SHRP 2 Renewal Project R09

Guide for the Process of Managing Risk on Rapid Renewal Projects

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SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP 2)
PROJECT R09 - DEVELOP A GUIDE FOR THE PROCESS OF MANAGING RISK ON RAPID RENEWAL PROJECTS (DR. J. BRYANT, PROJECT OFFICER)

FINAL

GUIDE FOR THE PROCESS OF MANAGING RISK ON RAPID RENEWAL PROJECTS

FEBRUARY 2011

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Golder Associates

Abstract

"Rapid renewal" transportation design and construction projects are specifically intended to minimize the delivery schedule and disruption during construction, while not adversely affecting project cost and longevity. Due to the innovative approaches and compressed schedules involved in rapid renewal, these projects can sometimes experience unexpected problems, or "risks", that lead to poor project performance. A formal and structured risk management approach, in which such potential problems can be adequately and efficiently anticipated, evaluated and addressed before they occur, can optimize project performance and significantly improve the chance of project success. This *Guide* describes such a risk management approach specifically for rapid renewal projects. However, the approach is also directly applicable to non-rapid renewal projects, and, in a general way, to even non-transportation projects and to programs comprised of individual projects.

This *Guide* is a relatively concise description of risk-management benefits, concepts, and process (the *"why"* and *"what"*). The *Guide* is supplemented by a set of companion implementation materials (the "*how-to")*, including: a) a two-day training course (with additional details and exercises in a separate notebook); and b) an MS PowerPoint overview presentation; c) forms; and d) an MS Excel workbook template (to facilitate documentation and analysis). These materials are specifically designed to help DOT risk management facilitators: a) conduct the critical parts of the risk management process on relatively simple projects, or b) supervise the other parts of the process or the evaluation of more complicated projects.

Preface

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 behaviour 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 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.

Golder Associates Inc. (lead by Dr. William Roberds and Dr. Travis McGrath) in association with Prof. Keith Molenaar (plus Michael Loulakis and Ted Ferragut) was awarded a competitively bid research project under the SHRP2 Renewal program, with Dr. J. Bryant as the TRB Program officer. The research project was entitled "R09 – Developing a Guide for the Process of Managing Risk on Rapid Renewal Projects" and was initiated in December 2007 and completed in June 2010.

The research expanded on substantial previous work by the research team, which included the development of the "Guide to Risk Assessment and Allocation for Highway Construction Management" and subsequent implementation materials (i.e., forms and an MS Excel template, and a training course) for FHWA. That document was completely rewritten (and the implementation materials expanded) to provide more detailed guidance (including checklists) and to specifically include consideration of rapid renewal projects, which tend to be more complicated and riskier, as well as traditional projects.

The primary objectives of the research were to:

- address the general lack of understanding and culture of risk management among DOTs, especially regarding rapid renewal projects; and
- develop practical guidance and tools for the application of risk management methods (which optimize project performance) to the rapid renewal project development process in a manner consistent with the business practices of DOTs, with the ultimate goal of developing an adequate capability for conducting risk management <u>within</u> those DOTs (to the extent possible).

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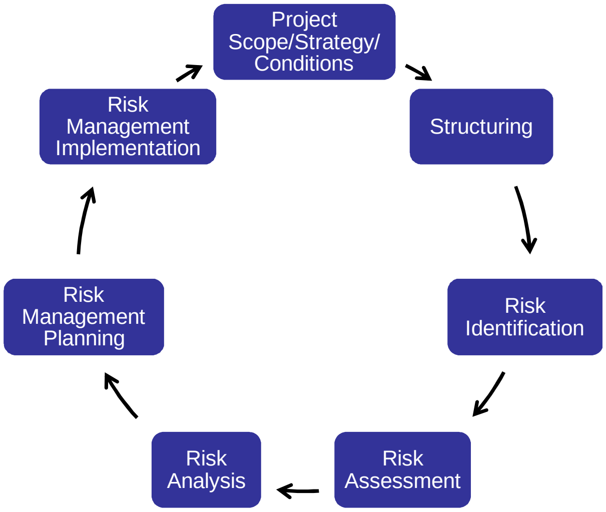
Executive Summary

In the past, many transportation projects have "performed" poorly (e.g., in terms of ultimate cost and schedule to completion), often due to unexpected problems. This might be amplified for rapid renewal projects, which are intended to accelerate schedule and minimize disruption through construction, while not adversely affecting either cost through construction or post-construction longevity. By definition, these rapid renewal methods are typically innovative with little past experience to learn from, and might be more susceptible to not performing as expected.



Risk Management Process

This *Guide* presents a formal risk management process to better understand and to actually optimize project performance specifically for rapid renewal projects, especially by anticipating and planning for potential problems ("risks") and potential improvements ("opportunities"). This process, which is a significant expansion of a previously developed risk management process for non-rapid-renewal projects (for which the expanded process is also applicable), consists of a well-defined series of steps, each of which has been described in appropriate detail, including possible variations, in this *Guide*. Sufficient guidance is also provided in this *Guide* to ensure compatibility and consistency among the various steps, and to ultimately ensure adequate accuracy and defensibility of results (where "adequacy" depends on how the results will be used), as efficiently as possible. The steps, which are sequential and in some cases iterative, include:

1. **"Structuring"** - Define the "base" project scenario (including the relevant project performance measures of cost, schedule and disruption through construction, and post-construction longevity, and tradeoffs amongst 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 (i.e., scenarios that might occur, changing the base project performance). In addition to brainstorming and then analysis of risks, lists of common risks have been developed that can be checked to ensure completeness. Document the set of risks and opportunities to start the project *risk register.*

3. **Risk Assessment** – Assess the "severity" of each of the risks and opportunities in the *risk register*, and then prioritize them on that basis. Generally this is done by: 1) subjectively assessing the relevant risk factors (i.e., impacts if the scenario occurs and the probability of the scenario occurring), either qualitatively (e.g., "high" vs. "low", where these descriptors are quantitatively defined by ranges of values) or quantitatively (in terms of mean-values or, for quantitative risk analysis, full probability distributions); and then 2) analytically combining the risk factors to determine changes in project performance measures and thereby severity. Document the risk-factor assessments in the project *risk register.*

4. **Risk Analysis** – Analytically combine the base and risk factors to determine the project performance measures (e.g., ultimate project escalated cost), as well as changes in those measures (e.g., combined using tradeoffs, as a measure of "severity") associated with each risk. This can include quantification of the uncertainty in (and correlations among) those performance measures, as a function of subjectively assessed uncertainties in the base and risk factors. Note that this requires specialized skills to conduct appropriately.

5. **Risk Management Planning** – Identify and evaluate possible ways to proactively reduce risks, focusing on those that are most severe. Evaluate each possible action in terms of its cost-effectiveness, considering changes in both base (e.g., additional cost) and risk (e.g., reduced probability) factors, and select those that are cost-effective. Consider subsequently re-analyzing the project performance measures for this risk reduction program, including quantification of uncertainty, based on which appropriate budgets and milestones can be established (e.g., to achieve a specified level of confidence). As part of these budgets and milestones, contingencies (in the form of additional funds and time, as well as recovery plans) and procedures to control their use would be established. Document 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 due to risk reduction or simply changes in project development, conditions, and information); and b) monitoring budget and milestones, especially with respect to contingencies. This might involve periodic updates (iterate previous steps 1-5) at regular intervals or at major milestones or changes. For example, contingencies might be reduced as engineering reports or designs are completed and risks are avoided or reduced.

This *Guide* also provides adequate guidance to help ensure successful implementation of the risk management process described in this *Guide*, which requires adequate planning and resources, especially regarding qualified facilitators and experts. As part of this, a course has been developed to train DOT staff to successfully implement this *Guide*, focusing on training DOT facilitators to: a) implement the risk management process directly on relatively simple rapid renewal (as well as non-rapid renewal) projects; and b) supervise the evaluation of more complex projects and/or quantitative risk analysis. In addition to this training course (which include annotated slides and application to a hypothetical project), to help these facilitators, an overview presentation of the process and forms for documenting inputs (which are also available electronically in an MS Excel workbook template that also automates the necessary analyses) have been developed for relatively simple projects.

The benefits of the risk management process described in this *Guide* include primarily improved project performance, as well as better understanding and clarity of the project and its range of possible performance. Moreover, it does this defensibly and efficiently. In fact, if done correctly (per the guidance presented herein), the “investment” (e.g., in training, workshops, and documentation) should be small relative to the likely benefits of improved project performance, plus the more intangible benefits of better project understanding and being able to better defend significant project decisions.

Chapter 1. Introduction

1.1 The “Problem”

The planning, design, construction and subsequent operation of highway projects is complex and fraught with uncertainty. The result is that many highway projects have exceeded initial cost estimates and expected completion dates, as well as experienced other undesirable consequences, such as greater than expected disruption and poor longevity. As one (albeit extreme) example, the cost for the “Big Dig” (Central Artery Project in Boston) went from an estimate (for the Environmental Impact Statement (EIS) decision) of $2.6 billion in 1983 to $14.6 billion by 2001 - see Figure 1-1. Albeit extreme, the example of the Big Dig is not uncommon. A study of 167 roadway projects over the last 70 years shows that most such projects are initially underestimated, by an average of about 20%, although there is a wide range of such underestimates, with some even being significantly overestimated – see Figure 1-2. Such poor predictions of project performance can have various undesirable consequences; for example:

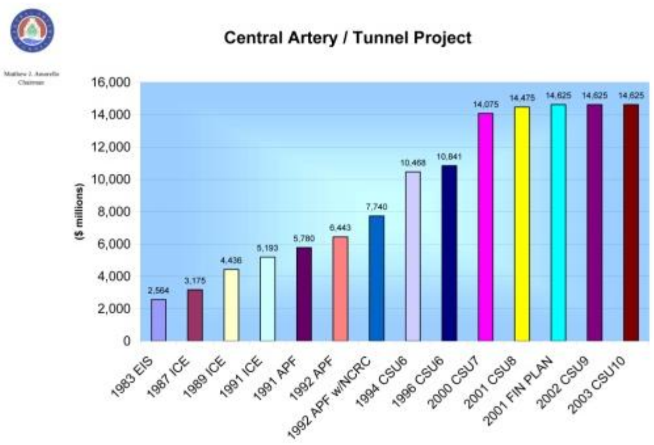


Figure 1-1. History of “Big Dig” Cost Estimate (MTA, 2003)

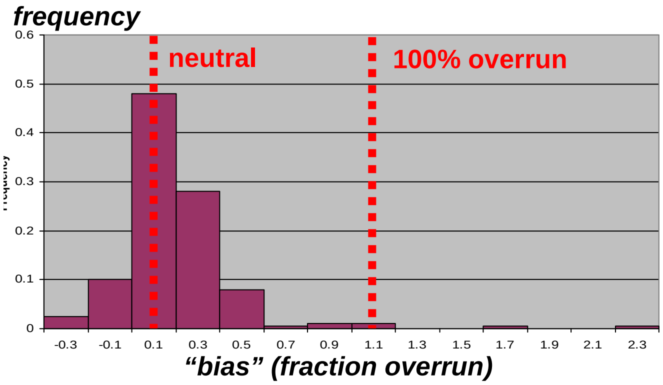


Figure 1-2. Statistics of past cost under-estimates for 167 road projects (Flyvbjerg et al, 2002)

- Underestimating costs can result in having to find additional funds (which might come from other projects) or in reducing project scope (and thus project benefits), and might result in project delays while being resolved or might result in decisions to reduce quality (and thus longevity). Conversely, overestimating cost can lead to “starving” other worthwhile projects and to unnecessary work and features.
- Underestimating schedule can result in extended overheads and extra inflation (and thus additional costs), and might result in additional disruption, as well as a delay in realizing project benefits.
- Underestimating disruption can result in public dissatisfaction, which in turn can lead to project delays while being resolved and additional costs to mitigate.
- Underestimating longevity can result in additional costs and disruption for operations and maintenance (O&M) and for replacement, which might be needed sooner than planned.
- All of the above, in turn, can lead to poor project decisions and affect the department of transportation’s (DOT’s) credibility, especially with the public. The loss of credibility and public confidence can make it difficult to obtain approvals and funding for future critical infrastructure projects.

Poor predictions of performance are due, at least in part, to the generally significant uncertainty in the factors that will determine project performance, especially due to unforeseen changes or problems that arise as the project develops. For example, many major scope and design decisions must be made during planning, which can significantly affect performance, and subsequent changes might be dictated by external stakeholders, such as regulatory agencies, public groups, etc. As another example, the conditions under which the project will be developed might change significantly over time (e.g., market pricing) or simply turn out to be different than expected (e.g., ground conditions). It is also conceivable that, in some cases, performance could even be intentionally underestimated to get project approval and commitment, after which it is difficult to stop a project, even though the underestimate eventually becomes obvious and the associated consequences noted above are realized.

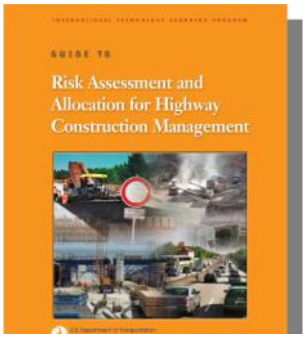
The "traditional" approach to estimating project performance, which has often lead to such poor predictions and subsequent problems, has generally consisted of a "deterministic" (single value) approach, in which a particular "scenario" (scope, strategy, design and conditions), with specific factor values and other assumptions that are intended to be appropriately conservative, is defined. However, clearly, many other scenarios (with different factor values and thus different performance) are possible, but the likelihoods of these other possible outcomes are not assessed and the actual level of conservatism in the deterministic approach is not evaluated. In some cases, the sensitivity of performance to the various project assumptions might be determined, but typically in an adhoc way either by judgment or by analysis, to guide further investigation and assessment of the important assumptions, as well as to guide project changes (e.g., via value engineering (VE) studies) and potential problem resolution (e.g., via risk management), with the general intent of optimizing project performance. However, because this is typically not done in a formal fashion and not quantified, such optimization cannot be assured, and in fact, as shown in Figure 1-2, has typically not been successful.

"Rapid renewal" projects, which by their nature tend to be innovative, create complexities above and beyond traditional projects (ref. TRB Special Report 296). Hence, the uncertainties in project assumptions and performance might be even greater for rapid renewal projects, possibly leading to even poorer predictions and sub-optimization of their performance via the traditional approach. This *Guide* will focus on rapid renewal projects. However, because non-rapid renewal projects are generally similar but less complex, this Guide will also generally be applicable to non-rapid renewal projects as well.

Some project issues are programmatic (affecting all the projects within a particular program of individual projects, e.g., delays in program funding), agency-wide (affecting all the agency's projects, e.g., agency resource limitations), or even nation-wide (affecting all projects, e.g., general inflation). These effects, and how they can best be managed, will generally vary as the number of projects affected increases. However, this *Guide* will focus on individual project-level risks, which generally include the larger scale risks as well.

1.2 The "Solution"

The best approach for effectively dealing with the problems identified above is an appropriate formal (as opposed to adhoc) risk management process. Risk management processes are new to the rapid renewal context, but a number of associations (e.g., Project Management Institute (PMI), Association for the Advancement of Cost Engineering (AACE), etc.) and governmental agencies (e.g., U.S. Department of Energy (DOE), Federal Highway Association (FHWA), and Federal Transit Association (FTA)) have employed risk management process on various projects and programs. A similar process has been previously developed (*Guide to Risk Assessment and Allocation for Highway Construction Management*, or "*Risk Guidelines*", FHWA 2006) and implemented through training workshops by the authors for the FHWA (Golder, 2008), although not specifically for rapid renewal projects. In this *Guide*, this existing and accepted process has simply been expanded and extended to rapid renewal projects.



FHWA "Risk Guidelines" (FHWA, 2006) – on CD

An appropriate formal risk management approach is primarily intended to optimize project performance. However, it also needs to be efficient and defensible, as well as adequate (as opposed to perfect), in achieving this objective. It also must be compatible with the DOT organization and their projects. The process generally consists of the following two basic sequential and iterative steps:

- “Diagnosis” - Identification of all the significant potential problems (and opportunities) that could affect project performance, and an adequate assessment of their current severity (either relative or absolute), in terms of their potential impacts and likelihood of occurrence. Such “problems” (including opportunities) are relative to an assumed “base” scenario, which must first be defined, and are adequately documented in a project-specific *Risk Register*. This might include an analysis of ultimate project performance, including quantification of uncertainty in that performance.
- “Treatment” - Identification of feasible ways to manage those potential problems: a) individually, with an adequate evaluation of their cost-effectiveness (in terms of reduction in severity, including more negative severity for opportunities); and b) collectively, in terms of appropriate “contingencies” (both cost and schedule allowances, as well as future project flexibility as needed). Such plans are adequately documented in a project-specific *Risk Management Plan*, which must be successfully implemented, including monitoring, updates (re-diagnosis), and decision making throughout project development and contract management.

It should be noted that formal risk management is similar to value engineering (VE), in that the primary objective is to optimize project performance, although risk management focuses on reducing risks (both individually and collectively) while VE focuses on optimizing opportunities. Because of this similar objective and a reliance on expert judgment, risk management is sometimes combined with VE, so that the severe risks are first identified and these are translated into the opportunities to be evaluated during the VE process.

Hence, a formal risk management process should optimize project performance (through a plan to cost-effectively reduce risks), and in the process will help develop better clarity and understanding of the project and its possible performance. In fact, the range in possible future project performance can actually be determined (through quantitative analysis) and effective strategies for dealing with that performance (e.g., budgeting at the 80% confidence level for success) can be developed early on in the project, to help ensure project success.

The business case for including risk management as a standard project management component of major capital projects is unambiguous – the ability to better understand potential risks and how to manage them yields benefits far in excess of the costs of adopting risk management practices. This approach is widely considered to be state-of-the-art. Perhaps the most compelling argument for pursuing risk management as a standard practice for rapid renewal projects is that the best agencies and organizations worldwide are doing it, and with great success. As previously mentioned, the authors have previously developed a similar (but more limited) formal risk management process for the FHWA. The authors have also helped develop parts of a similar (but again more limited) formal risk management process for Washington State Department of Transportation (WSDOT), who have successfully applied it to hundreds of their projects, as well as for Florida DOT, Utah DOT, Nevada DOT, and Ontario (Canada) Ministry of Transportation (MoT). Various portions of the process have also successfully been used by the authors on many other projects for various highway agencies (e.g., USDOT/FHWA, CalTrans, Colorado DOT, Virginia DOT, Wisconsin DOT, Kentucky DOT, Pennsylvania Turnpike Authority, King County (WA) DOT, Seattle DOT, Hong Kong Highway Department, etc.) and rail/transit agencies (e.g., USDOT/FTA, MTA (NY), CalTrain (SF), Transbay (SF), SunRail (Orlando), WMATA (Dulles), FasTracks (Denver), Evergreen (Vancouver, BC), etc.), as well as for non-transportation projects. It should be noted that, although basically similar processes (or parts of that process, albeit often greatly simplified) have been used in the industry to evaluate numerous other projects, the process has often been misused, producing misleading results and perhaps thereby leading to poor decisions.

1.3 The “Guide”

The primary objective for this *Guide* is to adequately but concisely describe an appropriate method(s) for risk management on rapid renewal projects, and provide adequate guidance on how to best implement that method(s). That method should result in optimizing project performance, achieving an appropriate balance of accuracy, defensibility, and schedule of results, as well as resource utilization (allowing the DOT to do as much as they can independently), consistent with DOT and project conditions and requirements. Secondarily: a) for wider application, the method should be applicable to non-rapid renewal, as well as rapid renewal, projects; and b) for easier acceptance, the method should be simply an extension of previously existing successful and accepted methods.

To achieve the above objectives, this *Guide* focuses on the “why” and “what”, whereas the “how” is covered in more detail in separate companion training and implementation materials. This Guide consists of the following sections:

- Chapter 2. Risk Management Process – provides an overview of the process, including an iterative set of steps;
- Chapter 3. Context for Rapid Renewal – describes the unique features of rapid renewal projects in that risk management process, supported by Appendix C (Inventory of Rapid Renewal Strategies and Methods) and Appendix F (Hypothetical Case Study);
- Details of each step in the risk management process, supported by an example application in Appendix F (Hypothetical Case Study):
    - Chapter 4. “Structuring” a Project for Risk Management - results in a definition of the “base” scenario against which risks and opportunities are relative to;
    - Chapter 5. Risk Identification - results in starting a *Risk Register*, and is supported by Appendix D (Rapid Renewal Risk Categories and Risk Management Action Categories);
    - Chapter 6. Risk Assessment – results in completing the *Risk Register*, including assessing risk severity and thereby prioritizing the risks*;*
    - Chapter 7. Risk Analysis - results in predictions of project performance that can be used to establish appropriate budgets and milestones (including contingencies), as well as to better guide subsequent risk management planning;
    - Chapter 8. Risk Management Planning - results in a *Risk Management Plan*, and is supported by Appendix D (Rapid Renewal Risk Categories and Risk Management Action Categories);
    - Chapter 9. Implementing the *Risk Management Plan* - includes monitoring, updating and decision making;
- Chapter 10. Implementing this *Guide* - includes planning and resources, and is supported by Appendix E (Simplified Risk Management Overview, Forms, and Template) and Appendix G (Simplified Risk Management Training) designed specifically for DOT facilitators to: a) evaluate (to a limited extent) relatively simple projects; or b) supervise more complex evaluations and/or the evaluation of more complex projects;
- Chapter 11. Conclusions; and
- Appendix A. Glossary and Appendix B (References).

> Each technical section (Chapters 2-10) is subdivided into following subsections:
>
> 1. *Introduction* – objectives and philosophy / concepts (plus insert for “in a nutshell”)
> 2. *Process* – methods and guidance (plus where applicable, inserts for input / analysis forms and template, ref Appendix E, and illustrative example, ref Appendix F, which is carried throughout)
> 3. *Conclusions*

1.4 Conclusions

In the past, many transportation projects have “performed” poorly, e.g., in terms of ultimate cost and schedule to completion, often due to unexpected problems. This might be amplified for rapid renewal projects, which are intended to accelerate schedule and minimize disruption through construction, while not adversely affecting either cost through construction or post-construction longevity. By definition, these rapid renewal methods are typically innovative with little past experience to learn from, and might be more susceptible to not performing as expected.

A formal risk management process is needed to better understand and to actually optimize project performance specifically for rapid renewal projects, especially by anticipating and planning for potential problems (“risks”) and potential improvements (“opportunities”). This process, which is a significant expansion of a previously developed risk management process for non-rapid-renewal projects, consists of a well-defined series of steps, each of which is described in appropriate detail, including possible variations, in this *Guide*. Sufficient guidance is also provided in this *Guide* to ensure compatibility and consistency among the various steps, and to ultimately ensure adequate accuracy and defensibility of results (where "adequacy" depends on how the results will be used), as efficiently as possible. This guidance includes a separate two-day training course (with annotated slides), especially for DOT risk management facilitators, and an overview presentation of the process and forms for documenting inputs (which are also available electronically in an MS Excel workbook template that also automates the necessary analyses) for relatively simple rapid renewal (as well as non-rapid renewal) projects.

The benefits of the risk management process described in this *Guide* include primarily improved project performance, as well as better understanding and clarity of the project and its range of possible performance. Moreover, it does this defensibly and efficiently. In fact, if done correctly (per the guidance presented herein), the "investment" (e.g., in training, workshops, and documentation) is small relative to the benefits of improved project performance, plus the more intangible benefits of better project understanding and being able to defend significant project decisions.

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Chapter 2. Risk Management Process

2.1 Introduction to Risk Management Process

Objectives

The primary objective of the risk management process, whether at the individual project level or for a “program” of individual projects, is to optimize project performance (e.g., minimize cost, minimize disruption, etc.). As discussed in Chapter 1, problems can arise during a project that lead to undesirable performance. Anticipating the problems upfront can lead to management strategies that minimize undesirable performance. For example, delays in property acquisition might delay a project, which in turn might increase project costs, whereas such delays might be avoided through early acquisition.

Develop and implement a formal, structured, and iterative but flexible and efficient process to:

- ➢ Anticipate and plan for potential project problems and opportunities
- ➢ Better understand and control project outcomes

The focus in this *Guide* is on individual rapid renewal projects.

Similarly, opportunities to improve project performance (e.g., reduce cost) might arise during a project. Anticipating these opportunities upfront can lead to management strategies that maximize such desirable performance. For example, reuse of excavated or demolished materials might reduce material and hauling costs, but would have to be adequately investigated and approved beforehand. Such opportunities are often the focus of value engineering (VE), which can be combined with risk management. Hence, the primary objective of the risk management process is to anticipate, evaluate, and plan for such potential problems and opportunities, in order to optimize project performance.

Another objective of the risk management process is to complete the process efficiently, while producing adequately accurate and defensible results. To achieve this efficiency, it is especially important that, among other aspects, the process be flexible (i.e., that the level of detail is appropriate and that reasonable approximations are made) and consistent with available information and expert judgment, as well as with the needs of the project. Consensus among a broad group of experts helps ensure accuracy and defensibility. For example, such consensus on the process and on the inputs, and thereby on the outputs (results), can often be achieved through well-planned, facilitated workshops. Such workshops can also help achieve a common understanding, among the project team as well as possibly among other stakeholders, of the important elements of the project.

Although there are many approaches to risk management, it is important to establish a relatively formal, structured process, compatible with the overall project management approach. The process described herein is applicable to individual projects, including rapid renewal projects as well as non-rapid renewal (and even non-transportation) projects, and to programs comprised of multiple individual projects. However the focus in this *Guide* is on individual rapid renewal projects.

Philosophy and Concepts

Project “performance” can be expressed in terms of specific “measures”, such as the ultimate project cost or the substantial completion date. Beforehand, such project performance measures, which are realized in the future, cannot be known with certainty. However, they can generally be predicted in advance for a specific set of assumptions (e.g., related to assumed quantities and unit costs for particular items). However, these assumptions might not necessarily turn out to be true. Other conditions might in fact actually occur, resulting in different performance. In this *Guide*, the following terms are used:

- “base” describes the conditions and related performance associated with a particular set of assumptions about the planned project, whereas
- “risks and opportunities” describe the other possible conditions and unplanned events, and their related performance changes, depending on whether they degrade or improve performance, respectively.

Hence, total performance consists of a "base" component, which is related to a specific set of assumptions, and a complementary "risk" component, which is related to the differences associated with other possible assumptions. These two components can be estimated separately and then combined appropriately to determine the total. However, in many cases, the risk component will be a function of the base component, so that the base component must be estimated first. Although conceptually the total performance could be estimated directly, this would generally be difficult to do accurately because of lack of detail and in any case would not provide information on the likely sources of poor performance (i.e., risks) for subsequent management action.

"*Total = Base + Risk*", *combined appropriately*

For example: Suppose that the "base" assumption for costing and scheduling a task is that suitable materials are on hand. However, there is a chance (e.g., 1 in 4) that suitable materials will not be there when needed, in which case it will cost extra and take extra time to obtain those materials – this is a "risk".

Conversely, if the base assumption is that suitable materials are not on hand and must be obtained, then there is a chance (e.g., 3 in 4) that suitable materials are already on hand, in which case the time and cost to obtain those materials will be saved – this is an "opportunity".

Once the base assumptions are established for project performance, a comprehensive set of risks and opportunities (i.e., "list") can be identified that might lead to changes in that performance. Ideally, to streamline the list and allow for meaningful analyses, the risks and opportunities should be comprehensive and non-overlapping. Eventually, the list will be prioritized in terms of their severity. The severity of a particular risk (or opportunity) is a combination of two risk "factors":

- its set of possible performance "impacts" if the risk occurs (e.g., changes in project costs if the risk occurs), where the impacts are often uncertain and might be described in terms of representative scenarios covering the range of possible outcomes; and
- the likelihoods of those various scenarios actually occurring during various project phases.

These risk factors will evolve over time as conditions change and the project develops. Ultimately the risks will either occur with specific impacts or not occur (with no impacts). For example, a design risk will generally occur during the design phase, after which it can no longer occur so that, if it hasn't happened during design, its chance of occurrence drops to zero and it can be "retired" after design. As another example, a design risk might have occurred and been incorporated as a change in the "base", in which case it too can no longer happen and it can be retired. The list of risks, including their relevant characteristics, forms the beginning of the project "risk register", which the DOT should maintain throughout the project as the risks evolve.

Once recognized, the DOT can proactively manage some risks through various actions, either aimed at reducing their chance of occurrence ("prevention") or at their impacts if they do occur ("mitigation"). For example, potential delays, which can result in additional costs, might be avoided by starting preliminary work early, even though that work might not eventually be needed. Presumably, this preliminary work should be done if its cost is less than the potential cost of delay considering its probability of occurring, as well as considering the other performance objectives (e.g., minimizing disruption, etc.). Such proactive risk management is similar to (and can be combined with) VE, in which opportunities to improve project performance are identified, evaluated and recommended.

Even after such proactive risk management, there will be "residual" risks, which the DOT must accept and thus accommodate in the budget and schedule. Typically, DOTs do this by establishing and controlling a "contingencies" for cost and for schedule, over and above the base cost and schedule. These contingencies can be established at various levels of conservatism or levels of confidence in their sufficiency – the higher the level of conservatism, the higher the chance that they will be sufficient, but also the more funds that must be committed to the project and not made available for other projects. The appropriate level of confidence should be a DOT policy, rather than a technical issue, balancing the consequences of going over budget with those of going under budget. For example, many agencies choose an 80% confidence level, for which there is a 20% of exceeding budget (without cutting scope).

Adequate controls, in the form of procedures, are needed to ensure that the contingency does not simply become self-fulfilling, but remains adequate to cover remaining risks throughout the project and surplus contingency is released. However, because contingency is established at less than 100% confidence level, there is a chance that it will not be adequate. In such cases, either additional funding must be found or the scope of work must be reduced in order to complete the project. These constitute contingency (or "recovery") actions (as opposed to contingency funds or time) and should also be planned beforehand.

Hence, once the project risk register has been developed, the DOT should develop and subsequently implement a plan to effectively manage those risks, thereby optimizing project performance to the extent possible. This plan consists of management actions to proactively reduce specific high-priority risks, to establish and maintain adequate budget and schedule to accommodate remaining risks, and to modify the project as necessary if the established budget or schedule is inadequate despite proactive management actions. Moreover, this plan should establish the procedures and organization necessary to successfully carry out those actions. This plan is called the project "Risk Management Plan", which should also be maintained throughout the project as conditions and thus risks change.

2.2 Process of Risk Management

Although the risk management process can be (and in the past has been) done in variety of ways with various degrees of success, the general process of successful risk management consists of a series of steps, which are applied at various times throughout a project. These steps, which are discussed individually in more detail in subsequent chapters specifically for individual rapid renewal project risk management, are shown in Figure 2-1 and consist of the following:

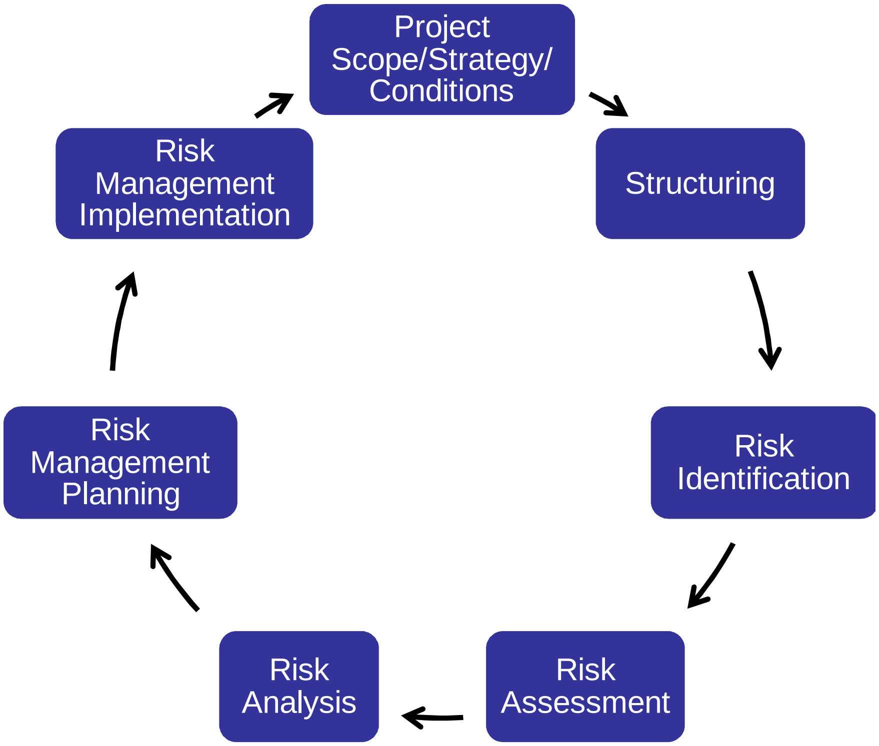


Figure 2-1. Iterative Risk Management Process

1. "Structuring"

Before risks can even be identified, much less managed, the DOT must adequately define the "base" project. This base consists of the planned project scope, strategy, and key conditions, as well as a set of assumptions regarding those aspects that are not yet known for certain. Base project performance (e.g., project cost, schedule, etc.) is then determined as a function of these base project elements. Generally, this base project description is developed at a relatively broad level of detail simply via facilitated discussions with the project team. A template that identifies all the relevant elements is often used to ensure that they are adequately described at the appropriate level of detail. This step, and the associated template, is subsequently discussed in some detail in Chapter 4.

2. Risk Identification

Once the base assumptions have been established and the project has been "structured" (in Step 1), the DOT must adequately identify the risks and opportunities relative to that base. The intent is to identify a comprehensive and non-overlapping set of risks and opportunities. To help accomplish this, the risks are often categorized; for example, in terms of the project phase in which they generally might occur. Generally, a combination of techniques, ranging from facilitated group brainstorming to "risk checklists", are used, considering all readily available information. As the project develops and conditions change, additional risks might be identified, while some existing risks will be retired. The updated list of risks is maintained in the project risk register. This step is subsequently discussed in some detail in Chapter 5.

3. Risk Assessment

Once the DOT has identified risks and opportunities (in Step 2), the DOT should adequately assess the relative severity of the risks and opportunities so that they can be prioritized for subsequent management (Step 5). If the DOT chooses to quantify uncertainty in project performance through risk analysis (Step 4), then the risk factors must also be adequately quantified, from which their severity and prioritization can be determined. The risk factors (i.e., the impacts if the event occurs and the probability of that event occurring) are assessed, either qualitatively or quantitatively, using a variety of techniques, ranging from statistical analysis to facilitated expert group opinion, considering all readily available information. As the project develops and conditions change, the risk factors for previously identified risks might change and need to be reassessed, while the factors for any new risks must be assessed. The updated assessments of factors describing the severity of each risk are maintained in the project risk register. This step is subsequently discussed in some detail in Chapter 6.

4. Risk Analysis

If the risk factors have been assessed quantitatively (in Step 3), the DOT can use the risk factors in conjunction with the base performance to determine total project performance. For some performance measures, such as uninflated costs, that are additive, this is a relatively simple analysis. However, for other performance measures, such as schedule (and thus inflated costs), that are not simply additive, this is a relatively complex analysis. Typically, numerical models are developed to adequately calculate each performance measure as a function of various input factors (e.g., the "base" and "risk"). The overall "mean value" (i.e., probability weighted average value) of the performance measure can then be approximated by using the mean value of each input factor, which for one risk would simply be its probability times its impact. The uncertainty (which is expressed by a probability distribution) in a performance measure can be approximated (e.g., typically by Monte Carlo simulation) by using the uncertainty for each input factor appropriately considering any relationships (correlations) among those input factors. This can be done at various levels of detail and complexity, considering risks explicitly or implicitly – if risks are treated explicitly, their severity can be calculated and used to meaningfully prioritize the risks. As the project develops and the risks (and their factors) change, the project performance must be reanalyzed. This step is subsequently discussed in Chapter 7. Note that risk analysis requires specialized skills and experience to conduct properly.

