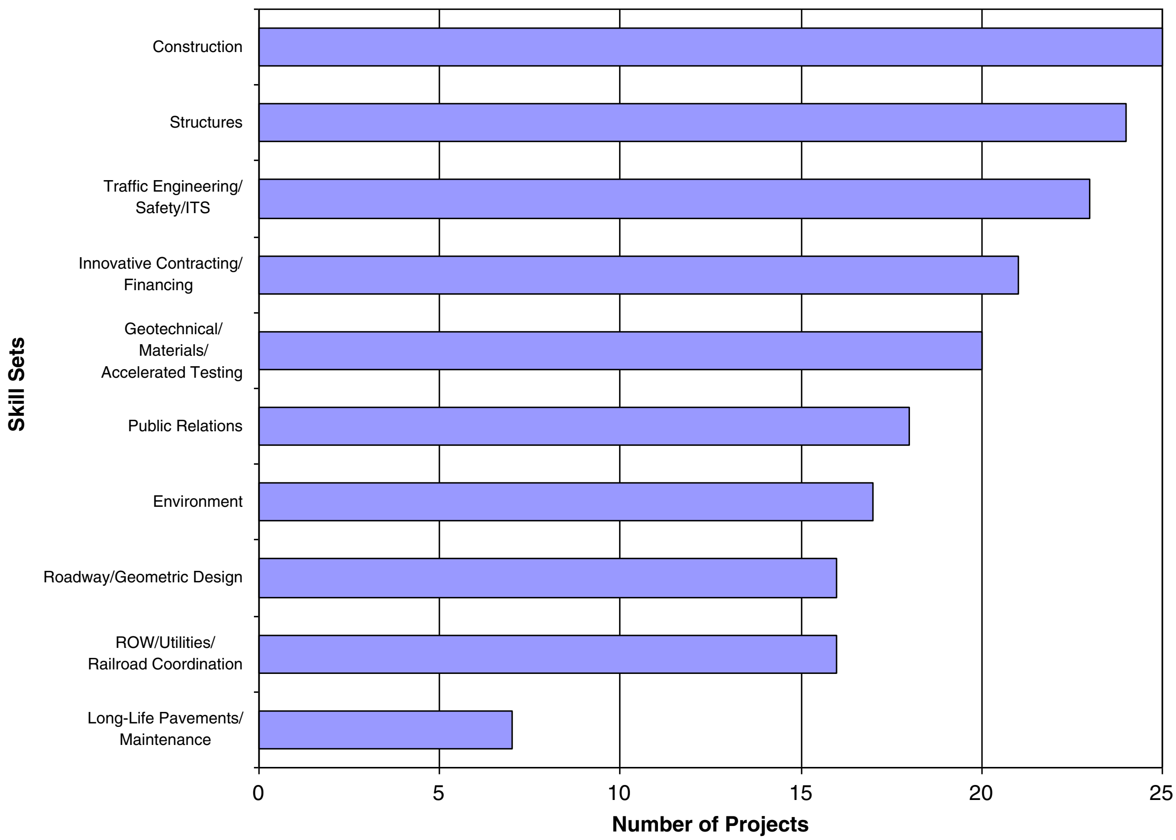

Figure 2.1. Summary of skill sets used in 25 ACTT projects.

that rapid renewal projects generally involve construction under traffic. Other skill sets—structures; traffic engineering, safety, and intelligent transportation systems; innovative contracting and financing; and geotechnical aspects, materials, and accelerated testing—were all represented in more than 80% of the workshops. These areas could also be considered a primary focus of rapid renewal projects as they promote the "get in, get out, stay out" philosophy of rapid renewal projects. The long-life pavements and maintenance skill set was represented in less than one-third of the projects. While long-life pavements and ongoing maintenance are considerations in the rapid renewal approach, they did not seem to be as urgent as the other issues being addressed.

Agency Surveys and Interviews

An important part of the R09 research in both Task 1 and Task 2 was to obtain relevant information from state DOTs. The R09 research team analyzed two surveys to complete the gap analysis. The first was a recent state-of-practice survey of various state DOTs on their risk management and cost estimation programs, which was conducted under a separate contract. The second survey analysis was conducted by team members under the SHRP 2 R09 contract, which followed up with DOT respondents of the previous state-of-practice survey. The second survey inquired about respondents' experience specifically with rapid renewal projects and the associated risks of those projects.

State-of-Practice Survey

Members of the R09 research team were simultaneously but separately working under a research contract with TRB's National Cooperative Highway Research Program (NCHRP). Under this separate contract—NCHRP 08-60, Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs—team members developed a state-of-practice survey to identify how different transportation agencies and organizations determine contingencies and manage risk-related costs throughout the process of project development (hereafter referred to as the state-of-practice survey). The survey received responses from 48 of the 52 DOTs (50 states, District of Columbia, and Puerto Rico), four Canadian agencies, and more than 130 individuals. Key results from this survey (those relating to risk management for rapid renewal projects) were as follows:

- Only one in five agencies had a formal, published definition of *contingency* that was used consistently throughout the

estimating process. Given the importance of contingency in managing budgets, this low proportion is unexpected, as is the fact that schedule contingency is generally even less defined.
- Only one in 10 agencies had a formal, published project risk management policy or procedure. As risk management is an emerging (rather than established) trend in the highway sector, this low proportion is perhaps less unexpected than the result of the previous item.

Risk Management Practices and Application of Contingency

Risk is inherent in every capital transportation project. One definition of *risk* is "the possibility that something unpleasant or unwelcome will happen." In this study, *risk* is defined as "an uncertain event or condition that, if it occurs, has a negative or positive effect on a project's objectives" (Project Management Institute 2008). Risk management, then, involves several specific steps: risk identification, assessment, analysis (qualitative or quantitative), planning, allocation, monitoring, and control.

While risk is inherent in every capital transportation project, the state-of-practice survey found that only three of the 48 state agencies had a formal, published project risk management policy or procedures. California, Florida, and Washington had formal risk management procedures (Utah was in the process of establishing such procedures). In those three states, it was clear how the risk analysis related to controlling cost escalation. Representatives from the three state agencies that had formal management procedures were interviewed and case studies were written in *NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs* (Molenaar et al. 2010). In the other states, the manner in which the agencies set their project and program contingency did recognize and incorporate risks into project estimates but not in a formalized risk management procedure. Appendix C includes short profiles of how 10 states set contingency and analyze risk in projects.

Contingency is a future event that is possible but cannot be predicted with certainty. In project estimates, contingency is the tool that estimators and project managers use to address risk and uncertainty. In this study, *contingency* is defined as the "estimate of costs associated with identified uncertainties and risks, the sum of which is added to the base estimate to complete the project cost estimate. Contingency [funds are] expected to be expended during the project development and construction process" (Anderson et al. 2009).

The transportation industry generally agrees that contingency is necessary but disagrees significantly about which risk-associated costs should be included in a contingency amount and how that amount should be calculated. The results of the state-of-practice survey showed that only one in six (8 of the 48) responding agencies had a formal, published definition of contingency. Without that formal definition, agencies will have difficulty in consistently calculating appropriate contingency amounts or communicating the elements that constitute contingency in an estimate.

Setting Contingency

The lack of a formal definition does not imply that agencies disregard contingencies in their estimates. Approximately four of five agencies responding to the state-of-practice survey stated that they apply contingency in at least one phase of the project development process. Agencies set contingency through use of three primary methods: (1) a standard predetermined contingency by percentage, (2) a unique project contingency set by individual estimators, and (3) formal risk analysis and associated contingency.

The first method uses a standard predetermined contingency by percentage across all projects. Sixteen of the 48 reporting state agencies employed some form of this method on their projects. Even when an agency applies a standard contingency, it can make exceptions for various reasons, including phase in the project development process, project type, project complexity, market conditions, geographic region, and estimated project value.

The second method has a unique project contingency that the engineers, estimators, or project managers set. The majority of agencies responding to the survey stated that they used this method. When a unique project contingency is applied, many tools are used to determine the contingency, including engineering judgment, statistical analysis of historical data, correlation of historical data with current market prices, and assignment of contingency for specifically identified risks.

The third method uses formal risk analysis and its associated contingency. The survey responses from agencies in California, Maryland, and Washington indicated that they use a combination of formal risk analysis and unique project contingency. Furthermore, the FHWA response stated that it uses formal risk analysis. The research team knew of other agencies using formal risk analysis to set contingencies on a project-by-project basis (e.g., Colorado, Florida, Minnesota, New York, and Texas), but the survey respondents did not enumerate that use in their answers. Tools for determining contingency through risk analysis include use of expected values through statistical analysis of historical data for assigning cost to risks, use of expected values through engineering judgment for assigning cost to risks, Monte Carlo or simulation methods, influence diagramming, and probability or decision trees. This third method, formal risk analysis, was a primary focus of this research and is explored in detail in the guide.

CONTINGENCY AT PROJECT LEVEL OR PROGRAM LEVEL

State agencies can apply contingency at an individual project level or a program level. Applying contingency at a project level determines a contingency amount for an individual project cost estimate on a project-by-project basis. Applying contingency at a program level spreads contingency across projects (e.g., as set-aside amounts in a state transportation improvement program). Depending on the phase of project development, state agencies can choose to apply contingency at one or both of these levels.

Over half of state agencies in the state-of-practice survey apply contingency at a project level for all three development phases. Only one state agency applied it at solely a program level, regardless of developmental phase. Just less than one in five agencies used a combination of project and program contingencies (19% at the planning phase and the programming and preliminary design phase and 16% at the final design phase). The remaining responding agencies do not apply contingency in their estimates (26% at the planning phase, 21% at the programming and preliminary design phase, and 21% at the final design phase).

Range Estimates Versus Point Estimates

One method of communicating estimates is as a single number (a point estimate). Point estimates can include a stated contingency to help convey uncertainty. Another method of conveying estimate uncertainty is through a range estimate, which may include simple best-case and worst-case points or may be shown graphically with a probability curve (probability mass function). Depending on the project phase, one method might be considered more appropriate than the other. Table C.3 in Appendix C summarizes the use of ranges by agencies to communicate estimates.

The state-of-practice survey that was developed under the NCHRP 08-60 research project provided valuable information for the R09 research team. It clearly demonstrated the need for guidance on risk management and estimation of contingencies. It highlighted common tools currently being used by agencies. When mapped against the literature review, the survey also revealed tools for risk analysis and risk management that are absent from the transportation sector. Finally, the survey pointed to the best agencies to interview in the next phase of the R09 research. For a more-detailed description of the state-of-practice survey, see Appendix C.

Follow-Up Survey

To narrow the focus of the research to rapid renewal projects, the R09 research team developed a focused, follow-up survey to the recent state-of-practice survey. It was developed for state DOTs to specifically address rapid renewal risks (hereafter referred to as the rapid renewal survey). This draft survey was developed to be as short and focused as possible to encourage participation. The survey was later revised and streamlined. The actual rapid renewal survey was conducted as part of Task 2 and is further discussed in the Task 2 subsection titled Research.

AASHTO Subcommittee on Construction Annual Meeting

On the recommendation of the SHRP 2 R09 program officer, a member of the research team attended the AASHTO Subcommittee on Construction (SOC) annual meeting in San Antonio, Texas, in August 2008 to discuss AASHTO's assistance in conducting the rapid renewal survey. The SOC publishes the guide specifications for construction and coordinates the practices of the several member DOTs regarding construction procedures. It hosts a forum to exchange information on construction procedures and endeavors to reduce construction cost, promote quality in construction, provide coordinated plans and specifications, mitigate traffic impacts, advocate environmental sensitivity in construction, promote safety for workers and travelers, and promote the best practices for administering construction contracts with all stakeholders (AASHTO 2013). The SOC annual meeting brought together representatives from the 52 member departments of SOC to discuss the committee's mission and agenda; 178 people were in attendance. (The SOC annual meeting website is located at http://construction.transportation.org/?siteid=58&pageid=732).

To assist the R09 research team in developing the rapid renewal survey, the vice-chairman posed the following two questions relating to rapid renewal risks during a general question-and-answer session of the SOC conference:

1. Does your organization have an established policy regarding rapid renewal?
2. Does your organization have established procedures for risk management?

None of the DOTs that responded had an established policy related to rapid renewal. Despite that initial negative response, subsequent discussions found that a number of states had innovative contracting groups or leaders within their agencies that address accelerating construction and conducting construction under traffic. The Utah DOT used construction manager at risk, design–build, accelerated bridge construction, and other innovative methods; and it had policies covering the circumstances under which the use of innovative project delivery is appropriate (e.g., to accelerate projects through rapid renewal techniques). California used design sequencing, A + B bidding, and lane rental. Washington used extensive design–build project delivery. Finally, Florida used all the alternative contracting approaches already mentioned, plus public-private partnerships. It also used advanced techniques with respect to accelerating construction through innovative contracting methods.

The second question regarding established risk management procedures confirmed the state-of-practice survey conducted under NCHRP 08-60 by members of the research team. Only California, Washington, and Florida confirmed having formal risk management procedures. Utah stated that it had risk procedures regarding the selection of insurance but not relating to risk management for scope, cost, and schedule. The Utah DOT is currently in the process of establishing a risk management program (most likely modeled on the Washington program).

Subsequent discussions with SOC members also identified a current report relating to the subject of rapid renewal: *Primer on Contracting for the Twenty-first Century* (AASHTO 2006). This report covers much of what was being addressed in the research team's proposed survey. As a result, it was determined that the survey could be further streamlined. The research team later reviewed this report for rapid renewal techniques and related risks.

Interviews

During the SOC session, volunteers were solicited for interviews. Representatives from the DOTs of California, Florida, Utah, and Washington were identified as candidates for interviews or case studies on the basis of their policies and procedures on risk management and their use of innovative contracting methods relating to rapid renewal. Several of these DOTs subsequently attended pilot workshops in Task 3.

Only Utah could provide a brief interview during the conference. The director of construction and materials at the Utah DOT was interviewed. Utah has an aggressive program for accelerating construction and using rapid renewal concepts. The state is actively using construction manager at risk, design–build, accelerated bridge construction, and other innovative methods. The director had not attended any risk analysis workshops, but he said that the state had conducted these workshops in the past. Utah does have stated policies for when to use innovative project delivery. A primary factor in deciding when to use innovative delivery relates to accelerating projects through rapid renewal techniques.

Conclusions

The AASHTO SOC 2008 annual meeting assisted the team in completing Task 1 of the research and identifying state highway agencies for Task 3 workshops. The AASHTO SOC was helpful in keeping the research team current with the state of the practice in rapid renewal techniques and risk management practices. However, on discussing the research topic in the general question-and-answer session at the conference and further discussing the topics informally with conference attendees, the research team concluded that an additional follow-up survey would not yield significantly new results. In summary, a review of existing SOC documents, the current state-of-practice survey, and the team's rich database of risks from previous analyses provided the information required for completion of Task 1.

Summary of Industry Experience

Several R09 research team members have extensive experience in conducting risk assessment and risk management for projects with rapid renewal elements (see the Appendix C section Summary of Industry Experience and Table C.9 for a summary of the rapid renewal projects in which R09 team members have been involved). Several members of the team worked with state DOTs including Florida, Iowa, Utah, and Washington on previous risk assessments. The team drew on this experience to identify categories of rapid renewal risks, as well as potential risk-mitigation strategies.

Review of Existing Risk Management Guidelines

As discussed in Chapter 1, the *Guide to Risk Assessment and Allocation for Highway Construction Management* (*Risk Guide*) developed in 2006 by FHWA provides only an overview and is not a how-to document (Molenaar et al. 2006). Thus, training materials and tools for implementing the *Risk Guide* were developed (Golder Associates 2008); these tools and materials were successfully applied in late 2007 and early 2008 to projects for four state highway agencies: Colorado, Florida, Texas, and Virginia. The development of implementation materials involved significant expansion of various parts of the *Risk Guide,* although actual revision of the *Risk Guide* was not included. The implementation materials can be viewed as products developed to support the implementation of the original FHWA guidelines.

The newly developed implementation materials deal with cost and schedule risks associated with completing a highway construction project through traditional delivery methods (such as design–bid–build, with one construction contract package), although they can apply to various ways of completing a project (e.g., accelerated construction methods). However, rapid renewal projects should consider more than just cost and schedule risks associated with completing a highway construction project (e.g., risks of disruption and durability consequences) and can involve nontraditional methods of project delivery (e.g., design–build), as well as accelerated construction methods. Moreover, less experience and understanding—and often more risk—are generally associated with some of the accelerated and nontraditional methods being considered. If agencies fail to evaluate these methods appropriately, the consequences might be poor decisions and poor project results. Thus, team members assessed the applicability of the *Risk Guide* and related materials to rapid renewal projects and recommended ways to expand them (see Tables C.10 and C.11 in Appendix C).

Subtask 1.3: Identify Additional Material Needed (Gaps)

On review of the guidelines and related information, the project team identified additional elements needed to develop the *Guide for the Process of Managing Risk on Rapid Renewal Projects.* The team found that generally the necessary tools and methods already existed. However, a database of significant risks and feasible risk mitigation for accelerated construction and innovative contracting methods and specifications did not yet exist, especially for some of the newer methods.

Recommended expansions and revisions of the FHWA *Risk Guide* for both traditional and rapid renewal projects are summarized in Appendix C, Table C.10. In essence, for traditional projects, the *Risk Guide* first needs to be updated to reflect the expansion associated with development of the implementation materials. Such updates include the following:

- Add a new chapter on baselining the project (identifying and documenting key assumptions, scope, delivery strategy, and baseline costs; developing the flow chart and baseline schedule). This would be the new Chapter 2.
- Add a new chapter on implementation (how to implement the guidance in the new Chapters 2, 3, 4, and 6). This chapter would reference the training workshop slides and the risk-management spreadsheet template. This would be the new Chapter 9.
- Modify/update the existing Chapters 1–8 as needed based on work done for the short-course development. These would be the renumbered Chapters 1, Chapters 3–8, and Chapter 10.
- Modify/update the existing Appendices A–D, glossary, and references/bibliography as needed based on work done for the short-course development. This would include adding case studies and a more complete generic risk checklist.
- Include the training workshop PowerPoint slides (printed with Notes pages) as the new Appendix E to the *Risk Guide.*
- Include the risk-management spreadsheet template as an electronic attachment (Appendix F).

Once the *Risk Guide* has been updated to cover traditional projects, the unique aspects of rapid renewal (especially expanded project performance objectives and different project delivery methods) would be covered primarily in a new Appendix G.

Similarly, the currently recommended changes to the associated implementation materials are summarized in Appendix C, Table C.11. In essence, for traditional projects, no changes are needed. For rapid renewal projects, the unique aspects of such an application (especially expanded project performance objectives and different project delivery methods) would be covered in a new Module 8 and by modifications to the software training module.

Subtask 1.4: Develop Report and Plan (with Input from State DOTs)

The research and discussions with various experts made clear that the scope and objectives of rapid renewal projects had to be more broadly but more carefully defined for the R09 project. The research scope included accelerated construction, planning, and maintenance methods, as well as accelerated project delivery methods (e.g., design–build and public-private partnerships). Furthermore, the project needed to address additional project performance objectives, including minimal disruption (during construction) and maximum longevity (considering cost and disruption of operations, replacement, and design life), as well as minimal planning–construction cost and schedule.

The team found that the necessary tools and methods for managing risk on accelerated projects already existed, although the ones needed for evaluating rapid renewal projects were not adequately described in the FHWA *Risk Guide.* The team also found that a database of significant risks and feasible risk mitigation for rapid renewal projects was the item most in need of development. In consultation with various DOTs that expressed interest in Subtask 1.2 (review of the guidelines and other background documents), the team developed a detailed plan for filling the gaps.

Once the needed developments had been identified, the project team prepared a draft report that (a) documented the review of the guidelines, other documents about accelerated construction and innovative contracting methods and specifications, and the survey of agencies; (b) identified gaps in the guidelines that needed to be filled to cover rapid renewal projects adequately; and (c) presented a plan for filling those gaps and thus developing a complete guide for rapid renewal projects. Specific recommendations for expanding the existing guidelines and implementation materials appear in Appendix C, Table C.10.

On the basis of the gap analysis, the team determined that a new, more-detailed guide for risk management—specifically addressing the unique features of rapid renewal projects (as well as traditional projects)—was required. Also needed were new tools and training materials for state DOTs to use internally, without external assistance, on relatively simple projects. The development of the guide and associated materials are discussed further in the next section.

Task 2: Develop a Draft Guide and Implementation Materials

After SHRP 2 approved the detailed work plan, the focus shifted to Task 2: developing the guide and accompanying implementation materials. To understand the risks (i.e., potential problems, potential opportunities, or both) of rapid renewal, the research team first developed an inventory of rapid renewal strategies and methods. That inventory informed the risk management process with the aspects unique to rapid renewal projects and their associated risks—in contrast to projects that follow the more traditional linear project development process and methods. The intent was to further expand on the FHWA *Risk Guide* and related implementation materials to cover the unique aspects of rapid renewal projects. The research team addressed these rapid renewal features:

- Considering additional project performance measures in evaluating a project (e.g., disruption and longevity, as well as construction cost and schedule);
- Considering the various potential project delivery methods (e.g., design–build, contractor-financed), as well as accelerated construction methods; and
- Understanding the risks typically associated with the various potential project acceleration methods (e.g., accelerated bridge construction, accelerated permitting) and how they might best be managed.

Task 2 consisted of two basic subtasks:

- Subtask 2.1: Research (on several parallel paths) to identify the various unique aspects of rapid renewal projects, the risks associated with those aspects, and feasible ways to manage those risks, considering the various project performance objectives (e.g., minimum schedule, minimum capital cost, minimum disruption, and maximum longevity).
- Subtask 2.2: Development of the draft guide and associated implementation materials that incorporate the above research.

Research was completed and submitted to SHRP 2 on September 1, 2009. The draft guide and associated implementation materials were completed and submitted to SHRP 2 on October 29, 2009.

Subtask 2.1: Research

The key elements of this research included the following:

- Establishing appropriate rapid renewal project performance objectives and related measures;
- Developing inventories of rapid renewal methods, risks, and feasible management actions;
- Establishing an appropriate risk management process;
- Developing a template for documenting assessments (also forms) and automatically calculating performance measures, consistent with that process; and
- Developing the guide, training materials, and other workshop materials.