5. Risk Management Planning

Once the DOT has evaluated and prioritized the risks (in Step 4 and possibly more definitively in Step 5), the DOT should identify and adequately evaluate proactive ways to manage those risks and select those that will be cost-effective, which is a process that is similar to (and possibly combined with) VE. The DOT should then develop adequate plans to accomplish those activities. Budgets and milestones that adequately account for the remaining residual risks must then be established (e.g., through use of contingency and float), based on agency policy regarding the appropriate level of conservatism. Adequate procedures must be established to control expenditure of that contingency, so that the project does not automatically "consume" the allocated contingency. Ways to meet budget or milestones if that contingency turns out to be insufficient (e.g., reduction in scope) at various milestones must be identified and adequately evaluated to select those that will be implemented if necessary. Adequate plans and decision criteria must be developed to accomplish those actions. As the project develops and the risks (and their factors) change, these plans must be reviewed and revised as necessary to optimize remaining project performance. The updated plans are maintained in the project Risk Management Plan. This step is subsequently discussed in some detail in Chapter 8.

6. Risk Management Implementation

Once the DOT has developed the Risk Management Plan (in Step 5), it must be adequately implemented. This involves the following:

- Implementing and monitoring progress on proactive risk reduction activities;
- Monitoring risks and updating the risk register, partly in response to proactive risk reduction activities but also due to other changes in conditions (e.g., changes in the base);
- Periodically reanalyzing risks, especially at major milestones or major changes in conditions;
- Periodically reviewing and updating the Risk Management Plan;
- Monitoring, controlling, and periodically revising contingency as necessary; and
- Deciding on whether to implement established contingency plans at various milestones.

Hence, as the project develops and the related Risk Management Plan changes, the plan must continue to be effectively implemented. This step is subsequently discussed in Chapter 9.

The appropriate details of the above process depend on each particular project's needs and conditions. Like most evaluations, the accuracy and defensibility can vary from very approximate with low defensibility, which can be achieved with relatively little detail, expertise, and thus effort (depending on project conditions), to very accurate with high defensibility, which requires significant detail, expertise, and thus effort (again depending on project conditions). The appropriate level of detail and expertise should be selected to achieve the needed level of accuracy and defensibility, considering the effort involved.

The actual "*how to*" details of implementing each of the above steps is covered in companion training materials, which are summarized in Appendix G. The logistics of implementing the above set of steps (e.g., through facilitated workshops), as well as when during project development they should be implemented, are subsequently discussed in Chapter 10.

2.3 Conclusions regarding Risk Management Process

Historically, risks and opportunities have significantly affected projects and thereby program outcomes. This might be especially true in the future for innovative rapid renewal projects, for which there is a more dynamic environment and less experience. However, by adequately anticipating these risks and opportunities, and subsequently evaluating and planning for them, project performance can be improved.

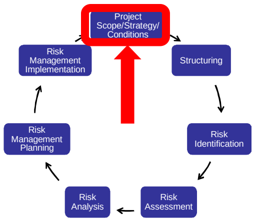
Although risk management can be done in a variety of ways with various degrees of success, a formal, structured risk management process, as an integral part of project management, is needed to provide adequate accuracy and defensibility. Risk management can create a better understanding of possible outcomes and then help to manage those outcomes to the greatest extent possible. This risk management process consists of a series of well-defined steps, which are iterative and applied at various times during a project/program. The process must be flexible (especially in terms of level of detail and expertise) for efficiency. Although this risk management process is generally applicable at the program- as well as project-level, and to non-rapid renewal and even non-transportation projects, the focus in this *Guide* is on application to individual rapid renewal projects.

Illustrative Example

A hypothetical case study by "QDOT" is used throughout this *Guide* to adequately illustrate the various steps of the risk management process. This case study, which includes a *Risk Management Plan (RMP)*, is presented in Appendix F. The basic risk management process discussed in this chapter is used in that example, as summarized below.

QDOT is planning a significant highway reconstruction/expansion project. The objectives are to minimize cost, minimize schedule, and minimize disruption during construction, and maximize longevity of the constructed facility after construction. Recognizing the uncertainty and risk inherent in this project, QDOT decided to conduct risk management planning, followed by implementation of the resulting *RMP*, to optimize satisfaction of these objectives (as described in general terms in this chapter and specifically for this application in *RMP* Chapter 1). However, it was decided not to conduct quantitative risk analysis (e.g., to objectively establish contingencies) at this time. To accomplish this (as subsequently described in *Guide* Chapter 10 and specifically for this application in *RMP* Chapter 9), QDOT:

Chapter 3. Context for Rapid Renewal



3.1 *Introduction to Rapid Renewal*

What is Rapid Renewal?

“Rapid renewal” projects constitute a unique subset of highway projects. Rapid renewal projects focus on three primary objectives: 1) complete renewal of existing highways quickly; 2) do so with minimal disruption to the community; and 3) produce facilities that are long-lasting. At the core of rapid renewal projects are elements intended to realize optimal benefits for the project and public: a new way of managing collaborative relationships and decision making; better integration of management, planning, design, construction, and maintenance; and more synergistic use of technologies and methods.

> Apply various management and/or technical techniques to reduce delivery time and disruption, without adversely affecting project cost and longevity, although might increase uncertainty and volatility in performance.

The following are examples of rapid renewal projects:

- Reconstruct a busy rural highway quickly by using pre-cast, post-tensioned concrete panels in critical intersections to reduce lane closure times; and using high-early strength concrete elsewhere to reduce curing times and achieve earlier opening. Ensure longevity by requiring a 10-year performance warranty.
- Accelerate delivery of a critical urban freeway reconstruction project by pursuing Public-Private Partnership (P3) to secure funding and deliver the project many years earlier than possible with traditional funding and delivery methods.
- Replace an aging overpass bridge structure in an urban area by pre-fabricating a replacement bridge “offline”, then moving the replacement bridge into place over a single weekend during a full road closure.
- Reconstruct a major urban freeway with a full closure or directional closures. In certain circumstances, full road closure can be less disruptive than attempting to maintain traffic through a construction area.
- Use contractor incentives to accelerate construction. Success with the use of contractor incentives on emergency projects (e.g., MacArthur Maze reconstruction in San Jose, California after a tanker fire and the I-35W Bridge reconstruction after the structural failure of the existing bridge) have led DOTs to use contractor incentives for non-emergency, rapid renewal projects.

These rapid renewal project examples clearly reflect more uncertainty (and risk) than traditional projects. Project acceleration makes schedules more volatile (e.g., any small delay can have significant impact on a highly-compressed schedule). This uncertainty can impact the public’s opinion of our DOTs and ultimately the performance of our transportation network. Formal and consistent risk management is prudent on any project, but it is essential on rapid renewal projects to help ensure that DOTs meet their performance objectives and promises to their stakeholders.

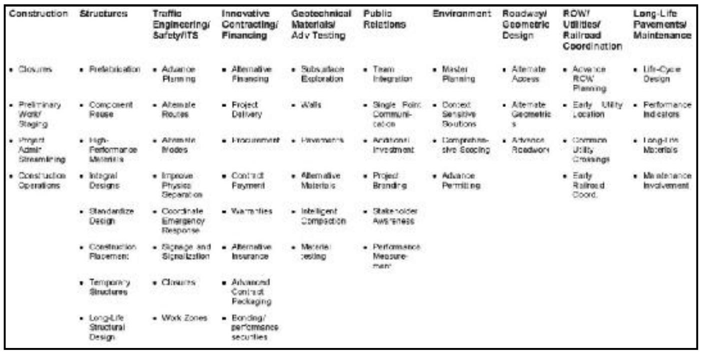
Background and Concepts of Rapid Renewal

The Federal Highway Administration (FHWA), American Association of State Highway Transportation Officials (AASHTO), and the Transportation Research Board (TRB) have been actively developing the concepts underlying rapid renewal. The FHWA and AASHTO have been at the forefront of the effort through their work on the Accelerated Construction Technology Transfer (ACTT) Program. Although “construction” is in the ACTT title, the program addresses all phases of project delivery. Appendix C contains more information on ACTT.

Unfortunately, however, there is still no single definition of a rapid renewal project. Rather, rapid renewal is typically referred to by project characteristics or the techniques implemented to compress the project schedule. A recent publication by TRB, Special Publication 296[1], defines several rapid renewal strategies. These strategies reflect general categories of approaches for meeting rapid renewal objectives, including completing on-roadway construction activities that impact traffic flow and the communities and businesses that rely on the roadway for services.

- *Perform faster in situ construction* by performing projects on a compressed schedule, which might require extended overtime shifts, mobilizing additional workers, employing innovative technologies, full road closures with detour, and strategic design. This strategy also typically involves the use of design-build project delivery, flexible performance specifications, and nondestructive testing.
- *Minimize field fabrication* by establishing techniques that minimize the amount of fabrication performed on the project site and maximize prefabrication that can occur off-site. This strategy may be achieved by prefabricating units of roadway or bridges, modular construction, and innovative installation strategies. Such modular and prefabricated elements allows for accelerated schedules, improved quality control, longevity, and enhances the overall level of performance of the project.
- *Perform faster construction inspection and monitoring* by ensuring that renewal projects are inspected and accepted quickly (e.g., using non-destructive testing) so that they may be reopened to the public. This strategy may include intelligent compaction and the use of contractor quality assurance/quality control techniques.
- *Facilitate an innovative and equitable contracting environment* by making decisions and accepting them rapidly (e.g., streamlined environmental/permitting process, streamlined design approvals through co-location, privatized operations and maintenance, private financing, alternative bonding, etc.). To effectively utilize this strategy, risk should be shared among project partners (e.g., DOTs, designers, private contractors, and partners), such as through incentives. Additionally, performance-based specifications can be utilized to provide the contractor with control over construction-related risks.
- *Improve customer relations* by recognizing the role that utilities and railroads play in the project development and execution. In order to prevent conflicts, institutional and procedural changes must be made and a proactive strategy for dealing with conflicts must be established in the early phases of project development. Similarly, right-of-way acquisition can be advanced and/or joint development encouraged.
- *Design and construct low-maintenance facilities* by addressing the practice of designing facilities in such a way that the need for future rehabilitation is minimized. This may involve the use of innovative materials (e.g., composites) or construction in controlled environments (e.g., modularization and prefabrication).
- *Preserve facility life* by investing in preserving facilities that are in good working condition to reduce the frequency of renewal required.

These strategies, in turn, result in specific rapid renewal tactics or methods that can be employed for specific projects. Appendix C contains a "rapid renewal inventory," or summary of specific rapid renewal tactics and methods as identified through ACTT and TRB publications and interviews conducted with several state DOTs as part of development of this *Guide*.



Construction	Structures	Traffic Engineering/ Safety/ITS	Innovative Contracting/ Financing	Geotechnical Materials/ Adv Testing	Public Relations	Environment	Roadway/ Geometric Design	ROW/ Utilities/ Railroad Coordination	Long-Life Pavements/ Maintenance
• Closures	• Prefabrication	• Advance Planning	• Alternative Financing	• Subsurface Exploration	• Team Integration	• Master Planning	• Alternate Access	• Advance ROW Planning	• Life-Cycle Design
• Preliminary Work/ Staging	• Component Reuse	• Alternate Routes	• Project Delivery	• Walls	• Single Point Communication	• Context Sensitive Solutions	• Alternate Geometrics	• Early Utility Location	• Performance Indicators
• Project Admin Streamlining	• High-Performance Materials	• Alternate Modes	• Procurement	• Pavements	• Additional Investment	• Comprehensive Scoping	• Advance Roadwork	• Common Utility Crossings	• Long-Life Materials
• Construction Operations	• Integral Designs	• Improve Physical Separation	• Contract Payment	• Alternative Materials	• Project Branding	• Advance Permitting		• Early Railroad Coord.	• Maintenance Involvement
	• Standardize Design	• Coordinate Emergency Response	• Warranties	• Intelligent Compaction	• Stakeholder Awareness				
	• Construction Placement	• Signage and Signalization	• Alternative Insurance	• Material testing	• Performance Measurement				
	• Temporary Structures	• Closures	• Advanced Contract Packaging						
	• Long-Life Structural Design	• Work Zones	• Bonding/ performance securities						

Rapid Renewal Inventory (Appendix C)

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[1] Transportation Research Board (2009). "Implementing the Results of the Second Strategic Highway Research Program," *Transportation Research Board of the National Academies,* Washington, DC, (viewed at trb.org/publications/nchrp/nchrp_rrd_296.pdf October 2009).

3.2 Process of Rapid Renewal

Objectives and Performance Measures for "Rapid Renewal" Projects

For the purpose of this *Guide*, the four key project performance objectives (and related "measures", or the bases for defining, assessing and managing risks) for evaluating rapid-renewal projects are as follows:

1. *Minimize cost* to complete project delivery (e.g., in terms of year of expenditure costs);
2. *Minimize time* to complete project delivery (e.g., in terms of completion date);
3. *Minimize disruption* during project delivery (e.g., in terms of hours lost by the public); and
4. *Maximize "longevity"* and minimize post-construction problems:
    - Minimize cost and disruption of operations & maintenance; and
    - Minimize cost and disruption for replacement and its frequency (e.g., ensure "longevity" in that the project meets or exceeds the design life per the specifications and design for ease of maintenance and replacement).

Additional performance objectives/measures for rapid renewal projects could include the following, depending upon project circumstances:

- Maximize chance to secure adequate project funding (funding delays covered in schedule performance measure);
- Minimize environmental impacts throughout project life;
- Minimize safety impacts during construction and throughout project life;
- Maximize quality for operations (separate from operations & maintenance and replacement);
- Maximize stakeholder satisfaction regarding other project performance measures; and
- Maximize revenue during operations, if applicable.

An overall project objective is to maximize satisfaction of the group of the above objectives, considering tradeoffs among them. One logical way to accomplish this is to translate all the objectives into common terms (e.g., equivalent cost) that can then be easily combined. For example, the "value" of changes in schedule, changes in disruption and changes in longevity can be assessed in terms of how much the decision maker would be willing to pay (in dollars) to make desirable changes or to prevent undesirable changes (e.g., cost per month of schedule change, regardless of the magnitude of change ("linear") and regardless of changes in other measures ("independent")). Once translated into equivalent cost terms, the various objectives can simply be summed to determine an overall value to be (in this case) minimized.

Different, expanded programmatic performance measures might also be defined for specific programs comprised of individual projects (e.g., minimize overall program cost, optimize programmatic cash flow, minimize overall program schedule, minimize overall program disruption, etc.).

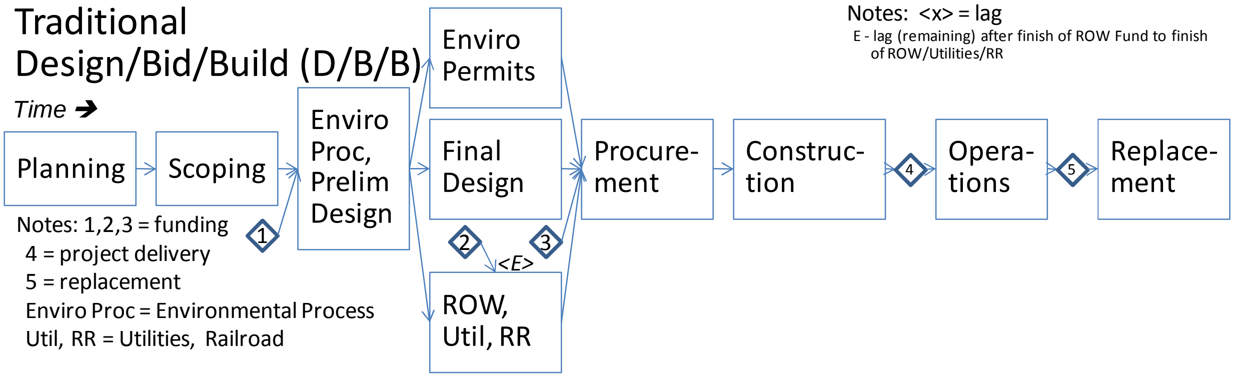
Rapid Renewal Project Phases

For the purposes of categorizing rapid renewal methods and their associated risks and risk management, it is convenient to characterize projects in terms of their various development "phases" (or major activities, e.g., final design). In general terms, most projects progress through the phases presented in Table 3-1. Table 3-1 also describes example rapid renewal strategies for each phase.

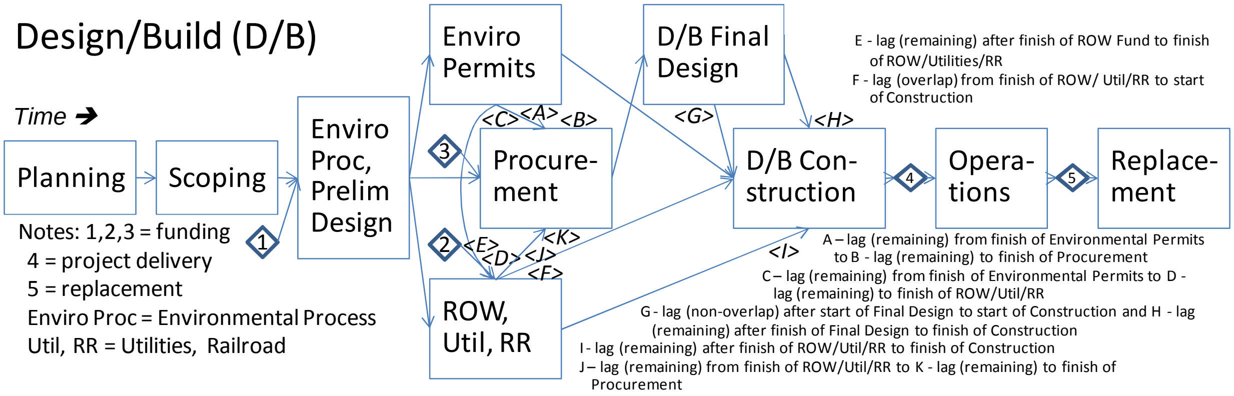
The order in which these phases occur can depend on the project characteristics and the selected project delivery method. Two general (simplified) "models" for the sequencing of these project phases are shown in Figure 3-1. These models, while simplified, provide a framework for the risk management process and assist in developing risk-based cost and schedule models. Figure 3-1a reflects traditional, linear design-bid-build project delivery, while Figure 3-1b depicts innovative approaches such as design-build in which construction and final design are completed concurrently by the builder to shorten project delivery schedules. Note that many variations are possible, but these two models can accommodate a wide variety of delivery strategies at a level that is appropriate for risk management efforts.

Table 3-1: Typical Project Phases and Example Rapid Renewal Strategies

Project Phases	Typical Activities	Example Rapid Renewal Strategies
Planning	Determine purpose and need; consider environmental factors; facilitate public involvement/ participation; consider interagency conditions; etc.	Conduct accelerated programmatic/ portfolio planning; conduct accelerated internal coordination; conduct accelerated external planning; etc.
Scoping	Determine design criteria and parameters; make preliminary plans such as alternative selections; assign geometry; project delivery strategy; programming; obtain funding authorization; etc.	Conduct accelerated and comprehensive scoping; employ master planning/integrated project development process; use innovative project delivery (e.g., design-build, construction manager at risk, etc.); etc.
Environmental	Conduct environmental analysis including discipline studies; NEPA/SEPA; alternatives analysis; documentation; public hearings; permitting; etc.	Accelerate the environmental documentation process; seek streamlined environmental approval process/approvals; streamline mitigation planning and implementation; etc.
Design	Develop plans (preliminary and final), specifications; estimates; traffic control plans; etc.	Accelerate design process; seek streamlined design approvals; hold early constructability reviews; use innovative and/or long-life designs; etc.
Right-of-Way, Utilities, and Railroad	Determine right of way impact; develop right of way approach; acquire right of way; determine utilities impacts; coordinate with utilities; develop railroad impact; coordinate with railroad; etc.	Accelerate right-of-way planning; accelerate right-of-way acquisition; conduct early utility planning and coordination of agreements; accelerate utility relocation; conduct early railroad planning and coordination of agreements; etc.
Procurement	Prepare contract documents, advertise for bid/proposals; hold a pre-bid conference; receive and analyze bids/proposals; etc.	Use alternative contract packaging; employ advanced procurement; etc.
Construction	Initiate contract; mobilize; conduct inspection and materials testing; administer contract; control traffic; etc.	Use prefabricated materials and construction techniques; use modular construction techniques; full road closures or other innovated management of traffic techniques; etc.
Operations	Operate facility; monitor performance; provide services for customers; etc.	Consider privatized operations and maintenance; etc.
Replacement (or Decommissioning)	Planning for replacement; design and construction or replacement; decommissioning if appropriate; etc.	Accelerate planning for replacement or decommissioning; etc.



a) Traditional Design/Bid/Build



b) Alternative Design/Build (D/B) Delivery

Note: Each box represents a phase, with the left side of the box representing the start and the right side representing the finish, and the top and bottom representing some point in between. Each arrow into a box represents a precedent requirement for that phase.

Figure 3-1. Example Sequencing of Major Project Phases

Subsequent chapters in this *Guide* present a formal process for identifying, assessing, and managing rapid renewal-related risks. A key part of this process is identifying the major project activities and their sequence (e.g., as shown in Figure 3-1), which is in turn based on the project's scope, delivery strategy, conditions, and key assumptions.

It should be noted that the project delivery selection process, as well as the accelerated construction method selection (and design in general) process, is beyond the scope of this *Guide*[2]. Rather, the scope of this *Guide* is to present an appropriate approach to comprehensively evaluating and managing the risks associated with any rapid renewal project, which might include innovative project delivery methods and/or accelerated construction methods – choices among project delivery methods and/or among accelerated construction methods can then be made at least in part based on such evaluations of alternatives. Because the analysis of risks involves different models for different project delivery methods, and many of the risks themselves are different for the different project delivery methods, specific project delivery methods (i.e., D/B or D/B/B) must be evaluated separately and then compared.

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[2] The reader is referred to various documents describing well-established processes for the selection of the project delivery method (e.g., by Canadian Provinces Ontario and British Columbia, as well as the UK Highways Agency's Gateway Process) that consider a range of factors in a collective, qualitative and quantitative manner.

However, risks for each delivery method, in the context of rapid renewal, are discussed in depth in Appendix D, which will help DOTs understand the risks involved with each project delivery method.

3.3 Conclusions regarding Rapid Renewal

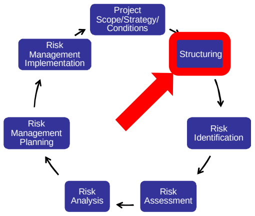
With the increasing challenges posed by aging infrastructure and reduced funding, rapid renewal strategies and tactics will be increasingly required to deliver long-lasting projects quickly, cost-effectively, and with minimal disruption. However, such rapid renewal strategies and techniques are, in many cases, somewhat innovative and thus might perform in unexpected ways. This uncertainty, especially in high-visibility projects that serve as critical transportation links, can impact the public's opinion of our highway DOTs and ultimately the performance of our transportation network. Formal and consistent risk management, as presented in this *Guide*, will be required to help ensure that DOTs meet their objectives for rapid renewal projects.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout this *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, consists of several rapid renewal elements as discussed in this chapter and summarized below.

QDOT is planning to reconstruct and expand segments of two existing (intersecting) highways, US 555 and SH 111, through a rapidly-developing suburban area. The existing highways are nearly 40 years old, have increasingly inadequate capacity, and are expensive to maintain. These facilities are the only viable east-west (US 555) and north-south (SH 111) routes for commercial traffic for several miles in either direction. Therefore, it is imperative that the necessary improvements be made quickly and with minimal disruption. QDOT would also like to minimize construction costs and future repair cycles and maintenance requirements, as well as eventual replacement issues. To help achieve these objectives, QDOT plans to encourage contractor innovation through the use of performance-based specifications and incentives, and to procure with an innovative project delivery method (i.e., design-build). It is expected that accelerated bridge construction techniques, minimally disruptive MOT (e.g., detour or realignment or full temporary closure), and innovative pavement design, among other rapid renewal elements (as described in *Guide* Appendix C), will be considered for this project. As described in this chapter, it is important that the project be adequately understood (and documented) before starting the risk management process. The project is described in *RMP* Chapter 2.

Chapter 4. "Structuring" a Project for Risk Management



4.1 Introduction to "Structuring"

As described in Chapter 2, the first step in the risk management process is to describe the "base" project to facilitate the rest of the process.

Adequately but efficiently define the "base" project scenario, against which risk and opportunity can be identified, assessed, and eventually managed.

Objectives

The primary objective of "structuring" a project for risk management is to adequately define the "base" project, relative to which risks can subsequently be identified, assessed, and eventually managed. As discussed in Chapter 2, the base project consists of a set of project assumptions regarding how the planned project will perform with respect to the project's performance measures (e.g., in terms of actual ultimate cost, schedule, etc.). The base project excludes other possibilities, which are generally described as risks or opportunities. The base project should not include any cost or schedule contingencies, or other conservatisms, which are intended to cover those risks (i.e., the project has been "de-biased" from these items to only planned or known items of work). If done appropriately, such structuring facilitates risk identification (Chapter 5) and risk assessment (Chapter 6), and forms the basis for risk analysis if needed (Chapter 7) and risk management planning (Chapter 8).

A secondary objective of structuring a project for risk management is to develop a clear and common understanding of that project, including the project scope and strategy, as well as the key project conditions and assumptions. Although this is not strictly within the scope of risk management, many project managers find it to be a valuable side benefit. It also allows for an evaluation of the consistency of project cost, schedule and other performance estimates with the project scope and strategy, considering the key project conditions and assumptions.

Another objective is to complete this step in the overall risk management process efficiently, producing accurate and defensible results that are compatible with the other steps of the process (which in turn is compatible with the project management approach). To achieve this efficiency, it is especially important that the level of detail be appropriate. This *Guide* includes examples and forms to assist in defining the appropriate level of detail for risk management. Facilitated consensus among a broad group of experts, both project-team and project independent, is key to successful structuring.

Philosophy and Concepts

As discussed in Chapter 3, the relevant project performance objectives for evaluating rapid renewal projects include minimizing project cost, schedule, and disruption during construction, and maximizing longevity. Also as discussed above (and in Chapter 2), each such performance measure consists of a *base* component (based on a particular set of assumptions or scenario) and a complementary *risk* component that covers all the other possible outcomes. The base component must be clearly defined before the "risk" component can be defined.

The DOT must develop cost and schedule estimates for a project to establish budgets and schedule milestones. These cost and schedule estimates are necessarily established on a large set of assumptions regarding planned project scope, strategy, and conditions. In deterministic estimates, some of these assumptions are explicitly stated, but most of them are implicit and incorporate various degrees of unstated bias or conservatism. Cost "contingencies" (as a percentage of base costs) are typically used to cover the cost risks. Schedule "contingencies" (time in addition to the base schedule) are sometimes (although not always) used to cover schedule risk.

However, the DOT can develop these cost and schedule estimates in a variety of ways and at various levels of detail, based on various types of information (e.g., ranging from past experience to direct contractor quotes). Generally, for costs, the DOT identifies a set of cost items, then estimates quantities and unit costs (uninflated) for each item, and then sums and inflates (based on an assumed schedule) the resulting costs. Similarly, for schedule, the DOT identifies a set of schedule activities, characterizes their sequence and precedence requirements (including external milestone dates), estimates the durations for each item (e.g., by estimating the quantities and progress/production rates), and then evaluates the critical path through the schedule.

The set of items used for cost analysis and for schedule analysis needs to be comprehensive (i.e., includes everything) but non-overlapping (i.e., does not double-count anything). Typically, but not always, the cost and schedule are estimated separately, in which case they might be based on different assumptions and therefore be inconsistent with each other. Clearly, it is important that these estimates be consistent with the specified project scope and strategy, as well as the known project conditions, and with each other. It is also helpful if all the other significant assumptions are clearly stated.

In establishing the base project cost and schedule for the risk management process the *DOT needs to remove from the estimates any conservatism and contingencies* that are intended to cover these risks. This conservatism and contingency will subsequently be accounted for in a formalized and structured manner in later steps of the risk management process. The risk management process will be used to replace these traditional estimate items with a more individually-defined set of risks and a conscious policy decision regarding the appropriate level of confidence (reliability) in planning.

It is also often useful to “abstract” detailed cost and schedule estimates to a common, relatively broad level of detail, which the DOT can explicitly link to establish a base cost-loaded schedule, which in turn can be used to more accurately determine inflation and cash flow. Such an explicit link can be provided, for example, by a simple matrix that allocates each portion of each item in the cost estimate to each schedule activity.

Similarly, the project scope and strategy, in combination with the actual project conditions, will also determine the actual disruption and longevity of the project. For consistency with the base cost and schedule estimate, the DOT should estimate the base disruption and longevity on the same set of assumptions. For example, as discussed in Chapter 3:

- Disruption might be determined by estimating the number of users affected during each project phase (e.g., average number of people affected per day times the number of days) and their average delay.
- Similarly, longevity might be determined by the net present value (NPV) of operations and maintenance (O&M) cost and replacement cost, appropriately considering the duration of operations, the cost and disruption of O&M (e.g., average per year) and of replacement, and a net discount rate.

Similar to base cost and schedule, the base disruption and longevity, to which the risks will subsequently be added, should be stripped of any conservatism and contingency.

It should be noted that, even before considering risks, there will typically be significant uncertainty in what the various base factors (e.g., unit cost, quantities, etc.) will actually be. Such base uncertainties are typically covered by conservatism in the estimate, as well as by contingency. The intent is to assess the ”mean” value for each uncertain base factor (before considering risks). Base uncertainties can then be treated as a risk (see Chapter 6) or, if quantitative risk analysis is being conducted, treated separately and explicitly (see Chapter 7).

4.2 Process of “Structuring”

This section provides an overview of methods and some guidance for successfully structuring a project for risk management. Details on *how* to conduct this process are not included here; instead, please refer to the companion training materials (Appendix G). As discussed briefly in Chapter 10, this process of structuring is usually finalized in a facilitated workshop, although much of it can be done off-line beforehand. The key elements of “structuring”, which the DOT should adequately document, include project scope, planned delivery strategy, key conditions and assumptions, and base project performance (cost, schedule, disruption and longevity), which are described individually below in more detail.

Project Scope

The *scope* of the project outlines what the project will construct, what it will remove or demolish, and, perhaps, what the project will *not* construct. This description determines, for example, the types and quantities of cost items, and consists of broad items such as the project limits, vertical and horizontal alignment, capacity, access, disruption requirements, and longevity (O&M and design life) requirements. In more detail, the scope includes, for example, the type, size, and location (TS&L) of new and/or rehabilitated lanes, interchanges and intersections; structures (and their foundations); cut and fill retaining walls; the type of pavement; the type and extent of mitigation required; etc.

Sometimes the DOT wishes to consider alternative scopes, such as different alignments or different types of structures. Because the different scopes might have some different risks, they might be evaluated separately and their performance compared to help make a decision between them. In this case, it is often useful to identify one scope as the basis for comparison and simply identify just the differences for any other scopes.

Often, it is useful in developing a common understanding and as a communication tool to develop a simple project schematic that adequately depicts the key scope elements (e.g., for each alternative, if more than one).

Planned Delivery Strategy

The *strategy* for delivering the project scope, which determines the project schedule as well as affecting project cost, disruption and longevity, consists of a series of project activities to accomplish each phase of project development. As discussed in Chapter 3, the project phases include primarily pre-construction, construction, O&M, and finally replacement, all of which require adequate DOT funding. Traditionally, all the pre-construction activities (e.g., design, funding, etc.) must be completed before going to procurement and then to construction. However, this could be done through multiple procurements (or contracts), which are phased to allow some construction to start before other parts are ready, or by having the builder complete the pre-construction activities and start construction in overlapping phases ("design-build"). Also, funding required for the project might be provided in phases or by the builder (instead of by the DOT), which might have to be paid back with interest or in exchange for some or all operating revenues. Hence, the delivery strategy consists of contract packaging (number and size of contracts), type of contract (design-bid-build vs. design-build), and funding source (DOT vs. private, and phases), as well as more detailed elements (e.g., approach to environmental process, approach to public involvement, construction phasing, etc.).

Often, it is useful for the DOT to develop a simple project "flow chart" to help gain consensus on a reasonable and accurate project-delivery and schedule logic, as well as to provide a common understanding and communication tool. This flow chart, which also serves as the basis for integrated cost and schedule analysis (Chapter 7), depicts the major project activities and their sequence and precedence requirements. As will be discussed later, the project schedule can subsequently be determined from this flowchart by assessing activity durations, lags, and external milestone dates.

Key Conditions and Assumptions

The key *conditions* under which the DOT will achieve the specified project scope via the specified strategy, which in turn will determine project performance, include items such as:

- Requirements and constraints, including:
  - political commitments,
  - design standards and specifications,
  - environmental standards / process (documentation, approvals, etc.).
  - mitigation requirements, and
  - procurement;
- Technical conditions, including:
  - existing infrastructure and potential interfaces (transportation, utilities, etc.),

    - environmental conditions (wetlands, streams, parks, historic areas, etc.),
    - real estate (land use, development pressure, etc.), and
    - subsurface conditions (geotechnical, groundwater); and
- Political or other external conditions, including:
    - Stakeholders,
    - owner policies,
    - funding, and
    - market conditions.

The DOT might know some of these conditions as fact, whereas others will be uncertain and must instead be assumed. When such assumptions must be made, they should of course be reasonable, as well as documented and recognized as only assumptions, not fact. Even though reasonable, some assumptions might eventually turn out otherwise, which constitutes risk (see Chapter 5).

Often, it is useful in developing a common understanding and as a communication tool to add these key conditions and assumptions to the simple project schematic (e.g., a one-page diagram) and simple project flowchart previously discussed. For example, it might be assumed that funding, which is a prerequisite for particular schedule activities, will be available by a particular date – this can easily be shown on the project flowchart.

Base Project Performance

Base project performance includes the base project schedule, cost, disruption, and longevity. All bias, conservatism, and explicit contingencies should be removed from the base performance measures as these will be added in the later risk assessment and analysis, as discussed in Chapters 5 through 7. The performance models and unbiased assessments of the model inputs should be confirmed by facilitated consensus among a broad group of experts, both project-team and project independent. If mean input values are used, then the approximate mean output value is produced by the model.

Schedule

After developing the project flowchart and assessing the base duration, lags, and external milestones consistent with the base project scope, strategy, and conditions (including any assumptions), the DOT can determine the base project *schedule* via "critical path" analysis. Various software packages (e.g., MS Project or Primavera Project Planner) are commercially available to accomplish this type of analysis. For the purposes of risk management (as opposed to project controls), the level of detail can be relatively broad (e.g., typically several tens of activities). In fact, very simple standard flowcharts have been developed for the two primary project delivery approaches, traditional design-bid-build and design-build (see Figure 3-1), and the base schedule analysis for each has been pre-programmed in MS Excel (see Appendix E).

Cost

The base project *cost* consists of the sum of the base costs of all the project activities, inflated to future ("year-of-expenditure") dollars depending on when they will occur and the appropriate inflation rate for that type of cost and time frame. Typically, however, the cost through construction is considered separately from post-construction cost, which will instead be considered under "longevity". The base cost of each project activity (e.g., for engineering, for real estate acquisition, for construction, etc.) in turn must be adequately assessed (e.g., as the product of assessed quantities and unit costs) consistent with the project scope, strategy, and conditions, including any assumptions. However, as for schedule, for the purposes of risk management (as opposed to project controls), the level of detail can be relatively broad, (e.g., several tens of key cost items, including miscellaneous items to collectively capture all the smaller items). These cost items can then be allocated to the project activities to determine a simple cost-loaded schedule, which allows relatively accurate determination of inflation and cash flow (if desired). As for schedule, if one of the simple standard flowcharts (Figure 3-1) is used, then the uninflated costs for each flowchart activity can be estimated and then readily analyzed, since the base cost analysis for each has been pre-programmed in MS Excel (see Appendix E).

Disruption

The base project *disruption* consists of the sum of the base disruptions associated with all project activities, typically expressed (as previously discussed) in terms of cumulative users' "lost" time. Typically, however, as for cost, disruption through construction is considered separately from post-construction disruption, which will instead be considered under "longevity". The base disruption for each activity in turn must be adequately assessed. For example, base disruption during construction could be calculated as the product of these assessed values:

- Number of days when delays will occur (e.g., as a fraction of that activity's duration),
- Average number of users affected each of those days, and
- Average delay for an individual user.

> *For example*: If disruption occurs during about 10% of the construction period, which is 1000 days long, and an average of 10,000 people per day are affected, losing an average of 1 hour each, then the disruption is 1 million hours.

These factors must be assessed consistently with the project scope, strategy, and conditions, including any assumptions. As for cost and schedule, if one of the simple standard flow charts (Figure 3-1) is used, the disruption for each flowchart activity can be estimated (as described above) and then readily analyzed, since the base disruption analysis for each has been pre-programmed in MS Excel (see Appendix E).

Longevity

The base project *longevity* consists of the combination of costs and disruption after construction, during O&M and replacement, discounted to net present value depending on when they will occur (e.g., schedule of replacement), the value of disruption, and the appropriate discount rate. The base cost and base disruption for O&M and for replacement must be adequately assessed, and the value of disruption and net discount rate specified. For example:

- replacement base disruption (M-hrs) could be translated to equivalent cost ($/hr), and then added to direct cost ($), and the net present value of this combined cost can be determined as a function of design life (yrs) and net discount rate (%/yr);
- O&M base disruption (M-hrs/yr) could be translated to equivalent cost ($/hr), and then added to direct cost ($/yr), and the net present value of this combined annual cost can be determined as a function of design life (yrs) and net discount rate (%/yr); and
- The NPVs of O&M and replacement can be summed as a reasonable measure of longevity.

> *For example*, if:
>
> - disruption averages 0.1 M-hrs/year during O&M and 1 M-hrs during replacement,
> - the "value" of disruption is $10/hr,
> - direct cost averages $1M/yr during O&M and $10M during replacement,
> - replacement is in 50 years, and
> - the net discount rate is 5%/yr,
>
> then the NPV of post-construction cost and disruption ("longevity") is:
>
> - O&M: $1M/yr + 0.1 M-hrs/yr * $10/hr = $2M/yr. which over 50 yrs at 5%/yr has NPV of $36.5M
> - Replacement: $10M + 0.1 M-hrs/yr * $10/hr = $20M, which over 50 yrs at 5%/yr has NPV of $1.8M
> - Longevity: $36.5M + $1.8M = $38.3M

As for cost, schedule and disruption, if one of the simple standard flowcharts (Figure 3-1) is used, then the cost and disruption for each post-construction flowchart activity can be estimated (as described above) and then (with values for disruption and net discount rate) readily analyzed, since the base longevity analysis for each has been pre-programmed in MS Excel (see Appendix E).

Combined Performance (for evaluating "severity" of risks)

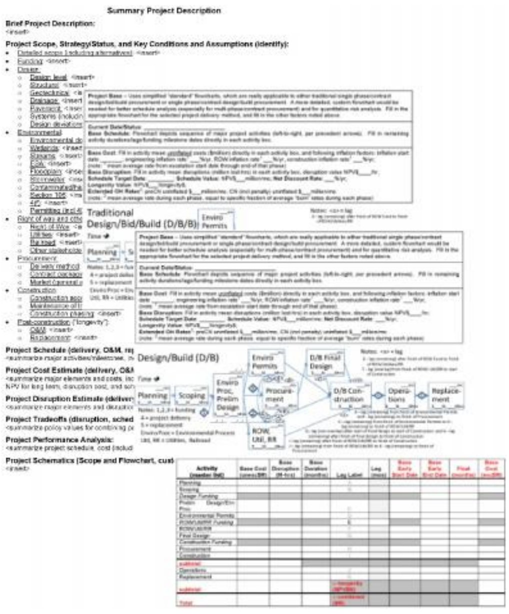
An overall measure that appropriately combines all the more detailed project performance measures (i.e., cost, schedule, disruption and longevity) is needed to express the "severity" of risks (in terms of change in combined performance associated with that risk), as well as to compare alternatives. This is done by defining "tradeoffs" among those more detailed project performance measures, so that they can be expressed in common terms and meaningfully combined. For example, if the tradeoffs are approximately linear and independent of each other:

- Base project schedule (i.e., completion date) could be translated to equivalent cost (YOE$/mo) based on the amount the decision maker would be willing to pay to change that schedule;
- Base project disruption during construction (M-hrs/yr) could be translated to equivalent cost (YOE$/hr) based on average user costs;
- Base project longevity (NPV$) could be translated to equivalent cost (YOE$) based on the amount the decision maker would be willing to pay to change longevity; and
- The above three translated measures could be summed with escalated base project cost (YOE$) as a reasonable measure of combined performance.

As for cost, schedule, disruption, and longevity, if one of the simple standard flowcharts (Figure 3-1) is used, then the tradeoffs for schedule, disruption and longevity can be specified and readily analyzed, since the base combined performance analysis has been pre-programmed in MS Excel (see Appendix E).

Documentation

It is important for the DOT to adequately document the base project scenario to provide the basis for subsequent risk management steps. As previously stated, risk management is an iterative process that is repeated at various key milestones and project phases. Documentation at each stage is a key to efficient and successful risk management. Similar to a “Basis for Cost Estimate”, the base documentation for risk management also helps to qualify the results of the process, so that if the base changes in the future (e.g., a major change in scope) it becomes clear that the old results might not be applicable any longer and should be updated. Such documentation can be done at a broad level of detail, suitable for qualitative risk assessment, using the forms provided in Appendix E. As described in Chapter 7 on quantitative risk analysis, however, more detail might be appropriate, including: a) a custom project flow chart with an explicit allocation of the various cost items and risks to those more detailed project activities; and b) explicit uncertainties in (and correlations among) the base factors (e.g., various unit costs), separate from risks.



Forms (Appendix E)

4.3 Conclusions regarding Structuring

“Structuring” a rapid renewal project for risk management is a necessary and valuable first step in the risk management process. It provides the “base” for identifying risks and opportunities, assessing them, and eventually managing them; and it also documents the current state for future reference. If done appropriately, structuring facilitates subsequent risk identification and assessment, as well as clarifies the important elements of the project, providing a common understanding and a communication tool. For relatively simple projects, the DOT can accomplish this efficiently (and compatibly with the other steps of Risk Management) through the use of the forms provided in Appendix E, which can be filled out before (to the extent possible) and then finalized during a facilitated workshop. For more complex projects and/or for quantitative risk analysis, more detail is typically required.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, was "structured" following the principles outlined in this chapter, as documented in *RMP* Chapter 2 and as summarized below:

1. QDOT presented the project's scope/strategy/status and key conditions/assumptions, and the associated cost, schedule and disruption estimates to the combined group of key project-team staff and independent subject-matter experts.
2. Facilitated by a "base lead", the group reviewed, "de-biased" (i.e., removed any over- or under-estimating), and validated the cost, schedule and disruption estimates for the stated assumptions. The results were "base" cost, schedule and disruption estimates, exclusive of risk and opportunity. <Note: Subsequently, a quantitative risk analysis was conducted, for which uncertainties in and correlations among the base costs, schedule and disruption estimates were assessed – see *RMP* Addendum X.>
3. Facilitated by a "risk lead", the group adopted a Design/Build (D/B) standard simplified graphical "flow chart" describing the sequence of major project activities (see Figure E-1), and the cost, schedule and disruption estimates were allocated to those flowchart activities. This simplified flow chart serves as the basis for subsequent risk identification and assessment, and then proactive individual risk reduction identification and evaluation. <Note: Subsequently, a quantitative risk analysis was conducted, for which a more detailed flowchart was developed – see *RMP* Addendum X.>
4. "Mean" (i.e., probability weighted average) base project performance (i.e., schedule, uninflated and inflated cost, and disruption, both total for the project and by project activity) was then approximately calculated using an appropriate risk model (an MS Excel workbook template). For subsequent risk and risk management evaluations, QDOT established "tradeoff values" (which are policy rather than technical issues) that allowed the various project performance measures to be combined, e.g.: a) combining post-construction schedule, cost and disruption into "longevity"; and b) combining schedule, cost and disruption through construction with longevity into "severity".

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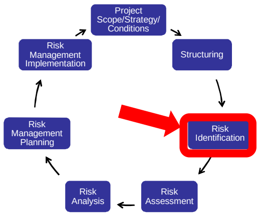
Chapter 5. Risk Identification



5.1 *Introduction to Risk Identification*

As described in Chapter 4, the "base" project describes the planned project scope, strategy, conditions, and assumptions. However, projects don't always go as planned, particularly when projects involve new or innovative methods like rapid renewal projects do. The DOT should identify what events *might* occur and change the project relative to the base assumptions, and therefore affect the project's performance objectives of minimizing project cost, schedule, and disruption during construction, and/or maximizing longevity of the constructed facility. The risks and opportunities are listed in the *risk register* for later risk management activities. As described previously, events that might occur and change the project outcomes can be risks (potential problems that degrade project performance) or opportunities (potential improvements that enhance project performance).

> Adequately but efficiently identify, categorize, and document (in a *risk register*) a comprehensive, non-overlapping set of "risks" (potential problems) and "opportunities" (potential improvements), which are events outside the base set of assumptions that *might* occur and change "base" project performance

Objectives

The objectives of risk identification are to:

- Identify, categorize, and document <u>all</u> risks and opportunities that could significantly affect the project's base performance measures;
- Start a risk register, which is a comprehensive set of non-overlapping risks and opportunities; and
- Set the stage for subsequent steps in the risk-management process, which include:
    - risk assessment (Chapter 6);
    - risk analysis, if needed (Chapter 7); and
    - risk-management planning (Chapter 8).

Another objective is to complete this step in the overall risk management process efficiently, producing accurate and defensible results that are compatible with the other steps of the process (which in turn is compatible with the project management approach). Facilitated consensus among a broad group of experts, both project-team and project-independent, is key to successful risk identification.

Philosophy and Concepts

Risk identification is a relatively straightforward process, but DOTs should still follow a basic set of principles to ensure that risk identification is conducted appropriately. Key principles of risk identification are outlined below. Guidance for following these principles is provided later in this chapter.

- *Risk identification is just that – identification*. To mitigate bias, it does not involve discussion of severity, screening, or prioritization. Similarly, risk identification does not involve re-designing the project to fix problems or identifying risk management actions.
- *Risk identification should be comprehensive*. Be careful not to miss or exclude risks or opportunities. Do not assume that risks will be avoided through later engineering efforts. Consider all project phases, elements, and components. However, it is inevitable that some risks will be missed – hence, to be comprehensive, there should be a "miscellaneous" risk to cover those unidentified risks.
- *Seek out both risks and opportunities.*
    - Don't focus solely on potential problems (risks).
    - Opportunities generally don't include potential risk management actions. Risk management actions are deliberately planned and implemented specifically to manage risk or exploit genuine opportunities.

- *Risks and opportunities should be defined relative to the "base".*
- *Risks and opportunities should be identified at an appropriate level of detail*.
- *Risks should be characterized and documented adequately (in a risk register)*, in order to provide enough basis for understanding the issue and subsequent assessment:
    - What is the nature of the risk? (What is the fundamental issue of concern?)
    - Who is affected by the risk? (Does the risk primarily affect the DOT?)
    - When could the risk occur? (Can it occur once during the project, or multiple times?)
    - Where could the risk occur? (What element of the project could it affect? Can it occur in more than one location or affect more than one element of the project?)
    - What could cause the risk to occur? (What are the causes or triggers, and how would they be recognized?)
    - How likely are these triggers to occur during various phases of the project?
    - What are the potential impacts if it occurs? (How would this affect the project's performance measures if it occurred?)
    - What are the potential relationships (correlations, dependencies) with other risks?

> *Example Risk Documentation (<u>not</u> the hypothetical case study):*
>
> **Additional wetland impacts result from changes to project design**
>
> Wetland impacts have been delineated and permitted for the planned sign gantry foundations. However, the contractor might need to change one or more sign locations. If so, that might introduce additional wetland impacts, which are likely to be small (e.g., under several thousand square feet). In any case, the contractor would have to get approval for any temporary impacts to the wetlands and develop and permit mitigation for any unavoidable permanent impacts, where permitting might involve the US Army Corps of Engineers.
>
> This problem could affect the DOT's project schedule (delaying permits, which is a precursor to other activities) and cost (in the form of a claim from the design-builder for additional mitigation and extended overheads).

- *Risks change* as the base project evolves, as conditions change, and new information becomes available. Eventually, each risk either happens (and becomes part of the base) or not (and can be "retired"). Generally, specific types of risk can only happen during specific project phases, after which they cannot occur.

5.2 Process of Risk Identification

There is not just one way to conduct risk identification. Risk identification can range from an informal, back-of-the-envelope, individual "thought exercise" to a very structured, very formal, and facilitated process. For DOTs attempting to identify risks for rapid renewal projects, a facilitated yet semi-formal group exercise, commonly known as the Delphi approach, is often the most efficient and effective approach to adequate risk identification. The following are key elements of a group process, which should be efficient, minimize bias, and maximize discovery and identification of risks:

1. *Include both project-team members and project-independent subject-matter experts in the risk identification exercise*. Ideally, these experts are the same group that developed the project "base" (as described in Chapter 4).
2. *Circulate "base" information to the participants beforehand.* Ensuring that the participants in the risk identification are already familiar with the project scope, strategy, conditions, and assumptions will promote much-more effective discussion during the risk identification exercise.
3. *Prior to the actual risk identification exercise, ask each expert to document his or her issues of concern.* This helps to ensure participant buy-in and subsequent consensus.
4. *In a facilitated meeting or workshop environment with the experts, the qualified facilitator leads the identification of risks, minimizing bias*. This is generally done:

    - *a.* first through group brainstorming (e.g., existing concerns of project team and reviewers, issues identified during structuring, and judgment/experience from other similar projects);
    - *b.* then through analysis (e.g., evaluation of scope, key assumptions/conditions, and project strategy/project phase, etc.); and
    - *c.* finally through comparison with "risk checklists" (see below).

5. *After the risks have been identified, the facilitator categorizes the risks to help establish a proper risk register*:
    - A risk register is a comprehensive, non-overlapping set of risks and opportunities. In a risk register, risks are often organized or categorized in some convenient fashion and should be at the appropriate level of detail (i.e., typically several tens of significant risks). The risk register is a dynamic document "owned by" the project team.
    - Categorization can be by type of risk, by project component, or by project phase (which captures both the type of risk and time element). For the purposes of this *Guide*, the recommended categorization is by project phase, because the authors' experience is that people often "organize" their thinking about the project by the type of project activity and when the activity occurs. In fact, it is recommended that risks be categorized by the phase they are most likely to occur within (which is not necessarily when the impacts would occur) and after which they can be "retired", which subsequently helps in developing contingency drawdown and risk monitoring plans (see Chapter 8). However, it is not important for the categories to be rigidly defined. In fact, many risks could easily be categorized into more than one category due to their impacts across many facets of the project.
    - Categorization serves to:
        - organize the list of risks at an appropriate level of detail;
        - combine highly correlated or dependent risks, which means that the remaining risks are often largely independent;
        - eliminate duplicate risks; and
        - identify missing risks within each category.

To help ensure a smooth and effective risk identification exercise, consider the following guidance (which parallels some of the previously identified principles):

- *Document all credible possibilities* outside the base set of assumptions in order to develop a comprehensive set of risks and opportunities (separate from potential risk management actions). However, recognize that regardless of how thorough the identification process is, there will still be risks that have not been identified, although they should not be major ones. A miscellaneous risk can capture all these unidentified risks ("unknown unknowns").
- *Do not debate the severity of issues* (i.e., the likelihood of occurrence and/or the magnitude of the impacts from occurrence) or *prematurely screen out "minor" issues* – this comes later during risk assessment.
- *Do not try to "fix" the problem* – this comes later during risk management.
- *Think broadly*. Individuals should consider other projects they've worked on, and reflect on how much those projects changed from original concept to completion. They should also consider both obvious and "implied" risks (e.g., as hinted in "base" project documentation by words such as "might", "maybe", "could", "assumes", or "likely"). Ideally, the group could, at the completion of the project in the future, look back and say, "we identified as a possibility every significant change that ultimately occurred".
- *If at all possible, do not intentionally exclude any significant issues* from the risk identification and subsequent risk assessment.
    - Excluding major uncertainties, risks, and opportunities is the quickest way to misleading or erroneous risk assessment results.

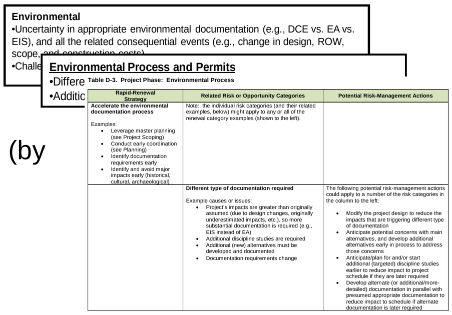
  - If a DOT must exclude something from the risk assessment (for whatever reason), document the exclusion explicitly. Remember that results will be conditional on the assumption that the excluded issues do not occur (which might be a big assumption), and results might be misleading if these exclusions are not clearly conveyed to those who use the results.

As mentioned earlier, to supplement the brainstorming and analysis by project and independent subject-matter experts, the facilitator should attempt to identify any missing risks through use of risk "checklists". These checklists are not intended to be proper risk registers *per se*, because they are often not comprehensive and contain items that might partially overlap one another. However, their purpose is to serve as memory prompts or "shopping lists" of issues that have been observed on other projects.

The facilitator can peruse these lists to identify types of risks that might be applicable to the current project but that were not identified through brainstorming and analysis. Note that risk checklists should only be used *after* the brainstorming and analysis in order to avoid pre-populating a risk register and therefore stifling creativity and jeopardizing buy-in.

Although various risk checklists are available in a number of risk assessment references, the authors' experience is that most lists are substantially incomplete for various reasons (Golder, 2008b). As a result, a significant focus for the research effort that led to this *Guide* was to develop a more-comprehensive, yet still usable, checklist of "risk categories", or types of risks, that could occur for rapid renewal projects. This checklist of rapid renewal risk categories is presented in Appendix D:

- *Appendix D-1 provides a summary of types or categories of risks for traditional (non-rapid renewal) transportation projects, by project phase*. This is presented because, as mentioned elsewhere in this *Guide*, DOTs with rapid renewal projects should, for comprehensiveness, address risks and opportunities for the entire project – not just for the project's rapid renewal elements.
- *Appendix D-2 provides a summary of risk categories specifically for rapid renewal projects, by project phase*. This appendix is intended to serve as a risk checklist for rapid renewal projects, but only in terms of generic *types of risks*. It is up to the DOT to extrapolate from the risk checklist and identify *specific risks* related to specific rapid renewal strategies and methods employed in the DOT's particular project.
- *Appendix D-3 provides more detail than Appendix D-2*. Each table in Appendix D-3 corresponds to one of the various project phases defined in Chapter 3:
  - Table D-1. Planning
  - Table D-2. Project Scoping (including project delivery and funding / financing)
  - Table D-3. Environmental Process and Permits
  - Table D-4a. Design and Construction (General Principles)
  - Table D-4b through D-4g. Design and Construction (by Discipline, such as Structures, Geotechnical, etc.)
  - Table D-5a. Right-of-Way
  - Table D-5b. Utilities
  - Table D-5c. Railroad
  - Table D-6. Procurement (including Contracting Strategy)
  - Table D-7. Operations and Maintenance
  - Table D-8. Replacement.



Environmental
•Uncertainty in appropriate environmental documentation (e.g., DCE vs. EA vs. EIS), and all the related consequential events (e.g., change in design, ROW, scope,
•Challe

Environmental Process and Permits
•Differe
•Additic

Table D-3. Project Phase: Environmental Process

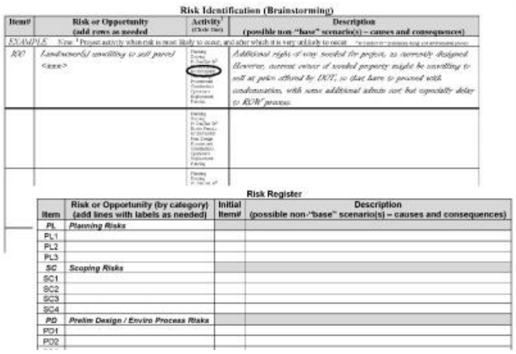
Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate the environmental documentation process Examples: • Leverage master planning (see Project Scoping) • Conduct early coordination (see Planning) • Identify documentation requirements early • Identify and avoid major impacts early (historical, cultural, archaeological)	Note: the individual risk categories (and their related examples, below) might apply to any or all of the renewal category examples (shown to the left).	
	Different type of documentation required Example causes or issues: • Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.), so more substantial documentation is required (e.g., EIS instead of EA) • Additional discipline studies are required • Additional (new) alternatives must be developed and documented • Documentation requirements change	The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Modify the project design to reduce the impacts that are triggering different type of documentation • Anticipate potential concerns with main alternatives, and develop additional alternatives early in process to address those concerns • Anticipate/plan for and/or start additional (targeted) discipline studies earlier to reduce impact to project schedule if they are later required • Develop alternate (or additional/more-detailed) documentation in parallel with presumed appropriate documentation to reduce impact to schedule if alternate documentation is later required

Check Lists (Appendix D)

  Tables D-1 through D-8 provide insight into the summary checklist provided in Appendix D-2. Within each table, the relevant major rapid renewal strategies and tactics/methods (distilled from Appendix C) are listed for that project phase. For each rapid renewal strategy in a given table, the general types of risks (risk categories) that could occur from employing that renewal strategy are identified. And for each rapid renewal strategy, potential proactive risk-management actions are also identified to manage the corresponding risks, as will be discussed in Chapter 8.

When considered together, Appendices D.1 and D.2 (which is expanded in Appendix D.3) constitute a relatively complete set of risk categories (types of risks) that could occur for projects with both traditional and rapid renewal elements. Again, remember that these risk checklists are not intended to be proper risk registers – they are only "brain ticklers".

To help the facilitator document and categorize risks during brainstorming, and to then add risks from analysis as well as from checklists and then edit risks to eliminate duplication, specific forms and a MS Excel workbook template have been developed (see Appendix E). These forms and template use the basic project phases shown in Chapter 3 for categorizing risks. The template automatically sorts risks (by category) from brainstorming and assigns each one a unique label. This set of risks can then be supplemented by other risks identified in each category by analysis and then by comparing with risk checklists, and then can be edited to eliminate duplication. This complete set of edited risks becomes the basis of the *risk register*.



Risk Identification (Brainstorming)

Item#	Risk or Opportunity (add rows as needed)	Activity¹ (Circle One)	Description (possible non-"base" scenario(s) – causes and consequences)
EXAMPLE	Note: ¹ Project activity when risk is most likely to occur, and after which it is very unlikely to occur		
R00	*Landowner(s) unwilling to sell parcel <###>*		*Additional right-of-way needed for project, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.*

Risk Register

Item	Risk or Opportunity (by category) (add lines with labels as needed)	Initial Item#	Description (possible non-"base" scenario(s) – causes and consequences)
PL	*Planning Risks*		
PL1			
PL2			
PL3			
SC	*Scoping Risks*		
SC1			
SC2			
SC3			
SC4			
PD	*Prelim Design / Enviro Process Risks*		
PD1			
PD2			

Forms (Appendix E)

The actual "*how to*" details of implementing each of the above steps is covered in companion training materials, which are summarized in Appendix G. The logistics of implementing the above set of steps (e.g., through facilitated workshop(s)), as well as when during project development they should be implemented, are subsequently discussed in Chapter 10.

5.3 Conclusions regarding Risk Identification

Risk identification is an important step in the risk management process. It involves identifying, categorizing, describing, consolidating/editing and documenting all the potentially significant risks and opportunities to the project's base performance measures. No screening or excluding is done at this time, since the significance of the various risks will be determined later, at which point those that are not significant will be identified as such and there will be a record of this determination. Similarly, no changes to the project to fix these problems are done (or assumed) at this time, since this will also be done at a later step after the risks have been prioritized. Risk identification forms the basis for a project *risk register*, risk assessment, risk analysis (if needed), and risk-management planning. Therefore, a qualified elicitor should facilitate identification (via brainstorming and then analysis) of a comprehensive and non-overlapping set of risks from the project team and an appropriate group of project-independent experts, efficiently achieving consensus among them, based on available information and expertise. A suitable risk checklist can subsequently be used to ensure completeness.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, was examined following the principles and process outlined in this chapter, as documented in *RMP* Chapter 3 and summarized below.

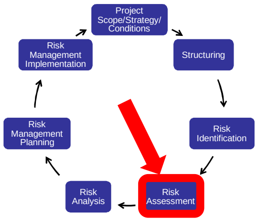
The facilitated combined group of key project-team staff and independent subject-matter experts identified, categorized, and documented in the project risk register nearly 60 current risks and opportunities (relative to the base) with potential cost, schedule, and/or disruption impacts (see table below for several examples). The risks and opportunities (hereafter collectively termed risks) spanned all remaining phases of the project, and were categorized by the project phase in which they were most likely to occur (and after which they could be "retired"); e.g., 4 planning risks, 7 scoping risks, 16 preliminary design / environmental process risks, 2 environmental permitting risks, 10 ROW/utilities risks, 8 procurement risks, and 12 construction risks. Note that at this point in the risk assessment, the group did not discuss the likelihood or severity for any of the risks.

Initially, risks were simply brainstormed by the group and then categorized. Once the initial list of risks were categorized, the group added risks to complete each category, finally referring to the checklists (*Guide* Appendix D), and then edited the risks to eliminate any overlap.

Select rapid renewal risks for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

Project Phase	Risk ID	Title of Risk or Opportunity
Preliminary Design / Environmental Process	PD13	Change in environmental documentation
Right-of-Way, Utilities, and Railroad	RU3	Unwilling sellers
Procurement	CP2	Uncertain D/B contracting market conditions at time of bid
Construction	CN3	Problems with planned Accelerated Bridge Construction technique

Chapter 6. Risk Assessment



6.1 Introduction to Risk Assessment

After identifying risks and opportunities as described in Chapter 5, the next step is to understand the importance that each risk and opportunity has on the project's performance measures. Assessing the "severity" of each risk and opportunity allows the DOT to better plan risk-management actions and make better project decisions.

Objectives

The primary objective of risk assessment is to adequately determine the significance of each risk and opportunity, in order to determine those risks and opportunities that should be refined further (e.g., by gathering additional information) and/or reduced (if possible) through proactive risk management actions (Chapter 8).

Adequately but efficiently assess the "severity" (combination of likelihood and various consequences), and therefore significance, of each of the risks (including opportunities) in the *risk register*.

Secondarily, when considered collectively over the complete set of risks and opportunities, this significance can provide some insight into ultimate project performance. A more quantitative determination of ultimate project performance is discussed in Chapter 7 (Risk Analysis) and plans for managing that performance (including establishing and managing contingency) are discussed in Chapter 8 (Risk Management Planning).

Another objective of risk assessment is to complete this step in the overall risk management process efficiently, producing accurate and defensible results that are compatible with the other steps of the process. How this information will be used in later steps of the process will determine its requirements. In all cases, facilitated consensus among a broad group of experts, both project-team and project-independent, is key to successful risk assessment.

Philosophy and Concepts

There are several important concepts regarding risk assessment that affect the accuracy and defensibility of the results, as well as the effort, including:

- Implicit vs. explicit rankings;
- Qualitative vs. quantitative assessments;
- Subjective vs. objective assessments; and
- Level of detail.

Implicit versus Explicit Rankings

The significance of a risk or opportunity is defined in terms of its "severity", or likely effect on project performance. This significance can be determined by ranking the various risks and opportunities in one of two basic ways:

- Implicitly assessing each risk's likelihood of occurring and its impacts on project performance if it occurs (e.g., Risk A is more significant than Risk B), both with respect to individual performance measures and to a combined measure. However, due to the many complexities involved (i.e., the difficulty in implicitly combining and adequately accounting for so many factors), this is difficult to do accurately and defensibly.
- Explicitly assessing and then appropriately combining the "risk factors" that characterize each risk, including:
    - the likelihood that the risk occurs (e.g., 25% chance), and
    - the magnitude of the consequences (impacts) to each performance measure if the risk occurs (e.g., $2 million cost increase and 6-month delay to construction).

  Assessing the individual risk factors is generally less complex and more tractable, and is generally more accurate and defensible, as well as more informative – if done appropriately – than implicit assessment. ~~This~~Generally this approach also allows for both identifying *and more* *accurately evaluating* potential risk-management actions (Chapter 8), as well as providing a foundation for risk analysis (Chapter 7), if needed.

This *Guide* focuses on the risk factor (explicit) approach.

Qualitative versus Quantitative Assessments

Qualitative assessment involves characterizing the likelihood and consequences in terms of non-quantitative "ratings." For example, a risk might be assessed to have a high ("H") likelihood of occurrence, and a corresponding medium ("M") cost impact and low ("L") schedule impact if it occurs. Another approach is to use numerical ratings (e.g., 1 through 5) instead of L, M, and H ratings. In both cases, these ratings are typically not defined with respect to quantitative values. The benefits of qualitative assessments may include:

- Relatively quick to conduct; and
- Provides a simple visual rating (depending on the method used).

The drawbacks of qualitative assessments may include:

- Ratings ~~are~~ can be vague, if qualitative ratings are not tied to specific values (e.g., what does a "High" likelihood of occurrence really mean?). As a result, different people can interpret qualitative ratings in different ways, which might lead to inaccuracies or problems in developing consensus.
- If the ratings (e.g., for likelihood and consequence) are not combined, then no overall measure of the risk is possible, which means that the register of risks cannot be ranked or prioritized.
- If the ratings are combined, the resulting risk rankings are generally ambiguous, relative (not absolute), and can even be misleading. To rank a risk based on assessed risk factors, the risk factors must generally be combined in some fashion. The most logical approach is to first determine the combined consequence rating from the various consequence types and then to determine the rank as the product of the likelihood rating and the combined consequence rating. However, qualitative ratings cannot actually be added or multiplied and, because the risk-factor ratings are often vague, the resulting risk ranking is ambiguous. For example, suppose a risk has been assessed to have a High (H) likelihood and a Low (L) combined consequence (which in turn was based on a Low (L) cost consequence and a Low (L) schedule consequence). Is the ranking for this risk H x L = M? And does this risk have the same ranking as another risk with M x M = M? And is this the same ranking as L x H = M?

Quantitative assessment generally involves characterizing the risk factors in one of two ways:

- Ratings: In terms of ratings that are defined by appropriate numerical scales (e.g., a High likelihood of occurrence might be defined to be a probability of occurrence between 40% and 70%). An example of this type of semi-quantitative assessment is presented later in this chapter.
- Numerically: Directly in terms of numerical values, which avoids ratings altogether. For example, a risk might be assessed to have a 25% probability to occur, and if it occurs, would result in a mean value of $1 million additional cost and 2-month project delay during construction. An example of this type of quantitative assessment is also presented later in this chapter.

  Note: To adequately quantify the uncertainty in project performance, it is generally necessary to assess the uncertainties in (and the correlations among) the various "conditional" consequences of the most significant risks, as well as in the base cost and schedule factors (see Chapter 4). This can be done in terms of likely ranges (continuous probability distributions) or scenarios (discrete probability distributions), as discussed further in Chapter 7.

Mean value is the probability-weighted average value.

Conditional value is the value if the risk occurs (ignoring the probability of that risk occurring).

Unconditional mean value is the mean value considering (accounting for) the probability of that risk occurring.

The benefits of quantitative assessments can include:

- No ambiguity in values.
- Can meaningfully combine risk factor assessments (analytically rather than subjectively):
  - Can combine risk likelihood and consequence. For example, the “unconditional” mean value of additional cost associated with a particular risk simply equals the product of the conditional mean value of additional cost if the risk occurs and the probability that it will occur.
  - Can determine the change in the various project performance measures (i.e., sensitivity) associated with each risk. For example, for additive project performance measures (such as uninflated cost), either: a) the conditional impacts can be used to determine the conditional change in the performance measure, which is then weighted by its probability of occurrence; or b) the unconditional impacts can be used directly. However, for non-additive performance measures (e.g., schedule), these two approaches might give different results, so that the conditional impacts should be used.
  - Can combine changes in various individual project performance measures associated with each risk into a change in one *combined performance measure* for that risk, as a measure of risk “severity”. For example, the “value” (in terms of equivalent cost, in dollars) of schedule, disruption and longevity can be determined, and combined with capital or direct cost, to determine a single combined performance measure in monetary terms. A method for determining the equivalent monetary value for non-monetary performance measures is described later in this chapter.

Performance measure – e.g., cost in monetary terms vs. schedule in non-monetary terms

Combined performance measure – translate non-monetary performance measures into equivalent monetary terms via tradeoff “value” (i.e., willingness to pay to change) and then combine

Severity – change in combined performance measure

For example: If schedule delay is two months and the value of such delay has been established at \$1M/mo (for deferred operations), then the delay’s equivalent cost, which can be compared directly to capital cost, is \$2M, plus any other time-related delay (increased overheads and escalation).

  - If the set of risks is comprehensive and non-overlapping, then the changes in project performance measures associated with that set of risks can be determined. For example, the mean value of the change in uninflated project cost associated with all the risks is the sum over all risks of the unconditional mean value of additional uninflated cost associated with each risk.
- Can meaningfully rank risks appropriately based on their unconditional mean values by consequence type (e.g., uninflated cost increase, schedule impact) or more completely by combined consequence (“severity”).
- Forms the basis for quantitative risk analysis (Chapter 7) and for quantitative evaluation of possible risk reduction actions, as part of risk management planning (Chapter 8).

The drawbacks of quantitative assessments can include:

- Takes additional effort to adequately:
  - Assess the risk factors more precisely, and achieve consensus among a broad group of experts. This is especially true if full uncertainty in conditional consequences of risks, as well as in base cost and schedule factors, is assessed, in which case correlations and dependencies must also be considered. This is discussed further in Chapter 7 (Risk Analysis).
  - Determine (by analysis) the change in project performance measures associated with the assessed risk factors, especially for non-additive performance measures. This can be

done to various degrees of approximation, and can become very complicated and prone to error (especially for full uncertainty). This is discussed further in Chapter 7 (Risk Analysis).
    - Assess the tradeoff values to determine equivalent costs of non-monetary performance measures so that a single combined performance measure can be developed. This is typically a policy (rather than a technical) issue, which should be addressed by DOT management.
- If computing total project risks (i.e., combining the set of risks), must have a non-overlapping and comprehensive set of risks to avoid double-counting and missing any items, respectively. A suitable “allowance” (e.g., loosely based on an 80:20 rule that suggests 80% of the total is associated with 20% of the items) is generally used for unidentified risks to make the set comprehensive. For example, a 50% chance of an extra 50% of identified risks, or a 100% chance of an extra 0% to 50% of identified risk, might be used for this allowance.

Subjective versus Objective Assessment

When an adequate “database” of information related to a particular risk is available, an objective, or statistical, approach can be used to assess the risk factors. Unfortunately, however, this is rarely the case in transportation construction projects and, in particular, for innovative rapid renewal projects. Similarly, when appropriate analytical methods are available to calculate changes in performance measures as a function of the risk factors, then this objective approach can be used, as opposed to assessing those changes in performance measures directly; e.g., it is better to assess the change in an activity duration and then analyze the change in project completion date (considering critical path) than to assess the change in project completion date directly.

However, when statistical information or appropriate analytical methods are not available, the expert opinion of subject-matter experts, based on all available information, can be elicited, de-biased, and quantified in the form of “subjective assessments.” Because most transportation projects – and particularly rapid renewal projects – are relatively unique, adequate data are generally not available and properly-obtained subjective assessments usually are required to develop risk-factor assessments. Subjective assessments, when properly developed and documented, and especially if they represent a consensus among a wide group of experts, are widely accepted in risk assessment practice. However, subjective assessments are subject to bias, which must be identified and mitigated. Guidance on how to mitigate bias is provided later in this chapter.