The main effort of Task 2 involved the development of a checklist of risks (or categories of risks) and associated risk mitigation for rapid renewal projects, in particular, innovative contract methods and specifications.

In general, methods and tools for identifying and assessing risks, as well as for identifying and evaluating risk mitigation, already exist. But the specific nature of the risks associated with rapid renewal projects and how they are handled tends to be unique and less understood—or at least less well communicated within DOTs and the contracting community. This, in turn, required a thorough understanding of the contractual relationships in rapid renewal projects and of the specifications appropriate to those relationships. Both experience with such contracting methods (which is generally limited) and with theoretical analysis (especially for newer methods) were required to identify risks and, even more so, risk mitigation.

The first steps in this process were to define the various performance measures to be considered and to identify the various potential project delivery methods and project acceleration methods that might be proposed for any given project. The next logical steps were to identify the risks that might be associated with each of the potential project acceleration methods, and how they should be assessed; and to identify possible ways to manage those risks, and how they should be managed.

This research to identify the risks and their mitigation involved the following three parallel approaches:

1. An additional literature review to supplement the one conducted under Subtask 1.2, including further development of an annotated bibliography focused on identification of risks and risk mitigation for rapid renewal projects. The analysis of the 25 ACTT project reports conducted in Subtask 1.2 yielded some common findings across the recommendations for accelerating the project. Although it might be argued that not all of these recommendations are unique

to rapid renewal (e.g., brand the project, consider owner-controlled insurance programs) or that some are actually risk management methods (e.g., require a pavement warranty), the research team synthesized these recommendations into a preliminary rapid renewal inventory.
2. A theoretical approach based on the expert judgment of team members used brainstorming to identify all the potential problems that could conceivably arise with each innovative contracting method. Then team members identified feasible ways to mitigate each of those problems using their judgment; this included identification of the factors that affect the severity of risk and the cost-effectiveness of risk mitigation. The theoretical approach involved an intensive 2-day workshop during which the team members identified contractual relationships and their effect on risk.
3. Interviews with DOT personnel helped refine the list of potential problems and mitigation approaches (see Appendix D) to validate the problem list and ensure identification of any additional mitigation approaches. (The interviews are discussed further in the next subsection, Interviews with DOT Personnel.)

The results of these three approaches was a list of risks (or categories of risks) related to each dimension of rapid renewal and innovative contracting methods with feasible risk mitigation, as well as factors that affect risk severity and risk mitigation cost-effectiveness.

An inventory of rapid renewal strategies and methods, as well as lists that present more-detailed descriptions of the recommendations, appear in the *Guide for the Process of Managing Risk on Rapid Renewal Projects* (http://www.trb.org/Main/Blurbs/168369.aspx). Table 2.1 provides an overview of the rapid renewal inventory; the guide provides more-detailed tables of rapid renewal dimensions, methods, risks, and mitigations.

Interviews with DOT Personnel

Additional surveys were conducted to support the development of inventories of rapid renewal methods, risks, and feasible management actions. A draft survey for DOTs was developed under Task 1 and revised under Task 2 to more efficiently solicit information from DOTs on rapid renewal methods and their risks and possible mitigation (see questionnaire in Appendix D, Figures D.1 and D.2). The team completed interviews with five DOT personnel. The interviews solicited details on accelerated construction projects from the Utah DOT, Center for Transportation Research at the University of Texas at Austin, Texas DOT, California Department of Transportation (Caltrans), and Colorado DOT (see Appendix A for agency contact information). Interviewees explained some of the main risks faced during rapid renewal projects and the risk management actions that their agencies employed. Table 2.2 presents the risk categories and risk management actions named; a summary of the interviews is also available in Appendix D.

Subtask 2.2: Development of Draft Guide

Once the general risks, risk mitigations, and their contributing factors were identified, the process of developing the final guide began. The team generated an outline for the guide and then proceeded to develop an annotated outline for the guide and associated implementation materials. (The investigators found this to be an important step in the research process.)

Development of a new, more-detailed guide and related implementation materials to appropriately fill the needs identified in the gap analysis included development of the following major components:

- Risk management process;
- Rapid-renewal project performance objectives;
- Rapid renewal methods, risks, and mitigation inventories;
- Risk management planning methods, tools, and guidance; and
- Risk management program guidance.

Risk Management Process

The research team developed a formal risk management process to improve understanding of rapid renewal projects and to optimize project performance, especially by anticipating and planning for potential problems (risks). This process, which is a significant expansion of a previously developed risk management process for non–rapid renewal projects (and for which the expanded process is also applicable), consists of a well-defined series of steps that are sequential and in some cases iterative (see Figure 2.2). Agencies must follow the steps in such a way to ensure compatibility and consistency of those steps and to ultimately ensure adequate accuracy and defensibility of results (“adequacy” depends on how the results will be used), as efficiently as possible.

The steps in the risk management process include the following:

1. *Structuring.* Define the base project scenario (including the relevant project performance measures of cost, schedule, and disruption through construction, postconstruction longevity, and trade-offs among them), against which risk and opportunity can subsequently be identified, assessed, and eventually managed.
2. *Risk identification.* Identify a comprehensive and non-overlapping set of risks and opportunities relative to the

Table 2.1. Rapid Renewal Inventory Overview

Construction	Structures	Traffic Engineering/ Safety/ITS	Innovative Contracting/ Financing	Geotechnical Materials/ Accelerated Testing	Public Relations	Environment	Roadway/ Geometric Design	Right-of-Way/ Utilities/ Railroad Coordination	Long-Life Pavements/ Maintenance
• Closures • Preliminary work/staging • Project administration streamlining • Construction operations	• Prefabrication • Component reuse • High-performance materials • Integral designs • Standardized design • Construction placement • Temporary structures • Long-life structural design	• Advance planning • Alternate routes • Alternate modes • Improved physical separation • Coordinated emergency response • Signage and signalization • Closures • Work zones	• Alternative financing • Project delivery • Procurement • Contract payment • Warranties • Alternative insurance • Advance contract packaging • Bonding/ performance securities	• Subsurface exploration • Walls • Pavements • Alternative materials • Intelligent compaction • Material testing	• Team integration • Single-point communication • Additional investment • Project branding • Stakeholder awareness • Performance measurement	• Master planning • Context-sensitive solutions • Comprehensive scoping • Advance permitting	• Alternate access • Alternate geometrics • Advance roadwork	• Advance right-of-way planning • Early utility location • Common utility crossings • Early railroad coordination	• Life-cycle design • Performance indicators • Long-life materials • Maintenance involvement

Note: ITS = intelligent transportation system.

Table 2.2. Risk Categories and Risk Management Actions

Risk Categories	Risk Management Actions
Potential failure of innovative equipment	Innovative delivery methods (design–build, CMR)
Coordination with utilities/stakeholders	Facilitated partnering sessions with utility partners
Accelerated bridge design	Use of performance specification for bridge design
Off-site prefabrication of bridge elements	Lane rental provisions
Delayed-start contract provisions to prepare for in-traffic work before starting	Incentives/disincentives
Coordination risk of maintenance of traffic and utilities	Extensive public outreach
Public relations	Hiring a general engineering consultant to coordinate contracts
Management of traffic	Focus on maintenance of traffic and utilities
Failure of innovative pavement materials	Incentives/disincentives at contract coordination points
Agency unfamiliarity with the process	Early and continuous stakeholder interaction and communication
ROW acquisition issues	Extensive mix design research and off-site testing
	Agency training
	Augmentation of ROW staff

base (i.e., scenarios that might occur to change the base project performance). In addition to first brainstorming and then performing project analysis to identify risks, use checklists of common risks (developed as part of this research) to ensure completeness. Document the set of risks and opportunities at the start of the project in a risk register (a record in which all project risks, including information such as risk probability, impact, and countermeasures, are listed).

3. *Risk assessment.* Assess and prioritize each of the risks and opportunities in the risk register on the basis of severity. Generally this requires (a) subjectively assessing the relevant risk factors (i.e., the probability of a scenario occurring and the impact if the scenario occurs), either qualitatively (e.g., high versus low, when these descriptors are quantitatively defined by ranges of values) or quantitatively (in relation to mean values or, for quantitative risk analysis, full probability distributions); and then (b) analytically combining the risk factors to determine changes in project performance measures and thus severity. Document the risk factor assessments in the project risk register.
4. *Risk analysis.* Assess and analytically combine the uncertain base and risk factors to determine the uncertain project performance measures (e.g., ultimate escalated project cost), as well as changes in those measures (e.g., combined using trade-offs, as a measure of severity) associated with each risk. The quantification of the uncertainty in the performance measures is expressed as correlated probability distributions and calculated as a function of subjectively assessed uncertainties in (and correlations among) the base and risk factors. To conduct this quantification appropriately requires that the analyst have specialized skills.
5. *Risk management planning.* Identify and evaluate possible ways to reduce risks proactively, focusing on those that are most severe. Evaluate each possible action in relation to its cost-effectiveness, considering changes in both base (e.g., additional cost) and risk (e.g., reduced probability) factors, and select those that are most cost-effective. Consider subsequently reanalyzing the project performance measures for this risk reduction program, including quantification of uncertainty, on the basis of which appropriate budgets and milestones can be established (e.g., to achieve a specified level of confidence). As part of these budgets and milestones, establish contingencies (additional funds and schedule float, as well as recovery plans) and procedures to control their use. Document all in the risk management plan.
6. *Risk management implementation.* Implement the risk management plan as the project proceeds, including (a) monitoring the status of risk reduction activities and changes in risk (whether from risk reduction or simply changes in project development, conditions, and information) and (b) monitoring budget and milestones, especially with respect to contingencies. This monitoring might involve periodic updates (iterate Steps 1 to 5) at regular intervals or at major milestones or changes. For example, contingencies

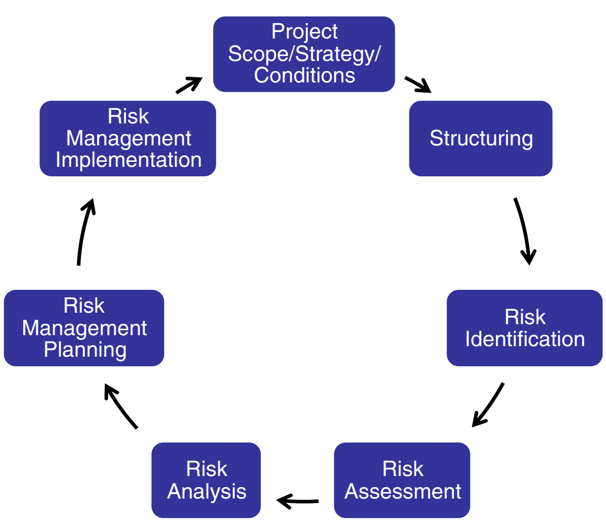

Figure 2.2. Risk management process.

might be reduced as engineering reports or designs are completed and risks are avoided or reduced.

Rapid Renewal Project Performance Objectives

As previously discussed, the performance objectives for rapid renewal projects had to be expanded beyond simply minimizing construction costs and schedule. The expanded objectives were to (1) minimize cost, time, and disruption of traffic (user costs) during construction; and (2) maximize longevity (i.e., minimize costs and disruption of traffic associated with operations and maintenance, as well as with ultimate replacement or decommissioning; and maximize the time from the end of construction to replacement or decommissioning).

Metrics, or performance measures, were defined by the research team for each of the objectives, as well as for the combination of objectives, as follows:

- *Time through construction* is expressed as the project operations date, which requires an analysis of the schedule through construction.
- *Cost through construction* is expressed as the total inflated [year-of-expenditure (YOE)] construction cost, which requires a construction cost–loaded schedule (i.e., uninflated construction cost estimate, schedule, and allocation of cost items to schedule items) and inflation rates.
- *Disruption through construction* is expressed as total equivalent lost person-hours, which requires a traffic disruption analysis (i.e., duration of disruption, average number of users affected, and average delay per user) and a business disruption analysis (if needed, for example, because it is not mitigated or translated to equivalent lost person-hours).
- *Longevity* is expressed as total equivalent postconstruction (i.e., operations and replacement) discounted cost [or net present value (NPV), to the end of construction], which requires uninflated cost for operations (i.e., schedule for operations and average cost per year) and for replacement, disruption during operations (i.e., schedule for operations and average number of days disruption per year) and during replacement, value of disruption (as of the end of construction), and net discount rate after construction.
- *Combined project performance* is expressed as equivalent total inflated cost [in year-of-expenditure dollars (YOE$)], which requires inclusion of these elements:
    - Cost through construction (in YOE$);
    - Time through construction (date) and the value of changing the operations date (in YOE$/month) from a specified milestone (date);
    - Disruption through construction (equivalent lost person-hours) and the average value of lost person-hours (in YOE$/h); and
    - Longevity [net present value dollars (NPV$) at the end of construction] and the value of changing longevity (in YOE$/NPV$).

Combined project performance appropriately merges all the various project performance objectives (on the basis of formal methods of decision analysis). Thus, changes in combined project performance can be used to define the severity of the various risks; on the basis of the relative severities, risks should be prioritized for managing and for gaining the benefits of such management.

Rapid Renewal Methods, Risks, and Mitigation Inventories

Comprehensive inventories of rapid renewal methods, risks associated with those methods, and potential ways to proactively reduce each of those risks were developed by the research team.

1. A comprehensive hierarchy of rapid renewal methods was developed by reviewing FHWA ACTT workshop reports (including those for 25 workshops and other information such as training materials) and by interviewing knowledgeable DOT personnel, supplemented by personal experience of the research team (see Appendix C and Appendix D).
2. A comprehensive set of risk categories for each rapid renewal method was developed, primarily on the basis of the personal experience of the research team and supplemented by interviewing knowledgeable DOT personnel (see Appendix D). The full risk checklists are available in Appendix B of the guide (Golder Associates et al. 2014).
3. A comprehensive set of management actions for each risk category for each rapid renewal method was developed, primarily on the basis of the personal experience of the research team and supplemented by interviewing knowledgeable DOT personnel. See Appendix B of the guide for the full list of rapid renewal risk categories and potential management actions.

In evaluating a project, these inventories should be used after brainstorming to help ensure that the risk register and the risk management plan have considered all conceivable options and potential problems.

Risk Management Planning Methods, Tools, and Guidance

In addition to rapid renewal performance objectives and inventories, successful and efficient implementation of the risk management process required development of various methods and tools, as well as guidance for their use.

For successful project structuring the research team developed the following:

- A comprehensive but efficient format or outline for adequately describing the relevant aspects of the subject project.
- Standard simplified project flowcharts that graphically depict the sequence of major project phases, specifically for relatively simple traditional (design–bid–build) and nontraditional (e.g., design–build) project delivery. See Figure 2.3 for nontraditional project delivery; the project flowchart for a traditional project is similar but more simple.
- A generic project performance model to calculate (e.g., using an MS Excel template) the various project performance measures (such as project schedule, escalated project cost and project disruption through construction, and postconstruction longevity, as well as a combined performance measure), as a function of various inputs (e.g., cost, schedule, disruption factors, and trade-offs), which must be assessed separately for each project consistent with the relevant simplified project flowchart. The base (exclusive of risk) project performance is determined by implementing the model with base input values; the mean (probability-weighted average) project performance is determined approximately by implementing the model with mean input values.
- Methods, tools (e.g., forms and an MS Excel template specifically for relatively simple rapid renewal projects), and guidance for assessing mean base inputs for a project.

For successful risk identification, in addition to developing a risk checklist, the team developed methods, tools (e.g., forms and an MS Excel template specifically for relatively simple rapid renewal projects), and guidance for identifying a comprehensive and nonoverlapping set of project risks (including opportunities relative to the base scenario). The team also categorized risks by the project phase during which they are most likely to occur and developed the structure of an appropriate project risk register.

For successful risk assessment, the team discussed available methods and tools for assessing the severity of identified risks. The team developed methods, tools (e.g., an MS Excel template), and guidance for calculating mean unmitigated (before additional risk management) project performance and its sensitivity (risk severity), using the same generic project performance model as discussed above but considering all the identified risks and their severity, as well as the base. The team also developed methods, tools (e.g., forms and an MS Excel template), and guidance for assessing mean risk inputs (either values or ratings) for a project.

For successful risk analysis, the team discussed available methods and tools, and developed guidance for conducting appropriate probabilistic performance and sensitivity analysis, including assessment of probability distributions for (and correlations among) base and risk inputs for a project. This project focused on a qualitative assessment of risk; there are tools available for quantitative risk assessments. Special methods and tools required for this risk analysis were previously developed by the authors outside this research project.

For successful risk management planning, the researchers developed the following:

- Methods, tools (e.g., forms and an MS Excel template), and guidance for identifying and evaluating possible risk management actions, including cost–benefit analysis for evaluating proactive individual risk reduction alternatives. In addition they developed a checklist for possible risk reduction actions (see the guide).
- Methods, tools (e.g., an MS Excel template), and guidance for calculating mean mitigated project performance and its sensitivity, using the same generic project performance model as discussed above, but considering the cost-effectiveness of the selected set of risk management actions, as well as the risks and the base.

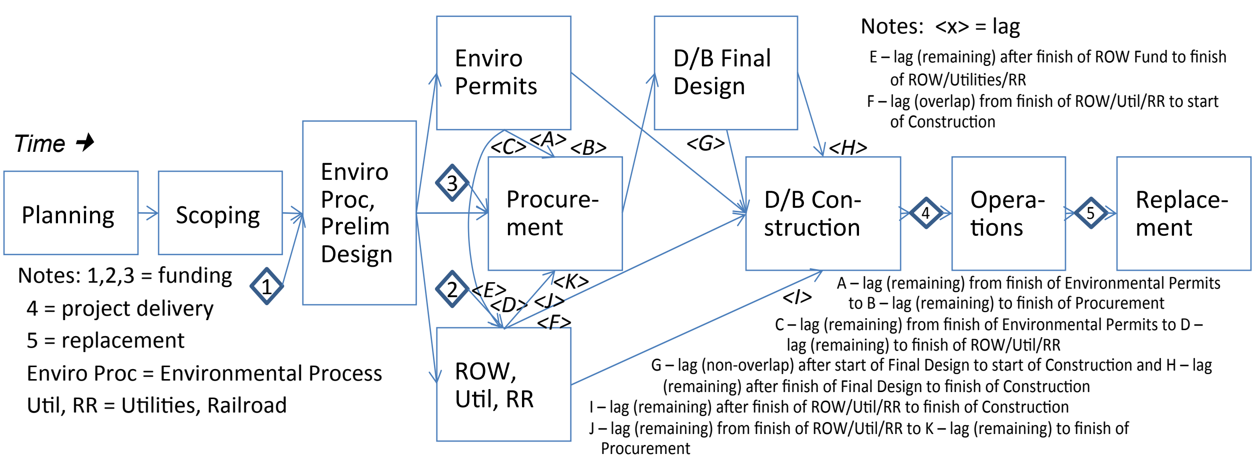

Figure 2.3. Design–build (D/B) project phases.

- Contingency and recovery analysis on the basis of mitigated project performance analysis (either quantitative risk analysis or the approximate mean value approach for relatively simple rapid renewal projects) and desired levels of confidence (target percentiles).
- Content requirements (i.e., an annotated outline) for an appropriate project risk management plan.

For successful implementation of risk management, the team developed methods, tools (e.g., forms and an MS Excel template), and guidance for monitoring and updating the risk management plan as the project proceeds, especially the following:

- Base project performance (e.g., as contracts and change orders are established and actual costs and schedule are monitored);
- Risk register (e.g., changes in severity of the risks, such as "retirement" of risks if they have not occurred by the end of a particular project phase);
- Proactive risk reduction plans (e.g., their status, including actual implementation costs and effectiveness); and
- Contingency and recovery plans (e.g., their status, including remaining capacity and changes in requirements).

In addition to development of a formal risk management process and set of performance objectives for rapid renewal projects, the researchers developed the following tools:

- An appropriate generic overview of the risk management process for a risk facilitator to present at the beginning of a workshop, specifically for a relatively simple rapid renewal project.
- A suitable set of paper forms to guide a risk facilitator through the various methods and tools, specifically for relatively simple rapid renewal projects.
- An MS Excel workbook template (with a comprehensive user's guide) to automatically document the inputs (consistent with the paper forms) and to do the calculations, specifically for relatively simple rapid renewal projects.
- Inventories of possible risks and their possible risk management actions for various rapid renewal methods to serve as checklists to help ensure comprehensiveness.
- An annotated outline for a suitable risk management plan for most rapid renewal projects.
- A complete hypothetical, relatively simple rapid renewal case study, including development of a complete risk management plan and quantitative risk analysis. The case study was evaluated by using all the other materials in this list.

Risk Management Program

Implementation of a risk management process, which can provide substantial benefits (e.g., in improved project performance), requires a formal risk management program within a DOT. Such a program consists of the following elements: policy, procedures, organizational structure (roles, responsibilities, authority, and resources), and an information network (for both gathering and distributing information).

A key requirement of a risk management program is skilled staff who can organize workshops; lead workshops and subsequently conduct analyses on relatively simple projects; write reports and plans, and monitor and update the risk register as risks arise and are addressed; and on complex projects, supervise others who are leading workshops, conducting analyses, and the like. A 2-day course was developed to train DOT staff to be capable of accomplishing these tasks; the course was supplemented by, essentially, an apprenticeship program in which staff members become increasingly proficient and ultimately independent. The training course, as well as the application of the methods and tools for risk management planning, were successfully tested and finalized during two pilot workshops (as discussed in the next section).

Once the *Guide for the Process of Managing Risk on Rapid Renewal Projects* and associated implementation materials were expanded and appropriately revised, they were submitted to the SHRP 2 Expert Task Group (ETG) for review and approval. After receiving ETG approval, the team completed and submitted all the materials to SHRP 2 for review and approval. The subsequent pilot workshops (see Task 3) were conducted to test the guide and implementation materials, after which the research team refined the material based on feedback and lessons learned (under Tasks 3 and 4).