Level of Detail

The level of detail, and therefore effort, put into risk assessment should be consistent with the level of information available on the project’s cost and schedule, the size and complexity of the project, and the objectives for the risk assessment. For example, if the objective for the risk assessment is:

- Simply to roughly identify the top risks, then less detail and “precision” (in terms of approximation, as opposed to the number of digits) is required;
- To be able to quantify the benefits of proposed risk management actions, then higher-quality and more-detailed assessments and analysis are required; and/or
- To quantify the uncertainty in project performance, then full uncertainty in (and correlation among) the various factors and more detailed probabilistic analysis are needed, as discussed further in Chapter 7.

6.2 Process of Risk Assessment

Methods

As mentioned previously, various methods exist to conduct risk assessment via risk factors (as well as implicitly). Several of the more common methods for assessing and combining risk factors include, in increasing level of complexity:

- Qualitative

    - "Red/Yellow/Green". This method uses qualitative ratings for risk factors, which generally are not defined and are combined subjectively.
    - "Rating Scale". This method uses numerical ratings, which generally are neither appropriately defined nor appropriately combined.
- Quantitative
    - "Mean-value *Ratings*". This method is an extension of the qualitative methods mentioned above, with mean-value ratings based on defined numerical scales and combined appropriately (analytically), resulting in mean risk severity ratings.
    - "Mean *Values*". As its name implies, this method bypasses ratings altogether, instead quantifying risk factors directly in terms of mean values (e.g., dollars, time), which are combined appropriately (analytically), and results in mean risk severity values ($) and mean performance values (e.g., dollars, time).
    - "Full Uncertainty". This method involves quantifying the uncertainties in (and correlations among) the risk factors, as well as the base factors, and then appropriately combining all of the uncertainties (analytically), as discussed in Chapter 7 (Risk Analysis), and results in probability distributions for project performance and contributions to specific target percentiles of project performance.

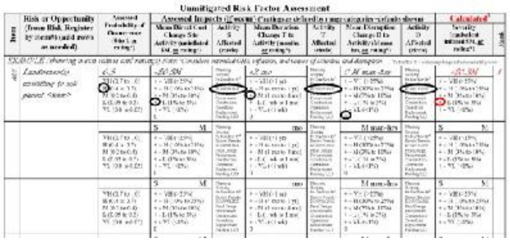
Quantitative "Mean Value" Method

The mean value method characterizes individual risk factors directly in terms of mean values in the corresponding units or dimensions (e.g., probabilities in %, consequences in dollars and time). As subsequently discussed, consensus among a broad group of experts is ideally achieved on these mean values, appropriately considering (either statistically or subjectively) all available information. These mean values of the various risk factors (i.e., probability and conditional consequence by type to specific activities) are then appropriately combined (e.g., by analysis) to determine a mean change in each performance measure, as well as a mean change in a combined performance measure ("severity"), in terms of equivalent inflated project cost (see example).

Equivalent inflated project cost is one possible combined performance measure (as described previously). The *change* in equivalent inflated project cost resulting from a risk reflects the following: a) the indirect cost of delays in the form of additional overhead/staffing costs, b) the time-value equivalent cost of schedule delay in terms of additional monetary inflation, c) the time-value equivalent cost of schedule, disruptions and longevity in terms of "value"; and d) the direct-cost consequence in uninflated monetary terms. If the set of risks is comprehensive and non-overlapping, then mean total (i.e., base+risk) performance can also be approximately determined by appropriately combining the base and individual risks, from which the mean collective risk can be determined. However, this is approximate and must be carefully done to avoid misleading results. In any case, because it ignores uncertainty in performance, the results should not be used for budgeting (see Chapter 7).

This method is the most straightforward method discussed in this chapter, because it avoids the ambiguities of intermediate risk-factor "ratings" and their combination. This method's results ~~are~~ can be the least ambiguous and perhaps the most useful, assuming that the DOT wants to use risk assessment results in some quantitative way, providing absolute measures of risk severity and a basis for quantitative risk analysis if needed (Chapter 7). The only drawback is that significant effort might be required to adequately assess the mean values for each risk factor of each risk, and to adequately conduct the analyses to convert the mean-values of the risk factors into the mean-value of severity. An example of this type of assessment, including an example calculation of the mean value of severity (in equivalent cost terms) and of the collective risk, is shown here. Clearly, automating this analysis is key.

The companion training course (Appendix G) addresses this method in more detail, including a form and an MS Excel workbook template (Appendix E) for conducting this type of risk assessment (including automatic analyses of risk severity and mean base+risk performance), appropriately considering risk and opportunities, as well as the performance measures and activities for rapid renewal, especially for simple projects. The risks are defined as impacts (by activity) to the base, with "values" specified (in equivalent monetary terms) for the various performance measures to determine "longevity" and "severity" (see Chapter 4).



Quantitative "Mean-Value Rating" Method

In this method, rating scales are used instead of actual mean-values. These scales are pre-defined so that each rating (e.g., H) corresponds to a specific range of values. Ultimately, for calculations, a mean value is assumed for each category and used in the same way as for the quantitative mean-value method For example, if a probability rating of M was defined to represent a range from 40% to 70%, for calculations, a mean value of 55% would be used. This approach therefore involves more approximation, which is the main disadvantage of this method, as compared to the mean-value method.

An example of the mean-value rating assessment is shown below. In this simple example (using only three categories), a High cost consequence rating corresponds to a range of cost change between $100,000 and $1 million, whereas a High probability rating corresponds to a range of probabilities between 50% and 100%. As shown, for visualization, the assessments can be color-coded (e.g., green for Low, red for High and yellow for Medium).

After the risk factors and risk factor ratings have been defined, the risk factors (i.e., likelihood and various consequence types) for each risk are assessed using the defined scales. Again, ideally the facilitator will achieve consensus amongst a broad group of experts. These assessments can typically be done very quickly by comparing the pre-defined rating scales, which is the main advantage of this method over the mean-value method. These risk-factor ratings are then combined to get an equivalent combined mean severity rating, either via:

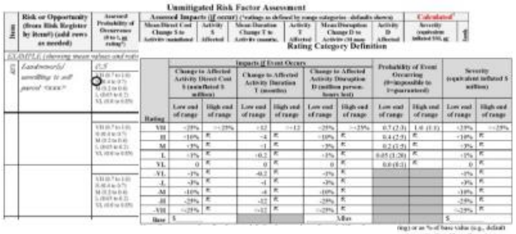
a) An approach that first converts the individual ratings into their equivalent mean values (e.g., middle of the range), then analytically combines those mean values into individual mean performance measures and then a mean combined performance measure in the same way as the mean-value method does, and finally converts the combined value back into an equivalent combined mean severity rating (i.e., an overall mean severity rating for the risk, considering all consequence types/performance measures). Because the combined value is determined *before* translating back into a rating, risks can be approximately ranked even within each consequence type.

b) An approach that pre-specifies the severity rating as a function of the risk factor ratings (e.g., by matrices), which in turn can be determined beforehand either:
   - o Analytically, determining the risk severity rating for each possible combination of risk factor ratings in the same way as discussed above; or
   - o Subjectively, based on consensus amongst a wide group of experts – however, this is difficult to do accurately and defensibly, but relatively easy to do analytically.

   However, in this method, risks cannot be ranked within a category (e.g., all Highs are equal).

c) Pure direct subjective assessment, implicitly considering how the various risk factors combine - however, as discussed above, this can be difficult to do accurately and defensibly, but may be relatively easy to do analytically, and can be very inefficient to do individually for each risk (e.g., in a workshop).

The companion training course (Appendix G) also addresses method a) in more detail, including the same form and spreadsheet template (Appendix E) as used for the mean-value method (in which mean-values and ratings can be mixed). Five (rather than three) ratings (VL, L, M, H, VH) are used, including negative values for opportunities. This is applicable for relatively simple projects.



Forms (Appendix E)

Example of a Quantitative Mean Value Assessment (<u>not</u> the hypothetical case study):
For a project, the base performance has been established and a set of risks (relative to that base) have been identified and their factors (mean value of impacts of various types by activity and likelihood of occurrence) have been assessed quantitatively. For each risk, severity is calculated as follows:

- Calculate the mean-value change in each performance measure as a function of the mean value of unconditional consequences, and then
- Combine those mean-value changes in each performance measure into a mean-value change in the combined performance measure.

If the set of risks is comprehensive and non-overlapping, then the mean value of the performance measure can be approximately determined by simply combining the changes associated with each risk. For example:

- Unconditional schedule-change consequence: Schedule critical path change is determined, and related extended overheads (OHs) are added to direct cost:
    - for Risk R1: (6 mo delay to ROW – 0 base float for ROW) * 15% probability = 0.9 months (mean value change to schedule performance measure)
    - for Risk B1: (2 mo to procurement – 0 base float for procurement)] * 40% probability = 0.8 months (mean value change to schedule performance measure)
    - for Risks R1 <u>and</u> B1: 0.9 months + 0.8 months = 1.7 months
- Unconditional cost-change consequence: Direct cost change must be inflated to account for: 1) schedule delay and the associated additional overhead costs (at $0.1M/mo for preconstruction), and 2) additional inflation of total cost due to schedule delay:
    - for Risk R1: {[$0.5M direct uninflated cost to ROW + (6 mo delay to ROW – 0 base float or ROW) * $0.1M/mo (extended OH for ROW)] * 1.10 (inflation factor for additional direct cost, incl delay, for ROW) + $100M (remaining cost after ROW) * 0.02 (increase in inflation in remaining cost after ROW due to 6 mo delay in ROW)} * 15% probability = $0.48M (YOE)
    - for Risk B1: {[$2.0M direct uninflated cost to construction + (2 mo delay to procurement – 0 float for procurement) * $0.1M/mo (extended OH for procurement)] * 1.20 (inflation factor for additional direct cost, including delay, for construction) + $90M (remaining cost after procurement) * 0.01 (increase in inflation in remaining cost after procurement due to 2 mo delay in procurement)} * 40% probability = $1.42M (YOE)
    - for Risks R1 <u>and</u> B1: $0.48M (YOE) + $1.42M (YOE) = $1.90M (YOE)
- Unconditional disruption consequence change is determined as follows:
    - For Risk R1: 0man-hrs * 15% probability = 0man-hrs
    - For Risk B1: 0man-hrs * 40% probability = 0man-hrs
    - For R1 <u>and</u> B1: 0man-hrs + 0man-hrs = 0man-hrs
- Longevity change is determined (see Chapter 4) based on changes in cost and disruption associated with operations & maintenance and replacement, as well as schedule of replacement, and various tradeoffs, but is zero in this case and not shown.
- Overall severity for a risk, in terms of a <u>combined</u> performance measure, is then determined (see Chapter 4) from changes in individual performance measures and separately assessed tradeoffs among the performance measures:
    - For Risk R1: 0.9mo * $0.5M/mo (delay "value", separate from extended OHs and inflation) + $0.48M + 0man-hrs * $10/man-hr (disruption "value") = $0.93M
    - For Risk B1: 0.8mo * $0.5M/mo (delay "value", separate from extended OHs and inflation) + $1.42M + 0man-hrs * $10/man-hr (disruption "value") = $1.82M
    - For R1 <u>and</u> B1: $0.93M + $1.82M = $2.75M

Example of a Quantitative Mean Value Assessment (cont.):

The above example (both inputs and outputs) has been summarized in the table below.

Risk	Scenario for Conditional Consequence (i.e., if risk occurs) to each Performance Measure			Scenario Probability	Risk Severity (equiv$)
	Direct Cost Change (uninflated $)	Schedule Change (months)	Disruption Change (hrs)		
...	...	...	...	...	...
R1. Landowner unwilling to sell key property	$0.5M to ROW	6 mo. to ROW	0	15% thru ROW	$0.93M
...	...	...	...	...	...
B1. Poor bidding climate for General Contractor	$2M to Construction	2 mo. to Procure.	0	40% thru Procure.	$1.82M
...	...	...	...	...	...
Total Unconditional Consequence	$1.90M	1.7 mo.	0		$2.75M

Notes: "$xM" means millions of dollars. "mo." means months. "YOE" means year-of-expenditure (i.e., inflated).

Example of Quantitative Mean-Value Rating Assessment (not the hypothetical case study):

Similar to the previous example, the base performance for a project has been established and a set of risks (relative to that base) has been identified and their factors (mean value of impacts of various types by activity and likelihood of occurrence) have been assessed qualitatively (i.e., L, M, H in this example). These risk factor ratings are defined below. The risk factor ratings are converted into approximate mean values, and then risk severity is calculated by first calculating the mean-value change in each performance measure as a function of the mean value of unconditional consequences, and then combining those mean-value changes in each performance measure into a mean-value change in the "combined" performance measure in the same way as for the "mean-value" method (see previous example), which is then translated back into a rating (as also defined below). For example, to determine the effect of Risk R1 on project completion date:

- "H" (>3 months) assessed change to duration of ROW translates to about 6 months
- "L" (<20%) assessed probability of occurrence translates to about 10%
- Mean change in critical path can be determined to be (6 month delay to ROW – 0 month base float for ROW) * 10% probability = 0.6 months (which translates back to "L" schedule change). Note: The mean value ratings result in slightly different mean values than the mean value (see previous example) because of approximation associated with ranges.

Rating definitions:

Rating	Consequence			Probability	Severity[4]
	Cost Change[1]	Schedule Change[2]	Disruption Change[3]		
L	<$100,000	<1 mo	<10,000	<0.2	<$200,000
M	$100,000 – $1 million	1 mo-3 mo	10,000 -100,000	0.2 - 0.5	$200,000- $2 million
H	>$1 million	>3 mo	>100,000	>0.5	>$2 million

Notes:

[1] Cost change in direct uninflated $ (to specific activity)

[2] Schedule change in months delay to specific activity (regardless of critical path)

[3] Disruption change in equivalent person-hours (to specific activity)

[4] Severity in equivalent inflated $

Example of a Quantitative Mean Value Rating Assessment (cont.):

The above example (both inputs and outputs) has been summarized in the table below.

Risk	**Scenario for Conditional Consequence (i.e., if risk occurs) to each Performance Measure**			**Scenario Probability**	**Risk Severity**
	Cost Change	**Schedule Change**	**Disruption Change**		
…	**…**	**…**	**…**	**…**	**…**
R1. Landowner unwilling to sell key property	M to ROW	H to ROW	L	L	M
…	**…**	**…**	**…**	**…**	**…**
B1. Poor bidding climate for General Contractor	H to constr.	M to procure.	L	M	M
…	**…**	**…**	**…**	**…**	**…**
Total Unconditional Consequence	H	M	L		H

Other Methods

The qualitative "Red/Yellow/Green" method is essentially the same as the quantitative mean-value rating method, except that:

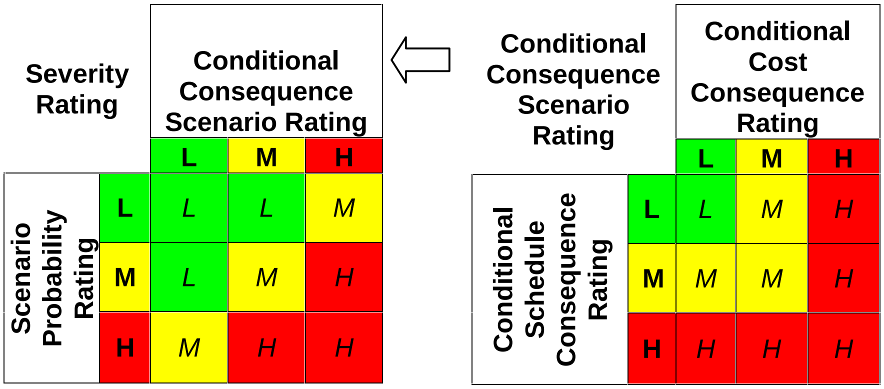
- The ratings involve only three categories (H, M, L), which are quick and color-coded (and thus visual). However, the ratings are generally undefined, and thus ambiguous (i.e., how much is "high"? what is the relationship between the risk consequence and the performance measure?).
- The risk factors are usually combined in a purely subjective (rather than in an analytical) way to assess risk severity. If not assessed directly (i.e., implicitly considering the various risk factor ratings), this combination is sometimes done through pre-defined matrices showing which combinations of likelihood and various consequences result in various categories of risk, although there would generally still not be any mathematical basis for the matrix (only judgment). Conceivably, these matrices could be developed beforehand through analysis, similar to what would be done for the mean-value rating method.
- Risks are only roughly categorized (e.g., as High) without any ranking within categories.
- Except by judgment, total risks cannot be determined (e.g., M + M = ?).

There is no significant advantage to this method compared to the quantitative mean-value rating method, except that it doesn't require analysis to determine risk severity as a function of the risk factor rating. However, this generally results in much less accuracy (and often even errors) in the subsequent severity ratings, with little increase of efficiency since the analysis can be done relatively easily. Hence, this method is not generally recommended.

The qualitative "Rating Scale" method is basically an extension of the Red/Yellow/Green method, and attempts to improve how the risk factors are combined to determine risk severity. This method is very similar to the mean-value method, except that dimensionless, numerical rating scales (rather than mean-values for the mean-value method, or just L, M, H for the Red/Yellow/Green method) are generally used for the risk factors. For example, 1="rare" to 5="certain" for likelihood, and 1="low" to 5="catastrophic" for consequences. These numerical ratings are then generally combined in essentially the same mathematical way as for the mean-value method, to determine unconditional consequences and then severity for each risk. For example, the numerical ratings for likelihood (e.g., P=1) and combined consequences (e.g., C=3), which in turn are either assessed directly or determined from the various types of consequences (e.g., as the maximum rating amongst them), are simply multiplied to determine the severity for each risk (e.g., severity = 1 x 3 = 3). The set of risks (i.e., all the risks in the risk register) can then be categorized and ranked based on the severity of each individual risk. This is intended to address a couple of the problems associated with the Red/Yellow/Green method (i.e., combining risk factors and ranking risks within categories), while still being quick.

However, this “rating scale” approach to combining likelihood and consequence ratings is only mathematically correct if the rating scales have been appropriately defined and the factors appropriately assessed (e.g., consequences in terms of changes in performance measures). This means that if ratings are being multiplied (as described above), then the individual rating scales should be linear, so that, for example, a consequence of 2 is twice as bad as a consequence of 1, and a likelihood of 4 is twice as high as a likelihood of 2. Otherwise, if the scales are not appropriately defined, the combination of individual likelihood and consequence ratings produces severity ratings that might scale non-linearly or even be non-comparable (e.g., does 1x3 = 3x1?). Conceivably, like the mean-value rating method, these numerical ratings (if adequately defined) can be translated into mean-values and then used, in which case it is essentially the same as the mean-value rating method. However, even if done properly, this method only provides a relative measure of risk (i.e., in terms of the non-dimensional rating scales, such as 1-5), and not an absolute measure (e.g., in terms of $ or months), which would be needed to evaluate cost-benefit of possible risk reduction actions (see Chapter 8). Hence, there is no advantage to this method compared to the mean-value method, and hence it is generally not recommended.

Example of a Qualitative “Red/Yellow/Green” Assessment:



Severity Rating		Conditional Consequence Scenario Rating		
		L	M	H
Scenario Probability Rating	L	L	L	M
	M	L	M	H
	H	M	H	H

Conditional Consequence Scenario Rating		Conditional Cost Consequence Rating		
		L	M	H
Conditional Schedule Consequence Rating	L	L	M	H
	M	M	M	H
	H	H	H	H

Note: Risk severity is either assessed directly (implicitly considering conditional consequence scenario and scenario probability ratings) or is based on pre-defined matrices (e.g., as shown above), which must be carefully developed to avoid errors

Guidance

This chapter has introduced a number of concepts and methods related to risk assessment. While this *Guide* is not meant to be a “how to” document (the companion training materials in Appendix G address implementation), it is worthwhile here to provide some key guidance related to the previously-introduced concepts and methods.

As previously discussed, risks (including opportunities) are uncertain events which might or might not happen, and if they happen, result in uncertain (i.e., difficult to predict) consequences to the project’s performance measures. Risk assessment attempts to “wrap its arms around” each risk, and characterize and quantify (or qualify) it. This is can be difficult, considering variability in conditions under which the project will be planned and constructed, and uncertainty in (i.e., our lack of knowledge or ignorance about) those conditions and what problems and opportunities exist, and what their impacts might be if they occur. Therefore, it is important to remember a few key points when conducting risk assessment to ensure that the risk assessment reasonably, accurately, and defensibly quantifies (or qualifies) the risks and opportunities:

- *Consequences must be consistent with likelihoods.* The assessed consequences reflect the anticipated magnitude of a risk’s impacts. The magnitude of the impacts implies a particular likelihood of occurrence. For example, catastrophic impacts are usually less likely than are minor impacts (but not always, depending on whether thresholds are defined). A number of realistic or feasible "scenarios" or outcomes could be defined for a particular risk. Therefore, the authors recommend defining a *realistic* risk scenario that pairs consistent likelihood and consequence values. Note that from a mean-value perspective, it is the combination of risk-factor values (i.e., the mean risk) that matters, assuming realistic scenarios. Hence, for example, a risk with a 25% probability of occurrence and a $4 million cost impact is equivalent to a risk with a 50% probability of a $2 million impact, because both have a mean risk of $1 million. Having said this, however, extreme scenarios (i.e., very low likelihoods of catastrophic consequences) are not usually selected as the basis for mean-value assessments if other, more "average" scenarios are possible.

- *Identify and mitigate bias*. The goal of risk-factor assessment is to obtain accurate, defensible assessments. As mentioned previously, subjective assessments are usually required to assess risk factors but are subject to bias. Bias essentially comes in two forms (Roberds, 1990):
  - "Motivational bias" occurs when someone says something that contradicts what they believe. This bias can be difficult to detect and counter, but is often present when participants have a stake in a project's continued "survival" or other conflict of interest. It can also occur when experts intentionally inject some conservatism into their assessments or intentionally exclude some scenarios. The various types of motivational biases include:
    - *Management* - tell them what they want to hear,
    - *Expert* - want to appear knowledgeable,
    - *Conflict* - self-serving,
    - *Conservative* - err on the "safe" side, and
    - *Peer pressure* - go with the crowd.
  - "Cognitive bias" occurs when someone believes something that is inconsistent with the facts. Most people will overestimate what they know about a particular topic, which leads to over-optimism and underestimating uncertainty. The various types of cognitive biases include:
    - *Anchoring* - focus on starting point (e.g., neglect extremes),
    - *Overconfidence* - ignore unlikely possibilities,
    - *Coherence/Conjunctive Distortions* - ignore combination of component parts (e.g., if event *x* requires a set of *y* independent events, then $P[x] = \Pi_y P[y]$),
    - *Availability* - focus on easily recalled info,
    - *Base Rate* - focus on most specific info (neglect data-based frequency of occurrence), and
    - *Representativeness* - ignore relevance of different types of information (treat all equally).

  These biases can often be effectively countered by a qualified facilitator and use of project-independent subject-matter experts. However, simply being aware of these potential biases is the first step toward mitigating them. In addition, avoiding these other common pitfalls (which a qualified facilitator should also help with) can help mitigate bias:
  - Poor problem structure (e.g., ambiguous definition of what is to be assessed, such as an average value or a random value),
  - Adverse group interactions (e.g., dominance by one person),
  - Ignoring important relationships among factors, and/or
  - Failing to consider all possibilities and all available information appropriately.
- *Methods for assessing risk factors*. A few methods are covered in the companion training course, but DOTs should be aware that a number of approaches are available to help ensure reasonable risk-factor assessments. A particular approach, or "tool" might resonate better with one group than another, so the DOT can experiment with each group to determine which works best for that group. Example methods include:
  - Ranges, which use thresholds

  - Comparative probabilities, which compares the likelihood of the risk being assessed against likelihood of common events (e.g., coin toss or roll of a die) with known probabilities, bracketing and converging on the risk.
  - Ranking and relative difference, which first ranks possible outcomes by pair-wise comparison, then assesses relative likelihoods (in terms of ratios) by pair-wise comparison, then uses the ratios from the comparisons to determine individual probabilities.
  - Probability wheel, which uses a wheel with a rotating wheel segment to visually cue for probability, or converging confidence intervals by pair-wise comparison.
  - Decomposition, which is the process of graphically "breaking down" a risk into its component causes and/or sequence of events or outcomes. Decomposition can be accomplished using well-established graphical tools:
    - "Event trees" (also known as "probability trees") are useful for graphically defining scenarios of outcomes and the corresponding probabilities and consequences that might result from a triggering risk event.
    - "Fault trees" can be used to evaluate the probability that a risk ("failure event") occurs, by "building up" the various combinations of events that are required to trigger the risk's occurrence.
  - Full probability distributions (see Chapter 7).
- *Methods for combining risk factors.* As described previously, a variety of methods are available for combining risk-factor assessments into a measure of risk severity, ranging from implicit subjective assessment to explicit mean value assessment and analysis to detailed probabilistic analysis (as discussed in Chapter 7). These methods involve different levels of skill and effort to apply, and result in different levels of accuracy and defensibility. The appropriateness of any particular method depends on how the information will be used, as well as the nature of the risk factor assessments. Within this context, the analysis of severity should adequately consider: a) all the relevant performance objectives and tradeoffs amongst them, b) the uncertainties in meeting those performance objectives, and c) how each risk or opportunity affects meeting those objectives, including the relationship between the risk consequence factors (e.g., uninflated direct cost, schedule delay, disruption), as assessed, and the performance objectives (e.g., inflated total cost, overall project schedule). As previously noted, for relatively simple projects, an MS Excel workbook template has been developed to document the assessments and automatically calculate risk severity and mean performance

6.3 Conclusions regarding Risk Assessment

The objective of risk assessment is to adequately describe the "severity" of project risks, in order to rank the risks for subsequent risk reduction planning, and if done quantitatively form a basis for probabilistic risk analysis, if needed (e.g., to objectively establish budgets/contingencies). Various methods are available for conducting risk assessment, and each has its strengths and weaknesses:

- Qualitative methods are quick, but prone to inaccuracy with limited usefulness; whereas
- Quantitative methods involve more effort, but are more accurate and useful, although:
  - Statistical basis has limited applicability, whereas
  - Subjective basis prone to bias (requiring mitigation by facilitator).

Two of the methods (mean value ratings and mean values), which are appropriate for relatively simple projects, have been incorporated in specific forms and in an MS Excel workbook template for this *Guide*. The DOT should select an appropriate method depending on its objectives for the risk assessment. Regardless of the chosen method, the DOT should take steps to ensure that risks are assessed defensibly and accurately, as well as efficiently, and documented appropriately (in the *risk register*). A qualified risk facilitator, who guides the assessment process (at the appropriate level of detail, considering the model and factors involved), mitigates bias, and develops consensus amongst a broad group of project team and independent experts, is key.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, involved assessments of each of the risks in the risk register (using the methods and guidance described in this chapter), as documented in Appendix F - *RMP* Chapter 3 and summarized below.

QDOT initially decided that assessing the current risks in terms of mean-value ratings (e.g., L, M, and H) would be sufficient for its intended use of the risk assessment results (i.e., prioritizing the risks for proactive individual risk reduction). Hence, the group first defined mean-value rating scales for the various risk factors:

- each of the three types (cost, schedule, and disruption) of impacts of occurrence (e.g., a Medium (M) cost impact was defined to correspond to a value between 3% and 10% of the base project cost, in uninflated dollars);
- the probability of occurrence (e.g., a Medium (M) probability corresponded to a probability of occurrence between 0.2 and 0.4); and
- the "severity" of combined impacts (considering the probability of occurrence and tradeoffs) (e.g., a Medium (M) severity was defined to correspond to a value between 3% and 10% of the base combined performance, in equivalent inflated dollars).

Risk factor rating scale definitions for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

	Impacts if Event Occurs									Probability of Event Occurring (0=impossible to 1=guaranteed)			(equivalent
	Cost Change (current unescalated $ million)			Schedule Change (months)			Disruption Change (million person-hours lost)						
Rating	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges	Low end of range	High end of range	Ranges (absolute or base %)
VH	>25%	4.0	8.0	>12	12	24	>25%	0.2	0.4	0.7 to 1.0 (1:1)	0.7	1.0	>25%
H	10 to 25%	1.6	$ 4.00	4 to 12	4	12	10 to 25%	0.1	0.2	0.4 to 0.7 (2:3)	0.4	0.7	10 to 25%
M	3 to 10%	0.5	$ 1.60	1 to 4	1	4	3 to 10%	0.0	0.1	0.2 to 0.4 (2:5)	0.2	0.4	3 to 10%
L	1 to 3%	0.2	$ 0.50	0.25 to 1	0.25	1	1 to 3%	0.0	0.0	0.05 to 0.2 (1:5)	0.05	0.2	1 to 3%
VL	0 to 1%	0.0	$ 0.20	0 to 0.25	0	0.25	0 to 1%	0.0	0.0	0.0 to 0.05 (1:20)	0.0	0.05	0 to 1%
-VL	-1 to 0%	-0.2	$ -	-0.25 to 0	-0.25	0	-1 to 0%	0.0	0.0				-1 to 0%
-L	-3 to -1%	-0.5	$ (0.20)	-1 to -0.25	-1	-0.25	-3 to -1%	0.0	0.0				-3 to -1%
-M	-10 to -3%	-1.6	$ (0.50)	-4 to -1	-4	-1	-10 to -3%	-0.1	0.0				-10 to -3%
-H	-25 to -10%	-4.0	$ (1.60)	-12 to -4	-12	-4	-25 to -10%	-0.2	-0.1				-25 to -10%
-VH	<-25%	-8.0	$ (4.00)	<-12	-24	-12	<-25%	-0.4	-0.2				<-25%
Base:	*16.04*			*35*			*0.7*						*16.0*

The group then discussed each of the identified risks in the risk register and quantified (by consensus) each of them in terms of mean-value ratings (or sometimes directly in terms of mean values) for the following, before any additional mitigation: a) the cost, schedule, and/or disruption impacts (and the affected activity) if the risk occurs; and b) the probability that the risk (as defined by its impacts) will occur (during the particular project phase it is categorized under). <Note: Subsequently, a quantitative risk analysis was conducted, for which these unmitigated assessments were refined – see Appendix F - *RMP* Addendum X.>

QDOT then used these assessments to determine (using an appropriate risk model, e.g., the Microsoft Excel workbook template that incorporates the algorithms presented in this chapter: a) the approximate unmitigated mean-value contribution of each risk to the project objectives of cost, schedule, and disruption; and b) by combining with QDOT's established "value trade-offs" among the objectives, an unmitigated mean-value "longevity" and then "severity" for each risk, based on which the risks were ranked. <Note: Subsequently, a quantitative risk analysis was conducted, for which the contribution of each risk and other uncertainty to the potential budget, before any additional mitigation, was determined more accurately – see Appendix F - *RMP* Addendum X.>

Illustrative Example (continued)

Unmitigated risk factor assessments for select rapid renewal risks for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

Project Phase	Example Risk or Opportunity	Probability of Occurrence	Mean-Value or Ratings (see definition) to affected activity		
			Mean Cost Change if Occurs	Mean Duration Change if Occurs	Mean Disruption Change if Occurs
Preliminary Design / Environmental Process	PD13. Change in environmental documentation	L	+M to Prelim Design / Env Proc	+H to Prelim Design / Env Proc	0
Right-of-Way, Utilities, and Railroad	RU3. Unwilling sellers	H	+M to ROW/Util/RR	0	0
Procurement	CP2. Uncertain D/B contracting market conditions at time of bid	25%	+10% of base (i.e., +$1.2M) to D/B construction	+1 month to procurement	0
Construction	CN3. Problems with planned accelerated bridge construction technique	H	+L to D/B construction	+L to D/B construction	+L to D/B construction

Unmitigated risk severity determination and ranking for select rapid renewal risks for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

Project Phase	Example Risk or Opportunity	Mean Severity (equiv YOE$M or rating- see scale definition)	Rank
Preliminary Design / Environmental Process	PD13. Change in environmental documentation	L	11
Right-of-Way, Utilities, and Railroad	RU3. Unwilling sellers	M	4
Procurement	CP2. Uncertain D/B contracting market conditions at time of bid	0.38	9
Construction	CN3. Problems with planned accelerated bridge construction (technology, procurement,	L	12

likelihood of occurrence. For example, catastrophic impacts are usually less likely than are minor impacts (but not always, depending on whether thresholds are defined). A number of realistic or feasible "scenarios" or outcomes could be defined for a particular risk. Therefore, the authors recommend defining a *realistic* risk scenario that pairs consistent likelihood and consequence values. Note that from a mean-value perspective, it is the combination of risk-factor values (i.e., the mean risk) that matters, assuming realistic scenarios. Hence, for example, a risk with a 25% probability of occurrence and a $4 million cost impact is equivalent to a risk with a 50% probability of a $2 million impact, because both have a mean risk of $1 million. Having said this, however, extreme scenarios (i.e., very low likelihoods of catastrophic consequences) are not usually selected as the basis for mean-value assessments if other, more "average" scenarios are possible.

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  - "Motivational bias" occurs when someone says something that contradicts what they believe. This bias can be difficult to detect and counter, but is often present when participants have a stake in a project's continued "survival" or other conflict of interest. It can also occur when experts intentionally inject some conservatism into their assessments or intentionally exclude some scenarios. The various types of motivational biases include:
    - *Management* - tell them what they want to hear,
    - *Expert* - want to appear knowledgeable,
    - *Conflict* - self-serving,
    - *Conservative* - err on the "safe" side, and
    - *Peer pressure* - go with the crowd.
  - "Cognitive bias" occurs when someone believes something that is inconsistent with the facts. Most people will overestimate what they know about a particular topic, which leads to over-optimism and underestimating uncertainty. The various types of cognitive biases include:
    - *Anchoring* - focus on starting point (e.g., neglect extremes),
    - *Overconfidence* - ignore unlikely possibilities,
    - *Coherence/Conjunctive Distortions* - ignore combination of component parts (e.g., if event *x* requires a set of *y* independent events, then $P[x] = \Pi_y P[y]$),
    - *Availability* - focus on easily recalled info,
    - *Base Rate* - focus on most specific info (neglect data-based frequency of occurrence), and
    - *Representativeness* - ignore relevance of different types of information (treat all equally).

  These biases can often be effectively countered by a qualified facilitator and use of project-independent subject-matter experts. However, simply being aware of these potential biases is the first step toward mitigating them. In addition, avoiding these other common pitfalls (which a qualified facilitator should also help with) can help mitigate bias:
  - Poor problem structure (e.g., ambiguous definition of what is to be assessed, such as an average value or a random value),
  - Adverse group interactions (e.g., dominance by one person),
  - Ignoring important relationships among factors, and/or
  - Failing to consider all possibilities and all available information appropriately.
- *Methods for assessing risk factors*. A few methods are covered in the companion training course, but DOTs should be aware that a number of approaches are available to help ensure reasonable risk-factor assessments. A particular approach, or "tool" might resonate better with one group than another, so the DOT can experiment with each group to determine which works best for that group. Example methods include:
  - Ranges, which use thresholds

    - Comparative probabilities, which compares the likelihood of the risk being assessed against likelihood of common events (e.g., coin toss or roll of a die) with known probabilities, bracketing and converging on the risk.
    - Ranking and relative difference, which first ranks possible outcomes by pair-wise comparison, then assesses relative likelihoods (in terms of ratios) by pair-wise comparison, then uses the ratios from the comparisons to determine individual probabilities.
    - Probability wheel, which uses a wheel with a rotating wheel segment to visually cue for probability, or converging confidence intervals by pair-wise comparison.
    - Decomposition, which is the process of graphically "breaking down" a risk into its component causes and/or sequence of events or outcomes. Decomposition can be accomplished using well-established graphical tools:
        - "Event trees" (also known as "probability trees") are useful for graphically defining scenarios of outcomes and the corresponding probabilities and consequences that might result from a triggering risk event.
        - "Fault trees" can be used to evaluate the probability that a risk ("failure event") occurs, by "building up" the various combinations of events that are required to trigger the risk's occurrence.
    - Full probability distributions (see Chapter 7).
- *Methods for combining risk factors.* As described previously, a variety of methods are available for combining risk-factor assessments into a measure of risk severity, ranging from implicit subjective assessment to explicit mean value assessment and analysis to detailed probabilistic analysis (as discussed in Chapter 7). These methods involve different levels of skill and effort to apply, and result in different levels of accuracy and defensibility. The appropriateness of any particular method depends on how the information will be used, as well as the nature of the risk factor assessments. Within this context, the analysis of severity should adequately consider: a) all the relevant performance objectives and tradeoffs amongst them, b) the uncertainties in meeting those performance objectives, and c) how each risk or opportunity affects meeting those objectives, including the relationship between the risk consequence factors (e.g., uninflated direct cost, schedule delay, disruption), as assessed, and the performance objectives (e.g., inflated total cost, overall project schedule). As previously noted, for relatively simple projects, an MS Excel workbook template has been developed to document the assessments and automatically calculate risk severity and mean performance

6.3 Conclusions regarding Risk Assessment

The objective of risk assessment is to adequately describe the "severity" of project risks, in order to rank the risks for subsequent risk reduction planning, and if done quantitatively form a basis for probabilistic risk analysis, if needed (e.g., to objectively establish budgets/contingencies). Various methods are available for conducting risk assessment, and each has its strengths and weaknesses:

- Qualitative methods are quick, but prone to inaccuracy with limited usefulness; whereas
- Quantitative methods involve more effort, but are more accurate and useful, although:
    - Statistical basis has limited applicability, whereas
    - Subjective basis prone to bias (requiring mitigation by facilitator).

Two of the methods (mean value ratings and mean values), which are appropriate for relatively simple projects, have been incorporated in specific forms and in an MS Excel workbook template for this *Guide*. The DOT should select an appropriate method depending on its objectives for the risk assessment. Regardless of the chosen method, the DOT should take steps to ensure that risks are assessed defensibly and accurately, as well as efficiently, and documented appropriately (in the *risk register*). A qualified risk facilitator, who guides the assessment process (at the appropriate level of detail, considering the model and factors involved), mitigates bias, and develops consensus amongst a broad group of project team and independent experts, is key.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, involved assessments of each of the risks in the risk register (using the methods and guidance described in this chapter), as documented in Appendix F - *RMP* Chapter 3 and summarized below.

QDOT initially decided that assessing the current risks in terms of mean-value ratings (e.g., L, M, and H) would be sufficient for its intended use of the risk assessment results (i.e., prioritizing the risks for proactive individual risk reduction). Hence, the group first defined mean-value rating scales for the various risk factors:

- each of the three types (cost, schedule, and disruption) of impacts of occurrence (e.g., a Medium (M) cost impact was defined to correspond to a value between 3% and 10% of the base project cost, in uninflated dollars);
- the probability of occurrence (e.g., a Medium (M) probability corresponded to a probability of occurrence between 0.2 and 0.4); and
- the “severity” of combined impacts (considering the probability of occurrence and tradeoffs) (e.g., a Medium (M) severity was defined to correspond to a value between 3% and 10% of the base combined performance, in equivalent inflated dollars).

Risk factor rating scale definitions for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

	Impacts if Event Occurs									Probability of Event Occurring (0=impossible to 1=guaranteed)			(equivalent
	Cost Change (current unescalated $ million)			Schedule Change (months)			Disruption Change (million person-hours lost)						
Rating	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges	Low end of range	High end of range	Ranges (absolute or base %)
VH	>25%	4.0	8.0	>12	12	24	>25%	0.2	0.4	0.7 to 1.0 (1:1)	0.7	1.0	>25%
H	10 to 25%	1.6	$ 4.00	4 to 12	4	12	10 to 25%	0.1	0.2	0.4 to 0.7 (2:3)	0.4	0.7	10 to 25%
M	3 to 10%	0.5	$ 1.60	1 to 4	1	4	3 to 10%	0.0	0.1	0.2 to 0.4 (2:5)	0.2	0.4	3 to 10%
L	1 to 3%	0.2	$ 0.50	0.25 to 1	0.25	1	1 to 3%	0.0	0.0	0.05 to 0.2 (1:5)	0.05	0.2	1 to 3%
VL	0 to 1%	0.0	$ 0.20	0 to 0.25	0	0.25	0 to 1%	0.0	0.0	0.0 to 0.05 (1:20)	0.0	0.05	0 to 1%
-VL	-1 to 0%	-0.2	$ -	-0.25 to 0	-0.25	0	-1 to 0%	0.0	0.0				-1 to 0%
-L	-3 to -1%	-0.5	$ (0.20)	-1 to -0.25	-1	-0.25	-3 to -1%	0.0	0.0				-3 to -1%
-M	-10 to -3%	-1.6	$ (0.50)	-4 to -1	-4	-1	-10 to -3%	-0.1	0.0				-10 to -3%
-H	-25 to -10%	-4.0	$ (1.60)	-12 to -4	-12	-4	-25 to -10%	-0.2	-0.1				-25 to -10%
-VH	<-25%	-8.0	$ (4.00)	<-12	-24	-12	<-25%	-0.4	-0.2				<-25%
Base:	*16.04*			*35*			*0.7*						*16.0*

The group then discussed each of the identified risks in the risk register and quantified (by consensus) each of them in terms of mean-value ratings (or sometimes directly in terms of mean values) for the following, before any additional mitigation: a) the cost, schedule, and/or disruption impacts (and the affected activity) if the risk occurs; and b) the probability that the risk (as defined by its impacts) will occur (during the particular project phase it is categorized under). <Note: Subsequently, a quantitative risk analysis was conducted, for which these unmitigated assessments were refined – see Appendix F - *RMP* Addendum X.>

QDOT then used these assessments to determine (using an appropriate risk model, e.g., the Microsoft Excel workbook template that incorporates the algorithms presented in this chapter: a) the approximate unmitigated mean-value contribution of each risk to the project objectives of cost, schedule, and disruption; and b) by combining with QDOT’s established “value trade-offs” among the objectives, an unmitigated mean-value “longevity” and then “severity” for each risk, based on which the risks were ranked. <Note: Subsequently, a quantitative risk analysis was conducted, for which the contribution of each risk and other uncertainty to the potential budget, before any additional mitigation, was determined more accurately – see Appendix F - *RMP* Addendum X.>

Illustrative Example (continued)

Unmitigated risk factor assessments for select rapid renewal risks for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

Project Phase	Example Risk or Opportunity	Probability of Occurrence	Mean-Value or Ratings (see definition) to affected activity		
			Mean Cost Change if Occurs	Mean Duration Change if Occurs	Mean Disruption Change if Occurs
Preliminary Design / Environmental Process	PD13. Change in environmental documentation	L	+M to Prelim Design / Env Proc	+H to Prelim Design / Env Proc	0
Right-of-Way, Utilities, and Railroad	RU3. Unwilling sellers	H	+M to ROW/Util/RR	0	0
Procurement	CP2. Uncertain D/B contracting market conditions at time of bid	25%	+10% of base (i.e., +$1.2M) to D/B construction	+1 month to procurement	0
Construction	CN3. Problems with planned accelerated bridge construction technique	H	+L to D/B construction	+L to D/B construction	+L to D/B construction

Unmitigated risk severity determination and ranking for select rapid renewal risks for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Chapter 3)

Project Phase	Example Risk or Opportunity	Mean Severity (equiv YOE$M or rating- see scale definition)	Rank
Preliminary Design / Environmental Process	PD13. Change in environmental documentation	L	11
Right-of-Way, Utilities, and Railroad	RU3. Unwilling sellers	M	4
Procurement	CP2. Uncertain D/B contracting market conditions at time of bid	0.38	9
Construction	CN3. Problems with planned accelerated bridge construction (technology, procurement,	L	12

Chapter 7. Risk Analysis

7.1 Introduction to Risk Analysis

The tasks of identifying, assessing, and managing risk for rapid renewal projects can produce results useful to project risk managers, in helping to understand and optimize project performance. However, there is another very valuable process within the sphere of risk management, *risk analysis*, which can provide additional valuable information to project managers when projects are more complex or the information required for decisions needs to be more precise.

Adequately but efficiently:
a) quantify uncertainties in (and correlations among) “inputs” (including risks and opportunities);
b) propagate those uncertainties through to “outputs” (e.g., project cost and schedule); and
c) quantify sensitivity.

Objectives

Risk analysis starts with the results from structuring, risk identification, and risk assessment, as described in the previous chapters. Risk analysis then expands upon those elements and combines them to quantify the key project performance measures, such as project cost and schedule, considering risk as well as base. This can be done in terms of mean values (as discussed in Chapter 6) or more completely in terms of full uncertainty (e.g., Figure 7.1). Results from risk analysis can then be used to help make important project decisions as they contain more detail and information than do risk assessments.

Hence, the primary objectives for risk analysis are to:

- adequately quantify uncertainty in the project performance measures, such as project inflated year-of-construction cost and completion date, appropriately considering risks as well as the base uncertainties;
- adequately a) quantify the likelihood for achieving existing budgets and milestones, or b) establish budgets and milestones (including contingencies) for a desired reliability or confidence level (e.g., 80% chance for success); and
- adequately quantify the sensitivity of those project performance measures to the individual risks and base uncertainties, which provides additional information for risk-management planning.

Ideally, this would be done not only from a current perspective, but also projected ahead to various milestones to determine remaining costs and schedule to finish (e.g., to establish defensible contingency drawdown requirements).

Another goal is to complete this step efficiently, producing defensible as well as accurate results that are compatible with the other steps of the process. How this information will be used will determine the requirements and the level of effort (which can be significant) for this step. However, adequate quantification of the significant uncertainties in the various base and risk factors, and development of an appropriate “risk model”, which allows for relatively easy updating, is key to successfully completing this step.

Philosophy and Concepts

Performance measures can generally be adequately estimated as a function of specific factors. For example, total project cost is simply the sum of all the various costs, both base and realized risks. As another example, the project completion date can be determined by critical path analysis, based on activity durations (both base and realized risks) and precedence requirements (including lags and external milestone dates). However, typically there is significant uncertainty in what those factors will eventually be (especially risks, which might or might not occur), which in turn results in significant uncertainty in what the performance measures will be. Generally (as discussed in Chapter 6), mean values of the performance measures can be adequately approximated as a function of the mean-values of those various factors. However, the determination of the full uncertainty in performance measures requires more sophisticated analysis, which can be done in various ways with different levels of accuracy and defensibility, and thus effort. The types of results produced by risk analysis are illustrated later in this chapter by example.

The various important concepts associated with risk analysis include:

- *Qualitative versus quantitative assessment*. This was addressed in Chapter 6 with respect to risk assessment. For risk analysis as described in this chapter, quantitative assessment is required, generally including explicit quantification of significant uncertainties (in terms of probability distributions) and correlations for input variables. The discussion in Chapter 6 focused on mean-value assessments, which are appropriate for some applications, but ignore uncertainties and correlations.
- *Uncertainty description*. Uncertainties can be described in terms of “probability distributions”, which express the relative likelihood of any one particular value for a factor which has a set of possible values. For example, the uncertainty in the value of a particular factor can be expressed in different ways, depending on the nature of that factor (Figure 7-1):
    - Two possible values (e.g., yes or no) – probability (Figure 7-1a)
    - Discrete set of possible values (e.g., several ranges of values, or scenarios) – discrete distribution (Figure 7-1b), which in turn can be combined into two-states (e.g., either more or less than a particular value, or either one or the other subset of scenarios)
    - Infinite set of possible values (e.g., cost) – continuous distribution (Figure 7-1b), which can be “binned” into a discrete distribution or even two-states (e.g., either more or less than a particular value)

  Probabilities are defined on a range from 0.0 (impossible) to 1.0 (guaranteed), so that the sum of probabilities of a comprehensive and mutually exclusive set of values must equal 1.0. Note: For continuous distributions, the relative likelihood value is defined so that it integrates to 1.0.

  Uncertainties in combinations of factors are generally described by the probability distribution of each factor, in combination with a “correlation coefficient”, or by “conditional” distributions (Figure 7-1c).

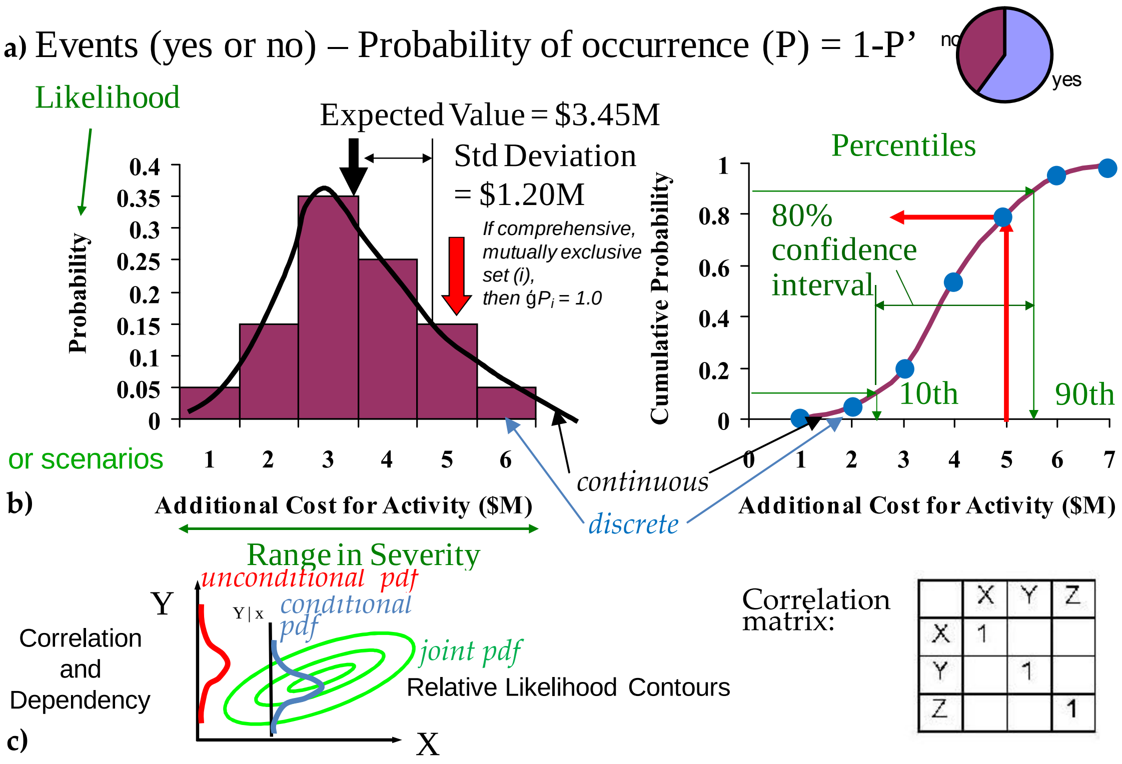


Figure 7-1. Probability Distributions

- *Performance measures*. As discussed in Chapter 3, several key performance measures are of interest for rapid renewal projects: schedule, cost, and disruption through construction, longevity after construction, and combined performance.

  Schedule – Typically, key milestone dates (e.g., start of operations) or durations (e.g., time to replacement) are of interest. The entire schedule can be modeled via critical path analysis, in which: 1) a complete and non-overlapping set of project activities is identified; 2) their sequence (in terms of precedence requirements) is identified (e.g., visually in a "flowchart"); 3) activity durations, lags, and/or external milestone dates are assessed; and 4) early start and end dates are determined for each activity, which defines the critical path (and float for non-critical path activities) and critical milestones/durations of interest.

  Cost – Typically, inflated costs through specific milestones (e.g., through construction) are of interest. Costs can typically be modeled as follows: 1) a complete and non-overlapping set of project cost items is identified; 2) quantities and uninflated unit costs (including appropriate markups) are assessed for each item, consistent with the schedule (e.g., for overheads); 3) uninflated costs are determined for each item by multiplying the quantities and uninflated unit costs; and 4) inflated costs are then determined depending on when the various cost items occur (schedule of project activities and their relationship to the cost items) and on relevant inflation rates. The various cost items can be allocated to the project activities (e.g., 60% to Activity X and 40% to Activity Y) to generate a cost-loaded schedule, and variable inflation rates for specific activities can be used.

  Disruption – Disruption is defined herein in terms of equivalent lost user person-hours, which includes traffic delays and detours, as well as business and other socio-economic impacts. Disruption is assumed to be approximately additive, and can thus be modeled as follows (as previously discussed in Chapter 4): 1) a complete and non-overlapping set of disruptive activities are identified; 2) the average disruption rate and duration for each activity are assessed, where the disruption rate might be determined based on assessments of the average delay per person and average number of people affected per day; 3) the disruption is then determined for each activity by multiplying the average delay per person for that activity, the average number of people affected per day during that activity, and the duration of that activity; and 4) the schedule of disruption can then be determined (if desired) by identifying when the disruptive activities will occur (e.g., per the schedule activities).

  Longevity – Longevity is defined herein (see Chapter 4) as the net present value (NPV) of costs and disruption (translated to equivalent cost) for O&M and replacement, appropriately considering schedule (time to replacement) and using an appropriate net discount rate (which is a DOT policy rather than a technical issue). The objective is to minimize this NPV. In this way, difficult (expensive or disruptive) O&M or replacement, or a short time to replacement, will be appropriately "penalized". Hence, longevity can be modeled as follows (as previously discussed in Chapter 4): 1) the average uninflated cost and disruption associated with O&M (e.g., on an annual basis) and with replacement, and the duration of O&M to replacement, are assessed; 2) the net discount rate and tradeoff "value" (cost equivalence) of disruption are established; and 3) the NPV of cost and disruption is determined by translating annual O&M and replacement disruption into equivalent cost terms and then adding them to annual O&M and replacement cost, respectively, and then finally discounting annual and replacement equivalent cost to NPV and adding them together.

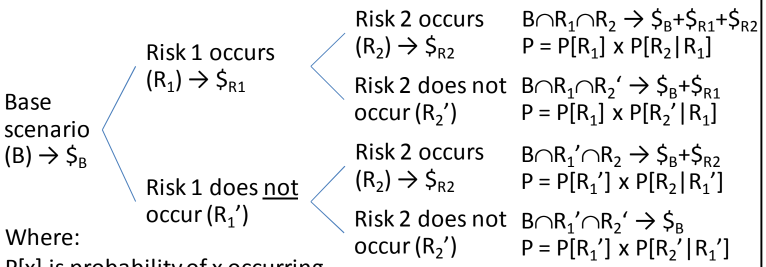
  Combined – Severity is defined herein as a change in the combination of the above performance measures, considering tradeoffs amongst them. Severity can be modeled as follows: 1) determine the change in each of the performance measures, as discussed above; 2) establish the tradeoff "value" of schedule (advancing the operations date), of disruption (decreasing lost person-hours), and of longevity (decreasing the NPV of O&M and replacement cost and disruption); and 3) determine the change in equivalent cost by summing: a) change in inflated cost; b) product of change in operations date and value of schedule change; c) product of change in disruption and value of disruption change; and d) product of change in longevity and value of longevity change.

- *Deterministic versus probabilistic analysis*. Deterministic (or traditional) analysis calculates one set of outcome values for one set of input values. It typically ignores the uncertainty in those inputs and the resulting uncertainty in the outcomes. Probabilistic analysis, on the other hand, calculates probability distributions for the outputs as a function of correlated probability distributions for the inputs (see Figure 7-1). Generally this is done in one of two ways: analytical solutions or Monte Carlo simulation.

  <u>Analytical solutions</u> can be done in several ways:

  - o A discrete probability distribution can be determined, as shown in this simple example for cost, for a set of representative scenarios. However, in most case there are too many scenarios to tractably represent all the possible combinations in such a combinatorial "tree".

  Example of Analytical Solution for Discrete Distribution:
  Base and two risks (*R_1 and R_2*), each with cost impact



  Where:
  P[x] is probability of x occurring
  P[x'] is probability of x <u>not</u> occurring = 1 – P[x]
  P[x|y] is probability of x occurring <u>if</u> y occurs
  $\$_x$ is cost impact if x occurs

  - o The mean value and standard deviation of the outputs can be determined approximately as a function of the mean and standard deviation of each input (in conjunction with the correlation coefficients between each pair of inputs), e.g., via first-order second-moment (FOSM) and related point-estimate methods. Although such approximate solutions are relatively simple for the mean (i.e., the mean value of an output is simply the deterministic function of the mean values of the inputs), it becomes more difficult and even impractical for the standard deviation (especially when inputs are correlated and for non-linear models, such as for schedule). Also, except for some special cases in which the form of the probability distribution can be assumed (e.g., the sum of a large number of independent variables is a Gaussian distribution, and similarly the product of a large number of independent variables is a lognormal distribution), the entire probability distribution is not developed (only its mean and standard deviation are), so that specific percentiles cannot be determined without further assuming a distribution form for the output.

  <u>Monte Carlo simulation</u> can approximate the entire probability distribution of each performance measure, as well as the sensitivity of each performance measure to the various inputs, as follows:

  1. a large number of possible sets of inputs (each set with a known probability of occurring) are developed by "sampling" (either randomly or more focused) the various input probability distributions (appropriately considering their correlations);
  2. a set of outputs is developed for each set of inputs, using the deterministic model – each set of outputs has the same probability of occurring as its set of inputs;
  3. the large number of possible outcomes for each performance measure, where each outcome has a known probability, are statistically analyzed to determine the probability distribution of that performance measure – this sampled population of outcomes is inferred to adequately represent the actual population of possible outcomes; and
  4. correlations among the performance measures, as well as between each performance measure and each input, can also be determined statistically.

- *Risk-based versus non-risk-based analysis*. Risk analysis can be conducted with or without identifying and quantifying individual risks, which might or might not occur.

  In a <u>non-risk-based</u> approach, project uncertainties are "lumped" or "rolled up" into allowances (or contingencies) that are applied at high levels within the analysis:

  - For <u>deterministic</u> analysis, these allowances are intended to "reasonably" cover the various uncertainties. For example, a contingency of 20% of the base construction cost might be considered appropriate (based on published guidance) at a particular point in project development.
  - For <u>probabilistic</u> analysis, uncertainties in specific items are assessed, <u>implicitly</u> combining base uncertainties and risks. For example, a factor can be applied to a base cost item to express the range of that item, ranging from the base cost item at the 10th percentile to the factor times the base cost item at the 90th percentile. Such a factor can be assessed based on judgment (which is very difficult to do accurately and defensibly at such a "lumped" level) or, if enough data is available for that base cost item (which is very unlikely), based on statistics, essentially averaging all the projects included in the data base ("one size fits all").

  On the other hand, <u>risk-based</u> approaches <u>explicitly</u> address individual risks that can affect particular project elements. Risk-based approaches allow for more detailed uncertainty analysis, considering the uniqueness of each project, and facilitate formal risk-management planning, and are the focus of this *Guide*.

- *Time-variable versus time-independent analysis*. For processes that vary significantly with time, the element of time should be considered in the risk analysis. For many applications, a 'pseudo-time-based' modeling approach (e.g., through use of a project cost-loaded schedule model) can adequately capture the key time-dependent features of projects without explicitly modeling the passage of time. For example, seasonal delays, inflation, and extended overheads can all be adequately incorporated in the model, and cash flow (or, in reverse, contingency drawdown) can be calculated.
- *Subjective versus objective assessment of input information*. As discussed in Chapter 6, when an adequate "database" of information related to a particular variable is available, an objective, or statistical, approach can be used to develop inputs to the risk analysis. However, when statistical information is not available, the opinion of experts can be elicited, de-biased (as discussed in Chapter 6), and quantified in the form of "subjective assessments." Because most transportation projects – and particularly rapid renewal projects – are relatively unique, adequate statistical information is generally not available and properly-obtained subjective assessments are required to conduct risk analysis. Facilitated consensus amongst a broad group of experts helps to enhance accuracy and defensibility of such assessments.
- *Decoupled versus integrated analysis*. It is possible to conduct risk analysis on various project performance measures (e.g., cost, schedule) separately from one another. However, typically such decoupled analyses either inappropriately ignore important relationships between these measures, or treat relationships in an ad-hoc manner. Integrated analyses explicitly identify, quantify, and model relationships (correlations and dependencies) between both input variables and output performance measures. For example, an integrated cost and schedule analysis explicitly models the various relationships between inflated project cost and schedule.
- *Initial versus updated analysis*. Risks as well as the base generally evolve over time as the project develops, and status, conditions and plans change and new information becomes available. Once significant changes have occurred, the previous analysis (and its results) becomes outdated and should be updated to stay relevant. For example, a risk analysis ("diagnosis") is typically done before risk management planning ("treatment") to identify targets for risk management. Plans will then change, based on risk management planning, so that the risk analysis should be updated considering those new plans.
- *Level of detail*. The level of detail can vary from simple algorithms with few but independent inputs to complicated algorithms with many correlated inputs. Although too little detail generally involves too much approximation, too much detail can introduce errors, as well as unnecessary effort.
- *Level of accuracy*. The level of accuracy is a function of the method of analysis and level of detail chosen, as well as the accuracy of the inputs.

- *Level of defensibility*. The level of defensibility is a function of: a) the level of consensus achieved on inputs and the credibility of those involved; b) the method of analysis chosen, especially its logic and transparency; and c) documentation of how the assessments were elicited or derived and how the analysis was conducted.
- *Level of effort*. The level of effort is a function primarily of the method of analysis and level of detail chosen, and on the accuracy, documentation, and level of consensus achieved and experts involved. Hence, the requirements for the levels of accuracy and defensibility must be balanced with the level of effort required to achieve those requirements.

7.2 Process of Risk Analysis

The risk analysis process is relatively straightforward, consisting of the following eight steps, which are subsequently described in more detail:

1. identify the desired "outputs" or types of results from the risk analysis;
2. select an appropriate method or approach for conducting the risk analysis;
3. define a model of the system (i.e., project development), which also defines the "inputs" and relates the "inputs" to the "outputs";
4. define a project "base" (exclusive of risks);
5. identify risks and opportunities relative to that base;
6. quantify the risk analysis "inputs" (both base and risk factors), including their uncertainties and correlations;
7. implement the model with uncertain (and correlated) inputs to determine uncertainty in the desired outputs and the sensitivity of the outputs to the inputs; and
8. document/check and update (as needed).

The above eight steps are discussed below in more detail:

1. Identify the desired "outputs" or types of results from the risk analysis.

It is important to identify and adequately, but efficiently, answer the right questions. A risk analysis that doesn't address the DOT's key questions is of limited use. As previously discussed generally in Chapter 2, typically, the desired outputs involve specific aspects of the project's performance measures, including:

- The project's total inflated cost, key schedule milestones, and cash flow through construction, and especially for rapid renewal projects, disruption through construction and longevity. Specific aspects of these broad performance measures might also be of interest, e.g., construction contract cost and duration. This might include uncertainty in those performance measures, to help determine appropriate budgets, milestones, and contingencies.
- Sensitivity of specific performance measures (e.g., a "combined" performance measure) to each of the inputs, especially risks, to help develop risk management plans and proper allocation of the risks in the contract.

These desired outputs should not be constrained by "canned" software outputs, since methods are available that can produce virtually any type of output. The accuracy and defensibility requirements for the results should be established, appropriately considering the level of effort required to achieve them.

Generally, the following guidance regarding the project scope and strategy to evaluate applies:

- *Evaluate the entire project*. Consider all project phases and elements, including maintenance and operation where applicable, as described in previous chapters. Be careful not to focus project risk assessments too narrowly on construction. This is a mistake, since many of a project's largest risks and other uncertainties can occur early in a project's development.
- *Evaluate all the relevant performance objectives*. For rapid renewal projects, consider disruption during construction and longevity (i.e., post-construction cost and disruptions, as well as post-construction schedule), as well as cost and schedule through construction.
- *Identify all possibilities, but stay focused on the key issues.* Make sure to consider all possible outcomes, but don't get bogged down on insignificant items. Do not artificially exclude any significant uncertainties (including risks and opportunities) from the analysis, since ignoring or otherwise excluding significant uncertainties, risks, and correlations will yield results that

underestimate the true uncertainties, and provide misleading or even incorrect results that will not "stand the test of time". However, if the DOT wants conditional analysis of various scenarios to help them evaluate internal decisions (e.g., regarding procurement method), then the results should be clearly "qualified".

2. Select an appropriate method or approach for conducting the risk analysis.

An appropriate method must be selected to provide the desired types of results, as identified in above Step 1. Also as discussed generally in Chapter 2, the appropriate method depends on the desired outputs. For example, for DOTs who want to establish project budgets and schedules with a quantified confidence level (e.g., 80% probability of success), as well as conduct risk management, a viable approach is probabilistic, risk-based, integrated cost and schedule modeling. However, if the DOT is only interested in quantifying project cost in current (uninflated) dollars, then there is no need to model project schedule (although there might be extended overheads). Similarly, if the DOT is only interested in project schedule, there is no need to model project cost. Typically, however, DOTs are interested in predicting both cost and schedule. Because inflated cost and schedule are functionally linked, DOTs should in this case conduct integrated (or joint) cost and schedule modeling. Furthermore, DOTs are often interested in evaluating the likelihood that their existing budgets will be met or establishing a budget (or contingency) with a reasonable likelihood for success. When this is the case, probabilistic modeling (i.e., appropriately considering uncertainties, correlations, and probabilities) is appropriate. Moreover, if contingency drawdown is desired, then an integrated cost and schedule model (which models cash flow) is needed.

As will subsequently be discussed, for determining sensitivity of performance measures to risk and opportunities, risk-based models are needed. However, if the DOT wants to determine the sensitivity of the target percentile of a performance measure (e.g., escalated cost) to the various risks and opportunities and other uncertainties, then special analyses are required, although still based on the results of a probabilistic, risk-based, integrated cost and schedule model.

Assuming a qualified modeler, DOTs can choose from a number of commercially-available software packages to perform probabilistic, risk-based, integrated cost and schedule modeling. A few "canned" packages also conduct risk-based analysis. Otherwise, an MS Excel workbook, with a commercially available add-in to do Monte Carlos simulation, can be used.

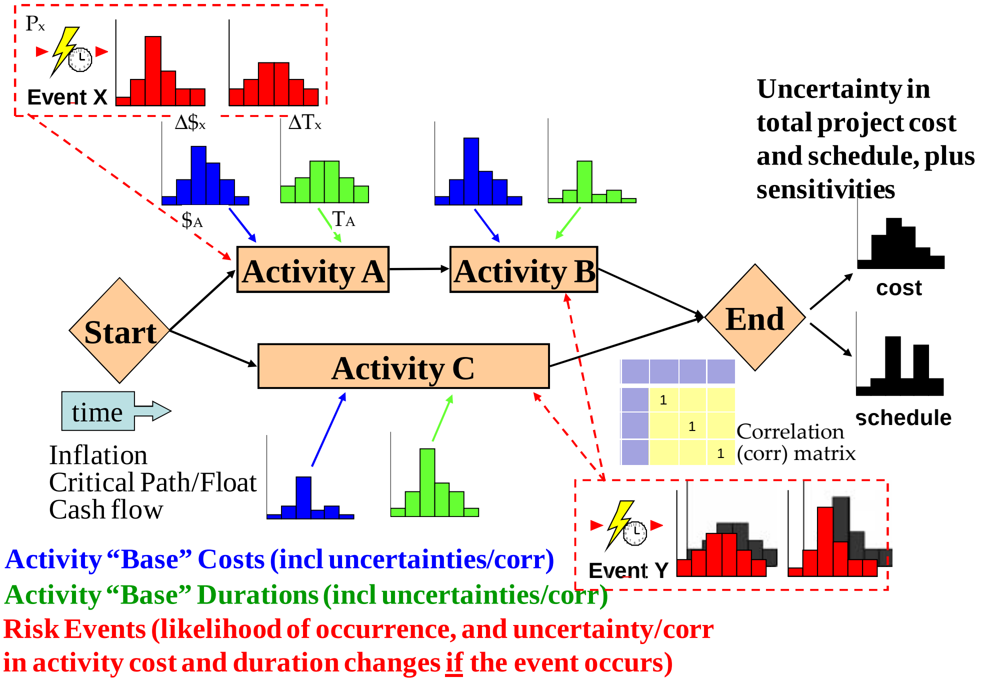


Figure 7-2. Probabilistic Risk-Based Integrated Cost and Schedule Model

3. Define a model of the system (i.e., project development), which also defines the "inputs" and relates the "inputs" to the "outputs"

For project risk analysis, a numerical model of the project's cost and/or schedule must typically be developed to adequately but efficiently combine and transform specific inputs into the desired outputs, consistent with above Steps 1 and 2. For example, cost-loadable scheduling software or a suitably-structured spreadsheet is typically used as a model to calculate the project's ultimate inflated cost and schedule. Such a spreadsheet can be expanded to include other performance measures (disruption and longevity), whereas scheduling software is generally not as flexible. Above all else, however, the numerical model must adequately represent the "system" (i.e., project development in this case) being modeled to avoid introducing significant model error that could produce misleading results.

For rapid renewal, the model should generally consist of the following linked elements (as previously described):

- *Schedule* – Calculate (via critical path analysis) early start and end dates, as well as float, of each flowchart activity based on either its precedence logic (including lags) and duration or, if no precedence requirement, its milestone date. Durations can be base only (which might be uncertain) or base plus realized risks, which in turn assume partial overlap of delays if multiple risks are realized in a particular activity.
- *Cost* – Calculate total unescalated cost by simply summing the costs of a comprehensive and non-overlapping set of cost items (i.e., the cost estimate). Calculate total escalated cost by allocating the cost items to the various flowchart activities (via a matrix), creating a simple cost-loaded schedule, and then escalating the cost of each activity based on its mid-point (from the calculated schedule) and its assessed escalation rate, which might vary among activities and from year to year. Typically, calculate total cost only through construction, with post-construction cost considered under "longevity" (see below). Each cost item can be a base cost (which in turn can be calculated from an average unit cost and a quantity, either or both of which might be uncertain) or a realized risk cost (some of which might be "triggered" by a schedule delay), which are assumed to be additive in a particular activity. Escalation rates might also be uncertain.
- *Disruption* – Calculate total disruption by summing the disruption associated with each flowchart activity. Typically, calculate total disruption only through construction, with post-construction disruption considered under "longevity" (see below). The disruption associated with each flowchart activity can be a base value (which in turn can be calculated as the product of the duration of disruption, the average number of people affected by disruption per day, and the average delay per affected person, any of which might be uncertain) or base plus a realized risk value (which might be "triggered" by a schedule delay), which are assumed to be additive in a particular activity.
- *Longevity* – Calculate the net present value (NPV) of post-construction cost and disruption, based on the unescalated cost and disruption associated with O&M and replacement, the calculated schedule of O&M and replacement, and the established net discount rate and value of disruption (see Chapter 4). The unescalated costs and disruption for each activity can be base only (which might be uncertain) or base plus realized risks (as discussed above).
- *Combined* – Calculate the total equivalent escalated cost of the project, by translating (via "tradeoffs") disruption through construction, construction completion date, and longevity into equivalent escalated cost and summing with the total escalated cost through construction (see Chapter 4). These can be base only (which might be uncertain) or base plus realized risks (as discussed above).

4. Define a project "base" (exclusive of risks)

The project base must be defined consistent with above Steps 1-3, as described generally in Chapter 4. As noted in Step 1, this might include alternative scenarios (e.g., representing internal decisions) for which conditional analyses are conducted to help make those decisions.

5. Identify risks and opportunities relative to that base

A comprehensive and non-overlapping set of project risks and opportunities must be identified consistent with above Steps 1-4, as described generally in Chapter 5. These risks and opportunities are relative to the base (Step 4).

6. Quantify the risk analysis "inputs" (both base and risk factors), including their uncertainties and correlations

The various risk analysis inputs must be adequately but efficiently assessed consistent with above Steps 1-5, and as described generally in Chapter 6. These risk analysis inputs include:

- the base factors, including the base uninflated direct cost of each activity (or more detailed factors such as quantities and unit costs of various items, and their allocation to activities), activity base duration/lags/milestone dates, activity base disruption, and base escalation rates for each type of activity;
- each impact scenario (in terms of quantitative changes in uninflated direct cost, duration, and disruption by activity) and its probability of occurring; and
- other "policy" factors, including post-construction discount rates, value of disruption, value of schedule, and value of longevity.