Task 3: Conduct Pilot Workshops

The scope of Task 3 of this research project included conducting two pilot workshops with state DOTs that used the draft guide and associated implementation materials. Feedback from these workshops would be the basis for finalizing the materials (under Task 4). The pilot workshops involved the following steps or subtasks (see Appendix E):

1. Plan pilot workshops.
2. Conduct first pilot workshop.
3. Evaluate first pilot workshop.
4. Conduct second (and final) pilot workshop.
5. Evaluate second (and final) pilot workshop.

Initially, both workshops were structured to be 2 days long, with lectures the first day and application of the training materials to an actual DOT rapid renewal project on the second day.

Six state DOTs were initially identified as potential candidates, being both interested and suitable for piloting a risk management workshop for rapid renewal. The six states were the following: Colorado Department of Transportation (CDOT), Florida Department of Transportation (FDOT), Minnesota Department of Transportation (MnDOT), New York State Department of Transportation (NYSDOT), North Carolina Department of Transportation (NCDOT) and North Carolina Turnpike Authority (NCTA), and Virginia Department of Transportation (VDOT).

A letter was sent to each of these DOTs inquiring into their interest and qualifications to pilot a risk management workshop for rapid renewal (see Appendix A for the contact information of these DOTs). Five of the six DOTs expressed interest in piloting a risk management workshop for rapid renewal.

The team developed a rigorous process for selecting two DOTs for the pilot workshops; this process was based on multiple characteristics of the project and the agency. To be fair in selecting from among the five remaining DOTs, a primary set of selection criteria was established. The team looked for the following:

- High chance of success of that DOT's workshop;
- High contribution to the chance of success for that DOT's future risk management program; and
- High contribution of that DOT to the chance of success of a future national risk management program.

The factors that contribute to meeting these primary criteria were identified, and the specific information needed to assess those factors and evaluate the criteria was identified. Another letter was then sent to the five remaining DOTs requesting that information, which would allow the research team to evaluate their suitability for piloting a risk management workshop for rapid renewal.

Each of the DOTs provided a candidate project for the training. The responses of the DOTs to the request for information were then rolled up into each of the three categories and subjectively graded, considering their suitability in that category (making some assumptions when information was missing). Scores were assigned to each grade (e.g., A = 4.0), and the categories were weighted to reflect their relative importance; these scores and weights were then combined to get a total weighted score for each DOT, with higher total weighted scores being preferred. The DOTs were then ranked on the basis of their total weighted scores. The sensitivity of these scores and ranking was then evaluated. Based on this evaluation, NCDOT and FDOT came out clearly ahead and were initially selected for the pilot workshops. For a summary of the request for information and the scoring of the DOTs, see Appendix E.

Subsequent to the selection of the two DOTs, the research team worked with both on logistics and, especially, on refining their projects. However, the primary purpose of the workshop was to train DOT staff, not to evaluate a project (a benefit that was merely a by-product). The first and second day targeted potential DOT risk management facilitators and subject matter experts who might be involved in future risk management assignments; the second day targeted relevant project staff for the example project. The training allowed a DOT to conduct simple risk management (develop a risk register and a risk management plan) on relatively simple rapid renewal projects without external resources, or to supervise external resources in conducting more-detailed analyses and/or evaluating more complicated rapid renewal projects.

A specific suitable (relatively simple) rapid renewal project was needed for the 1-day evaluation (on the second day of the workshop), to reinforce the training given on the first day. Such a project was expected to be in the $25 million to $100 million range and have a significant rapid renewal element, with one workshop evaluating an accelerated construction method and the other evaluating an innovative project delivery approach. The schedule did not allow for a risk analysis (i.e., quantification of uncertainty in project cost and schedule) on the example project, which would generally take more than 1 day. However, the schedule did include development of a preliminary risk register and a risk management plan (among other things) that could subsequently be used and developed further in a full risk analysis.

The first pilot workshop was held in Raleigh, North Carolina, for NCDOT/NCTA on October 29–30, 2009. The comments on the first workshop eventually led to a major change in the format of the training, eliminating evaluation of an actual project. After these changes had been made, the second pilot workshop was held in Redmond, Washington, on May 18–19, 2010, for representatives of various state and other DOTs.

Subtask 3.1: First Pilot Workshop—NCDOT/NCTA

The goal of the pilot workshop was to assist departments of transportation in understanding and applying risk management techniques throughout the project development process, especially for rapid renewal projects, thus improving project performance. The approach was a synergy of theoretical principles, practical tools for implementation, and guidance for using the results in decisions concerning construction-management risk. The intended outcome of the workshop was a heightened awareness within the highway construction management community that risk can be understood and managed in a structured and cooperative way of doing business. Workshop organizers also hoped to spur development of an independent capability within the department of transportation to accomplish this—either (a) actually doing the most important parts on relatively simple projects or (b) supervising others in doing the other parts (e.g., quantitative risk analysis) or in evaluating more complex projects. An MS Excel workbook template was provided to each participant and guided the user through the various steps of risk management, producing a risk register and parts of a risk management plan (RMP).

The workshop duration was 2 days. Day 1 consisted of lectures and exercises from the guide to provide a fundamental understanding of the risk management process and how to do each of the important steps, including project "structuring" for risk management, risk identification, risk assessment, risk management planning, and subsequent implementation. (Note that only an overview of risk analysis was provided.) Day 2 involved a practical application of the tools and techniques discussed on Day 1 for a preselected DOT project. In addition to providing education, the workshop resulted in a working risk register and parts of an RMP for that project. It was anticipated that NCDOT would subsequently implement those parts of the RMP (which includes the risk register) on the preselected project and might choose to use the risk register in a subsequent quantitative risk analysis (e.g., to determine appropriate budgets and contingencies).

This workshop, including the actual project evaluation, receives further coverage in Appendix E.

About 25 NCDOT/NCTA staff, two SHRP 2 staff, and three workshop facilitators attended the first pilot workshop in Raleigh, North Carolina. A preselected NCDOT rapid renewal project was used on the second day of the workshop to demonstrate the methods and tools taught on the first day. Appendix E provides a description of the rapid renewal project in Topsail Island, North Carolina. It should be noted that only construction cost and schedule, not disruption during construction or longevity, were of interest to the project team.

A hypothetical project scenario used to document the assessments and to automatically conduct the analyses is included in the guide (http://www.trb.org/Main/Blurbs/168369.aspx).

Evaluations of First Pilot Workshop

The research team requested feedback from both the NCDOT personnel and the SHRP 2 staff on the first pilot workshop. Although the feedback from the NCDOT participants was generally positive, comments from both them and SHRP 2 staff suggested a significant change to the format, which was to eliminate the application to a real DOT project on the second day and replace it with an expanded version of the illustrative example project from the guide. This change and several other revisions were made, and the team began planning for the second pilot workshop. The first workshop is further evaluated in Appendix E.

Course participants completed evaluations of the first pilot workshop (17 evaluations total), a summary of which is presented in Table E.3 in Appendix E. Average scores for each of the course evaluation questions range between 4 and 5 on a 1–5 scale (i.e., As and Bs). In summary, the comments reflected the assessment that it was a good course. However, participants found Day 1 to be overwhelming (too dense, too much theory especially in Module 5, too fast, too much lecture, and not enough interaction). In addition, the notebook needed better organization (e.g., the appropriate forms should have been with each module), and the forms were hard to read and understand. Participants indicated that the real project application on Day 2 clarified the process and material from Day 1 but should have been more integrated with that material.

Under a separate contract (using no research project funds), the research team conducted another risk identification, assessment, and management workshop for NCDOT/NCTA on January 27–28, 2010. The focus was a confidential, large design–build project, using the methods and materials developed for this research project. Like the second day of the first pilot workshop, this workshop did not involve training; it provided only a short introductory overview of the risk management process. However, it did involve use of the process, methods, inventories, and template. This workshop was successful and essentially validated the methods and materials (including the template and introductory overview presentation) developed for this research project. The project description, base cost and schedule, unmitigated risk register and performance, risk reduction plan development, and mitigated risk register and performance that were generated in the 1.5-day workshop proved to be very valuable to the project team; however, they are considered confidential and cannot be presented here. Nonetheless, feedback from this workshop was used to revise the template (and user's guide and forms) and the introductory overview presentation before the second pilot training workshop.

Revisions Based on the Evaluation of the First Pilot Workshop

On the basis of the approved changes that resulted from feedback on the first pilot workshop, the guide and materials were extensively revised before the second pilot training workshop in the following manner:

- The template (an MS Excel workbook) was revised and a user's guide for the template was developed to improve the template's functionality.
- The hard-copy forms, which are intended to provide all the inputs needed by the template but are designed to be filled out quickly by hand, were revised to be consistent with the revised template and to improve their functionality.
- A presentation (in MS PowerPoint) providing a relatively short overview of the simplified risk management process was developed, which would be appropriate for a facilitator to use as an introduction to a risk management workshop (possibly with some modification to customize it for each specific application). The slides contain significant animation (which can only be seen in presentation mode), as well

as significant notes (which can only be viewed completely in "notes page" view).

- The hypothetical example for the guide and for the pilot training workshop was significantly expanded to include (among other things) a complete risk management plan (including an application of the template and an addendum for quantitative risk analysis), to better illustrate concepts and methods.
- The syllabus (including an evaluation form) for the pilot training workshop was revised, as were the annotated slides (in MS PowerPoint) for the pilot training workshop, consistent with the revised guide and other materials.

Further detail about revisions to the guide and materials is provided in Appendix E.

Subtask 3.2: Second Workshop

As noted earlier, the second (and final) pilot workshop was postponed pending resolution of comments on the first workshop and subsequent revision of the guide and materials. The objectives of the second workshop were the same as the first workshop. The second workshop consisted of 2 days of lectures and exercises based on a hypothetical project. Time was allotted for discussion to provide a fundamental understanding of the risk management process and how to do each of the important steps, including project "structuring" for risk management, risk identification, risk assessment, risk management planning, and subsequent implementation. Only an overview of quantitative risk analysis was provided.

Because this workshop used a hypothetical project instead of a real project, members of a specific DOT project team were no longer needed in the workshop; only future risk managers (and, to a lesser extent, subject matter experts) who would apply the guide and materials to their DOT's projects needed to attend. Because only a few such people from any DOT would attend, representatives from various DOTs were invited to attend the workshop to have a sufficient number of participants. Staff from selected state DOTs (Arizona, California, Colorado, Florida, Hawaii, Iowa, Minnesota, Nevada, New York, North Carolina, Oregon, Utah, Virginia, and Washington) and Canadian provincial ministries of transportation (Alberta, British Columbia, and Ontario), as well as FHWA and SHRP 2 staff, were invited to attend the workshop (see Appendix A for agency contact information).

This pilot training workshop was conducted May 18–19, 2010, in Redmond, Washington, using the revised guide and materials. The course was ultimately attended by 13 staff from various organizations, including Washington, Minnesota, Nevada, and North Carolina DOTs, FHWA, SHRP 2, and a consultant for the Federal Transit Administration (FTA) (see Appendix E for list of organizational attendees).

Evaluations of Second Pilot Workshop

Feedback was requested from both the DOT participants and the SHRP 2 staff who attended the second pilot workshop. Only a few participants formally evaluated the course; in summary, the commenters said that the course was very good but needed some revisions. The standard flowcharts needed revision (to reflect that the environmental process is tied to preliminary design) and the practical exercise needed better implementation. They found the course still dense in places (e.g., regarding structuring exercise) and suggested that trainees would need "hand holding" for real applications.

A summary of course participants' evaluations is presented in Appendix E (only three evaluations total, because other attendees left before the end of the course and did not respond to subsequent requests). Average scores (which have limited value with such a small number of responses) for each of the course evaluation questions range between 3 and 5 on a 1–5 scale (i.e., As, Bs, and Cs).

Task 4: Finalize Guide and Implementation Materials

Based on the feedback on the guide and associated implementation materials, the project team resolved the comments from pilot workshops and generally improved the materials. The team finalized and submitted the guide and the associated implementation materials to SHRP 2 on February 15, 2011 for approval. The final guide and implementation materials are described further in Appendix D. The materials are available at http://www.trb.org/Main/Blurbs/168369.aspx.

Task 5: Manage the Study

The task of overall study management of the R09 research entailed coordinating research team members and the program officer, as well as regularly communicating the project status. Managing the research team involved coordinating the technical Tasks 1–4 (including technical meetings) and submitting technical reports. The gap analysis and detailed plan report, as well as the final report, were developed under this task. The team also responded to a request for recommendations of additional future work.

Throughout the duration of the project, regular communication was established through monthly and quarterly progress reports, interim meetings with staff, teleconferences, web meetings, and status reports and briefings at Technical Coordinating Committee meetings. The research team also completed miscellaneous SHRP 2–directed activities, such as presentations at conferences. More detail on study management is found in Appendix B.

CHAPTER 3

Conclusions and Suggested Additional Research

Conclusions

The major products of the research described in this report are

1. A comprehensive guide, including extensive checklists and a comprehensive example project application for illustration of concepts and training purposes.
2. Associated implementation materials for conducting risk management on relatively simple rapid renewal projects, including annotated training materials, a presentation introducing the risk management process, forms for documenting the process, and an MS Excel template with user's guide for documenting the process and automatically conducting the necessary analyses.

The guide and implementation materials were successfully tested on two rapid renewal projects and in two pilot training workshops for DOTs and are available at http://www.trb.org/Main/Blurbs/168369.aspx. The products will enable DOTs to facilitate risk workshops for relatively simple rapid renewal projects (as well as other design and construction projects) and to develop and subsequently implement comprehensive risk management plans. It is anticipated that, through the implementation of the principles and practices described in this work, DOTs can develop a culture of risk management and more successfully complete their rapid renewal projects, as well as non–rapid renewal projects.

Suggested Additional Research

Although the scope of work has been completed, the following additional work is suggested to maximize the benefits of the completed efforts:

- Knowledge and availability of the guide and materials are essential to success. It is recommended that papers and presentations on the guide (both the process and case studies, including metrics) be given at various appropriate venues to inform DOTs of its existence, value, and availability. Feedback and comments on the guide can be gathered and used to improve it, especially in relation to checklists of rapid renewal methods, risks, and risk reduction actions.
- The tools (e.g., forms and MS Excel template with user's guide) to implement the guide must be accurate and practical. Feedback and comments on the tools can be gathered and used to improve them (e.g., reporting and fixing of template bugs). The implementation materials also include development and maintenance of a database of project risks, input assessments, and value metrics.
- A specific program is generally needed within each DOT to conduct risk management. Such a program consists of a risk management policy and set of procedures, as well as an organization structure and infrastructure to carry it out. Therefore, DOTs may benefit from technical assistance to set up their risk management programs.
- Training of DOTs may be beneficial for their staff to digest the guide and materials so they can apply them, including technical assistance on actual applications. A streamlined (e.g., half day) version of the training can be developed and presented at venues (e.g., the TRB annual meeting). A web-based version of the training is recommended (with accommodations for planned discussions and practical exercises). Similarly, feedback and comments on the training materials can be gathered and used to improve those materials.

Additional work could be cost-effective in getting DOTs to successfully implement the risk management process described here so that they can realize its potentially significant benefits. Such additional work has been itemized, including cost estimates, in Table F.1 of Appendix F.

The research undertaken by the R09 project can improve project performance in relation to cost, schedule, disruption, and longevity if the guide and tools are appropriately applied to projects. However, before DOTs are organized and trained to conduct risk management, they must be convinced of its benefits. This can best be done by making DOTs aware of the process (e.g., through wide exposure) and clearly demonstrating its value (e.g., through case studies). In addition to marketing (e.g., papers and brochures, presentations and webinars, and user conferences), case studies can be collected and evaluated, and new applications can be encouraged and documented as case studies. To demonstrate the benefits of implementing the guide, specific metrics (e.g., total and average project cost savings) can be developed and reported. Furthermore, it is recommended that the guide and tools be updated and improved as needed and as appropriate.

In addition to marketing (emphasizing cost-effectiveness of risk management), such training can be encouraged in various ways. Training is essential to implement the guide. Such training can be delivered at different levels (from providing familiarity to developing full capability), as dictated by necessity, and can be available in different formats and media [live and recorded, on site and remote, National Highway Institute (NHI) and non-NHI format, lecture and application]. Some of the formats and media would need to be developed first.

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APPENDIX A

Annotated Bibliography and Agency Contact List

Annotated Bibliography

The following annotated bibliography was initially developed by members of the research team under a different contract for NCHRP Project 8-60, Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs, and then amended for this research (with much of the content remaining the same). The research team used the following resources for the literature review:

- General Internet search engines
- Transportation Research Board's TRIS (Transportation Research Information Systems) Online
- Academic engineering databases, such as LexisNexis and Engineering Village 2
- Academic business databases, such as EBSCO Business Source Complete and Management and Organizational Studies
- ASCE Civil Engineering database
- PMI Virtual Library
- Selected transportation agency websites

Literature Review

***A Code of Practice for Risk Management of Tunnel Works.* International Tunnelling Insurance Group, Jan. 30, 2006.**
The intent of this code is to promote and secure best practice for minimizing and managing risks associated with the design and construction of tunnels and associated underground structures, including the renovation of existing underground structures. It describes the process for identifying risks and for determining their allocation between the parties to a contract and contract insurers, and it discusses the management and control of risks through the use of risk assessments and risk registers. This code applies to the stages of tunnel works—project development, design, contract procurement for construction, and construction stages—their operation during any stipulated maintenance period, and the impact of their construction on third parties, including infrastructure.

Abi-Karam, T. Managing Risk in Design–Build. *AACE International Transactions,* CDR.07, Morgantown, W.Va., 2001, pp. 7.1–7.5.
This article provides an overview of the design–build method of project delivery, in which an owner contracts only with a design-builder, rather than the traditional method, in which an owner contracts with an architect, engineer, and contractor. The author proposes that there are inherent risks associated with design–build projects beyond those experienced on traditionally delivered projects and discusses each risk in detail.

Ahmad, I. Contingency Allocation: A Computer-Aided Approach. *AACE International Transactions,* F.5, Morgantown, W.Va., 1992, pp. 5.1–5.5.
This paper introduces a method for allocating contingency to individual work packages. For each package, ratios of actual cost to estimated cost are calculated for the highest, most likely, and lowest values as determined by historical information. Using simulation software, the practitioner can then determine a most likely cost and allocate an associated contingency value to each individual package.

Ali, R. The Application of Risk Management in Infrastructure Construction Projects. *Cost Engineering Journal,* Vol. 47, No. 8, Aug. 2005, pp. 20–27.
According to this paper, risk management plan (RMP) methodology provides a logically consistent framework for managing risk. An RMP methodology is used in this article to formulate a risk management model, incorporating infrastructure project costs for construction budgeting purposes, and applying it to the project to improve the evaluation and control of costs.

Amirkhalili, R. Risk and Capital Budgeting. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1997, pp. 4.0.1–4.0.4.
This paper presents a Monte Carlo simulation model using a spreadsheet and a personal computer. The paper demonstrates how managers can simulate the effect of changing the variables and examine the resultant range of the project NPV graphically.

Barrazza, G.A., and R.A. Bueno. Cost Contingency Management. *Journal of Management in Engineering,* Vol. 23, No. 3, July 2007, pp. 140–146.
In this article, the Monte Carlo simulation approach is recommended as part of a proposed methodology for cost contingency management, which also includes a heuristic for contingency assignment (allocation)

among project activities, as long as the activities have some degree of uncertainty regarding their future costs.

Bent, J.A. Evaluating and Calculating Contingency. *AACE International Transactions,* RISK.02, Morgantown, W.Va., 2001, pp. 2.1–2.5.
A method of calculating contingency using an SFC rating and a contingency chart is discussed in this paper. The data demonstrated in contingency charts are obtained from historical data, and the SFC rating (a percentage) is developed by calculating the total assessment of 25 factors comprising design, estimator performance, time, project conditions, and team experience.

Bjornsson, H.C. Risk Analysis of Construction Cost Estimates. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1977, pp. 182–189.
This paper briefly discusses the basics of risk simulation, and presents a computerized model for cost estimating that is designed to cope with the problems of correlation and interpretation. It explains how an estimate approach using probability is more beneficial than a single value or point estimate approach.

Buchan, D.H. Risk Analysis—Some Practical Suggestions. *Cost Engineering Journal,* Vol. 36, No. 1, Jan. 1994, pp. 29–34.
This article suggests some practical methods and solutions in the field of risk management, based on the author's experience in risk analysis work in the United Kingdom construction industry. He combines a logical approach and formal methodology with readily available computer software, including Lotus P-2-3 version 2.4, with add-ins @Risk 1.55, and What's Best 1.6.

Burger, R. Contingency: Quantifying the Uncertainty. *Cost Engineering Journal,* Vol. 45, No. 8, Aug. 2003, pp. 12–17.
In this paper, the author defines two methods for determining contingency. Zastrozny's method is used to calculate contingency; Simple Multi-Attribute Rating Technique (SMART) is used to obtain an uncertainty rating that, when used together with the calculated contingency, provides an estimate for the contingency needed on a particular project.

Burroughs, S.E., and G. Juntima. Exploring Techniques for Contingency Setting. *AACE International Transactions,* EST.03, Morgantown, W.Va., 2004, pp. 3.1–3.6.
This paper discusses the following commonly used techniques for determining contingency: predetermined percentage, expert's judgment, risk analysis, and regression analysis. Based on the performance of each of these techniques, the author asserts that certain techniques are more accurately and appropriately used depending on the project risks involved.

Caddell, C.P., S.R. Crepinsek, and G.P. Klanac. Risk Assessments: Value of the Process. *AACE International Transactions,* RISK.01, Morgantown, W.Va., 2004, pp. 1.1–1.6.
Conducting cost and schedule risk assessments on projects has proven to be a valuable exercise. This paper suggests that using the right process can significantly increase the quality of the risk analysis and its results, and provide a number of other benefits to the project. If these assessments are conducted properly, management and the project team can capture the inherent value in the effort and improve their chances for success because key project risks are evaluated and mitigation steps are known.

Caltrans. *Project Risk Management Handbook.* Office of Project Management Process Improvement, California Department of Transportation, Sacramento, June 2003.
This is California Department of Transportation's guide to risk and risk management. It describes the basic concepts and processes that guide risk management planning and implementation during project development.

Caltrans. *Project Risk Management Handbook: Threats and Opportunities,* 2nd ed., rev. 0. Office of Statewide Project Management Improvement, California Department of Transportation, Sacramento, 2007.
Directed to Caltrans department project managers, functional managers, and other staff engaged in the delivery of capital projects, this handbook is intended to provide its audience with a complete, uniform approach to managing project risks (both threats and opportunities). It describes the basic concepts and processes that guide planning and implementing of risk management during project development. An important purpose of the revision was to make the department's present policy more accessible to the audience than the handbook's first edition.

Carrier, K.C. A System for Managing Escalation and Contingencies. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1977, pp. 324–336.
This paper presents an approach to organizing, developing, maintaining, and reporting cost status situations on capital cost projects. The reporting and simulation techniques described result in predictions of the forecast of final project cost which is continually varying.

Cochrane, R.E. Using @Risk to Predict Project Costs. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1992, pp. F.3.1–F.3.5.
This paper is an analysis of a search for a better way of estimating the cost of a project under current operating conditions. Information was used from several papers on risk analysis and from annual meetings, including papers about developing a modified approach to estimating using the @Risk personal computer program.

Cohen, M.W., and G.R. Palmer. Project Risk Identification and Management. *AACE International Transactions,* INT.01, Morgantown, W.Va., 2004, pp. 1.1–1.5.
This paper recommends the use of the Critical Path Method (CPM) schedule as a mechanism to manage construction risk on a project. The project life cycle is defined and the author emphasizes the necessity to manage risks throughout the entire project life cycle using the CPM network to perform "what if" analyses to adjust a baseline schedule according to a set of risks brainstormed by the project team.

Committee for Oversight and Assessment of U.S. Department of Energy Project Management, Board on Infrastructure and the Constructed Environment, Division on Engineering and Physical Sciences, National Research Council of the National Academies. *The Owner's Role in Project Risk Management,* National Academies Press, 2014. www.nap.edu/catalog/11183.html.
This report was prepared as a summary of the most effective risk management practices used by owner organizations in project management in the public and private sectors. The primary objective is to provide U.S. Department of Energy project directors with an understanding of (a) the risk management role of an owner's representative member of a project management team, and (b) the knowledge needed for effective oversight of risk management activities that are delegated to contractors. The document identifies major steps in a specific risk management process based on a proactive approach that requires owners to take a set of basic actions to manage risk. It emphasizes that successful risk management must be performed by qualified personnel working within a project management process that includes review and approval by senior management.

Coppo, R.J. Risk Modeling with Influence Factors. *AACE International Transactions,* RISK.08, Morgantown, W.Va., 2003, pp. 8.1–8.2.
The influence factor risk model is based on an interview process that asks a series of questions about the source of uncertainty in the estimate. This presentation shows how to model risk by assigning probability functions and associated costs to the influence factors. The model output results in the total cost of uncertainty. Using this approach to risk modeling puts the focus on the work process and how it introduces uncertainty in the estimate.

***Cost Engineering Terminology: AACE International Recommended Practice No. 10S-90.* AACE International, Morgantown, W.Va., 2007.**
This publication contains terms that have been developed by various AACE International technical committees, special interest groups, or project teams. All terms have been subject to a thorough review process, followed by approval by the AACE International Technical Board. Portions of this document have been incorporated into the American National Standards Institute's (ANSI) Standard No. Z94.x.

Curran, K.M. Value-Based Risk Management (VBRM). *Cost Engineering Journal,* Vol. 48, No. 2, Feb. 2006, pp. 15–22.
As practiced in today's varied applications, traditional risk management is typically defined as a process to identify, analyze, mitigate, and control risks and opportunities in decision making. Although such actions move the ball, they do little to carry the decision maker over the goal line. Two additional requirements of risk management are presented in this paper: benchmarking and grading. Incorporation of these two attributes into traditional risk management practice produces a much-improved decision technology, value-based risk management.

Curran, M.W. Range Estimating—Coping with Uncertainty. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1976, pp. 366–372.
This paper explains why conventional methods of estimating come up short and why uncertainty needs to be considered and methods need to be changed. This paper proposes the idea of range estimating, with in-depth information about how it is used and can be beneficial to coping with uncertainty.

Curran, M.W. Range Estimating: Reasoning with Risk. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1988, pp. N.3.1–N.3.9.
This paper explains why our current methods of estimating come up short because of the methods we use, not the people who are performing these methods. It goes on to explain how we think about estimates and how we should think about estimates.

del Cano, A.D., and M.P. de la Cruz. Integrated Methodology for Project Risk Management. *Journal of Construction Engineering and Management,* Vol. 128, No. 6, 2002, pp. 473–485.
First, the article explains a complete or generic project risk management process to be undertaken by organizations with the highest level of risk management maturity in the largest and most complex construction projects. Next, factors influencing possible simplifications of the generic process are identified, and simplifications are proposed for some cases. Then the application to a real project is summarized. As a final validation, a Delphi analysis has been developed to assess the project risk management methodology explained here, and the results are presented.

Dey, P.K. Project Risk Management: A Combined Analytic Hierarchy Process and Decision Tree Approach. *Cost Engineering Journal,* Vol. 44, No. 3, March 2002, pp. 13–26.
This article demonstrates a quantitative approach to construction risk management through an analytic hierarchy process (AHP) and decision tree analysis. The entire project is classified to form a few work packages. With the involvement of project stakeholders, risky work packages are identified. As all the risk factors are identified, their effects are quantified by determining probability (using AHP) and severity (guess estimate). Various alternative responses are generated, listing the cost implications of mitigating the quantified risks.

Douglas, E.E. Contingency Management on DOE Projects. *AACE International Transactions,* RISK.03, Morgantown, W.Va., 2001, pp. 3.1–3.6.
This paper defines contingency, outlines the elements of risk management, provides guidelines for the application of contingency to the project baseline, and proposes a standard process to establish, track, and control contingency on a DOE project. While the paper is specific to DOE projects, the definitions and basic guidelines can easily be used by other industries to supplement their methods of contingency management.

Eschenbach, T.G. Risk Management Through Sensitivity Analysis. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1996, pp. 4.1–4.6.
This paper compares several approaches to identifying and describing key risks and to defining cost/time/risk trade-offs. The paper goes in depth, describing the advantages and disadvantage of using sensitivity analysis.

FHWA. *Major Project Program Cost Estimating Guidance.* U.S. Department of Transportation, Jan. 2007, pp. 1–12.
This guidance document explains key principals used when preparing a program cost estimate at any stage of a major project. It also explains the cost elements that should be included when preparing a program cost estimate for a major project and how program cost estimates should be used throughout the project.

Gunham, S., and D. Arditi. Budgeting Owner's Construction Contingency. *Journal of Construction Engineering and Management,* Vol. 133, No. 7, June 2007, pp. 492–497.
In this paper, the authors suggest that the common practice of allocating a fixed owner contingency (e.g., 10% of the contract value) to all projects contracted out by an owner is not appropriate. Instead, they propose a methodology in which the owner (1) analyzes historical project data; (2) identifies the line items that are problematic; (3) takes the necessary measures at the preconstruction stage to streamline these line items with respect to site conditions, time constraints, constructability issues, and project scope; and (4) budgets contingency funds based on this information.

Hackney, J.W. Applied Contingency Analysis. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1985, pp. B.2.1–B.2.4.
This paper describes what contingency is and why it is so important to a project's performance. It then talks about the different ways in which contingency will help a project and how it can be used or analyzed at different points in the project.

Hastak, M., and E.J. Baim. Risk Factors Affecting Management and Maintenance Cost of Urban Infrastructure. *Journal of Infrastructure Systems,* Vol. 7, No. 2, 2001, pp. 67–76.
This paper identifies risk factors that influence the cost-effective management, operation, and maintenance of bridges, roads and highways, and subway stations, as well as how and when in the project life cycle the identified risk factors affect the associated facility costs.

Hecht, H., and D. Niemeier. Too Cautious? Avoiding Risk in Transportation Project Development. ***Journal of Infrastructure Systems,*** **Vol. 8, No. 1, 2002, pp. 20–28.**
This research paper explores the relationship between risk-averse behavior (i.e., engineering judgment applied to certain types of situational problems) and transportation project development time/cost. It concludes that risk-averse behavior by project managers does not significantly affect project development time or cost and that the required project development process is simply too rigid and bureaucratic to allow an individual project manager to significantly reduce the time or cost of project development.

Highways Agency Framework for Business Risk Management. **Highways Agency, UK Department of Transport, London, 2001, pp. 1–9.**
This document sets out the UK Highways Agency's framework for risk management. It outlines both the agency's approach to risk management and the associated roles and responsibilities of the agency's colleagues.

Humphreys, K.K. ***Risk Analysis and Contingency Determination Using Range Estimating, AACE International Recommended Practice No. 41R-08, TCM Framework: 7.6–Risk Management.*** **AACE International, Morgantown, W.Va., 2008.**
This document offers guidelines for analyzing risk by using range estimating, which most practitioners would consider a reliable practice and would recommend be considered for use when applicable. This text aims to improve communication of the meaning of the practice called *range estimating* because its authors have found that methods being called range estimating in industry do not meet the definition in this document. The authors urge practitioners to confirm that any use of the term meets the definition found here.

Jarvis, J.A. Capital Estimates and Cost Control for a Long Term Construction Program. ***AACE Transactions,*** **AACE International, Morgantown, W.Va., 1976, pp. 63–69.**
The purpose of this paper is to examine, in context, the cost engineering problems associated with long-term strategies. These include projects that have taken more than 10 years.

Jordan, D.W. Managing Change: Making the Most of Contingency. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1989, pp. Q.1.1–Q.1.9.**
This paper describes a trend program that provides a means of identifying and evaluating the impact which changes have on the cost and schedule of a capital project. The program relies on the involvement and cooperation of all members of the project team. The resulting effort provides management with an up-to-date report of the status of the project, a projection of the direction it is taking, and a means of documenting what changes have occurred to cause variations from the original plan.

Kageyama, K. Probabilistic Cost Estimate Tree Analysis—Computer Program. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1979, pp. C.3.1–C.3.6.**
This paper describes (a) the probabilistic cost estimate tree (PCET) and risk data preparation required to use the tree; (b) the PCET computer program flow diagram with algorithm; and (c) a sample of a typical operation.

Kaliprasad, M. Proactive Risk Management. ***Cost Engineering Journal,*** **Vol. 48, No. 12, Dec. 2006, pp. 26–36.**
This article provides an overview of risk management, its concepts, components, and the associated terminology and methodology, together with different views on how risk management integrates into project management.

Karlson, J.T., and J. Lereim. Management of Project Contingency and Allowance. ***Cost Engineering Journal,*** **Vol. 47, No. 9, Sept. 2005, pp. 24–29.**
Cost overruns in engineering projects occur frequently because a certain margin of risk is inherent in all projects. As a result, risk management is continuously gaining the attention of the engineering industries. Reserves or contingencies represent the additional funding required to account for the cost of risk. However, many corporations have different practices for estimating and managing such reserves. This article presents several techniques and methods for estimating such reserves.

Kraemer, G.T. Quick and Effective Risk Analysis. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1977, pp. 177–181.**
This paper describes a different kind of approach to risk analysis.

Kumaraswamy, M.M. Appropriate Appraisal and Apportionment of Megaproject Risks. ***Journal of Professional Issues in Engineering Education and Practice,*** **Vol. 123, No. 2, 1997, pp. 51–56.**
This paper develops and describes strategies for appraising the synergistic potential and risk carrying capacities of prospective project participants, and for identifying, analyzing, and responding to risks by an appropriate appointment to those best equipped and motivated to control them.

Lewis, L. Range Estimating: Managing Uncertainty. ***AACE Bulletin,*** **Nov.–Dec. 1977, pp. 205–207.**
This paper describes range estimating. It also describes how and why it should be used. Range estimating quantifies the uncertainty of an estimate by addressing itself to the uncertainties of the critical elements of the estimate.

Lorance, R.B., and R.V. Wendling. Techniques for Developing Cost Risk Analysis Models. ***AACE International Transactions,*** **RISK.02, Morgantown, W.Va., 1999, pp. 2.1–2.6.**
This paper defines Monte Carlo simulation and discusses how the technique can be used to develop risk analysis models to manage risk and predict cost overruns.

Lukas, J.A. Managing Risk on Capital Projects. ***AACE Transactions,*** **AACE International, Morgantown, W.Va., 1995, pp. 7.1–7.4.**
This paper discusses risk management, covers the process phases that incorporate risk management, and then focuses on experiences with capital projects at Kodak in using risk management. Specific topics include the risk analysis process and how it is used to determine project contingency and the potential range of cost outcomes. Case histories comparing risk projections with actual project costs are reviewed, along with key lessons from more than 3 years of using risk management.

Mathur, K.S. Risk Analysis in Capital Cost Estimating. ***Cost Engineering Journal,*** **Vol. 31, No. 8, Aug. 1989, pp. 9–16.**
This article presents an approach to the analysis of historical cost data and the prediction of costs, which takes into account risk and contingency involved in budgeting and cost control. The method is a computer model based on statistical and operational research techniques.

Marshall, H.E., R.E. Chapman, and C.J. Leng. Risk Mitigation Plan for Optimizing Protection of Constructed Facilities. ***Cost Engineering Journal,*** **Vol. 46, No. 8, Aug. 2004, pp. 26–33.**
This article describes a three-step protocol for developing a risk-mitigation plan for optimizing protection of constructed facilities. Step 1 assesses the risk of uncertain, costly, man-made and natural hazards, including terrorism, floods, earthquakes, and fire. Step 2 identifies alternative risk-mitigation strategies, used singly or in combination, to reduce

the expected value of damages from such events. Step 3 evaluates the life-cycle economic effectiveness of alternative mitigation strategies.

Mlakar, P. F., and L. M. Bryant. Direct Range Cost Estimating. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1990, pp. K.4.1–K.4.4.
This paper describes the direct range of cost estimating and how to fix the shortcomings of range estimating. It also goes into detail about how range estimating works and why it is popular despite its shortcomings.

Molenaar, K. R. Programmatic Cost Risk Analysis for Highway Mega-Projects. *Journal of Construction Engineering and Management,* Vol. 131, No. 3, 2005, pp. 343–353.
This paper presents a methodology developed by the Washington State Department of Transportation for its cost estimating validation process. Nine case studies, with a mean cumulative value of over $22 billion, are presented and analyzed. Programmatic risks are summarized as economic, environmental, third-party, right-of-way, program management, geotechnical, design process, construction, and other minor risks.

Molenaar, K. R., J. E. Diekmann, and D. B. Ashley. *Guide to Risk Assessment and Allocation for Highway Construction Management.* Report No. FHWA-PL-06-032. FHWA, U.S. Department of Transportation, 2006.
This instructional report was developed by FHWA to help raise awareness of risk management techniques and to begin the process of incorporating elements of risk management into the institutional structures of DOTs. The goal of the report is to raise awareness within the highway construction management community that risk can be understood and managed. The more strategic goal is that DOTs and contractors, as appropriate, will actually identify, assess, analyze, mitigate, allocate, and monitor risk in a structured and cooperative way.

Moselhi, O. Risk Assessment and Contingency Estimating. *AACE International Transactions,* D&RM/A.06, Morgantown, W.Va., 1997, pp. 6.1–6.6.
This paper describes the common sources of risk associated with the delivery of engineering, procurement, and construction projects. It provides a basic anatomy for project risk. This paper focuses primarily on contingency as a vehicle for managing this risk. The paper presents a direct quantitative method for contingency estimation and avoiding time-consuming analyses.

Nabors, J. K., and P. A. Owen. Quantifying Risks in Capital Estimates. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1983, pp. B.5.1–B.5.7.
This article explains why traditional cost-estimating techniques cannot be used across all projects. It goes in depth on how to identify risk and uses an example of risk analysis and construction on a chemical plant.

Nassar, K. Cost Contingency Analysis for Construction Projects Using Spreadsheets. *Cost Engineering Journal,* Vol. 44, No. 9, Sept. 2002, pp. 26–31.
The purpose of this article is to present a quantitative approach for performing contingency analysis for a construction project using basic spreadsheet techniques. The approach is applied to a practical case study, and a sensitivity analysis of the results is carried out. Practicing contractors can use the developed spreadsheet to analyze cost overrun risks.

Neil, J. M. Management of Project Risks. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1989.
This paper is an introduction to management of risks associated with a construction project, specifically those faced by the contractor. The principles involved generally apply to management of risk associated with any endeavor. This paper is a condensation of the report *Management of Project Risk,* prepared by the Construction Industry Institute.

Noor, I., and R. L. Tichacek. Contingency Misuse and Other Risk Management Pitfalls. *AACE International Transactions,* RISK.04, Morgantown, W.Va., 2004, pp. 4.1–4.7.
In this article, the authors assert that the methodology that is to be used for the derivation of contingency funds should be based on the level of risks on a project. Contingency funds should be used to address specific risks as they occur along the project execution schedule. Any unspent funds should be returned for possible use on other projects or to fund other activities. Based on the results of the project risk assessments, contingency drawdown plots could be used to manage the contingency funds and to improve the project budgetary process.

Paek, J. H. Contractor Risks in Conceptual Estimating. *Cost Estimating Journal,* Vol. 36, No. 12, Dec. 1994, pp. 19–22.
This article describes the difficulties of bidding a job on the basis of conceptual drawings. It explains the major problems with the estimate and goes in depth on how to bid successfully and be competitive.

Parsons, A. Touran, and Golder Associates. *Risk Analysis Methodologies and Procedures.* Federal Transit Administration, U.S. Department of Transportation, 2004. http://www1.coe.neu.edu/~atouran/FTA%20White%20Paper%20on%20Risk%20Analysis-Final%20June%202004.pdf. Accessed Aug. 21, 2013.
This report describes procedures for performing risk analysis, which consists of two parts: (a) risk assessment, which includes identification and evaluation of risks in terms of their likelihood of occurrence and their probable consequences; and (b) risk management, which involves taking cost-effective actions to reduce risks and to realize opportunities.

Piekarski, J. A. Simplified Risk Analysis in Project Economics. *Professional Practice Guide to Risk,* AACE International, Morgantown, W.Va., 1984, pp. D.5.1–D.5.3.
The purpose of this paper is to demonstrate the use of a simplified method of incorporating risk analysis in project economics to bridge the technology gap and bring the decision maker in direct contact with the critical uncertainties of the project. This paper is meant to present another tool that can be used, not replace the computer model.

Ramgopal, M. Project Uncertainty Management. *Cost Engineering Journal,* Vol. 45, No. 12, Dec. 2003, pp. 12–24.
This article argues that all current project risk management processes induce a restricted focus on the management of project uncertainty because the term *risk* encourages a threat perspective. The article discusses the reasons for this view and argues that a focus on uncertainty rather than risk could enhance project risk management, in terms of designing desirable futures and planning how to achieve them.

Regan, S. T. Risk Management Implementation and Analysis. *AACE International Transactions,* RISK.10, Morgantown, W.Va., 2003, pp. 10.1–10.5.
The author of this paper defines the term *risk* and provides a guideline for developing a risk management program capable of being implemented and analyzed on any type of project.

Ripley, P. W. Contingency! Who Owns and Manages It? *AACE International Transactions,* CSC.08, Morgantown, W.Va., 2004, pp. 8.1–8.4.
This paper was used as a basis for discussion at the 2004 annual meeting of AACE International. The author defines contingency and discusses the various ways in which different project players use reserve funds.

Risk Management Committee, Association for the Advancement of Cost Engineering International. AACE International's Risk

Management Dictionary. ***Cost Engineering Journal,*** **Vol. 42, No. 4, April 2000, pp. 28–31.**
This article provides 50 definitions of terms related to the subject of risk management. It was originally published in an October 1995 issue of *Cost Engineering* and was the first article in AACE International's Professional Practice Guide to Risk. Many of the terms included deal with probability and statistics or are particular to project risk management.

Roberds, W., and T. McGrath. Quantitative Cost and Schedule Risk Assessment and Risk Management for Large Infrastructure Projects. ***Proc., 3rd Annual Conference of the PMI College of Scheduling,*** **Orlando, Fla., April 2006.**
This paper presents an innovative, practical, and cost-effective approach to problem solving by (a) quantifying actual project cost and schedule uncertainty within a probabilistic, risk-based, integrated cost and schedule model, in which the uncertainties in inputs are explicitly assessed (including de-biasing, through elicitation of technical experts) and incorporated; (b) identifying and prioritizing critical cost and schedule risks and opportunities, as well as quantifying the benefits of proposed mitigation strategies to address those critical risks and opportunities; and (c) improving owner and project team understanding and communication. While it is not yet possible to fully validate this new approach, this paper presents an initial evaluation, and discusses challenges related to better implementation.

Robert, J. Allocating Construction Risks: What, Why, How & Who? ***Guidelines for Improving Practice: Architects and Engineers Professional Liability,*** **Vol. 17, No. 5, 1987, pp. 1–5.**
This paper describes how design professionals and owners could benefit from taking a more global view of risk. The author describes how this could benefit everyone involved and improve the current state of risk assessment.

Rothwell, G. Cost Contingency as the Standard Deviation of the Cost Estimate. ***Cost Engineering Journal,*** **Vol. 47, No. 7, July 2005, pp. 22–25.**
This article compares project stages, accuracy ranges, and cost contingencies recommended by the Association for the Advancement of Cost Engineering International and the Electric Power Research Institute. It shows that current guidelines are consistent with contingencies equal to the standard deviation of the cost estimate. It suggests how this standard deviation can be derived from a confidence level (e.g., 80%) for a given accuracy (e.g., ±10%) for normal and lognormal probability distributions.

Rowe, J. F. A Construction Cost Contingency Tracking System (CTS). ***Cost Engineering Journal,*** **Vol. 48, No. 2, Feb. 2006, pp. 31–37.**
The author of this article presents a forward-looking cost contingency tracking system that uses readily available cost information and a simple spreadsheet format. Using the contingency tracking system, project managers can assign contingency to construction contracts, track its consumption, and manage a reserve for upcoming work. This article discusses the development of rules, using the perceived risk of each construction contract, to assign an initial contingency value to each construction contract.