If quantification of uncertainty in performance measures is desired, then the uncertainties in (and correlations among) these risk analysis inputs must be assessed.

Among all the steps in risk analysis, quantifying uncertain inputs is perhaps the most problematic, because unqualified personnel can easily miss or improperly assess uncertainties and correlations. Therefore, DOTs should ensure that only qualified staff (with formal probabilistic training and relevant experience) attempt to quantify probabilistic inputs. As stated previously, only limited guidance on how to conduct quantitative risk analysis is provided in this *Guide* because the topic is so expansive and a number of good references are available for probability theory and probabilistic/uncertainty analysis (see Appendix B). However, some key guidance for quantifying uncertainty, which is typically not highlighted in common references, is provided here:

- *Variable definition* - The variable being assessed should be clearly defined, so that everyone has a common understanding. Errors in input assessments, or their subsequent misuse, and difficulties in achieving consensus on such input assessments often arise from such misunderstandings. For example, the uncertainty in a value on any particular day, where that value varies significantly from day to day ("variability"), is very different from the uncertainty in the average value over all the days of interest ("ignorance"), which might be the intent and how the value is actually used in the analysis. In other words, there is a significant difference between "variability" and "ignorance", which should be recognized: uncertainty due to ignorance can be reduced by additional information, whereas variability cannot. Hence, the model will define the variable, and whether variability or ignorance is the main source of uncertainty.
- *Distribution* – For significant factors (i.e., those which can significantly affect the outputs), the full range of possibilities and their relative likelihoods should be assessed:
    - When the range of possibilities is continuous (e.g., a cost change of anywhere from $1 million to $2 million), a continuous probability distribution (as illustrated in Figure 7-1) should be used. To develop this distribution, reasonable lower and upper limits (bounds) should be identified first, and then intermediate values and their relative likelihoods should be addressed. The most-likely or mean values should not be focused on first, because this will tend to lead to underestimation of the actual bounds, and, therefore, of uncertainty. If low values are preferable (e.g., costs), then the reasonable lower bound represents a very optimistic value and the reasonable upper bound represents a very pessimistic value; conversely, if high values are preferable (e.g., benefits), then vice versa. The level of conservatism associated with these bounds should be clearly established beforehand, e.g., it is typically specified (based on research) that the reasonable lower bound corresponds to the 10th percentile (for which there is a 10% chance that the actual value will be less than that and a 90% chance that the actual value will be greater than that) and the reasonable upper bound corresponds to the 90th percentile (for which there is a 90% chance that the actual value will be less than that and a 10% chance that the actual value will be greater than that), so that there is an 80% (4:5) chance of being within this range. Some training of the assessors might be required to ensure that they understand what 10% chance means (e.g., by identifying common events that have a 10% chance of occurrence for comparison). Typically a common

probability distribution form (e.g., a "normal" or "Gaussian" distribution) is then fitted to the range and other percentiles, based on judgment regarding the shape of the distribution (e.g., symmetry, tails, etc.). However, there should not be a constraint of using only particular probability distributions (e.g., because they're convenient). Uncertain inputs should be quantified with reasonable representations of the relative likelihood for the various outcomes, and in particular should reflect the uncertainty as envisioned by the experts making the assessments.

    - When the range of possibilities is discrete (e.g., the risk either occurs or not) or based on outcomes from potential scenarios (e.g., the DOT either builds a bridge crossing, or a tunnel crossing, or an at-grade crossing), consider using a discrete probability distribution (as illustrated in Figure 7-1) or event tree (as illustrated in a previous example) to appropriately structure and quantify the risk. In the case of a comprehensive and mutually exclusive discrete set of possibilities, it is useful to first rank the possibilities (x is more likely than y) and then assess their relative differences (x is twice as likely as y) to determine their probabilities (recognizing that the probabilities must sum to 1.0).

  Conversely, for relatively insignificant factors, only the mean value (instead of the full range of possibilities) is generally needed. Assessing their full range of possible values would not significantly affect the results, while taking significant effort, and would thus not be cost-effective.

- *Correlations and dependencies* – As discussed above, a probability distribution expresses the uncertainty in the value of a particular factor (either input or output). However, the uncertainty in the complete set of factors (especially input factors) is generally needed. Some factors might be related (e.g., due to a common underlying factor), such that if one factor X is on the high end if its range, the related factor Y would also tend to be on the high end of its range ("positive correlation") or on the low end of its range ("negative correlation"). Some factors might be a function of ("conditional on") other factors (e.g.,, the probability of event B occurring might be different if event A happens or not). Such relationships can be expressed in terms of a "correlation coefficient" for continuous or discrete distributions, or in terms of "independent" and "dependent" variables, in which the dependent variable has a "conditional" probability distribution that is a function of the value of the independent variable. These relationships among uncertain input factors should be adequately assessed and subsequently incorporated in the analysis. Otherwise, the uncertainties in the outputs will not be correctly determined, typically being underestimated if such relationships are ignored (as subsequently discussed). However, correlations among factors that are described only by their mean value (as opposed to a distribution) do not need to be assessed. Also, dependencies among events (as described by conditional probabilities) can often be avoided by combining these related events into a set of scenarios, each of which has a probability of occurrence (e.g., probability of event A and event B occurring). It should be noted that probability distributions for outputs are conditional" on the probability distributions used for the inputs, which in turn are "conditional" on various assumptions (including exclusions). If these assumptions turn out to be invalid, then the probability distributions for the inputs and thus the outputs might not be correct and could be misleading.
- *Subjective assessment* – For factors that must be subjectively assessed (because a statistically valid data set is not available), judgment biases (both "management" and "cognitive", as discussed in Chapter 6) on the part of the assessor(s) can result in errors. However, such biases can and should be countered to the extent possible by qualified facilitators and by achieving consensus amongst a broad group of experts, including those that are independent of the project. The assessments should be consistent with all the available information, which will generally support some values as being more likely than others, and might even preclude some values. As subsequently discussed in Chapter 8, some key input uncertainties can generally be reduced by obtaining specific new information that reduces the degree of "ignorance".

7a. Implement the model with uncertain/correlated inputs to determine uncertainty in the desired outputs

The model must be adequately but efficiently implemented consistent with above Steps 1-6. For project risk analysis, this involves translating the various inputs (base factors and risk factors) into all the outputs of interest (project performance measures, such as cost, schedule, disruption and longevity), as previously discussed, but also includes translating uncertainties in the inputs into uncertainties in the outputs. A number of good, although technical, references are available on propagating uncertainty (see Appendix B). However, as previously discussed, for project risk analysis, there are essentially two general ways to propagate input uncertainties through a model: analytical approaches and numerical approaches (such as Monte Carlo simulation). A simple example of an analytical solution is shown for unescalated cost, which is a simple “linear” model. Although such analytical solutions are often not tractable for other performance measures, especially those which are more complex and non-linear, they do provide some insight. The results in the example at the end of this chapter, on the other hand, are based on Monte Carlo simulation. If performed properly, simulation is a convenient and appropriate way to propagate uncertainty (even for non-linear models), and to conduct project risk analysis. Simulation capability is available for most popular project cost and scheduling software packages, as well as for many modeling platforms (e.g., MS Excel).

As previously discussed, regardless of the modeling method used, it is important to adequately incorporate the correlations in inputs. As shown in the simple example, there are typically two extreme (bounding) cases for correlations: total independence and “perfect” positive correlation. The results, especially in the tails of the distribution, can be very different for these two extreme cases, with the variance and higher percentiles much greater for perfect positive correlation. Generally, for appropriate correlations, the distribution will be between these two extreme cases, with the total independent case underestimating (sometimes significantly) the uncertainty and the perfect positive correlation case overestimating (sometimes significantly) the uncertainty. Analytical approaches can incorporate correlations among the input factors through more complicated equations. Monte Carlo simulation can appropriately incorporate correlations among the input factors during the process of sampling those input factors, so that appropriate <u>combinations</u> of input factors are generated and used to determine the output populations.

For example, to determine the total unescalated project cost ($\$_T$) from the unescalated costs ($\$_{Ti}$) of a comprehensive and non-overlapping set of cost items (i):

$$\$_T = \sum_{all\ i} \$_{Ti}$$

The mean of $\$_{T:}$

$$m[\$_T] \approx \sum_{all\ i} m[\$_{Ti}]$$

The variance of $\$_{T:}$

- iff $\$_{Ti}$ are all <u>independent</u>, p[$\$_T$] is approximately “Gaussian” (normal, bell-shaped curve) with:

  $$v[\$_T] \approx \sum_{all\ i} v[\$_{Ti}]$$

  $$\%[\$_T] \approx m[\$_T] + \Phi_{\%} * \sqrt{v}[\$_T]$$

- iff $\$_{Ti}$ are all perfectly positively <u>correlated</u>:

  $$\%[\$_T] \approx \sum_{all\ i} \%[\$_{Ti}]$$

- otherwise

  $$v[\$_T] \approx \sum_{all\ i} v[\$_{Ti}] + 2 \sum_{i=1\ to\ n} \sum_{j=i+1\ to\ n} cov[\$_{Ti}, \$_{Tj}]$$

where:

p[x] is probability distribution of x
m[x] is mean value of x
v[x] is variance of x
%[x] is specific percentile value of x
$\Phi_{\%}$ is standard normal probability function for specific percentile (%), where, for example, $\Phi_{80\%} = 0.842$
cov[$\$_{Ti}$, $\$_{Tj}$] is covariance between $\$_{Ti}$ and $\$_{Tj} = \rho[\$_{Ti}, \$_{Tj}] \sqrt{v[\$_{Ti}]} \sqrt{v[\$_{Tj}]}$
ρ[$\$_{Ti}$, $\$_{Tj}$] is correlation coefficient between $\$_{Ti}$ and $\$_{Tj}$

Because model inputs can be correlated and because model outputs can be functionally related in the model (e.g., due to common inputs), it should be recognized that the various outputs might be correlated. For example, a risk that has a cost and a schedule impact will affect both cost and schedule, so that these two outputs would be correlated due to this common factor. On a bigger scale, escalated cost is affected by schedule (i.e., the escalated cost increases with increased schedule), so that these two outputs will obviously be correlated. These correlations in outputs are important if the outputs will be combined (e.g., into an overall measure of performance), as has been suggested herein, for the same reasons as discussed above (i.e., the uncertainty in that combined measure would be underestimated if such correlations are ignored). There are two primary ways to adequately deal with this correlation: a) determine the outputs separately, assess (e.g., subjectively) the correlation among those outputs, and incorporate those correlations in any analysis in which those outputs are combined; or b) determine all the outputs jointly and combine them appropriately using an integrated model during Monte Carlo simulation (Figure 7-2). Approach b) is recommended.

7b. Determine the sensitivity of the outputs to the inputs

For example (see previous example), to determine the sensitivity of $\$_T$ to each $\$_{Ti}$ (one at a time):

$\Delta\$_T = \Delta\$_{Ti}$

$\Delta m[\$_T] = \Delta m[\$_{Ti}]$

- iff $\$_{Ti}$ are all independent, p[$\$_T$] is approximately "Gaussian" with:

$\Delta v[\$_T] = \Delta v[\$_{Ti}]$

so that

$$\Delta\%[\$_T] \approx \Delta m[\$_T] + \emptyset_{\%} * \Delta\sqrt{v[\$_T]} \approx \Delta m[\$_{Ti}] + \emptyset_{\%} * \Delta\sqrt{}v[\$_{Ti}]$$

- iff $\$_{Ti}$ are all perfectly positively correlated:

$\Delta\%[\$_T] = \Delta\%[\$_{Ti}]$

The results must be adequately but efficiently analyzed to determine the sensitivity of those results to the various input factors (e.g., to subsequently guide risk management, as discussed in Chapter 8). The traditional way of determining sensitivity is to change each input by a specific amount (e.g., zero out a risk) and to then recalculate the outputs and measure their change (e.g., in the target percentile). However, this becomes quickly unmanageable, especially if the model involves Monte Carlo simulation. Fortunately, other approximate methods are available to do this more efficiently. For the previous example shown here, the sensitivity of various aspects (e.g., mean, variance, specific percentile) of an output (e.g., total unescalated project cost) to the various inputs (e.g., unescalated cost of each item) can be determined analytically for simple linear models, especially with independent inputs. For base factors, the contribution of their uncertainty to specific ("target") percentile values can be determined by assuming that their variance goes to zero (i.e., $\Delta v[\$_{Ti}] = -v[\$_{Ti}]$ in the simple example), with no change in the mean value. For risks, their contribution can be determined by assuming that both their mean value and their variance go to zero (i.e., $\Delta m[\$_{Ti}] = -m[\$_{Ti}]$ and $\Delta v[\$_{Ti}] = -v[\$_{Ti}]$ in the simple example), where:

- the mean value of a risk equals its probability of occurrence times its mean value if it occurs, and
- the variance of a risk equals the sum of:
    - its probability of occurrence times the square of the difference between a) its mean value if it occurs and b) its mean value; and
    - one minus its probability of occurrence, times the square of its mean value.

For more complex non-linear models, approximate linear models can be developed that use weights (actually first derivatives) for each input factor, where the weights are derived by regression analysis from the many results produced during Monte Carlo simulation. Then the sensitivity can be determined in the same way as described above. This is how the example at the end of this chapter was developed, in which the contribution of each of the many uncertain factors to the target percentile (80%) of total escalated cost was determined, with one particular risk identified as being most important on that basis. It should be noted that the sum of the changes in mean value associated with each risk will equal the change in the mean value associated with all the risks collectively, whereas the sum of the changes in a specific percentile (e.g., 80th) associated with each risk will generally not equal the change in that percentile value associated with all the risks collectively.

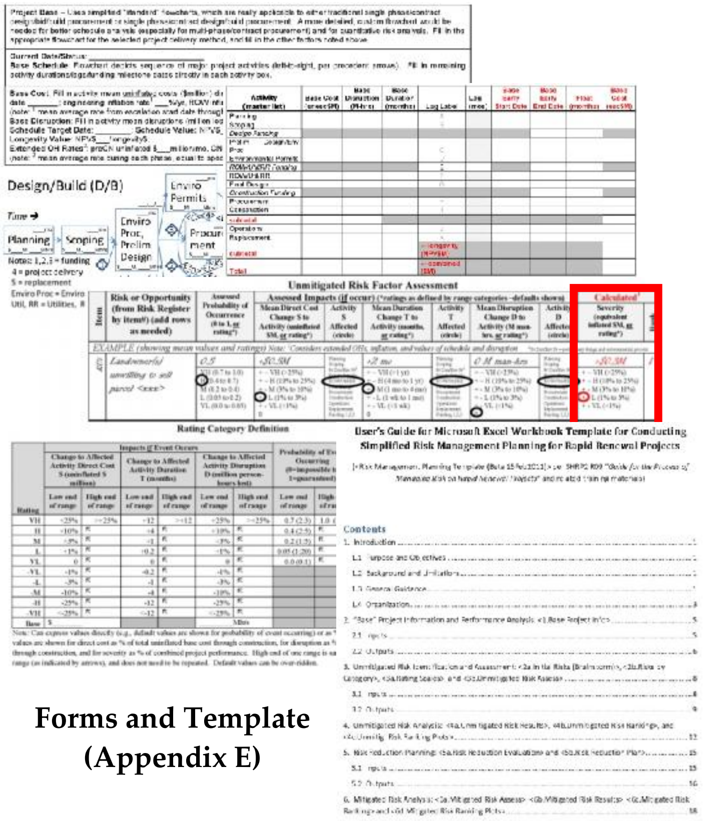
8. Document/check and update (as needed)

Each step in the above process should be adequately but efficiently documented, reviewed, and checked. In particular, another qualified person should review the model logic, inputs, and results to ensure the results are accurate and appropriate. Subsequently, as inputs change, their assessments, and the analysis, should be updated.

This process is often iterative, especially updating steps 4-8 as a project evolves over time and the risks, as well as the base (especially uncertainty), change with changing status, plans, conditions and information. For example, after an initial analysis has been conducted to identify the key risks, risk management planning is conducted to proactively reduce those risks, albeit often at some cost (see Chapter 8). Hence, for a particular *risk management plan*, the risks as well as the base will have changed, so that the risk analysis should be updated, presumably (if the risk management plan is cost-effective) resulting in better predicted performance and lower contingency requirements.

The forms and Microsoft Excel workbook template previously shown for structuring (Chapter 4) and for risk assessment (Chapter 6) have been developed to facilitate limited risk analysis for relatively simple projects (see Appendix E). The template incorporates appropriate models to automatically and adequately determine:

- the relevant mean base project performance measures as a function of specific mean base factors, as input on the project structure form;
- the mean changes in project performance measures, and thereby change in the mean "combined" performance measure (severity) for each risk, as a function of specific mean risk factors, as input on the risk assessment form; and
- the relevant mean "base+risk" project performance measures as a function of specific mean base and risk factors, as input on the project structure and risk assessment forms, respectively.



Forms and Template (Appendix E)

Although these models are deterministic, if mean-values are used for inputs, then the models produce reasonable approximations of the mean values of the outputs. More sophisticated analyses, typically using Monte Carlo simulation in conjunction with these (or more complicated) deterministic models and uncertain model inputs, are required to determine full uncertainty in the performance measures.

7.3 Conclusions regarding Risk Analysis

Risk analysis is a valuable (but not absolutely necessary) element of the overall risk-management process. The primary objective of risk analysis is to quantify a project's performance measures, including its uncertainty, which enables project decision-makers to make better decisions among project alternatives or for the selected alternative, to establish (or determine confidence in pre-established) budgets and milestones, as well as to quantitatively determine the severity of each risk with respect to that set of project performance objectives, which allows for better risk-management planning.

If the DOT plans to conduct risk analysis, which involves quantitatively assessing the inputs (and their uncertainties, including correlations) and developing a model to calculate the outputs (and their uncertainties, including correlations), it should select the best method for its particular application, and then be sure to have adequately-trained personnel conduct the analysis to avoid common pitfalls. If conducted and interpreted properly, the results can provide the DOT with valuable insight into potential future project performance. However, if not conducted or interpreted properly, the results can be misleading.

Illustrative Example

The hypothetical case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, involved using the principles and process outlined in this chapter, as documented in Appendix F - *RMP* Addendum X and summarized below.

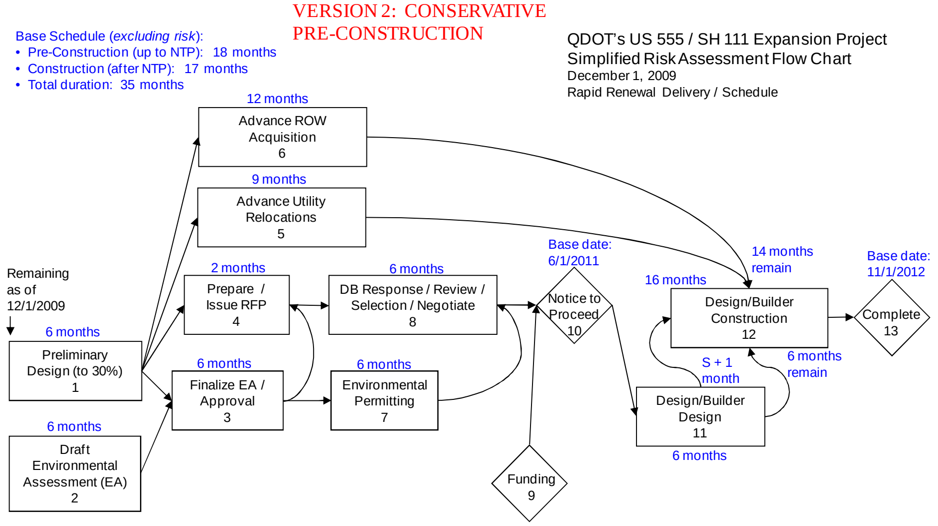
QDOT used the mean base and unmitigated risk assessments to determine (using the MS Excel workbook template) the approximate mean unmitigated project performance (i.e., schedule, uninflated and inflated cost, and disruption, both total for the project and by project activity) in the same way as for base project performance. Although these results were very approximate (due to simplifications in the analysis), it provided insight into the collective effect of the risks, before any additional mitigation. This information and these tools were also used to determine the mean severity of each risk, in terms of how much the combined performance measure is affected by that risk.

Subsequently, a quantitative risk analysis was conducted (see Appendix F - *RMP* Addendum X for inputs and results), for which:

- A more detailed flowchart was developed (by consensus) by the facilitated group (see below).
- Uncertainties in the unmitigated base cost estimate and schedule were assessed (by consensus) by the facilitated group; e.g., bridge structure cost ranges (10th to 90th percentile) from -20% to +20%, and is moderately correlated (coefficient of 0.75) with other construction cost items.
- Unmitigated risk factor assessments were refined (by consensus) by the facilitated group (see below).
- A more sophisticated, probabilistic (via Monte Carlo simulation) integrated cost and schedule model was developed to represent the more detailed flowchart and implemented with the more refined unmitigated base and risk assessments.
- Uncertainties in unmitigated project performance (i.e., project completion date and cost through construction, both unescalated and escalated) were determined (see below).
- Contributions of each risk and base uncertainty toward the target (80th percentile) escalated cost through construction and project completion date were determined (see below); e.g., EP2 contributes $0.2M to 80th percentile of escalated project cost, and ranks 13th.

As will subsequently be discussed, the uncertainties in project performance can be used to determine appropriate budget/milestone/contingency and the sensitivity of the budget (not just the mean cost) to the various risks can be used to better guide risk management.

Illustrative Example (continued):

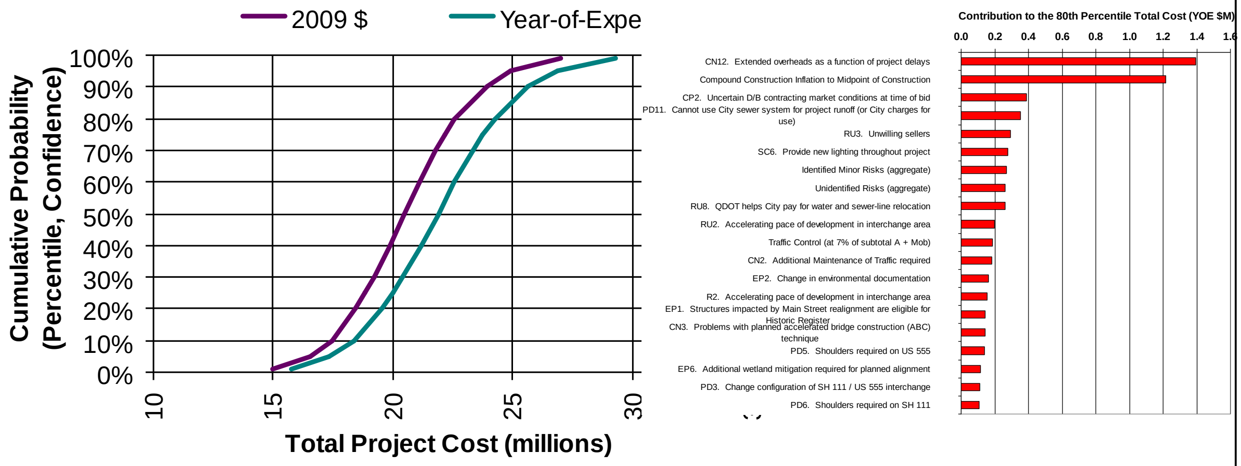


Notes:
1. Single Design/Build contract.
2. Advance Right-of-Way (ROW) Acquisition includes appraisals, offers, acquisition, relocation, and demolition for parcels that QDOT anticipates will be critical to early construction by the Design/Builder.
3. Advance Utility Relocations includes coordination, approvals, and relocations of utilities that QDOT anticipates will be critical to early construction by the Design/Builder. Additional relocations that might be required will be the responsibility of the Design/Builder during construction. Assumes minimal new ROW required for utility relocations.
4. QDOT will complete the Environmental Assessment (EA) and obtain all environmental permits before Notice to Proceed (NTP).
5. Construction duration *includes* typical winter shut-down period from November 15th through March 15th.
6. Construction includes construction permits, remaining utility relocations, and all construction-related effort. Remaining ROW acquisition by QDOT also occurs during this timeframe.

QRA flowchart for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Addendum X)

Risk or Opportunity	Probability of Occurrence	Cost Change if Occurs (2009 $ million)	Duration Change if Occurs (months)
PD13 Change in environmental documentation	Mutually exclusive scenarios: A. 50% (base) B. 40% C. 8% D. 2%	A. 0 (base) B. +0.1 to Activity #2 C. +0.5 to Activity #2 D. +0.5 to Activity #2 and +1.0 to Activity #12	A. 0 (base) B. +1 to Activity #2 C. +6 to Activity #2 D. +6 to Activity #2

Quantitative assessment for a select rapid renewal risk for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Addendum X)



Unmitigated project performance (cost) uncertainty and sensitivity of 80th percentile of escalated cost for QDOT US 555 / SH 111 Project (ref. Appendix F - *RMP* Addendum X)

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Chapter 8. Risk Management Planning

8.1 Introduction to Risk Management Planning

Objectives

The primary objective of risk management planning is to optimize future project performance, specifically with respect to risks. Value engineering (VE) has a similar objective of optimizing project performance, but generally focuses on improving the base rather than reducing risks (e.g., through changing project design, project delivery strategy and/or construction means/methods). Risks and opportunities from the risk identification process, with risk-factor assessments from the risk assessment or risk analysis, and the base factors from structuring, are necessary input for risk management planning. The risk management planning process develops specific actions and assigns responsibilities to cost-effectively deal with individual risks and capitalize on opportunities, and to then deal with the remaining risks collectively through “contingency” (both reserve and recovery plans). The *Risk Management Plan* (*RMP*) is the output of that process.

Develop (and commit to implementing) an adequate but efficient *Risk Management Plan* to address project risks, both proactively and individually, and then reactively and collectively, to optimize project performance

The *RMP* documents specific actionable items to deal with risks and opportunities. These actionable items require resources. The *RMP* provides a consistent format for assigning and documenting these resources. It answers the essential questions regarding risk management: *Who* will manage the risk? *What* will be done? *When* will it be done? *How* will they do it? What *resources* are likely to be required? What are the likely *benefits*?

The *RMP* should be accurate and defensible, as well as cost effective. Following a rigorous process (of risk identification, assessment, and possibly analysis prior to risk management planning) will help to ensure accuracy and defensibility. Documentation of each step in the process is essential for effective planning efforts. Decisions regarding the investment of resources in risk management alternatives should ultimately be made through a cost-benefit analysis. Following the steps of the risk management process will allow the team to use prior risk assessment outputs and weigh the benefits of risk management alternatives against the costs of implementation.

Ultimately, the *RMP* should fit within the context and culture of the DOT. Risk management (i.e., anticipating and addressing potential problems and improvements) is an essential element of project management, and should integrate into the project team’s approach to cost, schedule, scope, and quality management, and into the DOT’s goals for program delivery.

For example, one particular risk (of many) on a project consists of a 50% chance of an extra $1M (unescalated) and a 1 month delay, both during construction. However, one action for addressing this risk, which would cost $100k now, would reduce the chance of that risk happening by half (to 25% chance). The combined impact of the risk <u>if</u> it happened (considering the effect on the critical path, escalation of the cost impact and increased escalation of remaining costs, and the value of project completion delays) is $2M (equivalent YOE). Hence, the reduction in the probability of occurrence (from 50% to 25%) is worth $500k (equivalent YOE). Since this risk reduction exceeds its cost of implementation by $400k or 4:1, the action is cost-effective and should be adopted.

Philosophy and Concepts

At any point in time, future project performance is uncertain due to many factors, as previously discussed. However, this uncertainty generally decreases with time as the project develops, and various issues are resolved (e.g., risks either happen or not), although it cannot be predicted whether the mean value (or even the high or low ends of the range) will increase or decrease. Project teams can affect some aspects of future performance through proactive individual risk reduction. Ultimately however, a risk eventually either happens or it does not. Effective risk management planning establishes budgets and schedule milestones with contingencies (both reserves and recovery plans) for risks to adequately cover the uncertainty that remains – even after the best planning efforts.

A project team would ideally *avoid* all the risks and capitalize on all the opportunities through an investment of minimal resources, but this is generally not realistic in practice. *Risk reduction* – the proactive reduction of risk probabilities and/or impacts – is the next option when risk avoidance is not viable. As previously discussed, the mean impact value of a risk is the probability of its occurrence multiplied by the impact if it does occur. Comparing the reduction in the severity of the risks to the cost of individual mitigation actions, or a suite of actions, will help the project team to decide if the mitigation effort is cost effective. Ultimately, however, the effectiveness of risk mitigation is only realized upon implementation. Therefore, the assignment of a risk owner with adequate resources is necessary to ensure that the process is complete (see Chapter 9).

Residual risks are those future risks that the team cannot avoid or completely eliminate. Risk reduction, by definition, does not completely eliminate the risk, and in fact, new risks may surface during the reduction efforts. Contingency amounts and recovery plans are the tools to deal with residual risks. Effective risk management processes budget for contingency and plan for recovery on the basis of the residual risks to ensure that the project will meet budget and schedule milestones. Because risks are resolved as the project evolves (i.e., if they occur they are covered by contingency, if available, but if they do not occur during their phase, they are retired), the residual risks tend to decrease as the project evolves, regardless of what happens up to that point.

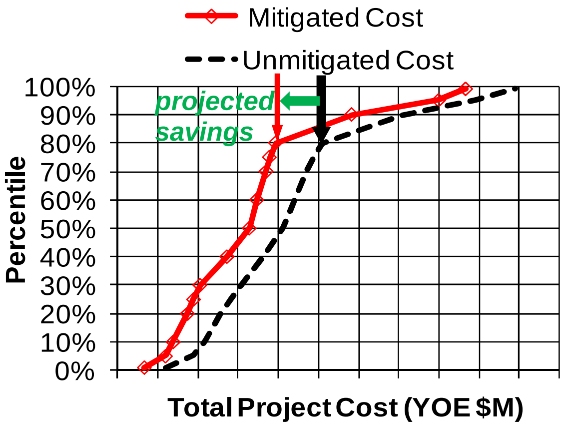
Some risks will remain when the project is let for a contract. Rapid renewal projects often involve the allocation of risks to the designer or construction through alternative project delivery methods such as design-build. The residual risks are allocated at this point in project development through the provisions of the contract. Such transfer of risk comes at a price (in the contractor's bid) and might turn out to be not as effective as expected.

With these objectives and philosophies in mind, the remainder of this chapter discusses the risk management planning process.

8.2 Process of Risk Management Planning

The process of risk management planning generally involves addressing risks: a) individually and proactively through risk reduction (including risk allocation); and b) collectively and reactively through contingency management and recovery plans. *Risk reduction* is a proactive process of employing cost-effective actions to reduce risks (e.g., through avoidance or transfer, including risk allocation, which involves contractually assigning the residual risks to a party in the contract). *Contingency management* involves the maintenance of adequate resources in the case that residual risks occur. Recovery plans involve ways to continue the project (possibly changed) if the contingency is exceeded. The *RMP* essentially documents these plans. This section briefly describes the risk management process.

Example benefits of risk management in terms of "mitigated" cost (can also evaluate other project performance measures):



8.2.1 Risk Reduction

The goal of risk reduction is to proactively and cost-effectively reduce (mitigate) individual risks. The risk identification process (Chapter 5) will identify many risks, even for the least complex projects. Since the list of risks can be extensive, teams should start with the most significant risks as identified through the risk assessment process (see probability and impact rating techniques in Chapter 6) or a more rigorous risk analysis process (see sensitivity analysis output in Chapter 7). These risk assessment and analysis techniques are important because intuition and informal engineering judgment are not always reliable when choosing the most significant risks on which to focus risk reduction effort. Additionally, the risk assessment and analysis efforts will yield useful information in terms of creating a risk “baseline” of unmitigated risks when considering the cost-benefit aspects of implementing risk reduction efforts.

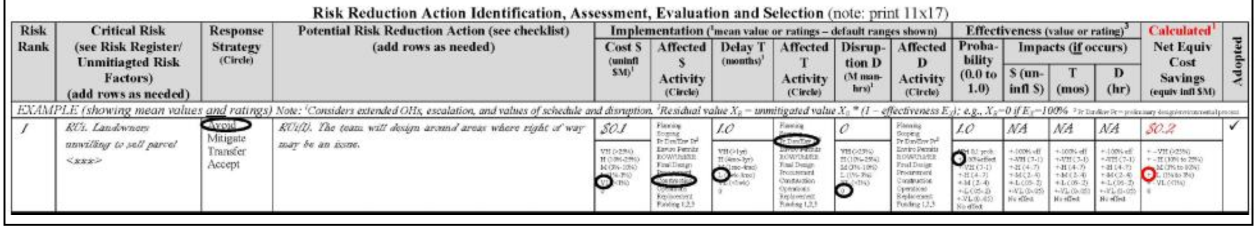
The project team will need to examine the most significant project risks to see if there are management strategies or actions for reducing a risk’s probability of occurrence and/or impact if it does occur; similarly, for opportunities, the objective is to increase (rather than decrease) its probability of occurrence and/or impact if it does occur. The identification of strategies and actions can be done through project specific team efforts (e.g., brainstorming) or through the use of generic risk management action lists. Appendix D.3 of this *Guide* contains a comprehensive list of risk management actions that correspond to common rapid renewal strategies and related risk categories that can commonly occur with these actions. Teams should use this table after they have exhausted their own ideas on risk reduction to spur new ideas or improve the team’s ideas for risk reduction. An example from the project scoping phase of Appendix D.3 is shown below. This example identifies risk management actions that can help to reduce risks. There are likely to be many potential risk management actions for each risk. The risk management actions will require an investment and the risk management action that results in the highest reduction with the least investment (i.e., most cost-effective) should be selected for implementation. Note that in some cases, combinations of actions might be employed to manage a particular risk or set of risks; in this case, synergy and overlap among the various actions should be considered to avoid underestimating or overestimating (respectively) the combined effect of those management actions. Also, in some cases, one risk management action might affect multiple risks; in this case, the multiple benefits should be considered to avoid underestimating the overall benefit of that action.

Example of potential risk-management actions (from Appendix D.3)

Rapid-Renewal Strategy	**Related Risk or Opportunity Categories** Note: The individual risk categories (and their related examples, below) could apply to any or all of the renewal category examples in the column to the left.	**Potential Risk-Management Actions** Note: The potential risk-management actions could apply to a number of the risk categories in the column to the left:
Accelerate the environmental documentation process Examples: • Leverage master planning (see Project Scoping) • Conduct early coordination (see Planning) • Identify documentation requirements early Identify and avoid major impacts early (historical, cultural, archaeological)	**Different type of documentation required** Example causes or issues: • Project’s impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.), so more substantial documentation is required (e.g., EIS instead of EA) • Additional discipline studies are required • Additional (new) alternatives must be developed and documented • Documentation requirements change	• Modify the project design to reduce the impacts that are triggering different type of documentation • Anticipate potential concerns with main alternatives, and develop additional alternatives early in process to address those concerns • Anticipate/plan for and/or start additional (targeted) discipline studies earlier to reduce impact to project schedule if they are later required • Develop alternate (or additional/more-detailed) documentation in parallel with presumed appropriate documentation to reduce impact to schedule if alternate documentation is later required

The implementation materials for this *Guide* provide instructions and tools for how to calculate the cost-benefit analysis for each option. The example below provides a format for conducting these analyses. It provides for the four primary categories of risk response: avoid, mitigate, transfer (allocate), and accept. Some actions may use more than one of these strategies. The intent of using these categories is to spur the development of possible risk management actions. Implementation of these efforts will require resources (e.g., additional design hours, additional coordination efforts, use of more expensive materials, etc.). The results of the management actions will be a reduction in the probability of occurrence for the risk event and/or a reduction in the impact. All of this data will provide the necessary information for a cost-benefit analysis of each risk management option. However, care must be taken to not underestimate the implementation "costs" and to not overestimate risk reduction "benefits".