Shafer, S. L. Estimate and Project Risk Analysis Approaches. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1991, pp. K.5.1–K.5.5.**
This paper discusses the different methods that can be used to identify risk and with that set contingency. It tells which method to use based on the individual characteristic of the project at hand.

Shafer, S. L. Risk Analysis for Capital Projects Using Risk Elements. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1974, pp. 218–223.**
This paper introduces a definition of risk based on cost engineering standards and not the mathematical approach. The purpose of the paper is to present a simple mathematical aid, based on "risk assessments," for (a) determining undefined costs, (b) evaluating range of accuracy, and (c) presenting the results of analysis to management.

Smith, G. L. Monte Carlo Simulation: A Tool for Combating Uncertainty in Economic Analysis. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1966, pp. 1–17.**
This paper describes how a Monte Carlo simulation can and should be used. It describes how the simulation will handle the uncertainty and produce the best estimate from the given data.

Smith, K. A., and R. L. Thoem. Project Cost Evaluation Using Probability Concepts. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1974, pp. 275–279.**
This paper outlines a stronger technique for preparing realistic cost estimates for major capital investments by using probability techniques. These probability concepts for project evaluation are then compared with traditional approaches.

Smith, R. J. ***Owner's Guide to Saving Money by Risk Allocation: Report to the American Consulting Engineers Council and Associated General Contractors of America.*** **American Consulting Engineers Council, Washington, D.C., 1992, pp. 1–17.**
This report examines the ability to divide up the risk of a project so as not to affect any one party more than another. This can be done if the risk is properly handled and assigned to the appropriate member of the construction team.

Sonmez, R., A. Ergin, and M. T. Birgonul. Quantitative Methodology for Determination of Cost Contingency in International Projects. ***Journal of Management in Engineering,*** **Vol. 23, No. 1, pp. 35–39.**
This paper presents a quantitative methodology to determine financial impacts of risk factors during the bidding stages of international construction projects. Project and country data for 26 construction projects from 21 countries were collected for evaluation of the international risk factors. The factors affecting cost contingency were identified using correlation and regression analysis technique.

Stevenson, J. J., Jr. Determining Meaningful Estimate Contingency. ***Cost Engineering Journal,*** **Vol. 26, No. 1, Feb. 1984, pp. 35–41.**
This article describes the problems that a power plant company went through to establish a program for setting contingency on the retrofitting operations of many of their power plants. It describes their goals for the project and how they went about attaining them.

Stukhart, G. Sharing the Risks of the Cost of Inflation. ***Professional Practice Guide to Risk,*** **AACE International, Morgantown, W.Va., 1982, pp. M.1.1–M.1.7.**
This paper discusses the risk of inflation over the period of a construction project. It discusses how and to whom the effect of inflation should be dispersed. It also talks about how the contract can help divide some of these costs for the contractor.

Touran, A. Probabilistic Model for Cost Contingency. ***Journal of Management in Engineering,*** **Vol. 129, No. 3, June 2003, pp. 280–284.**
This paper proposes a probabilistic model for the calculation of project cost contingency by considering the expected number of changes and the average cost of change. The model assumes a Poisson arrival pattern for change orders and independent random variables. The probability of cost overrun for a given contingency level is calculated.

U.S. Department of Energy. ***Program and Project Management for the Acquisition of Capital Assets.*** **Order DOE O 413.3B, Nov. 29, 2010.**
This document provides program and project management direction for the acquisition of capital assets that are delivered on schedule,

within budget, and fully capable of meeting mission performance and environmental, safety, and health standards.

U.S. Department of Energy. *Project Management Practices, Risk Management.* U.S. Department of Energy Office of Management, Budget, and Evaluation, and Office of Engineering and Construction Management, June 2003.
This document is designed to provide acquisition professionals and program and project management offices with a reference for dealing with system acquisition risks. It is intended to be useful as an aid in classroom instruction and as a reference for practical applications.

U.S. Department of Transportation. *Risk Assessment Methodologies and Procedures.* Prepared by Parsons, San Francisco, Calif., June 2004.
The report explains in detail the rationale for risk analysis of public transit capital projects. The emphasis is on probabilistic methods for evaluating risks—as this approach provides an effective way to model uncertain events—and describes the procedures a project owner should follow to carry out the process.

Washington State Department of Transportation, Olympia, Wash. http://www.wsdot.wa.gov/.
This site was used to conduct research and contains many valuable links and much useful information.

Wright, P. A., and T. V. Hill. Cost Estimating: Dealing with Uncertainty. *Professional Practice Guide to Risk,* AACE International, Morgantown, W. Va., 1986, pp. E.5.1–E.5.8.
This paper discusses the problem of cost estimating and how to deal with other types of markets. It goes into detail about how to use a probabilistic method for construction cost estimates when dealing with other economic market uncertainties. It also describes how to forecast future competitive activity in other economic markets.

Yeung, D. K. L., S. Cheung, K. K. W. Cheung, and H. C. H. Seun. Web-Based Project Cost Monitoring System for Construction Management. *AACE International Transactions,* IT.09, Morgantown, W. Va., 2003, pp. 9.1–9.11.
This paper discusses the concepts of developing an automated online cost control/monitoring and assessment system for construction projects. One of the key functions of a project cost monitoring system is as a detector of potential risks and hazards in cost management, or as a warning sign to the client and professionals that the preset cost budget is overrun and requires immediate corrective action.

Zeanah, P. H. Advanced Techniques for Contingency Evaluation. *Professional Practice Guide to Risk,* AACE International, Morgantown, W. Va., 1973, pp. 68–75.
This paper reviews the fundamentals of probability and then uses these techniques—along with Monte Carlo simulation and decision trees analysis—to better understand an estimate when uncertainty is involved. It explains how to use these techniques when using objective data.

SOC Annual Meeting 2008

The AASHTO Subcommittee on Construction (SOC) 2008 annual meeting was held August 3–7, 2008, in San Antonio, Texas. The following papers relevant to risk management of rapid renewal projects were presented:

- Seven Bridges in 75 Days, E. Powell, North Carolina Department of Transportation.
- Risk Assessment for Bonds for Highway Contracts, M. McCallum, National Association of Surety Bond Producers.
- An Update on the Accelerated Construction Technology Transfer Program, Experiences and Lessons Learned, C. Schneider, FHWA.
- Accelerated Bridge Construction (ABC) and the Utah Experience, K. Peterson, Utah Department of Transportation, and M. L. Ralls, Ralls Newman, LLC.
- Quality Assurance in Design–Build Projects, D. Gransberg, University of Oklahoma.
- Alternative Contracting Approaches to Accelerate Project Completion, I. Damnjanovic, Texas Transportation Institute.

The AASHTO SOC has posted these papers on its website: http://construction.transportation.org/Pages/default.aspx (accessed Aug. 22, 2013).

Additional Sources

Contract Administration Section, AASHTO Subcommittee on Construction. *Primer on Contracting: for the Twenty-first Century,* 5th ed. AASHTO, Washington, D.C., 2006. http://construction.transportation.org/Documents/PrimeronContracting2006.pdf. Accessed Oct. 16, 2013.

Pakkala, P. *Innovative Project Delivery Methods for Infrastructure: An International Perspective.* Finnish Road Enterprise, Helsinki, Finland, 2002.

Texas Department of Information Resources. http://www.dir.state.tx.us/eod/qa/risk/.

Agency Contact List

The following is a list of contact information for agencies whose representatives participated in interviews or who were invited to attend a pilot workshop.

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

Federal Highway Administration
Headquarters, Southeast Federal Center Building
1200 New Jersey Avenue, SE
Washington, DC 20590-9898

Federal Highway Administration
Resource Center
61 Forsyth Street SW, Suite 17126
Atlanta, GA 30303

Federal Highway Administration
Washington Division
711 South Capitol Way, Suite 501
Olympia, WA 98501

Arizona Department of Transportation
Room 131A, MD 102A
206 South 17th Avenue
Phoenix, AZ 85007

California Department of Transportation Headquarters
1120 N Street
P.O. Box 942873
Sacramento, CA 94273-0001

Colorado Department of Transportation
Project Development Branch
4201 East Arkansas Avenue, 4th Floor
Denver, CO 80222

Florida Department of Transportation
605 Suwannee Street
Tallahassee, FL 32399

Hawaii Department of Transportation
Aliiaimoku Building
869 Punchbowl Street
Honolulu, HI 96813

Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010

Minnesota Department of Transportation
1000 Highway 10 West
Detroit Lakes, MN 56501

Nevada Department of Transportation
1263 South Stewart Street
Carson City, NV 89712

New York State Department of Transportation
50 Wolf Road
Albany, NY 12232

North Carolina Department of Transportation and North Carolina Turnpike Authority
5400 Glenwood Avenue, Suite 400
Raleigh, NC 27612

Oregon Department of Transportation, Region 1
123 NW Flanders Street
Portland, OR 97209-4012

Seattle Department of Transportation
Capital Projects and Roadway Structures Division
700 Fifth Avenue, Suite 3900
Seattle, WA 98104

Utah Department of Transportation
Mail Stop 141200
4501 South 2700 West
Salt Lake City, UT 84114-1200

Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219

Washington State Department of Transportation
Cost Risk Estimating Management
310 Maple Avenue SE
P.O. Box 47336
Olympia, WA 98504-7336

Ministry of Transportation Alberta
Twin Atria Building, 2nd Floor
4999 - 98 Avenue
Edmonton, AB T6B 2X3
Canada

Ministry of Transportation British Columbia
940 Blanshard Street
Victoria, BC V8W 9T5
Canada

Ministry of Transportation Ontario
301 St. Paul Street
St. Catharines, ON L2R 7R4
Canada

Other contacts include Texas DOT, Idaho DOT, Wisconsin DOT, Alaska DOT, King County (WA) DOT, and the Federal Transit Administration (FTA).

APPENDIX B

Study Management

Task 5, the task of overall study management of the R09 project, entailed the following:

- Managing the research and the research team. This involved coordinating the technical Tasks 1–4 (including technical meetings) and submitting technical reports.
- Completing miscellaneous SHRP 2–directed activities (e.g., developing and presenting a poster for the 2009 TRB annual meeting).
- Communicating regularly with SHRP 2 regarding project status throughout the duration of the project, including
    - Monthly and quarterly progress reports, including work completed to date, remaining work, potential problems, and budget and schedule status;
    - Interim meetings with SHRP 2 staff (one in Washington, D.C. and one in Seattle, Washington);
    - Teleconferences and web meetings as needed; and
    - Status reports, including a briefing at a meeting of the Renewal Technical Coordinating Committee.
- Responding to a SHRP 2 request for recommending additional future work.
- Developing and submitting to SHRP 2 the draft Task 1 Gap Analysis and Detailed Plan Report on October 31, 2008.
- Developing and submitting to SHRP 2 on July 16, 2010, the draft of this research report, and on February 15, 2011, this final research report, which documents the process and results (e.g., of the pilot workshops) but is separate from the guide and implementation materials.

APPENDIX C

Gap Analysis

Research was conducted to ascertain what gaps exist in the current FHWA *Risk Guide* and associated implementation materials with respect to application in rapid renewal projects. The gap analysis leading to the development of a detailed work plan (Task 1) consisted of the following:

- Literature review (see Appendix A)
- Review of ACTT program (see Chapter 2)
- Agency surveys and interviews (see this appendix below)
- Summary of industry experience (see this appendix below)
- Review of existing guidelines (see Chapter 2)

The gap analysis and the resulting detailed work plan for completing the project are summarized in this appendix.

Surveys

An important part of the research under this project (both in Task 1 and in Task 2) was to obtain relevant information from state departments of transportation (DOTs). This research into DOTs consisted of the following:

1. A recent successful survey of DOTs regarding their risk management programs—conducted by members of the research team under a separate contract (see Chapter 2).
2. Development of a rapid renewal survey to follow up on DOTs' experience with rapid renewal projects and their risks, conducted under this project (in Task 2), and subsequent interviews with DOTs and with other SHRP 2 Renewal contracts (see Chapter 2 and Appendix D).

Previous State-of-Practice Survey

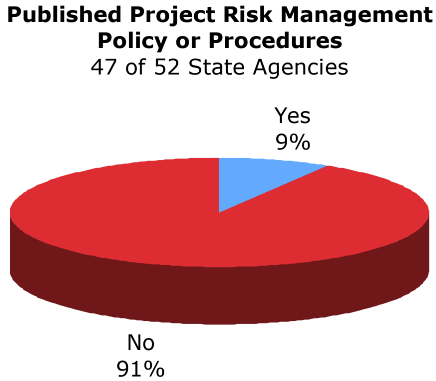
Introduction

The research team on NCHRP Project 8-60, Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs, consisted of members also on the SHRP 2 Project R09 research team. These researchers developed a state-of-practice survey to identify how different transportation agencies and organizations determine contingencies and manage risk-related costs throughout the project development process. The team received responses from 48 of the 52 state highway agencies, from four Canadian agencies, and from more than 130 individuals. Beyond receiving responses to the survey questions, the team received many e-mail and web addresses with which to find additional agency information. California, Ohio, and the FHWA sent their risk and contingency planning guides. Other agencies provided web links. This information provided the team with a snapshot of current practice in setting contingencies and dealing with risk.

Figure C.1 displays the results of two survey questions. They are Numbers 10 and 19:

10. Does your organization have a formal, published definition for contingency that is used consistently throughout the estimating process?
19. Does your organization have a formal, published project risk management policy or procedures?

As seen in Figure C.1, only one in five agencies has a formal published definition for contingency that is used consistently throughout the estimating process, and only one in 10 agencies has a formal, published project risk management policy or procedure. Both of these results describe the need for research into standard risk management practices and analysis tools. The research team was not surprised at the small number of published risk management policies and procedures. The literature review confirmed that the use of risk management for cost estimating and project management is an emerging trend in the highway sector. However, the research team was surprised by the low number of agencies that have a published definition for contingency. The use of



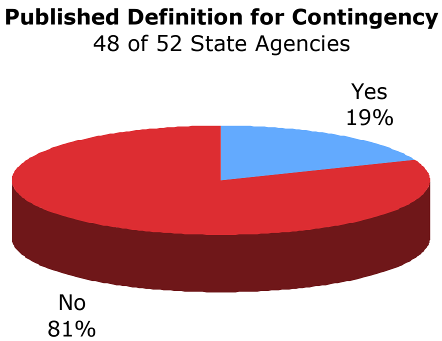


Figure C.1. Current state of practice in contingency and risk management.

contingency becomes linked to risk management in the estimating phase of project development. In the early planning stages of a project, contingencies represent the project's uncertainties. If agencies want to be effective in managing project costs and controlling cost escalation, it is essential to recognize contingencies (uncertainties) and include them in their early cost estimates. An important first step in that recognition is for agencies to develop and publish a definition of *contingency;* doing so provides for its transparent and consistent application and helps promote accuracy in cost estimates throughout project development.

Agency Estimating Organizations

To develop an applicable guide for risk management practices aimed at controlling transportation project costs, it is essential to understand how an agency organizes itself to create cost estimates during the project development process. This research project simplified the project development process to three distinct phases: planning, programming and preliminary design, and final design. In discussions with agencies, the research team found that organizations for creating estimates fell into three categories: a separate section that is solely responsible for estimates; planners, designers, and project managers who join together to develop estimates; and a combination of the first two categories. Table C.1 provides a summary of the survey results.

As Table C.1 shows, few agencies maintained a separate group solely for estimating. Only about one-third of them have such a separate group to support designers and managers in the planning stage and programming and preliminary design stage. This proportion rose to over one-half for the final design stage. This decentralized estimating function in the early stages of planning and project development implied that the risk management function must also be decentralized, or at least not solely dependent on a central risk management unit.

For the planning phase, the Illinois DOT was the only state agency that solely used a separate estimating group. A strong majority of the state agencies—31 of the 48 that responded—left the responsibility for estimating to the planners at this stage. The remaining 16 state agencies used a combination of both methods. These planners could have been internal agency planners, consultants, or metropolitan planning organizations, depending on the agency.

For the programming and preliminary design phase, no respondents used a separate estimating group. Again, a large majority of the state agencies—32—relied solely on designers and project managers to develop the cost estimates. The same 16 states used a combination of both methods.

For the final design phase, agencies from only two states, Mississippi and Wyoming, solely used a separate estimating section. At this stage in project development, 21 of the 48 state agencies relied solely on designers and project managers while the majority used both a separate group and designers and project managers.

The survey asked for the names of separate estimating sections. Table C.2 provides a listing of the estimating section names to provide a sense of who is supporting the planners, designers, or project managers with their estimating tasks.

Table C.1. Agency Organizations for Creating Estimates

Phase of Project Development Process	Type of Organization Used: Separate Group of Estimators	Planners, Designers, and Project Managers	Combination of Both
Planning	1 (2%)	31 (65%)	16 (33%)
Programming and preliminary design	0 (0%)	32 (67%)	16 (33%)
Final design	2 (4%)	21 (44%)	25 (52%)

Note: 48 of 52 state agencies reporting.

Table C.2. Agency Estimating Sections

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

Table C.3 summarizes the use of ranges by agencies to communicate estimates. The results of the survey showed that over half the states were using ranges to communicate estimates. The results also showed, as expected, a decrease in the use of ranges as projects developed. Theoretically, the communication of estimates through ranges would be most appropriate at the earliest stages of project development when the project scope is most uncertain. As the level of information increases, estimate certainty increases and point estimates become more reliable.

Table C.3. Agency Use of Ranges to Communicate Estimates

Project Phase	Never Use Ranges (%)	Sometimes Use Ranges (%)	Always Use Ranges (%)
Planning	36	55	9
Programming and preliminary design	53	38	9
Final design	70	19	11

Note: 48 of 52 state agencies reporting.

The results of this survey show that range estimates are being used to communicate project cost estimates. The guide presents tools to help agencies accurately and consistently estimate appropriate ranges.

Risk Management Practices

Risk is inherent in every capital transportation project. Risk is defined in the dictionary as the possibility that something unpleasant or unwelcome will happen. In this study, *risk* is defined as an uncertain event or condition that, if it occurs, has a negative or positive effect on a project's objectives. Risk management involves all of the steps associated with managing risks: risk identification, risk assessment, risk analysis (qualitative or quantitative), risk planning, risk allocation, and risk monitoring control.

State-by-State Risk Management and Contingency Application

While risk is indeed inherent in every capital transportation project, the survey found that only three of the 48 state agencies had a formal, published project risk management policy or procedures. In these three states, it was clear how the risk analysis related to controlling cost escalation. In the other states, the manner in which the agencies set their project and program contingency implied that they recognize and incorporate risks into project estimates, just not in a formalized risk management procedure. The following paragraphs describe how different states set contingency and analyze risk in projects.

California

The California State Department of Transportation (Caltrans) has different definitions for contingency based on the phase of the project. The Caltrans *Project Risk Management Handbook* defines *contingency* as the amount of money or time needed above the estimate to reduce the risk (Caltrans 2007). The Caltrans *Project Development Procedures Manual* (PDPM) states that contingency factors for project planning cost estimates vary depending on the cost estimate type.

Contingencies are intended to compensate for the use of limited information. The percentage goes down as the project becomes more defined and thus less unknown. As stated in the PDPM, contingencies are not intended to take the place of incomplete design work. Project alternatives and their associated cost estimates must be thoroughly compiled by diligently using all of the available data, modifying that data with good judgment, and using past cost estimating experience so that the cost estimates can be used with confidence.

Table C.4 shows the contingency breakdown based on type of estimate.

Caltrans has developed a capital project risk management process, which is intended to result in the effective management of project risks (threats and opportunities). The objective of the process is to help project sponsors and teams make informed decisions regarding project alternatives. Together the project manager, sponsor, and team members develop a plan for how to identify, assess, quantify, respond to, monitor, and control capital project risks. If a quantitative risk analysis using the capital project risk management process shows that the contingency percentage is inadequate, an exception can be made to exceed this number (Caltrans 2007).

This summary of the Caltrans process was written primarily from the survey response. An in-depth case study of the Caltrans risk management process is provided in the NCHRP 8-60 report.

Florida

The Florida DOT (FDOT) does not have a formalized definition of contingency. However, the state does employ both program and project contingencies. FDOT has a program contingency that is applied across the board on all projects. Each district, based on its available funds, sets the contingency amount. This contingency is a general catchall but includes project changes, additional projects added to the program, cost increases, and supplemental agreements (change orders). There is also a project contingency (known as project unknowns) that is used to cover scope additions/refinements and bid unit price escalations. Table C.5 provides FDOT's general guide for determining the project unknown factor in each estimate.

Maryland

The Maryland DOT does not have a formal definition of contingency but does have a guide that is used as estimates are developed with the project phases. The agency sets the guidance, but the engineers/project managers have discretion based on the level of engineering done for each phase. The survey response stated that the estimator's discretion is based on a general risk analysis of how confident the DOT is that the cost estimate includes the entire project scope. The general percentages of contingency can be seen in the Table C.6.

Table C.4. Caltrans Sliding-Scale Contingency

Estimate Type	Contingency (%)
Planning estimates	25
General plan estimates	20
Marginal estimate/final PS&E	5

Note: PS&E = plans, specifications, and estimates.

Table C.5. Florida Sliding-Scale Contingency

Project Phase	Project Unknown Factor (%)
Initial cost estimate	25
Design scope of work	20
Design Phase I (30%)	15
Design Phase II (60%)	10
Design Phase III (90%)	5
Design Phase IV (100%)	0

Missouri

The project manager and design team evaluate risks and include the consideration of risk in the estimate. The survey response stated that this is not done through a formal risk analysis such as a Monte Carlo simulation but indicated that the input collected from varied sources is similar to what a risk assessment workshop would yield.

Montana

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

Nevada

The Nevada DOT did not provide a formal definition for contingency or risk management. However, the agency has a published procedure that documents a sliding scale for contingency at three levels. Table C.7 lists these percentages.