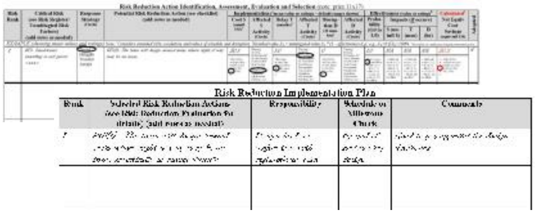
Example risk reduction evaluation (<u>not</u> the hypothetical case study):
On a project, there was a risk of a landowner being unwilling to sell a parcel needed to construct a project. When it was first identified, there was a high probability (50%) that the owner would not be willing to sell and the impact of this risk was $500,000 and 2-month delay, with an "expected value" of about $300,000 (including increased escalation and extended OHs) and 1 month (critical path). However, a management action was identified that would avoid this risk by designing around the parcel, at a cost of about $100,000 ($150,000 including increased escalation and extended OHs) and 1 month delay. The resulting reduction in risk meant that about $300,000 and 1 month less contingency was required; however, the resulting cost ($150,000) and delay (1 month) of the mitigation effort had to be added to the base cost and schedule. This is clearly cost effective, with a net cost savings of $150,000 and no net schedule impact. Based on such updates of the various inputs if the action is adopted, the contingency requirements (and recovery requirements) could be recalculated .



Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)	Response Strategy (Circle)	Potential Risk Reduction Action (see checklist) (add rows as needed)	Implementation (¹mean value or ratings – default ranges shown)						Effectiveness (value or rating)³				Calculated¹ Net Equiv Cost Savings (equiv infl $M)	Adopted
				Cost $ (uninfl $M)¹	Affected $ Activity (Circle)	Delay T (months)¹	Affected T Activity (Circle)	Disruption D (M man-hrs)¹	Affected D Activity (Circle)	Probability (0.0 to 1.0)	Impacts (<u>if</u> occurs) $ (un-infl $)	T (mos)	D (hr)		
EXAMPLE (showing mean values <u>and</u> ratings) Note: ¹Considers extended OHs, escalation, and values of schedule and disruption. ²Residual value X_R = unmitigated value X_U * (1 – effectiveness E_X); e.g., X_R=0 if E_X=100%															
1	*RU1. Landowners unwilling to sell parcel <xxx>*	[✓ Avoid] Mitigate Transfer Accept	*RU1(1). The team will design around areas where right of way may be an issue.*	*$0.1*		*1.0*		*0*		*1.0*	*NA*	*NA*	*NA*	*$0.2*	✓

The companion training course (Appendix G) addresses risk reduction in more detail, including a form and a spreadsheet template (Appendix E) for conducting evaluations of cost-effectiveness (including automatic analyses), appropriately considering risk and opportunities, as well as the performance measures and activities for rapid renewal, especially for simple projects.



Forms (Appendix E)

As will subsequently be discussed, to illustrate, risk reduction plans have been developed for the hypothetical QDOT case study (see Appendix F).

8.2.2 Risk Allocation

Risk allocation is one specific way to reduce project risks for the owner, but warrants further discussion, especially for risky rapid renewal projects. The contract is the vehicle for risk allocation. Whether the contract is for construction, construction engineering and inspection, design, or design-build, or some other aspect of rapid renewal design and construction, the contract defines the roles and responsibilities for risks. Risk allocation in any contract affects cost, time, quality, and the potential for disputes, delays, and claims.

The risk allocation principles embedded in the industry's guide specifications are tested and well established in case law. However, their use can promote a "one size fits all" process of risk allocation.

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

The objectives of risk allocation can vary depending on unique project goals, but DOTs should attempt to follow four fundamental tenets of sound risk allocation:

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

A fundamental tenet of risk allocation is to allocate the risks to the party that is best able to manage them, as long as, if it is being transferred (e.g., to the contractor or to the insurer), the transfer price is reasonable. The party assuming the risk should be best able to evaluate, control, bear the cost, and benefit from its assumption. For example, the risk of an inadequate labor force, a breakdown in equipment, or specific means of construction is best borne by the contractor, while a risk of securing of project funds or project site availability is best borne by the DOT. Following this principle of allocating the risks to the party that is best able to manage them will ultimately result in lowest overall price because contractors will not be forced to include as much contingency for possible financial losses or take gambles in an extremely competitive bidding environment. Inappropriate risk shifting from the owner to the contractor can result in higher prices, misaligned incentives, mistrust, and an increase in disputes.

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

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

The ultimate goal of risk allocation should be to help align the project team with customer (e.g., public)-oriented performance goals. While this concept may seem to be a significant departure from traditional practices in the United States, DOTs are already doing this through the use of alternative contracting techniques. For example, A + B (time + cost) procurement is used on selected projects in the majority of DOTs in the U.S. In essence, A + B procurement passes the risk for completion delays to the contractor to achieve a customer goal of satisfaction with the service. In an extreme example, the use of Public Private Partnership techniques is shifting the risk for customer satisfaction almost entirely to the private sector. DOTs and the industry should strive to innovate and develop new risk allocation techniques that align all team members with customer goals.

8.2.3 Contingency Management

Contingency is an amount of money or time that is included in an estimate to cover residual risks. Contingency "management" involves the maintenance of adequate resources in case significant risks occur in the future. Risk management practices and tools can assist in the calculation of appropriate contingencies to account for these potential costs and delays.

If a risk occurs, its impacts are realized and the base should be adjusted accordingly, i.e., costs are transferred from contingency to base. On the other hand, if a risk does not occur during its "window", then it will never occur and contingency is not needed to cover that risk any longer.

Figure 8-1. Determination of Contingency

Contingency can be established either (see Figure 8-1):

- Objectively, to achieve a specified (DOT policy) level of confidence (e.g., 80th percentile), but only if quantitative risk analysis (see *Guide* Chapter 7) has been conducted; or otherwise
- Subjectively (consistent with available information) or even empirically (if enough historical information is available to analyze), although it might not achieve the desired level of confidence..

Contingency is only needed to cover remaining risks at any point in time. Typically, as previously discussed, risks (and thus the need for contingency) decrease as the project develops. As shown in Figure 8-2, contingency can be determined by phase (based on the risks that might occur during that phase).

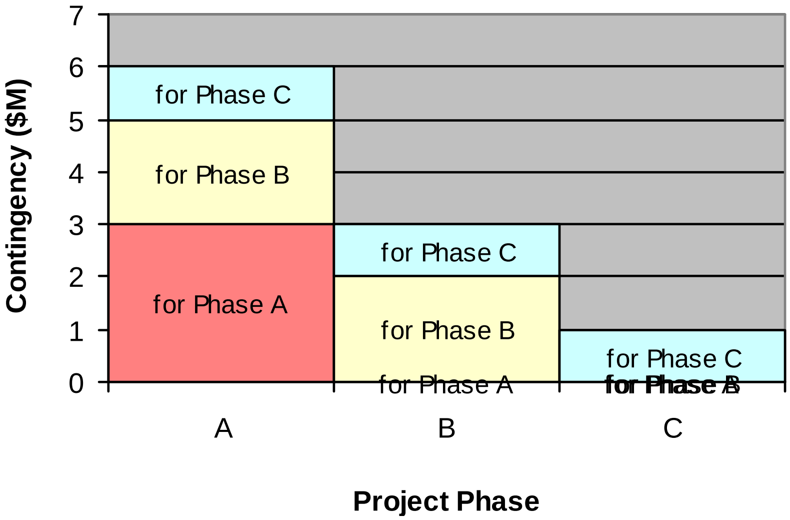


Figure 8-2. Contingency by Project Phase

Contingency must be carefully managed to ensure it is not wasted and is available when (and if) needed. Similar to any project expenditure, drawing on contingency should be subject to DOT approval, with increasing scrutiny as the amounts get larger. DOTs should have a policy to describe what project teams should do with any unused contingency. If the purpose and need of the project is met, this policy would ideally ask the project team to return the unused contingency to the overall program (for use on other less fortunate projects) instead of adding scope to the project baseline. Otherwise, contingency becomes a self-fulfilling budget, which is never under-run.

As will subsequently be discussed, to illustrate, contingency has been developed (by project development phase) for the hypothetical QDOT case study (see Appendix F).

8.2.4 Recovery Plans

Project teams should develop options to improve project performance, if needed, as risks are realized at various stages in project development. In some cases, remaining contingency funds might not be enough to pay for the realized risk (or schedule float might be used up), so that the realization of risks will trigger a need to adjust the project approach (i.e., adjust the project's base plan, as described in Chapter 4). In some cases, this might result because some realized risks might also create new risks that are difficult to foresee. For example, many rapid recovery strategies will require early coordination of innovative designs with partner permitting agencies. If a permit is not granted in a timely fashion, the project team will need to spend additional resources on an alternative approach to complete the project. This new approach might in fact have its own new risks.

Recovery plans consist of specific options that are available during each phase of project development to "recover" project cost or schedule. Typically, each such option is only available through a particular phase of project development, and is no longer available, or its recovery value substantially reduces, after a particular point. Some typical examples of recovery plans include:

- Overtime or additional crews/equipment to accelerate remaining schedule, for which there is less "capacity" later in the project;
- Reduction (or "deferral" for political reasons) of project scope, especially to reduce cost, which might be relatively easy to implement prior to bid (during design, although it often results in delays, especially if it affects the environmental process) but might require contractual "options" (e.g., to include the reduced scope only if money is available) to implement after contract award.

Clearly, to prevent delays and expedite decisions, recovery plans should be developed prior to depletion of contingency and their implementation. As part of this, DOTs should establish policy on release of contingency (i.e., should unused contingency be retained, e.g., as program reserve, for later phases to reduce the need for recovery or must it be returned to the program?). Similar to contingency, specific cost and schedule recovery "capacity" should be specified for each phase. Ideally, such recovery capacity would be determined objectively in the same way as contingency (Figure 8-1), to provide (in conjunction with contingency) a specified level of confidence in meeting project budgets and milestones. For example, if the contingency provides an 80 percent confidence, recovery might be designed to increase the confidence level to 90 or 95%.

As will subsequently be discussed, to illustrate, recovery plans have been developed (by project development phase) for the hypothetical QDOT case study (see Appendix F).

8.2.5 Risk Management Plans

A structured risk management process will result in a formal *Risk Management Plan* (*RMP)*. The project development team's strategy to manage risk provides the project team with direction and a basis for planning. The *RMP* should ideally be developed during the planning and programming phases, and then updated during the preliminary and final design phases.

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

1. Introduction (including Summary, Definitions, Project Description, Risk Management Strategy and Approach, and Organization, Roles, Responsibilities)
2. Risk Identification, Assessment and Analysis (including *Risk Register*)
3. Risk Reduction
4. Contingency (including reserve and recovery plans)
5. Implementation (including Risk Monitoring/Updating, information gathering/distribution)
6. Risk Register, Documentation, and Reports

Each *RMP* should be adequately documented, but the level of detail will vary with the unique attributes of each project. Smaller projects might employ a risk register as the only formal *RMP*, while larger projects should have a formal *RMP* with the sections above and might also employ computer-based risk management information systems. Ideally, the *RMP* will integrate into the overall project management plan through coordination with tasks such as periodic cost estimates, value engineering, constructability reviews, and design reviews.

As will subsequently be discussed, to illustrate, a formal *RMP* has been developed and is presented for the hypothetical QDOT case study (see Appendix F).

8.3 Conclusions regarding Risk Management Planning

The primary objective of risk management planning is to optimize future project performance, specifically with respect to risks. Risks and opportunities that have been identified and analyzed earlier in the risk management process serve as the inputs to the risk management planning for the project. Risk management planning develops specific actions and assigns responsibilities to cost-effectively deal with risks and capitalize on opportunities. The *Risk Management Plan* (*RMP)* is the output of the process.

The *RMP* should be accurate, defensible, and cost effective. Following a rigorous process of risk identification, assessment, and analysis prior to risk management planning will help to ensure accuracy and defensibility. Effective risk management planning establishes budgets and schedule milestones with contingencies to adequately cover the uncertainty that remains, even after the best risk reduction planning efforts. The process of risk management planning generally involves proactive risk reduction, risk allocation, contingency management, and the development of recovery plans. Risk reduction is a proactive process of employing the most the most cost-effective actions, through a cost-benefit analysis, to mitigate risks that cannot be avoided. Risk allocation involves contractually assigning the residual risks to a party in the contract. The party assuming the risk should be best able to evaluate, control, bear the cost, and benefit from its assumption, at a reasonable risk transfer price. Contingency management involves the maintenance of adequate resources in the case that residual risks occur. If many significant risk events do in fact occur, exceeding available contingency, recovery plans must be put into action. The *RMP* essentially documents these plans. With this context of risk management planning in place, Chapter 9 will discuss implementing the *RMP*.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan* (*RMP*), involved management of each of the significant risks in the risk register individually and collectively (using the methods and guidance described in this chapter), as documented in that *RMP* and summarized below.

After risk assessment and prioritization, QDOT identified and planned specific risk-management actions to address the key risks to its project objectives, both individually and collectively. The complete project *RMP* (see Appendix F) consisted of: 1) proactive risk-reduction plans (*RMP* Chapter 5), 2) contingency-management actions per QDOT procedure (by project phase) (*RMP* Chapter 7), and 3) recovery plans (by project phase) (*RMP* Chapter 8).

QDOT first focused on identifying cost-effective actions for reducing the highest-rated (i.e., highest-priority) risks, considering synergy among risk-management actions as appropriate. For each of the high ranking risks, the following was done: a) possible proactive risk-management actions were identified; b) the estimated mean cost, schedule and/or disruption (by activity) to implement each action was assessed; c) the anticipated mean effectiveness regarding reducing the various risk factors from each action was assessed; and d) the overall cost-effectiveness (in terms of reduction in "severity") for each action was calculated (using the MS Excel template). Cost-effective actions were then selected, and responsibility and schedule for implementing those actions were established.

Illustrative Example (continued)

Below is one example of risk reduction action identification and evaluation for one rapid renewal risk for this project. The cost-effectiveness of this particular action was determined to be a net savings of about $250,000 (regarding change in severity, in equivalent YOE), which was the fourth highest of the actions identified and would be recommended.

Risk or Opportunity Addressed (see Risk Register for description)	**Potential Risk Management Actions** (Proactive actions: Mitigate, Avoid, Allocate)	**Change in base factors**	**Change in risk factors**	**Respon-sibility**	**Schedule**
RU3. Unwilling sellers	QDOT's principal risk from unwilling sellers is increased right-of-way acquisition cost. Hence, QDOT could take the following actions to reduce this risk (see *Guide*, Table D-5a): <u>Make reasonable, early offers</u>: conduct thorough research on the values of these properties, and present reasonable offers to the property owners. Do this early to provide more time to reach negotiated settlements (and therefore avoid court proceedings). This action would likely reduce the probability of cost increase, but not the magnitude of a cost increase if it occurs.	+$0.05M to ROW. Minor delay and disruption	Reduce probability of occurrence in ½ (from H to M). Minor change in impacts.	Design Manager (design) and ROW Manager (public outreach)	Implement now; check by end of 30% Design

QDOT then determined the revised base and residual risks (assuming the selected risk reduction actions were actually implemented), from which they determined approximate <u>mitigated</u> mean project performance (i.e., for completion date and escalated cost) in the same way (using the MS Excel template) as for unmitigated mean project performance (as documented in *RMP* Chapter 6). Based on this information, in conjunction with industry guidance, QDOT used judgment to establish appropriate contingency requirements (as documented in *RMP* Chapter 7) and recovery requirements (as documented in *RMP* Chapter 8). <Note: Subsequently, a quantitative risk analysis was conducted, which <u>objectively</u> determined the values for the specific QDOT-established target percentiles of 80% and 95% confidence of the mitigated project performance (i.e., completion date and escalated cost) for establishing contingency and recovery requirements, respectively; this was done in the same way as for unmitigated project performance – see Appendix F - *RMP* Addendum X.>

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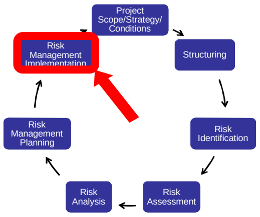
Chapter 9. Implementing Risk Management Plan



9.1 Introduction to Implementing the Risk Management Plan

As discussed in Chapter 8, the *Risk Management Plan* is intended to optimize project performance through the following three basic elements:

- Specific actions intended to reduce particular individual risks, focusing on the higher priority risks;
- Management of contingency to cover most of the residual risks and other uncertainties; and
- Recovery if established contingency is inadequate (i.e., to cover the rest of the residual risks and other uncertainties).

Adequately and efficiently implement the *Risk Management Plan*:

- ➢ Proactively reduce individual risks
- ➢ Address changing conditions
- ➢ Establish, track, and control contingency
- ➢ Decide on “recovery” (if needed)

However, like any plan, the *Risk Management Plan* must be appropriately implemented in order to be successful and actually achieve optimal project performance. Also like any plan, successful implementation requires the following (at a minimum):

- Responsibility – assignment of a risk manager and “owners” of significant individual risks;
- Commitment – the organization has to commit to the plan;
- Resources – adequate resources (funding and staff) have to be provided to carry out the plan; and
- Authority – specific individuals have to be given adequate authority, as well as resources, for carrying out their assigned plan responsibilities.

A unique feature of the *Risk Management Plan*, unlike most plans, is that it is actually an evolving document, with the expectation that it will be adjusted to reflect changes in the project as that project develops (including any changes due to recovery). This means that those project actions and conditions must be monitored, and the plan periodically updated to reflect observed changes. For example:

- Planned risk reduction actions should be carried out generally as planned. Their progress should be monitored and their actual impact on risks should be assessed. However, these plans might be adjusted based on their progress and projected results, considering changing needs. For example, it might be determined (based on new information) that the risk being addressed is not as important as previously thought.
- Risks will either happen or not during various project phases. If they haven’t happened while their “window” is open, they won’t happen after their window has closed and they can be “retired” in the risk register. Conversely, if they have happened, contingency should be reserved for that risk and this should be noted in the *risk register*. However, such expenditure of contingency needs to be carefully controlled.
- As conditions change, particular risks (either their assessed probability or impacts) whose windows have not yet closed can change (e.g., either becoming more or less likely). In fact, sometimes previously unidentified (“new”) risks are identified, and should be assessed and included with the other existing risks. Such changes in remaining risks should be noted in the risk register.
- As noted above, realized risks might result in spending or reserving some of the established contingency, leaving less contingency for the rest of the project. Conversely, if few risks are realized, there might be excess contingency. The adequacy of the remaining contingency needs to be periodically re-evaluated to give as much advance warning as possible of either possible future inadequacy (which might trigger recovery plans) or excess contingency (which can be released for other purposes).

This process of implementing the *Risk Management Plan* (which includes monitoring, updating and implementing protocols for making significant project decisions, e.g., regarding contingency and recovery) needs to be effective but should also be efficient and compatible with the DOT organization and project.

9.2 Process of Implementing the Risk Management Plan

Implementation of the *Risk Management Plan* consists of first getting set up to carry out the plan, and then actually implementing the various elements of the plan.

Preparing to carry out the plan requires the following steps:

- Organizationally committing to the plan;
- Assigning responsibility for the plan;
- Providing adequate authority and resources to carry out the plan; and
- Gathering/distributing information.

Without these steps, the plan will likely not be successfully implemented – it will be just another document on the shelf. As part of this, it is recommended that a risk manager, a position reporting directly to the project manager, be named for the project and given overall responsibility for implementing the plan – for small projects (which should not require much effort) the risk manager might simply be the project manager, whereas for larger projects (which might require significant effort) it would be a separate person (e.g., the assistant project manager). The risk manager will then typically delegate responsibility for various elements of the plan to those who are in the best position to complete them, and will then follow-up with them to ensure that they actually complete those elements. For this to happen, the risk manager must be given adequate authority and resources (e.g., budget). However, this needs to be done as efficiently as possible to prevent wasting resources. For example, periodic risk management status meetings should be short and simply integrated into regular project status meetings. Similarly, risk management status reports should be streamlined, simply highlighting changes since the last report, and appropriately distributed in a timely fashion.

With an adequate organizational structure and set of procedures in place, the various elements of the plan can then be successfully implemented. The basic elements of the plan, which are somewhat flexible in order to be most efficient, include the following (see Chapter 8):

- Risk reduction actions – A set of actions are specified in the *Risk Management Plan* for reducing individual risks. These actions must be successfully carried out to realize any risk reduction, although the actual amount of risk reduction, and typically to a lesser extent their cost and schedule to implement, will be uncertain beforehand. However, such actions can be adjusted (e.g., stopped) as their projected performance or need changes. The DOT must assign responsibility for each action, and then track progress of that action. Both cost and schedule, as well as the results (in terms of risk reduction), of implementing that action will be reported. Figure 9-1 provides an example based on the Risk Management Plan form provided in Appendix E. In this example, the project team has determined that it will be more cost effective to design around an area with a significant right-of-way risk. The management actions provide an estimate of the resources, an estimate of the risk reduction, and a person who is responsible for verifying that the risk plan has been implemented by a key milestone. Status updates can then be documented on this form.

Example Risk Reduction Action from Risk Management Plan (not the hypothetical case study):

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	*RUi(1). The team will design around areas where right of way may be an issue, specifically at US555-SH111 junction.*	*Design lead, in conjunction with right-of-way lead*	*By end of preliminary design*	*Need to get approval for design deviations.*

action successfully completed, and risk eliminated <by name and date>

- Contingency management – Contingency allowances for cost and schedule are established in the *Risk Management Plan* to cover the residual risks (after they have been reduced) with appropriate confidence. As risks are realized, some of the contingency must be "reserved" to cover them. However, like any project costs, such expenditures must be carefully controlled; similarly, giving up project float in the project schedule must also be carefully controlled. Conversely, if few risks occur and contingency is not used, then the excess contingency can be "released" for other purposes. As shown in Figure 9-1, such contingencies are typically allocated to, and tracked by, the different phases of the project. For the case shown in red circles in this example, the contingency actually spent in each phase (and thus cumulatively) was less than that budgeted (e.g., in Phase A, only $2M of the budgeted $3M was spent) – after each phase, unused contingency could be released. DOTs typically have established protocols for approving and tracking contingency expenditure and releases, with approvals generally required at higher organizational levels as the amounts increase.

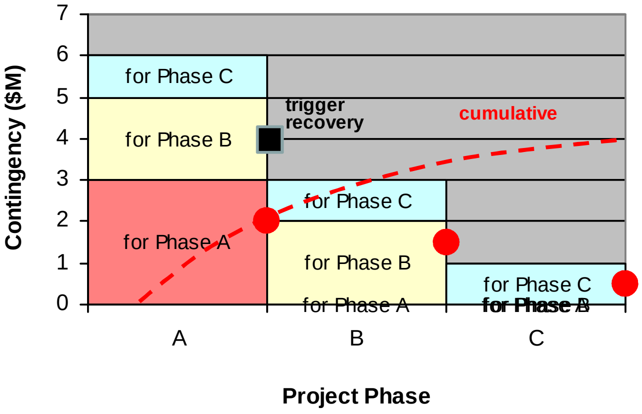


Figure 9-1. Contingency Drawdown and Recovery

- Recovery – Contingency (or recovery) plans are identified in the *Risk Management Plan* just in case the contingency allowances are found to be inadequate after all (e.g., if a disproportionate number of significant risks actually happen). For example, if as shown in the black square in Figure 9-1, the reserved contingency exceeds the allowable contingency during a phase, then recovery is triggered (e.g., in Phase A, $4M was spent, which was $1M more than the $3M budgeted for that phase, meaning that there is not enough left for later phases). Typically, such plans are somewhat drastic (e.g., deferring or eliminating scope to save cost and/or schedule) and are only intended as a last resort. However, in general, each such plan is only possible up to a specific point in project development, e.g., savings associated with deferring some scope cannot be realized once that scope has been built. Clearly, such decisions must be made at a high organizational level.

Because (as described above) the plans are somewhat flexible to adapt to changing conditions, in order to be successfully completed, each of the above elements of the *Risk Management Plan* requires specific information at various points in time:

- The status and projected results of the various risk reduction actions, as well as projected needed performance improvements;
- The status/availability of contingency, as well as projected contingency needs; and

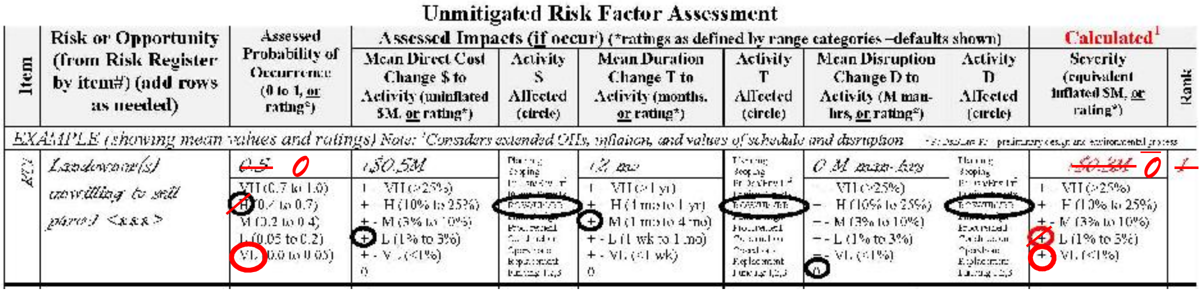
- The status/availability of recovery actions, as well as projected recovery needs.

In particular, to determine changes in needs (whether for risk reduction, for contingency or for recovery), the changes in risks should be adequately monitored and updated. Such changes in risks are due to inevitable changes in project conditions with time.

Monitoring is relatively quick, but informative. The following should be monitored periodically (e.g., monthly, or less frequently at moderately important points or changes in project development): project development status and conditions, risk reduction action status and projected results, existing risks, and contingency and recovery plans. These should be adequately documented (e.g., in a memo or directly in the *risk register*). For example: a) the status of a risk reduction action is illustrated in the above example; b) qualitative changes in risk might simply be described, including their cause; and c) the status of contingency is illustrated in Figure 9-1.

Updating is more involved (including reassessment and reanalysis, if needed), but also more informative, than monitoring. The following should be updated periodically (e.g., quarterly, or less frequently at important points or changes in project development, as indicated by monitoring): base performance, risks (including adding new risks), and contingency and recovery requirements. These should be adequately documented (e.g., in the risk register and in the *Risk Management Plan*).

Example Risk Register Update (not the hypothetical case study):
On a project, there was a risk of a landowner being unwilling to sell a parcel needed to construct a project. When it was first identified, there was a high probability (50%) that the owner would not be willing to sell and the impact of this risk was $500,000 and 2-month delay, with an “expected value” of about $300,000 (including increased escalation and extended OHs) and 1 month (critical path). However, as seen in a previous example, the management action was successfully taken to avoid this risk by designing around the parcel, at a cost of about $100,000 ($150,000 including increased escalation and extended OHs) and 1 month delay. The resulting reduction in risk meant that about $300,000 and 1 month less contingency was required; however, the resulting cost ($150,000) and delay (1 month) of the mitigation effort had to be added to the base cost and schedule. Based on such updates of the various inputs, the contingency requirements (and recovery requirements) could be recalculated.



Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur¹) (*ratings as defined by range categories –defaults shown)						Calculated¹	
			Mean Direct Cost Change $ to Activity (uninflated $M, or rating*)	Activity S Affected (circle)	Mean Duration Change T to Activity (months, or rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, or rating*)	Activity D Affected (circle)	Severity (equivalent inflated $M, or rating*)	Rank
EXAMPLE (showing mean values and ratings) Note: ¹Considers extended OHs, inflation, and values of schedule and disruption [illegible] preliminary design and environmental process										
RUi	*Landowner(s) unwilling to sell parcel <xxx>*	~~*0.5*~~ 0 VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	*$0.5M* + VH (>25%) + H (10% to 25%) + - M (3% to 10%) + L (1% to 3%) + - VL (<1%) 0	Planning Scoping [illegible] Procurement Construction Operation Replacement Funding 1,2,3	*2 mo* + VH (>1 yr) + H (1 mo to 1 yr) + M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping [illegible] Procurement Construction Operation Replacement Funding 1,2,3	*0 M man-hrs* - VH (>25%) - H (10% to 25%) - - M (3% to 10%) - - L (1% to 3%) - - VL (<1%) 0	Planning Scoping [illegible] Procurement Construction Operation Replacement Funding 1,2,3	~~*$0.3M*~~ 0 + VH (>25%) + H (10% to 25%) + - M (3% to 10%) + L (1% to 3%) + VL (<1%)	~~1~~

***Risk RUi* updated <by *name and date*>**

Management Plan (RMP), describes an effective and efficient implementation of its *RMP* following the principles and process outlined in this chapter, as documented in *RMP* Chapter 9 and summarized below.

After QDOT developed the *RMP*, its implementation was adequately supported by management and adequately resourced. The *RMP* included an organizational structure with specified responsibility and authority (i.e., the project manager served as the risk manager) to implement that *RMP* throughout project development. The project’s designated Risk Manager then successfully implemented that *RMP*, including:

- Proactively and cost-effectively reducing individual risks that were within QDOT’s control, including monitoring and updating the risks and the *RMP* as time progressed – several large risks were successfully reduced;
- Using established protocols for contingency control, including monitoring and periodic updating of contingency status (expended to date and capacity required for completion) and recommending contingency expenditure (to cover actual risk occurrences as needed) and releasing excess contingency (when no longer needed) – the initially established contingency was adequate throughout the project, with the unused contingency subsequently released; and
- Using established protocols for recovery decisions, including monitoring and periodic

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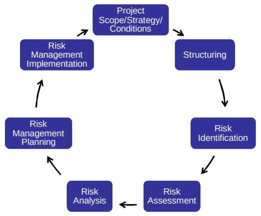
Chapter 10. Implementing this *Guide*



10.1 Introduction to Implementing this Guide

This *Guide* has outlined an efficient and effective process for managing risks on rapid renewal projects. However, adequate planning and logistical support is required for a DOT to successfully implement this process. This chapter summarizes key logistical issues to consider when planning, staffing, and conducting the risk management process.

Adequately but efficiently plan and implement the risk management process described in this *Guide*

Adequate planning, appropriate resources, careful coordination, and integration into continuous project management processes are the keys to successful risk management implementation. The DOT should initiate the risk management process early in the project's life cycle, and then update as appropriate. The DOT also needs to engage the appropriate participants and provide them with relevant information for each of the risk management process steps. The DOT ultimately needs to adequately plan and resource the meetings, workshops, and project management staff throughout the process to ensure an efficient and effective process. A good planner and a qualified facilitator are keys to successful implementation.

10.2 Process of Implementing this Guide

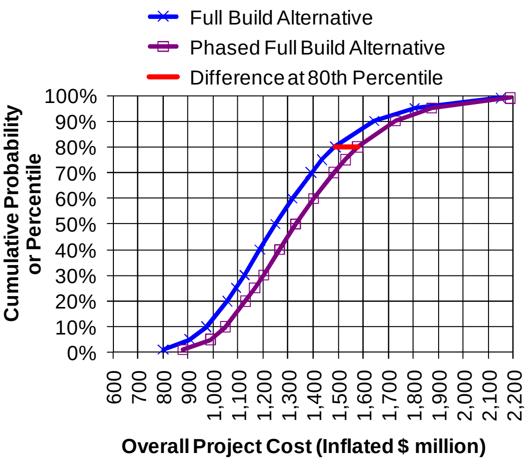
When to Apply this Guide

Risk management is beneficial in all phases of project development. In general, the earlier risk management is started, the more time the project team has to react to the identified risks and the easier the risks are to manage, and thus the more benefits the project will realize from risk management. However, there is such a thing as "too early" to conduct effective risk management for individual projects. This can be true when a program is just being established, but the purpose and overall scope for individual projects have not yet been established.

Once a project's purpose and overall scope have started to take shape, various elements of the risk management process can be applied to maximize benefits. The following guidance applies to large and/or complex projects, or projects with significant specialty elements:

- When a project is in the scoping phase and/or preliminary design (e.g., prior to approximately 10% design) and the DOT has yet to select a preferred alternative, the process can be particularly useful for evaluating the risks of each alternative relative to the other alternatives. The process applied at this point includes: structuring (Chapter 4); risk identification (Chapter 5); risk assessment (Chapter 6); and considering some elements of risk management (Chapter 8), especially proactive risk reduction for significant risks. This comparison can help the DOT make decisions among alternatives, such as design alternatives, funding alternatives, or project-delivery alternatives. If cost and schedule estimates also exist for each alternative at this point in time, risk analysis (Chapter 7) can also be conducted to quantify uncertainty in the cost and schedule for each alternative, which can then be compared among alternatives to help make decisions. An example of this type of comparison for project cost, where one alternative (full build) is about $100 million (or 6%) less than the other (phased full build), is shown here. The corresponding project schedule, disruption and longevity can also be compared in a similar way. At this stage of

Example Comparison of Cost Uncertainty for Project Alternatives:



project development, these elements of the risk management process can be conducted in less detail than would normally be done for a preferred alternative, especially if results are being used only to compare alternatives.

- After the DOT has selected a project alternative (e.g., after completion of environmental documentation, or near 30% design), the original structuring, risk identification, and risk assessment for the preferred alternative (if done previously) can be updated to reflect the greater level of project development. Additional detail can also be included at this stage in order to get a better "picture" of the preferred alternative's risks and opportunities. The DOT can also conduct risk analysis (Chapter 7) in this phase if cost and schedule uncertainty and defensible development of contingency to adequately cover those uncertainties are of interest to the DOT. Risk management planning (Chapter 8) and implementation (Chapter 9) are now also appropriate and beneficial for the preferred alternative. Again, the earlier in project development that the risk management process can be started, the greater the benefits.
- As the project progresses beyond preliminary design and the environmental process to final design, right-of-way acquisition, and utility relocations, the DOT should update the risk management process at key project milestones, at some pre-determined time interval, or both. For example, the US Federal Transit Administration (FTA) has historically required risk management updates at key project milestones, such as entry to final design and application for FTA's funding grant. Other agencies, such as the Washington State DOT (WSDOT), will typically conduct annual updates for its large, complex, or high-visibility projects. When appropriate, risk management can be integrated with Value Engineering (VE), where ways to proactively reduce significant risks or capitalize on VE opportunities can be explored.
- When a project nears construction procurement, some agencies will update the risk management process to develop a validated engineer's estimate (including contingency) and to guide risk allocation for contract-document preparation. The agency could also conduct a more-detailed assessment of construction risks (e.g., management of traffic or construction staging) and plan specific risk management actions for those risks (either individually or collectively), if not done previously. This could be particularly useful for rapid renewal projects, which often employ innovative construction technologies and materials.
- Unless a project has particularly complex construction staging and/or specialty construction, the risk management process during construction usually focuses on continuing to manage previously-identified risks (rather than identifying, evaluating and managing new risks) and on managing contingency. However, there are cases when risk identification and subsequent steps might be conducted (or repeated) during construction. For example, when a major failure has occurred during construction, the owner might want to make sure that the contractor has identified and can effectively manage similar potential problems through project completion.

The risk management process is easily "scalable" to match project type, size, complexity, and needs. For projects that are not as large or complex, the risk management process should be much simpler. For example, structuring, risk identification, risk assessment, and risk management planning might only be conducted once, although risk management implementation would have to be carried through to the project's completion to realize the maximum benefits. For example, WSDOT has such a policy for any project with an estimated cost between $25 million and $100 million.[1]

How to Apply this Guide

The keys to success for the risk management process include proper planning, allocation of appropriate resources, careful coordination, and integration into continuous project management processes. Lack of preparation and focus can grind a group to a standstill, resulting in inefficiency, frustration, and wasted effort. In order to ensure that the risk management process fulfills its potential, the DOT must properly plan and resource the effort. To conduct an effective and efficient risk management process, a DOT should do the following:

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[1] http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/, accessed August 7, 2009.