During the course of a project's development, the division establishes a level of confidence for the project data called a

Table C.6. Maryland Sliding-Scale Contingency

Project Phase	Contingency (%)
Planning	35–40
Programming and preliminary design	25–35
Final design	0–25

Table C.7. Nevada Sliding-Scale Contingency

Project Phase: Level of Design Confidence	Contingency (%)
Preliminary design: Design Level 1	15
Intermediate design: Design Level 2	10
Final design: Design Level 3	3

design level. These levels indicate to design managers, in very general terms, how much confidence they can have in project information currently available to them. The design team must keep the accuracy of the schedule and estimate compatible with the design level of the project.

During preliminary design, the confidence level is at Design Level 1. The project schedule should be based on the work breakdown structure template for the appropriate project type. The schedule should be maintained using historical data from previous projects of similar nature, conversations with major project contributors, and the judgment of experienced project management professionals. A project coordinator should be able to predict the quality assurance (QA) review submittal date to within 3 to 6 months. At this level the design team should maintain the estimate using rough estimating techniques, the best information readily available, and 15% for contract contingencies. The design team should always develop its own estimates and not rely on previous attempts.

During the intermediate design, the confidence level is upgraded to Design Level 2. The schedule should be correlated with the final scope to include all remaining tasks and be maintained using man-hour estimates, detailed conversations with major project contributors and the judgment of experienced project management professionals. A project coordinator should be able to predict the QA review submittal date to within 1 to 3 months. At this level the estimate should reflect costs for all work being contemplated, and the design team should have rough calculations to back them up. There should be few, if any, lump sum “guesstimates” at this level. All items of work should be identified, the associated units of work should be incorporated into the engineer’s estimate, and the contract contingencies should be set to 10%.

During final design, the confidence level is changed to Design Level 3. The schedule should be based on the actual man hours needed to complete the remaining work and guaranteed delivery dates from major project contributors. A project coordinator should be able to predict the QA review submittal date to within 1 to 3 weeks. At this level, the estimate should be based on actual units of work, the associated quantities should reflect checked calculations, and contract contingencies should be set to 3%.

Ohio

The survey respondents from the Ohio DOT believe that reasonable contingencies should be built into the total project budget estimate. Although contingencies are not included for the final engineer’s estimate, a contingency based on different levels of design completion are included in the project’s total cost estimate. For example, at the beginning of the detail design, a design development contingency around 30% may be appropriate. As the actual design approaches 100%, the design development contingency should approach 0%. These contingencies may be developed based on previous historical data for projects of similar type and size.

The Ohio DOT also e-mailed the research team a copy of its Excel-based procedure for construction budget estimating. It has multiple areas that address risk and contingency, including design contingency, constructible risk/contingency, and inflation contingency. A process for determining each of these three contingency values is described in the procedure. Figure C.2 shows a sliding-scale contingency for design from the procedure.

Utah

The Utah DOT develops contingencies on a case-by-case basis. The agency provides some initial suggested values but allows the designers/developers to use independent judgment to finalize the correct contingency. The initial suggested values were not specified by the survey respondents. However, the respondents did state that a 10% change order contingency is added on all projects at advertisement.

Virginia

Standard practice is to use 10% for contingency on the construction phase. However, project managers do have the flexibility to ask for an increased contingency if unique aspects of the project have a higher associated risk. Means and methods for setting contingency would be unique to the project and based on a risk profile that highlights probability and impact.

Washington

The Washington State DOT (WSDOT) defines contingency as a markup applied to account for substantial uncertainties in quantities, unit costs, and minor risk events related to quantities, work elements, or other project requirements. WSDOT uses a combination of a standard predetermined contingency and a risk-based analysis. Table C.8 provides the standard predetermined contingencies from the survey response.

For all projects over $25 million, a formal risk analysis is performed and a range estimate and risk register of identified risk events are produced. From this risk profile, the higher end of the range, usually the 90th percentile, is selected. A miscellaneous item allowance percentage is also applied to the design depending on the development

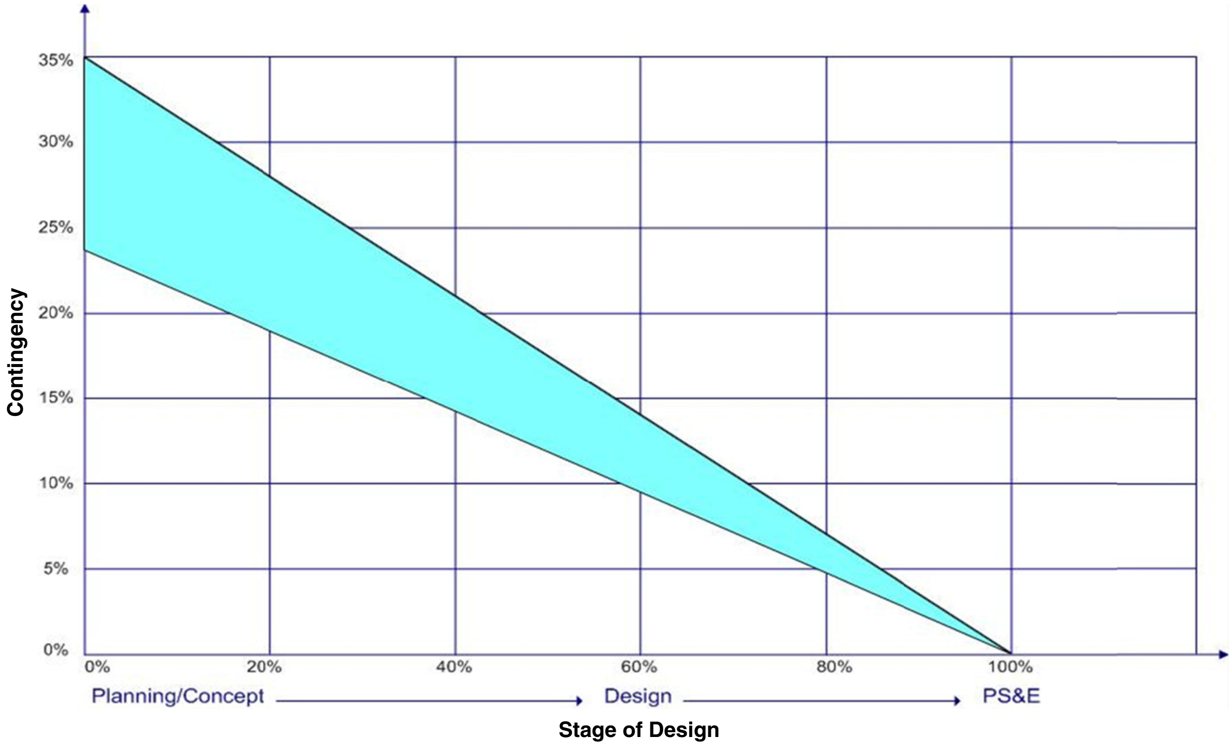


Figure C.2. Ohio DOT design completion contingency guidelines for cost estimating of major projects.

level of the project. The general percentages can be seen in Table C.8.

WSDOT has developed a cost risk assessment (CRA) process. CRA describes a broad program of risk-based assessments being conducted within WSDOT. CRA also describes a workshop process similar to but less intense than WSDOT's Cost Estimate Validation Process (CEVP). Risk management is an integral part of the WSDOT project management process. A key difference between conventional estimating and CEVP/CRA is the representation of project cost and schedule as a distribution (range) rather than as a point estimate. A major aspect of the CEVP/CRA method is to parse a conventional project estimate into those components representing base and those representing risk. The risk elements, treated as variables, are then described in terms of their possible consequences and probability of occurrence.

Table C.8. Washington State Sliding-Scale Contingency

Project Phase	Miscellaneous (%)
Planning	30–50
Programming and preliminary design	20–30
Detailed design	10–20

Conclusions

The state-of-practice survey provided valuable information for the research team. It clearly demonstrated the need for guidance on risk management and estimation of contingencies. It highlighted common tools currently being used by agencies. When mapped against the literature review, the survey also revealed tools for risk analysis and risk management that are absent from the transportation sector. Finally, the survey pointed to the best agencies to interview in the next phase of this research.

Rapid Renewal Survey

A rapid renewal survey, which followed up on the state-of-the-art survey, was conducted with state DOTs to focus on rapid renewal risks. A draft of the survey questionnaire was developed during Task 1. After further research, the survey was revised and streamlined under Task 2. The final version of the rapid renewal survey is presented in Appendix D.

Summary of Industry Experience

As previously noted, several of the research team members have extensive experience in managing risks for rapid renewal projects. Some of this experience is summarized in Table C.9.

Table C.9. Rapid Renewal Elements from Previously Conducted Risk Assessments by Golder Associates Inc.

Owner	Project	Existing Facility?	Rapid Renewal Elements	Notes
Colorado DOT	I-70 Mountain Corridor	Yes	• Opportunity to use alternative delivery method (e.g., design–build; CM/GC). • Opportunity to use separate (early) procurement contracts for owner-supplied materials or other major specialty items.	Overall, not a rapid renewal project (conventional delivery method anticipated; funding constrained), but there may be opportunities to incorporate rapid renewal elements.
Florida DOT	I-595 Corridor Improvements (Fort Lauderdale)	Yes	• Fund and deliver using PPP (DBFOM) to complete improvements up to 10 years sooner than if delivered conventionally. • Replace aging facility with minimal disruption to traffic during construction.	www.i-595.com/faq.aspx
Florida DOT	US-92 near DeLand	Yes	• Minimize disruption during construction (reduce lane closures, reduce intersection closures) by using precast, posttensioned concrete panels at critical intersections and high early-strength concrete to shorten curing times for the rest of the roadway.	New approach for FDOT.
Florida DOT	First Coast Outer Beltway	No	• Fund and deliver using PPP (DBFOM) to complete improvements years sooner than if delivered conventionally.	
Iowa DOT	Council Bluffs Interstate System Improvements Project	Yes	• Early utility relocations.	Overall, not a rapid renewal project (design–bid–build, funding constrained).
Iowa and Illinois DOTs	Illinois–Iowa Corridor Project (I-74, including Mississippi River crossing)	Yes	• Early utility relocations.	Overall, not a rapid renewal project (design–bid–build, funding constrained).
Kane County, Illinois	Stearns Road/Fox River Bridge	Mostly no (improving existing and extending into new alignment; the bridge is a new crossing over the Fox River)	• Advance steel-fabrication contract for bridge steel.	Otherwise, not a rapid renewal project.
Nevada DOT	NEON	Yes (I-15)	• Considering alternative funding/delivery (PPP).	Risk assessment not yet done on this project.
Pennsylvania DOT/Port Authority of Allegheny County	Pennsylvania High-Speed Maglev	No	• Early design and procurement of guideway steel beams. • Design–build delivery system for civil construction. • Early right-of-way acquisition for early utility relocations.	Overall, not a rapid renewal project. Not sure this project is moving forward (no news on website dated later than 2005).
Port Authority of New York and New Jersey	PATH (World Trade Center Site)	Yes (replacing existing facility destroyed in 9/11 attacks)	• Alternative project delivery method (CM/GC).	
Utah DOT	I-15 NOW	Yes	• Design–build delivery. • Early right-of-way acquisition. • Early utility relocation.	

(continued on next page)

Table C.9. Rapid Renewal Elements from Previously Conducted Risk Assessments by Golder Associates Inc. (continued)

Owner	Project	Existing Facility?	Rapid Renewal Elements	Notes
Utah DOT	I-15 South	Yes	• Design–build delivery. • Early utility relocation.	
Utah DOT	Mountain View Corridor	No	• Design–build delivery. • Early right-of-way acquisition for early utility relocation.	
Washington State DOT	Everett High-Occupancy Vehicle (HOV) Project	Yes	• Design–build delivery system to speed delivery of urban project.	Completed.
Washington State DOT	SR-99/Alaskan Way Viaduct Projects	Yes	• Opportunity to use alternative delivery method for one or more projects. • Early right-of-way acquisition. • Early utility relocations.	Overall, not a rapid renewal project (conventional delivery method anticipated), but there may be opportunities to incorporate rapid-renewal elements.
Washington State DOT	SR-167 High-Occupancy Toll (HOT) Lanes	Yes	• Design–build delivery to quickly implement civil and systems construction of demonstration HOT lanes.	Completed.
Washington State DOT	I-405 Corridor	Yes	• Design–build delivery.	Various phases of design and construction.
Washington State DOT	SR-519	Yes	• Design–build delivery.	
Washington State DOT	SR-509	Yes	• Design–build delivery being considered, but project is unfunded.	
Washington State DOT	Various projects (e.g., SR-304 Bremerton tunnel; SR-522 Snohomish River Bridge)	Yes	• Early right-of-way acquisition and/or early utility relocations.	Generally not rapid renewal projects, but they employ one or more rapid renewal elements.

Note: PPP = public–private partnership; DBFOM = design–build–finance–operate–maintain; CM/GC = construction manager/general contractor.

Task 1 Report

After completion of Task 1, to develop a detailed work plan for the entire project, the project team documented its work in a report. In addition to reporting the results of the gap analysis, the Task 1 Project Report documented the recommended revisions and updates to FHWA's *Guide to Risk Assessment and Allocation for Highway Construction Management* (*Risk Guide*), which focus on rapid renewal projects. These recommendations also drew from recently conducted FHWA risk workshops. Tables C.10 and C.11 summarize these suggested revisions to the *Risk Guide* and accompanying materials.

Table C.10. *Suggested Revisions or Updates to FHWA's* Guide to Risk Assessment and Allocation for Highway Construction Management (Risk Guide)

Location	Suggested Revision or Update	Reason	Reference
New Chapter 2	Add a new chapter on developing a project "baseline" for risk assessment. A project baseline consists of (1) identifying and documenting key project assumptions, scope, delivery strategy, and baseline costs and (2) developing a sequence of major activities (flowchart) and baseline schedule. An approximately five-page chapter would be required to describe this content. This chapter would be consistent in style and detail with the existing chapters in the *Risk Guide.* This would be the new Chapter 2.	Establishing a project baseline (i.e., the project without risk) is an important first step in the risk assessment process, because risks must be identified and measured against some baseline. While the current version of the *Risk Guide* addresses identification, assessment, management, monitoring, and tracking of risks, it does not address the concept of a baseline or how to develop a baseline.	FHWA workshop training materials (MS PowerPoint slides with notes). Included as an appendix.
New Chapter 9	Add a new chapter on implementing the guidance presented in previous chapters of the *Risk Guide.* This chapter would present step-by-step instructions for implementing the *Risk Guide* to conduct identification, assessment/prioritization, and management of cost and schedule risks for many projects (i.e., how to implement the guidance in the new Chapter 2 and renumbered Chapters 3, 4, and 6). This chapter would summarize (and reference) the more-detailed FHWA workshop training materials and MS Excel FHWA risk management spreadsheet template and forms (in appendices), which were designed as tools to help project managers implement the *Risk Guide.* A discussion would be added regarding how to set up a program within a DOT to conduct such risk assessment/management. This 10–15-page chapter would be the new Chapter 9.	The existing *Risk Guide* presents a philosophy and set of concepts but doesn't provide specific information or detail required to actually implement those concepts and conduct risk assessments on real projects.	FHWA workshop training materials (MS PowerPoint slides with notes; risk "forms" in MS Word) and FHWA risk management spreadsheet template (in MS Excel). Included as appendices.
New Appendix E	Include the FHWA workshop training materials (including the MS PowerPoint slides printed with Notes pages, as well as forms and other materials) as the new Appendix E to the *Risk Guide.*	The FHWA workshop materials were designed to serve as (1) a more detailed set of information on the concepts presented in the *Risk Guidelines* and (2) a set of instructions on how to implement elements of those concepts for project risk assessment/management.	FHWA workshop training materials (MS PowerPoint slides with notes; risk "forms" in MS Word).
New Appendix F (electronic)	Include the FHWA risk management spreadsheet template as an electronic attachment (Attachment A or Appendix F).	The FHWA risk-management spreadsheet template (in electronic form) can be used directly by project teams to help conduct a risk identification, assessment/prioritization, and management exercise for many projects.	FHWA risk management spreadsheet template (in MS Excel).
New Appendix G	Add an appendix discussing application specifically to rapid renewal projects. This would include the following: 1. Expansion of performance objectives regarding baseline and risks; 2. Inventory of rapid renewal methods; 3. Changes in baseline model for specific rapid renewal methods; 4. Checklist of risks and their potential mitigations for each rapid renewal method; 5. Modification of risk "forms" (in MS Word) and risk management template (in MS Excel) for additional performance objectives and baseline models to cover rapid renewal projects; 6. Example; and 7. References/bibliography.	Risk assessment/management methods/guidance are generally the same for rapid renewal projects as for other projects. However, there are some unique aspects associated with rapid renewal projects, so the FHWA forms and template cannot always be used directly. These unique aspects need to be identified and the methods/tools appropriately modified to deal with them. This will allow project teams to conduct a risk identification, assessment/prioritization, and management exercise for rapid renewal projects.	SHRP 2 R09 guide and implementation materials.

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Table C.10. Suggested Revisions or Updates to FHWA's* Guide to Risk Assessment and Allocation for Highway Construction Management (Risk Guide) *(continued)

Location	Suggested Revision or Update	Reason	Reference
Existing Chapters 1–8 (i.e., Chapter 1, and renumbered Chapters 3–8 and 10)	Modify/update the existing Chapters 1–8 as needed based on work done for the FHWA workshop/short-course development, referencing new Appendix G for unique aspects regarding rapid renewal. These chapters would be Chapter 1 and the renumbered Chapters 3–8 and 10. (Note: This is a generalized comment that will require a complete pass through the guidelines to ensure complete consistency with the workshop training materials. Not all of these changes, many of which are editorial in nature, are listed in this table. However, some of the more significant suggested modifications and revisions are called out in individual items below.)	Make the existing chapters consistent with revisions and modifications that resulted from development and delivery of the FHWA workshops. However, those methods/guidance are not applicable to all projects (e.g., some rapid renewal projects). Refer to new Appendix G for these special cases.	FHWA workshop training materials (MS PowerPoint slides with notes). Included as appendix.
Appendices A–D	Modify/update the existing Appendices A–D as needed based on work done for the FHWA workshop/short course development. (Note: This is a generalized comment that will require a complete pass through the appendices to ensure complete consistency with the workshop training materials.)	Make the existing chapters consistent with revisions and modifications that resulted from development and delivery of the FHWA workshops.	FHWA workshop training materials (MS PowerPoint slides with notes). Included as appendix.
Existing Chapters 1 (p. 9), 2 (pp. 13, 14), 3 (p. 20), 4 (p. 26), 5 (p. 30), 6 (pp. 25, 26), and 7 (p. 40)	Modify/update the existing hypothetical (QDOT) case study as needed based on work done for the FHWA workshop/short course development. This hypothetical case study is referred to in most existing chapters of the *Risk Guide,* so it would need to be updated appropriately throughout the *Risk Guide.*	The existing description of the hypothetical project was enhanced for use in the FHWA workshop's practical exercises. The hypothetical description now includes more detail, as well as a baseline description and descriptions of potential cost and schedule issues in multiple disciplines.	FHWA workshop training materials (MS Word document with hypothetical project description and schematic). Included as appendix.
Existing Chapter 1	1. Update risk management process figure (Figure 5) to include Define Baseline step. Make the same modification anywhere else this process diagram occurs. 2. Discuss project overruns, as well as the need to compare alternatives with different risk profiles, as other reasons for conducting risk assessment/management. 3. Add discussion of why risk management is particularly critical to rapid renewal projects. A definition of rapid renewal projects will be provided here, and it will be noted that most of the unique aspects of rapid renewal projects will be covered in Appendix G.	1. To ensure consistency with modifications/revisions mentioned previously. 2. Generally, the primary reason for conducting risk assessment/management is to reduce the actual ultimate project cost and schedule and to get more for the money and/or prevent overruns (which often happen with sometimes disastrous consequences). 3. To ensure a focus on rapid renewal projects and describe why risk management is different on these projects.	1. FHWA workshop training materials (MS PowerPoint slides with notes). 2. FHWA workshop training materials (MS PowerPoint slides with notes). 3. Rapid renewal inventory.
Existing Chapter 2 and Appendix B	Add a more-comprehensive risk checklist as a resource, or replace one or more of the existing examples with a more comprehensive checklist. Refer to Appendix G for rapid renewal–related risk lists. Also, point out the following: 1. Risk registers (charters) need to be comprehensive, nonoverlapping lists of risks and opportunities; and 2. Risk checklists, although intended to be comprehensive in a generic way, are often at different levels of detail and not necessarily intended to be nonoverlapping lists of risks (i.e., they are not proper risk registers or charters).	The existing example lists are illustrative, but none are particularly comprehensive because they come from one owner or type of project. A more comprehensive and generic list based on many risk assessments for multiple owners and project types could be useful to agencies that are new to risk assessment.	FHWA workshop training materials (MS Word document with a more comprehensive, generic risk checklist). Included as appendix.

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Table C.10. *Suggested Revisions or Updates to FHWA's* Guide to Risk Assessment and Allocation for Highway Construction Management (Risk Guide) *(continued)*

Location	Suggested Revision or Update	Reason	Reference
Existing Chapter 3	1. Modify the presentation Risk Screening (Section 3.4 and on, and related figures) to include two additional risk identification and rating/ranking methods. Also include a comparison of the pros and cons of the three presented methods for identifying and rating/ranking risks. 2. Discuss subjective assessments and biases.	1. The method presented in the existing *Risk Guide* is vague and often misused. Alternative methods are available, depending on the owner's risk-identification and rating/ranking objectives. Two such methods were presented in detail in the FHWA workshop/short course, and the FHWA risk management spreadsheet template has one of these methods built into it. 2. Due to the general lack of representative databases, most assessments will be subjective (i.e., based on opinion). Such subjective assessments are prone to bias, which must be recognized and mitigated to the extent possible.	FHWA workshop training materials (MS PowerPoint slides with notes) and FHWA risk management spreadsheet template. Included as appendices.
Existing Chapter 4	Modify discussion of the following: 1. Sensitivity to consider impacts on target percentile of escalated cost rather than on either (but not the combination of) the mean or variance of various performance; and 2. Correlation among uncertain factors.	1. The impact of any particular factor on the budget (which is typically a target percentile of the total escalated cost) is typically of most interest in prioritizing risks. 2. Correlations among uncertain factors have a major impact on the results. If correlations (which are most often positive) are ignored, then the uncertainty in the outputs (and thus in the target percentile) is underestimated.	FHWA workshop training materials (MS PowerPoint slides with notes). Included as appendix.
Existing Chapter 5	Add discussion of the following: 1. Evaluation of potential risk mitigation actions; 2. Determination/management of contingency drawdown (currently in Chapter 7.4); and 3. Recovery plans.	Guidance is needed on how to evaluate mitigation actions, how to determine appropriate contingency for various project milestones, and how to develop an appropriate recovery plan (if contingency is inadequate).	FHWA workshop training materials (MS PowerPoint slides with notes) and FHWA risk management spreadsheet template. Included as appendices.
Existing Appendix A	Add summary/reference to case studies developed as part of research projects for FHWA (TxDOT, FDOT, CDOT, VDOT).	The methods presented in the workshops were successfully implemented on projects, which have been adequately documented in separate case studies.	FHWA case studies.
Existing Glossary	Refine and add definitions, as needed.	The glossary is incomplete and needs to be consistent with modifications/revisions mentioned previously.	FHWA workshop training materials (MS PowerPoint slides with notes). Included as appendix.
Existing References and Bibliography	Add items as needed.	Many additional references were used in the development of the FHWA workshop training materials.	FHWA workshop training materials (MS PowerPoint slides with notes). Included as appendix.

Table C.11. Suggested Revisions or Updates to Implementation Materials

Location	Suggested Revision or Update	Reason	Reference
New Module 8	Add a module discussing application specifically to rapid renewal projects. This would include: 1. Expansion of performance objectives regarding baseline and risks; 2. Inventory of rapid renewal methods; 3. Changes in baseline model for specific rapid renewal methods; 4. Checklist of risks and their potential mitigations for each rapid renewal method; 5. Modification of risk "forms" (in MS Word) and risk management template (in MS Excel) for additional performance objectives and baseline models to cover rapid renewal projects; and 6. Example.	Risk assessment, management methods, and guidance are generally the same for rapid renewal projects as for other projects. However, there are some unique aspects associated with rapid renewal projects, so the FHWA forms and template cannot always be used directly. These unique aspects need to be identified and the methods/tools appropriately modified to deal with them. This will allow project teams to conduct a risk identification, assessment/prioritization, and management exercise for rapid renewal projects.	SHRP 2 R09 guide and implementation materials.
Existing software training	Modify training to include different forms and templates for rapid renewal projects.	Different forms and templates will probably be used for rapid renewal projects.	SHRP 2 R09 guide and implementation materials.
All other training materials	Modify/update all the existing training materials as needed based on work done for the SHRP 2 R09 development. This would probably include primarily adding reference (as appropriate) to new Module 8 in the slide notes.	Most of the risk assessment/management methods will be the same for traditional and for rapid renewal projects. The unique aspects of rapid renewal projects will be contained in one module.	SHRP 2 R09 guide and implementation materials.

APPENDIX D

Other Research Activities and Results

The key elements of the SHRP 2 R09 project research include the following:

- Establishing appropriate rapid renewal project performance objectives and related measures;
- Developing inventories of rapid renewal methods, risks, and feasible management actions;
- Establishing an appropriate risk management process;
- Developing a template for documenting assessments (also forms) and automatically calculating performance measures, consistent with that process; and
- Developing the guide, training materials, and other workshop materials.

Of these key elements, all except additional surveys conducted to support development of inventories are adequately discussed in the main text and in other appendices or are covered in the guide. The following section provides more details on these additional surveys.

Follow-Up Survey

A draft survey for DOTs was developed early on in the project and then later revised under Task 2 to more efficiently solicit information on rapid renewal methods, their risks, and possible mitigation from DOTs (see final version of questionnaire in Figures D.1 and D.2). The team completed interviews with select DOT personnel. The results of those interviews are summarized as follows:

1. *Deputy preconstruction engineer, Utah Department of Transportation (UDOT).* The interview focused on UDOT's accelerated bridge construction (ABC) program for 17 bridges using self-propelled modular transporters (SPMTs), which is currently in design and construction. The main risk categories involved the potential failure of innovative equipment and the coordination with utilities/stakeholders. Risk management actions included use of innovative delivery methods (design–build and CMR) and facilitated partnering sessions with utility partners.
2. *Research engineer, assistant director, Texas Center for Transportation Research.* The interview focused on the High Five Project in Dallas, which was constructed from 2001 to 2007. The main risk categories involved accelerated bridge design, off-site prefabrication of bridge elements, and the use of delayed-start contract provisions to allow contractors to prepare for in-traffic work before starting. Risk management actions included the use of performance specification for bridge design, lane rental provisions, incentives/disincentives, and extensive public outreach.
3. *Director, construction, Texas Department of Transportation (TxDOT).* The interview focused on the I-10 program of nine accelerated projects in Texas that was constructed from 2003 to 2008. The main risk categories were the coordination risk of maintenance of traffic and utilities on phased projects. Risk management actions included hiring a general engineering consultant to coordinate contracts with a focus on maintenance of traffic and utilities. TxDOT also employed incentives and disincentives at contract coordination points.
4. *Senior transportation engineer, partnering coordinator, California Department of Transportation (Caltrans).* The interview discussed the Fix I-5 in Sacramento, which was recently completed; it accelerated a 305-day project to 35 days through a full closure approach and use of innovative materials. The main risk categories involved public relations, management of traffic, and failure of innovative pavement materials. Risk management actions included early and continuous stakeholder interaction and communication. Caltrans also conducted extensive mix design research and off-site testing.

Project Number SHRP 2 R09
Guide for the Process of Managing Risk on
Rapid Renewal Projects:
Short (Fifteen Minute) Survey Questionnaire on Managing Risk on Rapid Renewal Projects

You are invited to participate in a study of managing risk on rapid renewal projects under the SHRP 2 program. Our project (R09) will develop a guide for risk management on rapid renewal projects. The guide is intended for use by transportation agencies to manage risk during the project development process. The guide will address methods for risk identification, assessment, analysis, mitigation, allocation, and monitoring, including methods to objectively prioritize risks and to objectively evaluate their mitigation/allocation. As part of developing the guidelines, the guidelines will be applied to at least two projects (case studies) and materials will be developed to implement the guidelines for these projects.

Background

To address the challenges of moving people and goods efficiently and safely on the nation's highways, Congress has created the second Strategic Highway Research Program (SHRP 2). SHRP 2 is a targeted, short-term research program carried out through competitively awarded contracts to qualified researchers in the academic, private, and public sectors.

SHRP 2 addresses four strategic focus areas: the role of human behavior in highway safety (Safety); rapid highway renewal (Renewal); congestion reduction through improved travel time reliability (Reliability); and transportation planning that better integrates community, economic, and environmental considerations into new highway capacity (Capacity). The *Risk Guidelines* are being developed under the Renewal Focus Area.

The overall goal of the SHRP 2 Renewal program is to develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities, as well as satisfies the other transportation development objectives (e.g., minimum capital cost, minimum environmental impacts, maximum transportation benefits, etc.). The renewal scope applies to all classes of roads.

Additional background on this topic is presented in the Task 1 (Gap Analysis and Detailed Plan) Report for this project, which is available from Dr. W. Roberds of Golder Associates by phone at xxx-xxxx or by email at xx@xxx.com.

Figure D.1. Final survey questionnaire (page 1).

5. *Project manager Region 1, Colorado Department of Transportation (CDOT).* The interview focused on the widening of I-25 south of Denver, which is currently in the request for proposal preparation stage using a design–build approach. The main risk categories involved agency unfamiliarity with the process and ROW acquisition issues. Risk management actions included agency training and augmentation of ROW staff.

See Appendix A for these agencies' general contact information.

Questionnaire

Basic Survey Participant Information

1. Name / Position / Organization?
2. Primary state / region working in?
3. Address, Phone, Email contacts?
4. Please check the item below which best describes your organization
    A. State DOT
    B. Other public agency
    C. Consultant
    D. Contractor
    E. Other—please explain
5. Please check your primary construction sector
    A. Highway
    B. Transit
    C. Other—please explain
6. Approximate size of your program ($/yr)?

Rapid Renewal Policy/Market

7. Does your organization have an established policy re. rapid renewal? If so, please summarize.
8. Have you done or are you considering doing rapid renewal projects? If not, why not? If so, please continue below.

Rapid Renewal Methods and Risks (if you have done or are considering doing Rapid Renewal Projects)

9. What rapid renewal methods (if any) have you used, or are you considering (please distinguish between actual and considered), in each of the following areas?
    A. Innovative Contracting/Financing
    B. Roadway/Geometric Design
    C. Structures
    D. Traffic Engineering/Safety/ITS
    E. Environment
    F. Construction
    G. Right-of-Way/Utilities/Railroad Coordination
    H. Geotechnical/Materials/Accelerated Testing
    I. Long Life Pavements/Maintenance
    J. Public Relations
10. What problems (with regard to the project performance objectives of Cost, Schedule, Disruption, Quality/longevity) have arisen (if used), or would you be concerned about (if being considered), with each of these rapid renewal methods?
11. How might each of these problems have been (if occurred), or could be (if not yet happened), addressed beforehand?
12. Are you interested in reducing risks (and thereby better meeting the project performance objectives of Cost, Schedule, Disruption, Quality/longevity) associated with Rapid Renewal Projects? If not, why not? If so, do you want to be actively involved in this research (e.g., have one of your Rapid Renewal projects evaluated using the methods developed in this research)?

Figure D.2. Final survey questionnaire (page 2).

APPENDIX E

Pilot Workshops

Pilot Workshop Planning

As explained in Chapter 2, an evaluation process was devised to fairly select from among the five DOTs identified as potential candidates for pilot workshops of the guide and implementation materials. A primary set of selection criteria was established:

- High chance of success of that DOT's workshop;
- High contribution to the chance of success for that DOT's future risk management program; and
- High contribution of that DOT to the chance of success of future national risk management program.

The factors that contribute to meeting these primary criteria were identified, and the specific information needed to assess those factors and evaluate the criteria was identified. The five DOTs were sent a request for information that would allow the research team to evaluate their suitability for piloting a risk management workshop for rapid renewal. The responses of the DOTs to the request for information have been summarized in Table E.1, which allows a side-by-side comparison. The table also summarizes the scoring based on the selection criteria.

First Pilot Workshop

During the first pilot workshop, participants tested the guide and implementation materials on a North Carolina Department of Transportation (NCDOT) rapid renewal project on Topsail Island in the Outer Banks. The description reflects the status of the project at the time of the pilot workshop in 2009.

Base Project Description: Topsail Island Bridge Replacement (TIP B-4929) Alternative 5

NCDOT proposed to build a new bridge to replace the existing swing bridge No. 16 over the Intracoastal Waterway on NC-50/210 in Surf City (see Figure E.1). This is one of two bridges providing access to Topsail Island (the other is 7 miles away). The existing bridge, a steel-truss swing-span bridge, was built in the 1950s and was due for replacement (see Figure E.2 for a view of the replacement plan). The new bridge will address the following needs:

- Provide a connecting structure between the mainland and the island with sufficient capacity allowing for emergency access, hurricane evacuation, and acceptable travel times.
- Improve the structural capacity of the bridge.
- Provide consistency with state and local land use and transportation plans (NCDOT 2009).

Planned Project Scope, Strategy, Key Conditions, and Assumptions

There are currently 16 alternatives for this bridge replacement. Each of the 16 alternatives is essentially a variation on location of the replacement bridge. There are several "bascule" bridge options in addition to high-rise bridges. For the purposes of this pilot risk management training course, Alternative 5 is assumed for evaluation (a cost estimate exists for this alternative). Therefore, all notes in this base description reflect Alternative 5. At this time, all design criteria are assumptions based on similar bridges. Uncertainty about which alternative is ultimately selected is excluded from this training course.

- *Scope elements.* Major scope elements included in Alternative 5 are as follows:
  - Replacement bridge will lie on an alignment approximately 450 ft north of the existing bridge that ties back to NC-50-210 at both ends.
  - Cost estimate is based on a single 42-ft by 2,647-ft bridge.
  - Bridge will accommodate two 14-ft-wide lanes, plus 2-ft shoulders and 5-ft sidewalks on each side of the bridge.

(text continues on page 55)

Table E.1. Evaluation of Proposals

Questions	FDOT	MnDOT	NCDOT	VDOT	NYSDOT
A. Briefly describe the workshop logistics:	Good attendance, but too much project team and not enough potential facilitators. Reasonable location/facility. Their dates are unavailable—we can see if they can do Oct. 15–16 (maybe), Oct. 22–23, or Nov. 12–13.	Good attendance, but too much project team and not enough potential facilitators. Reasonable location/facility—easiest to get to. They can do Oct. 22–23 (we can also see if they can do Nov. 12–13).	Good attendance, but too much subject matter experts and not enough potential facilitators. Assume reasonable facility, but hardest to get to. Their dates are flexible—assume they can do Oct. 15–16 (maybe), Oct. 22–23, or Nov. 12–13.	Poor attendance for training and small facility. Reasonable location—relatively easy to get to. Their dates are unavailable—we can see if they can do Oct. 15–16 (maybe), Oct. 22–23, or Nov. 12–13.	Assume good attendance for training (future facilitators). Assume reasonable facility, but hard to get to. Their dates are flexible—assume they can do Oct. 15–16 (maybe) or Oct. 22–23 (we can also see if they can do Nov. 12–13).
1. Proposed workshop attendance (i.e., type/role of participants within the SHA and number)? (Note: max attendance is 23 plus up to two FHWA staff.)	23 (project VE team, project team, district and HQ VE).	23 (MnDOT district staff, MnDOT central staff, several from Wisconsin).	20 (design, construction, maintenance, ROW/utilities, environmental, contracts, VE).	12 (district PM, innovative project delivery assistant director, discipline managers).	23 (max).
2. Proposed workshop venue (i.e., location, size, facilities, etc.)?	Miami, FL District 6 Office Auditorium (several miles from Miami AP; nonstop flight into Miami from SEA, 6:47 p.m. flight out of Miami to SEA; airfare is $420 RT and 14 hours flying time).	Capacity of 30 [e.g., Stoney Creek Inn in La Crosse, WI (previous workshop), near project site; 150 miles/2.5 hours from MSP, which has nonstop from SEA and 9:50 p.m. flight to SEA; airfare is $240 RT and 7 hours flying time plus 4 hours driving].	NCDOT HQ in Raleigh (up to 20 mi/30 min from Raleigh AP, which has one-stop flight into Raleigh AP from SEA, and 6:50 p.m. flight out of Raleigh AP to SEA; airfare is $220 RT and 15.5 hours flying time).	(a) In VDOT northern district office in Chantilly, VA (near Dulles airport, which has nonstop from SEA, and 7:11 p.m. flight to SEA; airfare is $290 RT and 12.5 hours flying time). (b) Small facility (15).	NYSDOT Schenectady conference and training center (less than 10 mi from Albany AP, which has one-stop flight from SEA but last flight out to SEA is at 5:50 p.m.; airfare is $350 RT and 14.5 hours flying time plus extra night hotel).
3. Available dates for workshop (two contiguous days)?	Oct. 26–27 or Nov. 4–5	Week of Oct. 19 or 26	Flexible	Oct. 26–27 (Mon.–Tues.)	2nd, 3rd, or 4th week of Oct.
B. Briefly describe the rapid renewal project(s) that would be evaluated in the workshop, specifically in terms of the following key attributes:	Project is too big/complex for training workshop and insufficient info provided or available on website. Presumably can either use portion of this project or select from among other projects—should be able to identify a suitable rapid renewal project with adequate info.	Project is too big/complex for training workshop and insufficient info provided or available on website, but has had RA recently. Also unclear what rapid renewal feature is. However, presumably can select from among other projects—should be able to identify a suitable rapid renewal project with adequate info.	Projects (a) and (c) are too small; not clear what rapid renewal feature is for (b) and (d). Need to select from among many projects—should be able to identify a suitable rapid renewal project with adequate info.	Suitable project/info, but not clear what rapid renewal feature is besides D–B.	Need to select from among many projects—should be able to identify a suitable rapid renewal project with adequate info.

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Table E.1. Evaluation of Proposals (continued)

Questions	FDOT	MnDOT	NCDOT	VDOT	NYSDOT
4. Name and location of project?	SR-93/I-75 Corridor Study [including Homestead Extension of Florida Turnpike (HEFT)].	Dresbach Bridge Replacement (SP8580-149) I-90 over Mississippi River near Dresbach, MN.	Choices: (a) Hillsborough St. in Raleigh. (b) US-74 Independence Blvd. in Charlotte. (c) I-277 in Charlotte. (d) NC-55 in Durham.	Route 27/244 IC, Arlington, VA.	? For example, (a) Tappan Zee Bridge replacement. (b) BQE triple cantilever project in NYC. (c) Other less complex projects (many projects to choose from).
5. Approximate size of project (e.g., construction cost in inflated $)?	Total: $900 million (without contingency). Without HEFT: $400 million (without contingency).	Construction cost: $231 million YOE.	Construction amount: (a) $3.0 million. (b) $77.3 million. (c) $3.6 million. (d) $25.8 million.	Construction contract: $40 million.	? (Many projects to choose from.)
6. Scope of project (including rapid renewal elements)?	(a) Add two managed lanes in each direction on I-75 and SR-826. (b) Three new special-use lane Ices, and one other new IC. (c) Road/IC improvements. (d) P&R lot and noise walls.	New bridge over Mississippi River offset from old bridge, requiring realignment of approaches and reconstruction of IC. Adjacent to RR, lock/dam, and recreation area.	(a) Bridge replacement. (b) Widen corridor, roadway, structures (including reversible lane BRT accommodations). (c) New IC on major urban Interstate. (d) Widen/replace RR bridges.	Replace Washington Blvd. Bridge and related road improvements. Rapid renewal element(s): only D–B?	? (Many projects to choose from.)
7. Procurement method (D–B–B or D–B)?	D–B or D–B–O (toll)	D–B–B	?	D–B	? (Many projects to choose from.)
8. Current status of project?	Draft EIS.	30% design (draft EA).	(a) Let date: Nov. 2009. (b) Let date: June 2012. (c) Let date: May 2012. (d) Let date: May 2014.	30% design—RFQ.	? (Many projects to choose from.)
9. Major project decision alternatives (e.g., regarding scope or strategy)?	(a) D–B vs. D–B–O (toll) vs. PPP. (b) ICs. (c) Interagency coordination.	(a) D–B vs. D–B–B. (b) Change alignment (less offset and cost). (c) Innovative construction techniques to reduce disruption.	?	?	? (Many projects to choose from.)
10. Quality of information available for workshop (e.g., cost estimate, schedule, and project description)?	Only website provided.	Apparently late 2008 CRAVE report (not provided). Some info available at MnDOT website (but not cost or schedule).	?	(a) Parametric estimate. (b) Schedule. (c) D–B design/contract requirements. (d) Preliminary design/RFP. Some info available on website.	? (Project description, cost estimate, and schedule should be available for selected project.)

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Table E.1. Evaluation of Proposals (continued)

Questions	FDOT	MnDOT	NCDOT	VDOT	NYSDOT
11. Key project issues?	Funding and project delivery, MOT, Ices, inter-agency coordination.	MOT (I-90 truck freight), RR, lock/dam, recreation area, topography (500-ft high bluffs).	(a) Urban, utilities, MOT, constructability, coordination. (b) Urban, MOT, utilities, constructability, coordination with city and transit. (c) Urban, MOT, utilities, constructability, coordination with city. (d) Urban, MOT, utilities, constructability, coordination with RR.	MOT, utilities, environmental, contract administration.	? (Many projects to choose from.)
C. Briefly describe the interest your SHA has in setting up a formal risk management program:	Large need, but currently developing RM program—high interest.	Moderate need, but developing RM program—moderate interest.	Large need and no RM program—high interest.	Moderate need and no RM program—moderate interest.	Large need, but currently developing RM program—high interest.
12. What experience does your SHA have with formal risk management (including an existing formal risk management program within your SHA)?	Have conducted formal risk analysis on several mega projects. Currently developing RM program through Office of Design team (with district and HQ staff), procuring an external resource and drafting procedure.	Starting to establish formal risk management program, both at broad project level and at project level. Have established Project Scope and Cost Management Office.	RM not used on regular, recurring basis.	To date: informal RA for D–B projects. Currently: no formal RM program.	Starting to establish formal risk management program. Have draft guidance.
13. Is your SHA interested in implementing formal risk management more widely and, if so, why and to what extent?	Currently setting up RM program to satisfy FHWA requirement of developing risk-based cost estimates if >$100 million.	Need to broadly implement RM strategies.	Yes (enthusiastically).	Yes for larger/more complex projects.	Yes—high priority.
14. How would such a program likely fit in your organizational structure (e.g., centralized with VE group versus decentralized, internal resources versus outsourced, etc.)?	HQ Office of Design for policy, procedures, and oversight; districts responsible for doing RM.	Policy, Analysis, Research and Innovation Office charged with RM at broad program level. Project Scope and Cost Management Office established to cover RM at project level.	Centralized (along with constructability, VE, etc.).	Centralized using internal/external resources.	Decentralized RM practice with oversight and QA from HQ.

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Table E.1. Evaluation of Proposals (continued)

Questions	FDOT	MnDOT	NCDOT	VDOT	NYSDOT
15. Approximate size of your SHA capital program (i.e., $/year) and portion that would be considered rapid renewal (i.e., %)?	$3 billion to $4 billion per year. Rapid renewal (e.g., D–B): 25%.	2009–2011: $950 million per year. Rapid renewal: 30%.	$1.0 billion per year for next 5 years in traditionally financed projects. 2010: $3.0 billion by NCTA. Rapid renewal: 15–20%.	Currently $1.5 billion under contract. 2010: 276 contracts to ad at $1.1 billion. 2011: 70 contracts to ad at $350 million. 2012: 38 contracts to ad at $205 million. But D–B (not included above) increasing rapid renewal: ?	$2.5 billion per year (including ARRA). Rapid renewal: 25% (and growing).
16. Approximate average cost increase and delays on your recent capital projects (i.e., in %) from planning through construction?	Cost increase just during construction: 5%. Schedule increase just during construction: 8%. Presumably, generally more from planning.	40% of projects have time overruns (how much?). ?% of projects have cost overruns.	>25% cost and >25% time overruns.	TBD.	0% to 100% cost increase (refers to website).
Timeliness/quality of response	On time, moderate quality (little re candidate project).	On time, moderate quality (little re candidate project).	1 week late, moderate quality (little re candidate project).	On time, good quality (good candidate project info).	1 week late, moderate quality (little re candidate project).

Category	FDOT	MnDOT	NCDOT	VDOT	NYSDOT
A	B+	A–	B+	B–	B
B	B	B–	B	A–	B–
C	A–	B–	A	B	B+
Weighted score	3.42	3.05	3.555	3.035	3.075

Grade	Points
A+	4.3
A	4.0
A–	3.7
B+	3.3
B	3.0
B–	2.7
Category	**Weight**
A	0.35
B	0.2
C	0.45

Source: NCDOT.

Figure E.1. Topsail Island bridge replacement.

  - Structure type for the bridge is assumed to be prestressed concrete (posttensioned girders at channel). The bridge will be a fixed structure (i.e., not movable over the waterway).
  - Vertical clearance of the bridge over the navigation channel is 65 ft.
  - Assumed substructure (foundation) type is drilled piers. Number of foundations/piers is 2.
  - Bridge will have 19 to 22 spans.
  - Total project length is 0.92 miles. Construction of new roadway section is required for most of the alignment; thus, fill import, compaction, roadway construction and asphalt paving are also included.
  - Removal of existing bridge No. 16 and its approaches is included.
  - A fender system may be required.
- *Funding.* Project is funded (State Transportation Improvement Program) as follows: $200,000 for PE/design; $1 million for right-of-way (ROW); $25 million for construction.
- *Design*
  - Design level: Alternative 3 is at 0% design overall.
  - Structural: See above.
  - Geotechnical: No information yet on subsurface conditions.
  - Pavement: No pavement design has been determined yet.
  - Design deviations: None expected.
- *Environmental*
  - Environmental documentation: NCDOT will prepare an Environmental Assessment (EA) for this project and is completing a National Environmental Policy Act (NEPA) checklist.
  - Wetlands: The area is surrounded by wetlands to the north and south; bridging of most of these wetlands is anticipated.
  - Streams: Intracoastal Waterway.
  - Endangered Species Act (ESA) and Migratory Bird Treaty Act (MBTA): Impacts to ESA are not yet known. Colonial water bird nesting sites are present in the project area. Mitigation may be required.

Source: NCDOT.

Figure E.2. Topsail Island bridge replacement (plan view).

The project is also located within a Primary Nursery Area.

- Floodplain: The project is in the 100-year floodplain, and the area is tidal influenced.
- Storm water: It is assumed that a collection system will be required; there will be no direct discharge into the waterway.
- Contaminated/hazardous waste: No known sites.
- Section 106: Existing bridge is eligible for listing in the national register of historic places; no historic districts or individual properties are known at this time.
- Section 4(f): Soundside Park is located adjacent to the roadway on the south side. Wildlife Resources Commission also has a boat landing at this site; it is the only public boat access in the vicinity.
- Permitting (including 404): Coastal Area Management Act (CAMA) major development and/or dredge/fill permit is required; state storm water permit is also required. Permits will be required with the U.S. Coast Guard, U.S. Army Corps of Engineers, and North Carolina Division of Water Quality.

- *Right-of-way and other agreements*
  - Right-of-way: The project assumes that a 100-ft right-of-way will be required. Beyond that, easements will be required.
  - Utilities: No major utilities are involved in Alternative 5.
  - Railroad: There is no railroad involvement.
  - Other: Additional stakeholders include Surf City, North Topsail Beach, Topsail Beach, and various service agencies (e.g., North Carolina Department of Environmental and Natural Resources, U.S. Army Corps of Engineers, U.S. Coast Guard).
- *Procurement*
  - Delivery method: The project expects to use traditional procurement.
  - Contract packaging: Single contract.

- *Construction*
  - Construction access/restrictions (including seasonal, events, shifts/hours): There will likely be an in-water construction moratorium from February 15 to September 30 for the Primary Nursery Area.
  - Maintenance of traffic/business (disruption): During construction, traffic will continue to use the existing movable bridge. There will be interruptions due to intersection tie-ins. Services to businesses and residences will be affected.
  - Construction phasing
    - Assumption is that new bridge will be built first, then tie-ins, and then the old bridge will be removed.
    - During construction, traffic will remain on the existing movable bridge No. 16. On completion of construction, the existing bridge will be removed (demolished).
  - Rapid renewal: There are no plans for rapid-renewal construction elements/methods.
- *Postconstruction (longevity)*
  - Operations and maintenance (O&M): No projections for operation/maintenance.
  - Replacement: 75 years.

Table E.2 shows the project activity and planned start and completion dates.

Project Cost Estimate (Delivery, O&M, Replacement)

- Professional engineer (preliminary and final design/PS&E): $5 million, 2009 dollars, without contingency.
- Right-of-way: $12.5 million, 2009 dollars, without contingency.
- Utilities: $546,000, 2009 dollars, without contingency.
- Construction: Contract cost of $30.7 million, including 15% E&C.
  - Estimate is in October 2009 dollars (per the spreadsheet).
  - Line items labeled “Misc. and Mob” allowances for known costs and contingency for risk.
- O&M: Estimated average annual O&M for new bridge is $50,000/year.
- Replacement: Not estimated.

Project Schematics

See Figures E.1 and E.2.

Evaluation of First Pilot Workshop

The evaluation of the first pilot workshop was held in Raleigh, N.C., for NCDOT/NCTA on October 29–30, 2009. It consisted of the following:

- Participants’ evaluation of the workshop (using an evaluation form that accommodated comments; see Table E.3);
- Initial SHRP 2 staff comments on the workshop and materials, and the research team response to those comments; and
- Additional SHRP 2 staff comments on the workshop and materials, and the research team response to those comments.

A proposal was developed by the project team and subsequently approved by the SHRP 2 program officer to resolve some of the major comments (see the subsection Approved Changes).

Table E.2. Project Schedule

Project Activity/Phase	Planned Start Date	Planned Completion Date
Scoping	Complete	Complete
Preliminary design/engineering	Ongoing	6/2013
Environmental process [NEPA, environmental assessment, Finding of No Significant Impact (FONSI)]	Ongoing	EA: 11/2010 FONSI: 12/2011
Permitting	12/2010	6/2014
Final design/plans, specifications, and estimates (PS&E), including approvals	6/2013	3/2015
ROW acquisition (including demolition, relocation, and certification)	6/2013	3/2015
Utility coordination/relocation	7/2013	6/2015
Procurement (e.g., advertisement/bid/award/notice to proceed)	3/2015	6/2015
Construction	8/2015	8/2017

Table E.3. Summary of Participants' Evaluations of First Pilot Workshop

Question	1	2	3	4	5	Total	Average
1. Did the presentation follow the course materials?				11	6	17	4.35
2. Were the workshop goals and objectives clear?			2	11	4	17	4.12
3. Were the goals and objectives met?			3	10	4	17	4.06
4. Did the workshop advance your knowledge of risk management?				6	11	17	4.65
5. Was the workshop useful in assessing and managing risk on the project reviewed on Day 2?			3	4	10	17	4.41
6. Will the workshop help you assess and manage risk for your projects?			4	8	5	17	4.06
7. For your DOT implementation, what type of implementation do you believe would have benefit?	Yes	No	Total	Average (0 = no, 1 = yes)			
Use for moderately sized conventional projects [design–bid–build (D–B–B)].	4	13	17	0.24			
Use for major conventional projects (D–B–B).	15	2	17	0.88			
Use for nonconventional projects [design–build (D–B), concessionaire, etc.].	6	11	17	0.35			
Provide general training to department staff.	5	12	17	0.29			
Develop a formal risk management program that is integrated in the project development process.	13	4	17	0.76			
Other	1	16	17	0.06			
Please provide your comments/suggestions on the workshop.	<in comments>						
Would your DOT be interested in having additional training or project evaluations?	7	0	7	1.00			

Participant Evaluations of First Pilot Workshop

Seventeen course participant evaluations of the first pilot workshop were submitted. Those responses are tallied and summarized in Table E.3.

Approved Changes

A change in scope was proposed to remedy most of the substantive issues identified in the first pilot workshop evaluation, which led to the postponement of the second workshop.

The primary issue associated with the first pilot workshop was that there was too much lecturing on Day 1 (although this was balanced by the real project application on Day 2). Instead more exercises needed to be integrated with the lectures. Also, feedback suggested that too much material was presented too quickly on Day 1. Instead, a slower pace was needed, with more introductions, summaries, and reviews of each module, as well as more breaks.

The original agenda had been developed to accommodate the original scope of work, which included a real project application, while minimizing the time of busy project staff (who needed to attend only on Day 2 and would otherwise dilute the class on Day 1). The original agenda had also worked successfully on a previous, similar training course and been approved for this course.

The proposed rescoping consisted of replacing the real project application in the course with a more fully developed hypothetical project. The hypothetical project then allowed for more extensive exercises to be integrated with each lecture and did not require attendance by project staff. The course was still to be completed in 2 days but at a more relaxed pace, with adequate time for discussions, introductions, reviews, summaries, and breaks. The rescoping also involved inviting primarily potential future facilitators from the various state DOTs that had submitted proposals to host a pilot workshop to the second and final training workshop. The course instructors (under additional or separate funding) could subsequently observe and advise the newly trained facilitators when they conduct risk management on their own projects, as needed.

Other comments that were addressed related primarily to presentation style (some of which was affected by the fast pace noted above) and material format.

It was also agreed that the following changes would be made to the guide and implementation materials:

- Expand the example rapid renewal project (including a complete risk management plan) to become a central and integral part of the guide and training (per the approved change in scope), replacing the actual project evaluation on the second day of the workshop. Note that to generate a risk management plan, this would include a project description, base cost and base schedule (including ranges/correlations for full uncertainty version), risk register (identification and assessment, for both expected value and full uncertainty version), risk analysis model/results, and risk mitigation identification/evaluation.

- Revise the guide, slides, and syllabus to incorporate the example rapid renewal project throughout (per the approved change in scope), replacing the actual project evaluation on the second day of the workshop. Note that the example rapid renewal project was to be used throughout the guide and training to illustrate the process. Once finalized, this example project was to be integrated into the training materials as the primary learning exercise for each module (i.e., each step of the risk management process would be conducted by the students for this example project using the provided methods, guidance, and forms), followed by the instructors' "solution," which would be used going forward to subsequent steps in the process.
- Edit the guide and materials.
  - Revise Chapter 8 of the guide (in particular) to be more consistent with the slides and other chapters.
  - Revise the template (an MS Excel workbook) and hard-copy forms to be more functional, and develop a user's guide for the template.
  - Develop an introductory slide module (in MS PowerPoint) for risk workshops.
  - Reformat animated/annotated training slides (in MS PowerPoint) to the extent possible.
    - Simplify slides as necessary and as possible (considering available budget and original scope of work).
    - Avoid red/green colors when possible.
    - Add definitions as necessary (e.g., in notes).
    - Identify learning outcomes better (e.g., in objectives).
    - Make training module number same as guide chapter number.
  - Reformat the notebook.
    - Print some of the paper forms on 11 × 17 paper (as needed) and include copies of the relevant ones at the end of each module for use in the exercises (as well as in the guide for future use).
    - Create a specific exercise packet (i.e., the hypothetical project write-up) that can be easily removed from the notebook for use during the class and then reinserted back into the notebook, along with the relevant filled-in forms when done (both student version and instructor version). This would create a sample stand-alone risk register and risk management plan for the hypothetical project and enhance student learning.
    - Produce the rapid renewal risk and risk management inventories (which are guide appendices) so that they can be easily removed from the notebook for use during the class and then reinserted back into the notebook when done.

Second (and Final) Pilot Workshop

Attendance at the second pilot workshop was opened up to various DOTs. Positions of attendees are found in Table E.4.

Evaluation of the Second (and Final) Pilot Workshop

A survey was handed out to participants at the second pilot workshop. The results of that survey are documented in Table E.5.

Table E.4. Attendance List at Second Pilot Workshop, May 18–19, 2010, Redmond, Washington

Affiliation	Position
TRB	SHRP 2 program officer
FHWA	Columbia River Bridge (major project) engineer
FHWA	Washington Division: Construction, pavements, materials engineer
Washington State DOT	Cost risk estimating team leader
Washington State DOT	Manager of project development
Washington State DOT	Director of project control and reporting
Washington State DOT	Lead risk modeler
Washington State DOT	Transportation technical engineer
Minnesota DOT	Director of Office of Project Scoping and Cost Management
Minnesota DOT	Office of Project Scoping and Cost Management
Nevada DOT	Program director
North Carolina DOT	Quality Enhancement Unit
Oregon State University	Professor
University of Colorado	Co-principal investigator/professor
Golder Associates	Co-principal investigator/principal
Golder Associates	Principal

Table E.5. Summary of Participants' Evaluations of Second Pilot Workshop

Question	1	2	3	4	5	Total	Average
1. Did the presentation follow the course materials?				1	2	3	4.67
2. Were the workshop goals and objectives clear?				2	1	3	4.33
3. Were the goals and objectives met?				3		3	4.00
4. Did the workshop advance your knowledge of risk management?		1		1	1	3	3.67
5. Was the workshop useful in assessing and managing risk on the project reviewed on Day 2?			1	2		3	3.67
6. Will the workshop help you assess and manage risk for your projects?		1	1	1		3	3.00
7. For your DOT implementation, what type of implementation do you believe would have benefit?	**Yes**	**No**	**Total**	**Average (0 = no, 1 = yes)**			
Use for moderately sized conventional projects (D–B–B).	2	1	3	0.67			
Use for major conventional projects (D–B–B).	1	2	3	0.33			
Use for nonconventional projects (D–B, concessionaire, etc.).	1	2	3	0.33			
Provide general training to department staff.	2	1	3	0.67			
Develop a formal risk management program that is integrated in the project development process.	3	0	3	1.00			
Other	0	3	3	0.00			
Please provide your comments/suggestions on the workshop.	<in comments>						
Would your DOT be interested in having additional training or project evaluations?	1	0	1	1.00			

APPENDIX F

Recommendations for Future Work

Table F.1. Recommendations for Future Work

Proposed Activity	Short Term		Longer Term		Total
	Assumptions	Estimated Cost	Assumptions	Estimated Cost	Estimated Cost
Regarding the Guide (and Tools)	Sum of all short-term guide work (excluding management)	$65,000	Sum of all longer term guide work (excluding management)	$187,000	$252,000 (excluding management)
• Develop webinar (possibly paid in part by participants—"cost sharing").	40 h (develop) × 50% cost sharing with attendees	$4,000	20 h (update) × 50% cost sharing with attendees	$2,000	$6,000
• Write papers and make presentations (including webinars, if developed), as well as develop brochures, on guide. Present at various venues (e.g., TRB Annual Meeting, AASHTO Annual Meeting, TCM International Conference) for exposure.	Prepare and present paper at 2010 AASHTO (50 h + travel cost) and develop/distribute brochure (30 h + material costs)	$20,000	Present at 2011 TRB, 2011 AASHTO, 2011 TCM (150 h + travel costs)	$36,000	$56,000
• Plan and conduct 1- or 2-day users' conference in conjunction with well-attended event (e.g., TCM International Conference). Possibly paid in part by participants—cost sharing.	80 h (planning only) × 50% cost sharing with attendees	$8,000	120 h + travel and material costs (three staff to conduct) × 50% cost sharing with attendees	$15,000	$23,000
• Continue to obtain feedback and plan/improve materials (e.g., fix bugs in template, incorporate "inventories" into template, improve user interface).	20 h (minimal fixes)	$4,000	100 h (for improvements)	$20,000	$24,000
• Define and monitor metrics (e.g., collective and average project cost savings) to describe the benefits of implementing the guide.	20 h (define only)	$4,000	40 h (monitor)	$8,000	$12,000
• Plan, develop, and maintain database of approved case studies (e.g., considering confidentiality, including metrics).	20 h (planning only)	$4,000	200 h (capture 25 projects in database, at 8 h each)	$40,000	$44,000
• Plan, develop, maintain, and ultimately transfer website that would contain latest materials (i.e., guide, template, overview presentation, training presentation, references) for downloading, news, approved case studies (if collected), implementation metrics (if developed), and contact/help.	40 h (planning only)	$8,000	200 h (develop, maintain, transfer)	$40,000	$48,000
• Assist DOTs in setting up internal risk management group and implementing guide, in addition to training (which is separate). Include "hand-holding" and review during initial applications (which might become case studies) and recommending organizational structure/procedures (possibly cost sharing).	Sum of short-term application/organizational assistance	$13,000	Sum of longer term application/organizational assistance	$26,000	$39,000
○ On site (one staff, includes travel).	One DOT (80 h + travel cost) × 50% cost sharing with DOT	$9,000	Two DOTs (each 80 h + travel cost) × 50% cost sharing with DOT	$18,000	$27,000
○ Remotely (e.g., review).	One DOT (40 h) × 50% cost sharing with DOT	$4,000	Two DOTs (each 40 h) × 50% cost sharing with DOT	$8,000	$12,000

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Table F.1. Recommendations for Future Work (continued)

	Short Term		Longer Term		Total
Proposed Activity	**Assumptions**	**Estimated Cost**	**Assumptions**	**Estimated Cost**	**Estimated Cost**
Regarding Training	Sum of all short-term training work (excluding management)	$81,000	Sum of all longer term training work (excluding management)	$144,000	$225,000 (excluding management)
• Plan/develop (convert to) NHI course. Conducting is separate (see below).	40 h (planning only)	$8,000	200 h (develop)	$40,000	$48,000
• Plan/develop streamlined (half day) version for familiarization (e.g., for TRB Annual Meeting, TCM International Conference, DOT executives). Conducting is separate (see below).	80 h (planning and develop)	$16,000	20 h (update)	$4,000	$20,000
• Conduct additional live training (possibly cost sharing).	Sum of short-term live training	$21,000	Sum of longer term live training	$42,000	$63,000
○ Existing version or NHI version (if developed).	Sum of short-term existing/NHI training	$15,000	Sum of longer term existing/NHI training	$30,000	$45,000
▪ On site (two instructors, includes travel and materials).	One DOT (80 h + travel and material costs) × 50% cost sharing with DOT	$10,000	Two DOTs (each 80 h + travel and material costs) × 50% cost sharing with DOT	$20,000	$30,000
▪ Via web meeting (includes two instructors, if interaction developed).	One DOT (50 h) × 50% cost sharing with DOT	$5,000	Two DOTs (each 50 h) × 50% cost sharing with DOT	$10,000	$15,000
○ Streamlined version (if developed).	Sum of short-term streamlined training	$6,000	Sum of longer term streamlined training	$12,000	$18,000
▪ On site (one instructor, includes travel and materials).	One DOT/conference (30 h + travel and material costs) × 50% cost sharing with DOT/attendees	$4,000	Two DOTs/conferences (each 30 h + travel and material costs) × 50% cost sharing with DOTs/attendees	$8,000	$12,000
▪ Via web meeting (one instructor).	One DOT (20 h) × 50% cost sharing with DOT	$2,000	Two DOTs (each 20 h) × 50% cost sharing with DOT	$4,000	$6,000
• Develop remote version (with or without practical exercises—see below). Conducting is separate (see below).	Sum of short-term remote development work	$24,000	Sum of longer term remote development work	$6,000	$30,000
○ Record training course (slides plus audio) for web download.	80 h (initial)	$16,000	20 h (update)	$4,000	$20,000
○ Develop a way for instructors to interact with participants (e.g., they submit questions via e-mail and instructors reply via e-mail) and to conduct practical exercises remotely (e.g., at end of each module: (a) if self-study, students submit answers to instructors via web and receive corrections from instructors via web; or (b) if via web meeting, have discussion via teleconference and then discuss instructors' answers).	40 h (initial)	$8,000	10 h (update)	$2,000	$10,000

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Table F.1. Recommendations for Future Work (continued)

	Short Term		Longer Term		Total
Proposed Activity	**Assumptions**	**Estimated Cost**	**Assumptions**	**Estimated Cost**	**Estimated Cost**
• Respond to remote learning issues (e.g., respond to submitted questions and correct submitted practical exercises) if developed (possibly cost sharing).		$0	400 h (100 participants × 4 h each average) × 50% cost sharing with participants	$40,000	$40,000
• Arrange for continuing education credit (CEU) for participants (based on specific criteria, such as passing practical exercises or exam, which would have to be developed).	40 h (initial)	$8,000	20 h (update)	$4,000	$12,000
• Assist in applications by trainees to enhance their training, separately and in addition to simply helping with application (possibly cost sharing).	Sum of short-term application assistance	$4,000	Sum of longer term application assistance	$8,000	$12,000
○ On site during workshop (includes travel).	One DOT (20 h in addition to guide application) × 50% cost sharing with DOT	$2,000	Two DOTs (each 20 h in addition to guide application) × 50% cost sharing with DOT	$4,000	$6,000
○ Remotely (e.g., review).	One DOT (20 h in addition to guide application) × 50% cost sharing with DOT	$2,000	Two DOTs (each 20 h in addition to guide application) × 50% cost sharing with DOT	$4,000	$6,000
Subtotal (excluding management)	Sum of all short-term work (excluding management)	$146,000	Sum of all longer term work (excluding management)	$327,000	$473,000 (excluding management)
Regarding Management (e.g., monthly/quarterly reports, other miscellaneous requests)	10% of short-term work	$15,000	10% of longer term work	$33,000	$48,000
Total	Sum of all short-term work + management	$161,000	Sum of all longer term work + management	$360,000	$521,000

Related SHRP 2 Research

Performance Specifications for Rapid Highway Renewal (R07)
Project Management Strategies for Complex Projects (R10)
Integrating the Priorities of Transportation Agencies and Utility Companies (R15)
Identification of Utility Conflicts and Solutions (R15B)
Strategies for Improving the Project Agreement Process Between Highway Agencies and Railroads (R16)