- Regarding <u>leadership and facilitation</u> of the risk management process:
    - *Project leadership should provide "command emphasis" for the risk management process*. The project leadership has to establish and continually reinforce the need for risk management to ensure that project-team members participate appropriately. Project leadership should also communicate the need for risk management "up the chain" to ensure that the proper external resources (including independent subject-matter expertise) are provided.
    - *Effective facilitation is essential* for efficient and effective meetings and workshops that are inevitably part of the risk management process. A weak or untrained facilitator can cause a meeting or workshop to lose focus and fail. The facilitator should be knowledgeable (in general, but not necessarily with the specifics) about the various phases of rapid renewal projects. The facilitator also needs to be adequately trained in the risk management process and the underlying principles and guidance, and should have practical facilitation experience (preferably for risk management). A few key points on facilitation include:
        - Maintain a positive, engaging presence.
        - Try to achieve consensus, as well as project team buy-in. Be fair – let all qualified voices be heard equally and don't let strong personalities dominate (bias) the discussion. Encourage participation and responsibility. As long as no adverse group dynamics are at work, follow a policy that "silence is acquiescence".
        - Appropriately consider all available information.
        - As tactfully as possible, keep the group focused – stay on task and on time. If bogged down, stimulate the discussion by asking different questions or asking questions differently ("from a different angle").
        - Always keep in mind the goals for the risk management process – adequate but efficient. Keep the level of detail and quality of the assessments appropriate and consistent with the purpose for the risk management process.
        - Try to remain neutral, but don't be a "pushover". The facilitator must believe (be convinced) that the assessments are reasonable and bias-free.
- Regarding <u>participation</u> in the risk management process:
    - *Project leadership should actively participate in the risk management process*. Without consistent engagement by the project leadership, the risk management process will falter. Consistent leadership will ensure that the risk management process is carried to its conclusion and that risk management objectives are met. For example, project leaders often must provide key input to the risk management process, as well as make risk-based decisions regarding the project's development. Project staff often does not have the knowledge or authority to make such decisions, which can slow project development and hobble risk management. Project staff does, however, often have information on potential risks and risk management options. Project leaders should invite and encourage the entire team's input into the process.
    - *Participants should be adequately qualified in their respective areas of expertise*. Expertise can come in the form of project expertise (project-team members are experts about the particular project) and subject-matter expertise (discipline experts). A given participant can fulfill more than one role in the risk management process, if qualified to do so. However, the facilitator should tactfully request that participants who are not knowledgeable on a particular topic refrain from offering opinions on that topic. Unqualified opinions degrade the quality of assessments, as well as reduce the efficiency of the effort.
    - *Participants should include key project team members (including the cost estimator and scheduler) and independent subject-matter experts*. Perhaps the easiest way to avoid bias in the risk management process is to include both project experts and *project-*

independent experts. The interactions of these two groups is extremely useful for highlighting potential project issues – and for reaching potential solutions. The independent experts could be the same as used for VE, realizing some efficiency.

  - *Participants should be at least minimally trained on the risk management process*, their roles within the process, and on how to perform those roles. Previous chapters in this *Guide* and the companion training course provide a good training basis for participants. Otherwise, the facilitator should provide minimal training at the beginning of the workshop (see Appendix E for an introductory overview presentation that provides such training and should be made at the beginning of a workshop).

- Regarding <u>planning</u> of the risk management process:

  Planning for the risk management process is important and non-trivial. A good checklist, as well as a good planner, can help immensely when planning for the risk management process. The typical planning tasks and logistics considerations for a project risk management process include:

  1. **Initiate the Risk Management Process**
     - Identify the need and scope, as well as commitment, for risk management – This includes (but is not limited to):
       - Coordinate with the project team;
       - Consider tying risk management and VE processes together at key milestones; and
       - Determine if qualitative or quantitative analyses are needed (e.g., to quantify project performance uncertainty, from which appropriate budget and contingency can be determined).
     - Identify the funding source and secure funding for risk management - Coordinate with DOT management and the project team, and complete funding administrative requests / actions.
  2. **Prepare for the Risk Management Meetings / Workshops**
     - Identify the risk management process steps to be covered in a meeting/workshop – The DOT might implement a number of risk management process steps in one meeting (e.g., structuring, risk identification, risk assessment, and risk management planning), or have separate meetings, to suit the needs of the DOT. The DOT might tie risk management and VE together, and/or conduct a separate preparatory session upfront to plan subsequent workshops and meetings, including identification of participants.
     - Implement necessary contracts and task orders (DOT internal and for consultants) - Give sufficient lead time to contracting personnel, and follow up as required.
     - Identify and confirm participants, including facilitator, independent subject-matter experts and project-team members - *Follow up as needed. Iterate when the study schedule changes, or for project risk management updates.* Identify key project issues for which experts are needed (e.g., independent cost estimator and scheduler). Communicate the workshop schedule/agenda, responsibilities, and logistics to all members.
     - Identify the schedule for risk management, including risk management meetings and workshops - *Iterate when member participation and/or facilities change, or for project risk management updates:*
       - Select the format for the workshop (e.g., single, all-encompassing meeting, versus more linear with extended schedule and several, smaller workshops, or even interviews);
       - De-conflict the schedule with other major events involving significant resources or personnel; and
       - Develop a meeting / workshop agenda and distribute to all participants.

- Identify, schedule, and confirm facilities for risk management meetings / workshops. *Iterate when the study schedule changes* - Visit the facilities prior to the workshop start date to meet the necessary contacts and to assess the facilities. Facilities include:
    - Venue: location, building(s) (including access, after-hours access, and visitors' passes), quiet main meeting room to comfortably accommodate all participants and 1-2 smaller breakout rooms, and parking.
    - Support services and materials: printing and copying; Information Technology (computer network; phone; e-mail); LCD projectors (x2); notebook computer (for technical documentation); projection screen; dry-erase board and markers; paper flipchart and markers; power extension cords (3-prong grounded); daily refreshments; "working" meals; and miscellaneous office supplies.
- Send a risk management workshop "requirements packet" to the project team (i.e., instructions for project-team preparation), such as project description and cost/schedule estimates. Follow up as needed.
- Review and modify the requirements packet as needed, and deliver to the project team as soon as possible.
- Establish and communicate the deadline for project team's response.
- Send project information (with instructions) to independent experts to review beforehand – especially review relevant design and cost/schedule estimate information for subsequent structuring.

3. *C*onduct the Risk Management Meetings / Workshops (per Chapters 4 through 8 of this *Guide*)

- Kick-off the risk management meeting workshop - Ensure that participants' travel schedules are consistent with their required workshop participation. The risk management facilitator should arrive early to set up the facilities and provide an overview of the process (see Appendix E) and develop common understanding of the project.
- Develop consensus on all risk management inputs - Document assessments in real time (e.g., on computer screen using MS Excel template, on whiteboard, etc.). Having a separate note taker working with the facilitator helps immensely for this. Breakout in smaller groups for specialized topics, for which a second facilitator would be needed. Note: A second facilitator also provides redundancy in case something happens to the first facilitator, thereby protecting the large investment made for the workshop. Provide adequate time (e.g., after the workshop) to review and finalize risk management inputs, as well as to subsequently develop/implement the risk model (if needed).
- Prepare a workshop risk management results briefing (if results are to be briefed outside workshop participants) - As early as possible, forecast the briefing schedule and communicate to briefing attendees (especially if not participating in a workshop). For example, the briefing might precede a separate VE workshop.
- Present and discuss risk management results.

4. Document the Risk Management Process and Results

- Prepare and submit a draft risk management report, including Risk Management Plan (which includes the risk register).
- Finalize the risk management report based on feedback from the project team and other workshop participants.

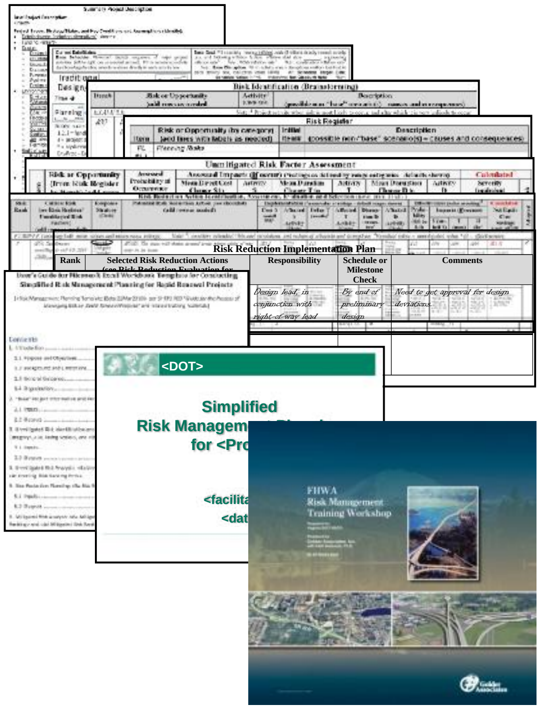
5. Implement the Risk Management Plan (per Chapter 9 of this *Guide*)

- Ensure DOT commitment and resources.
- Establish responsibility and authority.
- Plan for and conduct monitoring and updates as appropriate (as above), as well as manage contingency.

A separate logistics planner, working in concert with the risk facilitator, can help accomplish the above steps.

Companion Implementation / Training Materials

As previously noted, a qualified facilitator, as well as DOT management and project team commitment, planning, and participation of appropriate project team and independent experts, are key to successful implementation of the risk management process outlined in this *Guide*. A companion training course for this *Guide* has been developed especially to train DOT facilitators to conduct important parts of the risk management process described in this *Guide* on relatively simple projects (see Appendix G). Also, forms and an MS Excel workbook template have been developed (and are included in the training) to help the facilitator conduct the important aspects of risk management on simple projects (see Appendix E). This training is also useful for DOT management and potential participants, including key project team members and independent experts (e.g., from DOT headquarters), to help them better understand the process. However, this training is not required for everyone who participates in the risk management process. Typically, the facilitator will provide a short overview of the process at the start of a workshop to adequately explain the process for the participants, and it will be up to the facilitator to subsequently guide the participants through that process. Such an overview presentation has been developed and is provided (see Appendix E).



Overview Presentation, Forms and Template (Appendix E) and Training (Appendix G)

The training course is two days long, in which a hypothetical (but realistic) DOT rapid renewal project is evaluated for illustration and concept reinforcement. The class consists of individual modules, generally one for each chapter in this *Guide*. However, whereas this *Guide* focused on the concepts ("*what*"), the class focuses on the implementation ("*how to*") and includes simple exercises and examples to accomplish this. Notes, in the form of annotated versions of all the slides shown in the class, provide additional details to what is provided in this *Guide*. The focus is on structuring, risk identification, risk assessment (including risk severity analysis and prioritization), risk management planning and risk management implementation, especially for relatively simple projects that a DOT can evaluate in-house, which will help to optimize the performance of those projects.

The class does *not* include detailed training in full quantitative risk analysis (Chapter 7) to quantify the uncertainty in project performance, which can be used to defensibly establish budgets and milestones (and contingencies). Such analyses require specialized skills that cannot be developed in a two-day class. Instead the training will allow a DOT to effectively supervise such analyses, as well as supervise the evaluation of more complex projects.

As previously noted, to help the facilitator conduct selected parts of the risk management process on relatively simple projects, specific forms have been developed to guide and document information developed in the workshop. In addition to hard copy forms (in PDF), these forms have also been replicated in an MS Excel workbook template for data entry and subsequent automatic analysis of that information. Such analyses include determination of: a) the mean values of base and total ("base + risk") performance measures; b) the severity (in terms of combined change in total performance measures) of each risk and opportunity, based on which they are prioritized; and c) the cost-effectiveness of possible risk-management actions, based on which such actions can be recommended and resulting revised mean values of total performance measures are determined. The training includes the use of these forms and template.

10.3 Conclusions regarding Implementing this Guide

The risk management process presented in this *Guide* has the potential to greatly improve the ability of project leadership and team members to make critical decisions, as well as improve project performance with respect to the rapid renewal objectives. However, the process must be adequately planned and resourced, and followed through to its completion, to obtain these benefits in an efficient way. The following are keys to success:

- Prepared technical resources (project-team and project-independent experts);
- A (preferably two) qualified facilitator/analyst (to ensure an accurate, defensible and efficient process);
- A good planner (for logistics);
- Organizational leader and system to provide:
    - Active organizational support,
    - Adequate resources and participation, and
    - Commitment to implement the process .

This chapter has provided some important guidance on the logistics of the risk management process, including when and how to apply the process, to help ensure that the DOT realizes the full benefits of risk management. Additional guidance is provided in companion materials, including training materials, workshop introductory overview presentation, and specific forms and an MS Excel workbook template.

Illustrative Example

The hypothetical QDOT case study (see Appendix F), which is used throughout the *Guide* to adequately illustrate the various steps of the risk management process and includes a *Risk Management Plan (RMP)*, involved implementation of the risk management process on this project (as described in *Guide* Chapters 2-9), following the principles and process outlined in this chapter, as documented in the *RMP* and summarized below.

QDOT did the following (as documented in the *RMP*):

- assembled relevant project information (i.e., regarding scope, strategy/status, conditions/assumptions, cost estimate, schedule, etc.);
- convened a group of key project-team staff and independent subject-matter experts from the key project disciplines, in a series of workshops facilitated by a qualified risk elicitor/analyst, to conduct risk assessment and risk management planning (consistent with the principles, processes and guidance described throughout the *Guide*), culminating in an *RMP* (including the *risk register*); and
- assigned a Risk Manager (with appropriate authority and resources) to implement the resulting *RMP*, including monitoring/updating/recommending project risks, risk reduction plans, contingency and recovery.

This process was well planned, supported by management, and adequately resourced. Adequate support and resources (including an organizational structure) were then provided to implement that plan throughout project development.

Construction of the QDOT project was successfully completed on 31 January 2013 at an inflated cost of $22.0M (with $2.0M remaining cost contingency and 2.0 months remaining schedule contingency), with few unanticipated problems and no recovery actions.

Performance of QDOT US 555 / SH 111 Project

Project Performance	**Base**	**Base + Contingency**	**Actual**	**Unused Contingency**
Cost (YOE$M)	$17.0M	$24.0M	$22.0M	+$2.0M
Schedule (mos)	35.0 mos	40.0 mos	38.0 mos	+2.0 mos

Chapter 11. Conclusions

In the past, many transportation projects have "performed" poorly (e.g., in terms of ultimate cost and schedule to completion), often due to unexpected problems as described in Chapter 1. This might be amplified for rapid renewal projects as described in Chapter 3, which are intended to accelerate schedule and minimize disruption through construction, while not adversely affecting either cost through construction or post-construction longevity. However, by definition, these rapid renewal methods are typically innovative with limited past experience to learn from, and might be more susceptible to not performing as expected.

This *Guide* presents a formal risk management process (Chapter 2) to better understand and to actually optimize project performance specifically for rapid renewal projects, 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 (for which the expanded process is also applicable), consists of a well-defined series of steps (Figure 11-1), each of which has been described in appropriate detail, including possible variations, in this *Guide*. Sufficient guidance is also provided in this *Guide* to ensure compatibility and consistency among the various steps, and to ultimately ensure adequate accuracy and defensibility of results (where "adequacy" depends on how the results will be used), as efficiently as possible. The steps, which are sequential and in some cases iterative, include:

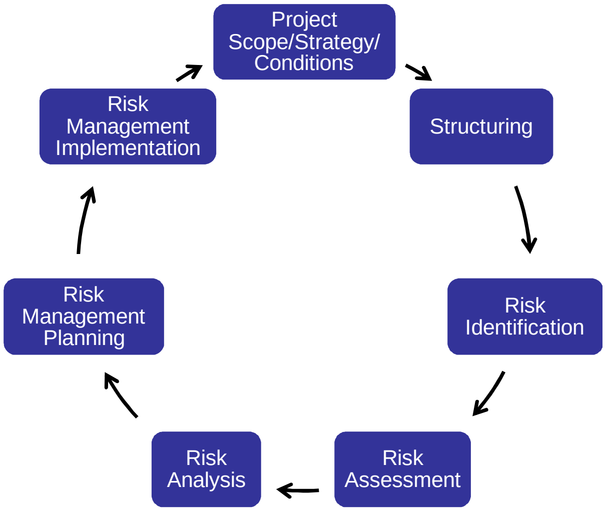


Figure 11-1. Risk Management Process

1. **"Structuring"** (Chapter 4) - Define the "base" project scenario (including the relevant project performance measures of cost, schedule and disruption through construction, and post-construction longevity, and tradeoffs amongst them), against which risk and opportunity can subsequently be identified, assessed, and eventually managed.
2. **Risk Identification** (Chapter 5) – Identify a comprehensive and non-overlapping set of risks and opportunities (i.e., scenarios that might occur, changing the base project performance). In addition to brainstorming and then analysis of risks, lists of common risks have been developed that can be checked to ensure completeness (Appendix D). Document the set of risks and opportunities in the start of the project *risk register.*
3. **Risk Assessment** (Chapter 6) – Assess the "severity" of each of the risks and opportunities in the *risk register*, and then prioritize them on that basis. Generally this is done by: 1) subjectively assessing the relevant risk factors (i.e., impacts if the scenario occurs and the probability of the scenario occurring), either qualitatively (e.g., "high" vs. "low", where these descriptors are quantitatively defined by ranges of values) or quantitatively (in terms of mean-values or, for quantitative risk analysis, full probability distributions); and then 2) analytically combining the risk factors to determine changes in project performance measures and thereby severity. Document the risk-factor assessments in the project *risk register.*
4. **Risk Analysis** (Chapter 7) – Analytically combine the base and risk factors to determine the project performance measures (e.g., ultimate project escalated cost), as well as changes in those measures (e.g., combined using tradeoffs, as a measure of "severity") associated with each risk. This can include quantification of the uncertainty in those performance measures, as a function of subjectively assessed uncertainties in (and correlations among) the base and risk factors. Note that this requires specialized skills to conduct appropriately.

5. **Risk Management Planning** (Chapter 8) – Identify and evaluate possible ways to proactively reduce risks, focusing on those that are most severe. Evaluate each possible action in terms of its cost-effectiveness, considering changes in both base (e.g., additional cost) and risk (e.g., reduced probability) factors, and select those that are cost-effective. Consider subsequently re-analyzing the project performance measures for this risk reduction program, including quantification of uncertainty, based on which appropriate budgets and milestones can be established (e.g., to achieve a specified level of confidence). As part of these budgets and millstones, contingencies (in the form of additional funds and schedule float, as well as recovery plans) and procedures to control their use would be established. Document in the *Risk Management Plan*.
6. **Risk Management Implementation** (Chapter 9) – Implement the *Risk Management Plan* as the project proceeds, including: a) monitoring the status of risk reduction activities and changes in risk (whether due to risk reduction or simply changes in project development, conditions, and information); and b) monitoring budget and milestone, especially with respect to contingencies. This might involve periodic updates (iterate previous steps 1-5) at regular intervals or at major milestones or changes. For example, contingencies might be reduced as engineering reports or designs are completed and risks are avoided or reduced.

This *Guide* also provides adequate guidance to help ensure successful implementation of the risk management process described in this *Guide*, which requires adequate planning and resources, especially regarding qualified facilitators and experts (Chapter 10). As part of this, a two-day course has been developed to train DOT staff to successfully implement this *Guide* (Appendix G), focusing on training DOT facilitators to: a) implement the risk management process directly on relatively simple rapid renewal (as well as non-rapid renewal) projects; and b) supervise the evaluation of more complex projects and/or quantitative risk analysis. In addition to this training course (which include annotated slides and application to a hypothetical project, Appendix F), to help these facilitators, an overview presentation of the process and forms for documenting inputs (which are also available electronically in an MS Excel workbook template that also automates the necessary analyses) have been developed for relatively simple rapid renewal (as well as non-rapid renewal) projects (Appendix E).

The benefits of the risk management process described in this *Guide* include primarily improved project performance, as well as better understanding and clarity of the project and its range of possible performance. Moreover, it does this defensibly and efficiently. In fact, if done correctly (per the guidance presented herein), the “investment” (e.g., in training, workshops, and documentation) is small relative to the benefits of improved project performance, plus the more intangible benefits of better project understanding and being able to defend significant project decisions.

However, the risk management process described in this *Guide* currently has some limitations, which must be carefully managed and communicated:

- *DOT Commitment* – A formal risk management process, in which potential project problems and uncertainties are acknowledged upfront, is:
    - A different way of dealing with such potential problems, and such changes are often difficult to implement within a DOT; and
    - Incompatible with some current DOT cultures, which (although generally conservative and risk averse) tend to ignore risks, either because they are optimistic or because they are afraid such acknowledgement will affect project approvals.

  A lack of DOT commitment often leads to inadequate resources and, as discussed below, poor results, which in turn can be used to justify that lack of commitment.
- *Accuracy and defensibility* – For accuracy:
    - Comprehensive and non-overlapping sets are needed for risks and opportunities, as well as for base cost, schedule and disruption, and for potential risk management actions. However, this is typically difficult to achieve, especially for innovative project delivery methods where experience might be limited.
    - Adequate assessments of the various base and risk factors (including changes in those factors associated with risk reduction actions) are needed. However, this is typically

    difficult to achieve, because the unique nature of individual projects creates general lack of definitive information on risks. Subjective assessments, which involve interpretations of all available information and are thus subject to various types of biases, are generally required.
    - Adequate models of project performance are needed. However, this is typically difficult to achieve, especially to quantify the uncertainty in (and sensitivity of) those project performance measures, because of their complex nature. Too much approximation, or possibly even errors, which might not be recognized because of model complexity, can cause misleading results.

  Similarly, the above must not only be accurate enough, but must also be defensible enough, for the purpose. This in turn requires clear and reasonable, as well as adequately documented, logic and basis, especially regarding subjective assessments and models.
- *Efficiency* – A formal risk management process on a project can take significant effort, analogous to a VE Study in both its initial conduct and subsequent implementation. It must be adequately planned, resourced, and facilitated to provide adequate accuracy and defensibility as efficiently as possible. However, if poorly planned, resourced or facilitated, it might take a lot of unnecessary effort to achieve the required level of accuracy or defensibility. For example:
    - Some resources or information might not be available when needed, so that the process is delayed while they are gathered, or some resources might not be needed during part of the process, but they have not been released;
    - The model and/or assessments might be defined in too much detail ("lost in the weeds" and bogged down) or in not enough detail, necessitating a re-do; and
    - Assessments, models or documentation might be incomplete (or even erroneous), necessitating a re-do.

Additional work may be necessary in the future to reduce the above identified limitations of the risk management process described in this *Guide*. In particular:

- Publication and distribution of this *Guide*, accompanied with training at various levels of detail and pilot applications, will help explain why, what, when, and how such a formal risk management process should be conducted. This should help change the DOT culture and develop DOT commitment, as well as foster adequate accuracy and defensibility in an efficient manner.
- Detailed training of DOT facilitators and planners, including quality control and pilot applications, will help ensure adequate accuracy and defensibility, as well as efficiency, of the application of the process on particular projects.
- Analysis of the results of many applications of the process (case studies) will:
    - Demonstrate feasibility and value of the process, where value might simply be a qualitative evaluation by the project manager, to further DOT commitment;
    - Even before projects are complete, enhance the check list of risks and potential risk reduction actions, as well as the assessment of the risk factors and of risk reduction factors, improving accuracy and defensibility; and
    - After projects are complete, help to validate the process, which in turn will result in better defensibility and furthering DOT commitment.
- Further development of the following elements of the risk management process will enhance accuracy and defensibility, as well as efficiency, which in turn will further DOT commitment:
    - Databases regarding input assessments (from many applications);
    - Improved and more accessible (less complicated) risk models, especially to evaluate more complicated projects or to conduct full uncertainty analysis; and
    - Better documentation formats (especially of forms, and ultimately of the *risk register* and *Risk Management Plan*).

It is anticipated that this additional work will eventually proceed, resulting in an improved risk management process and thus even better project performance.

Hence, the following additional work is recommended:

- **Regarding the *Guide* (and tools):** The benefit of the research will be in the form of improved project performance (regarding cost, schedule, disruption, and longevity) but only if the *Guide* (and tools) is appropriately applied by DOTs to their projects. However, before organizing and then training a DOT to conduct risk management (which is discussed separately below), DOTs must first be convinced of the benefits of risk management. This can best be done by making DOTs aware of the process (i.e., wide exposure) and clearly demonstrating its value (e.g., through case studies). Hence, in addition to "marketing" (exposure is needed in multiple ways, i.e., in the form of papers/brochures, /presentations/webinars, and users' conference), case studies should be collected/evaluated, and new applications encouraged (e.g., through cost sharing/subsidies) and documented as case studies. In order to demonstrate the benefits of implementing the *Guide,* specific metrics (e.g., total and average project cost savings) should be developed and reported. Also, the *Guide* and tools should be "fixed" (as needed) and improved (as appropriate).
- **Regarding Training:** Training is needed to implement the *Guide*. Such training needs to be at different levels (from developing full capability to only familiarity), depending on needs, and needs to be available in different ways/formats (live vs. recorded, on-site vs. remote, NHI vs. non NHI format, lecture vs. application) – some of which (e.g., recorded, remote, NHI) would need development first. In addition to marketing (emphasizing cost-effectiveness of risk management), such training can be encouraged in various ways, e.g., cost sharing/subsidies and offering CEUs.

Appendix A. Glossary

$B – billion dollars
$k – thousand dollars
$M – million dollars
DOT – department of transportation
Iff – if and only if
NPV – net present value
OH - overhead
RMP – Risk Management Plan
SME – subject matter expert
VE – value engineering
YOE – year-of-expenditure

Base (in risk context) – value exclusive of risk and opportunity (i.e., per specific set of assumptions)
Bias (in risk context) – error in value (e.g., due to conservatism)
Conditional value – value if specific condition is true
Contingency – value in addition to base intended to cover risks and other uncertainties (e.g., for project cost and for project schedule)
Contingency management – process of establishing appropriate contingency (e.g., to achieve specific level of confidence that budget and milestones will not be exceeded) and controlling its expenditure
Correlation (or correlated) – relationship between uncertain variables (e.g., tendency for one variable to be on the higher end of its range if another variable is on the high end of its range)
Critical path – the set of project activities that have zero float (i.e., a delay in an activity on critical path will delay project completion)
Critical path analysis – process of analyzing a project schedule to determine each activity's float and to identify the critical path
Deterministic analysis – process of calculating a single value for each output, based on single values of each input
Disruption - a measure of project performance expressed in terms of the amount of hours lost by the public, which when combined with an average cost per hour produces user cost
Escalation – process by which the costs of things change with time (including inflation)
Escalation rate – rate at which the cost of something changes with time, typically expressed in terms of percent cost increase per year (which might vary from year to year and for different items)
Expected value – mean value
Facilitator (in risk context) – specialist who guides the risk management process, e.g., working with appropriate project staff and SMEs to structure the project, identify and assess project risks, and develop risk management plans, and conducting the various analyses
Float (in schedule context) – amount of time an activity can be extended before it becomes critical path
Ignorance (in risk context) – lack of perfect information about the value of a particular factor, which leads to uncertainty
Impacts (in risk context) – changes in base performance values (e.g., in project cost) associated with occurrence of a particular risk; often described as an impact "scenario"
Independent (in risk context) – no relationship between uncertain variables (i.e., not correlated)
Longevity – a measure of project performance considering cost and disruption associated with operations and replacement, in combination with the time to replacement
Mean value – measure of the middle of the range of an uncertain variable; probability-weighted average value
Mitigated (or mitigation, in risk context) – after additional proactive risk reduction is attempted
Monte Carlo simulation – numerical method of approximately calculating probability distributions of outputs by sampling numerous sets of input values from their probability distributions, calculating the output values for each set of input values, and statistically analyzing the sets of output values

Opportunity – potential event that, if it occurs, would impact project performance, often expressed in terms of an impact “scenario” (a particular set of project performance impacts, such as acceleration to a particular project activity) and its probability of occurring; typically refers to potential events with desirable impacts

Percentile (in probability context) – value associated with a particular cumulative probability (e.g., the 90th percentile has a 90% chance of not being exceeded)

Probability – chance of occurrence, with possible values ranging from 0% (will not occur) to 100% (will occur)

Probability distribution – expression of relative likelihood of each possible value of an uncertain variable

Recovery (in risk context) – actions to reduce project cost and/or schedule (e.g., scope reductions), typically in reaction to exceeding available contingency

Residual risk – remaining risk, typically after mitigation

Risk – potential event that, if it occurs, would impact project performance, often expressed in terms of an impact “scenario” (a particular set of project performance impacts, such as delay to a particular project activity) and its probability of occurring; typically refers to potential problems with undesirable impacts, although can include opportunities as negative risks

Risk analysis – process of calculating project performance including risks, and often the sensitivity of that performance to the various risks (i.e., to prioritize the risks for further assessment or for risk reduction)

Risk assessment – process of assessing the factors describing each identified risk (i.e., impacts and likelihood of occurrence)

Risk identification – process of identifying project risks (e.g., through brainstorming, checklists, etc.), typically with the objective of developing a comprehensive and non-overlapping set of risks, as documented in a *risk register*

Risk management – process of controlling risks (and thereby project performance) through proactive risk reduction, contingency management and/or recovery, as documented in a *risk management plan*

Risk Management Plan – documentation of the plans for conducting risk management, including organization; should be kept up-to-date

Risk reduction – process of proactively taking actions intended to reduce the impacts and/or probability of specific risks

Risk Register – documentation of project risks, ideally comprised of a comprehensive and non-overlapping set of risks (typically categorized), including adequate descriptions of their impacts and likelihood; should be kept up-to-date

Severity (or risk severity) – a measure of a risk’s impact on project performance, combining mean values of cost, schedule, and disruption through construction, and post-construction longevity

Standard deviation – measure of the range of an uncertain variable; square root of the variance

Subjective assessment – process of assessing a value based on judgment, in the absence of definitive data

Tradeoff (or tradeoff value) – equivalent amounts of different project performance measures, often expressed in terms of the amount a decision maker would be willing to pay to change each project performance measure by a unit amount (e.g., $ per month of schedule)

Uncertainty – value of a particular variable is not known for certain, and might have various values

Unconditional value – value which does not depend on specific conditions being true

Unmitigated (in risk context) – before any additional proactive risk reduction is attempted

Variance - measure of the range of an uncertain variable (probability-weighted square of the differences relative to the mean value); square of the standard deviation

Variability – different values of a particular factor (e.g., at different times or locations), which leads to uncertainty

Appendix B. References

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Appendix C. Inventory of Rapid Renewal Strategies and Methods

As noted in Chapter 3, rapid renewal addresses aging infrastructure through rapid design and construction methods that cause minimal disruption and produce long-lived facilities. To understand the "risks" (i.e., potential problems and/or potential opportunities) associated with rapid renewal, it was first necessary to develop an inventory of rapid renewal strategies and methods. This inventory informs the risk management process as to what aspects, and their associated risks, are unique to rapid renewal projects as opposed to those projects following the more traditional linear project development process and methods. However, the process of selecting a particular rapid renewal strategy/method (or any other project element, for that matter) is outside the scope of this *Guide*. Instead, the "performance" of particular alternatives can be evaluated, based on this *Guide*, and used to help select the optimal one.

The inventory of rapid renewal strategies and methods is summarized in hierarchical form in Figure C-1, and in more detail in the bulleted lists that follow. This inventory is based primarily on the following:

- A review of 25 case studies from the FHWA Accelerated Construction Technology Transfer (ACTT) Program, which represent the state-of-the-art in rapid renewal innovations - each case study involved an intense two-day workshop in which a multidisciplinary team of 20 to 30 national transportation experts with various skill sets worked with local agency professionals to identify and recommend rapid renewal strategies and methods for that project (which varied in size from $1 million to $3.4 billion.
- A survey of various state DOTs.
- Personal experience of the research team members.

It should be noted that some of these rapid renewal strategies and methods are not truly unique to rapid renewal (e.g., brand the project, consider OCIP) while some others are actually risk management (e.g., require pavement warranty). However, they have all been included for comprehensiveness.

The extensive inventory of rapid renewal strategies and methods summarized here (Figure C-1 and subsequent bulleted lists) was subsequently "boiled down" to a more-generalized and more-manageable set of rapid renewal strategies. This refined set served as a basis for identification and classification of categories of risks (Appendix D) that are relatively unique to rapid renewal projects, and their subsequent prioritization and management.

Construction	Structures	Traffic Engineering/ Safety/ITS	Innovative Contracting/ Financing	Geotechnical Materials/ Adv Testing	Public Relations	Environment	Roadway/ Geometric Design	ROW/ Utilities/ Railroad Coordination	Long-Life Pavements/ Maintenance
Closures	Prefabrication	Advance Planning	Alternative Financing	Subsurface Exploration	Team Integration	Master Planning	Alternate Access	Advance ROW Planning	Life-Cycle Design
Preliminary Work/ Staging	Component Reuse	Alternate Routes	Project Delivery	Walls	Single Point Communication	Context Sensitive Solutions	Alternate Geometrics	Early Utility Location	Performance Indicators
Project Admin Streamlining	High-Performance Materials	Alternate Modes	Procurement	Pavements	Additional Investment	Comprehensive Scoping	Advance Roadwork	Common Utility Crossings	Long-Life Materials
Construction Operations	Integral Designs	Improve Physical Separation	Contract Payment	Alternative Materials	Project Branding	Advance Permitting		Early Railroad Coord.	Maintenance Involvement
	Standardize Design	Coordinate Emergency Response	Warranties	Intelligent Compaction	Stakeholder Awareness				
	Construction Placement	Signage and Signalization	Alternative Insurance	Material testing	Performance Measurement				
	Temporary Structures	Closures	Advanced Contract Packaging						
	Long-Life Structural Design	Work Zones	Bonding/ performance securities						

Figure C-1. Rapid Renewal Inventory Hierarchy

Construction

- Closures
    - Use total and/or directional closures (closing one direction at a time) and use alternate routes
    - Include specified minimum closure times and appropriate incentives/disincentives
    - Consider partial closures if total closure isn't feasible
- Preliminary Work/Staging
    - Perform any preliminary work ahead of mainline work, i.e., local roadway improvements, advanced substructure work, etc.
    - Consider staging other work:
        - Overpass structures
        - Drainage, grading and fencing
        - Retaining walls and sound walls
        - Substructure work
- Project Administration Streamlining
    - Consider DOT construction management (a single point of contact) for the whole corridor
    - Have higher approval authority/a streamlined process for contract change orders
    - Utilize a dispute review board
- Construction Operations
    - Recycle existing materials such as concrete, asphalt and base
    - Consider innovative construction materials such as precast panels, high early strength concrete, thin white topping, etc.
    - Add temporary/permanent lighting for 24-hour construction

Structures

- Prefabrication
    - Utilize precast/prefabricated components such as full depth decks, partial depth decks, decks with girders, substructures and barriers
- Component Reuse
    - Re-use existing piers
    - Re-use existing substructures
- High-Performance Materials
    - Utilize high performance steel (HPS).
    - Utilize high performance concrete (HPC), i.e., lightweight concrete, self consolidating concrete, etc.
- Integral Designs
    - Use integral abutments
    - Utilize integral overlays
- Standardize Design
    - Standardize design for repetitive elements
- Construction Placement
    - Utilize horizontal skidding or longitudinal launching
    - Consider using barges
    - Utilize self propelled modular transporters (SPMTs)
- Temporary Structures
    - Use temporary bridge structures
- Long-Life Structural Designs
    - Aim for a 75- to 100-year design life

Traffic Engineering/Safety/ITS

- Advanced Planning
    - Conduct an origin-destination study.
    - Prepare traffic impact statement/concept of operations.
- Alternate Routes

  - Prepare for closures through the use of alternate routes
  - Provide for turn-lane improvements and ramp enhancements
- Alternate Modes
  - Prepare for closures through the use of alternate modes of transportation, i.e., transit services, employer-based programs, etc.
- Improve Physical Separation
  - Use barrier or buffer lane separation
  - Implement enforcement/crash investigation sites
  - Build emergency pullouts
- Coordinate Emergency Response
  - Coordinate with local jurisdictions and emergency responders
  - Have a stronger police presence
  - Have a pre-defined incident response plan, and use an incident detection system
  - Utilize an on-call wrecker service/DOT highway helpers, i.e., HERO
  - Develop a worker safety plan/provide agency and contractor work zone training
  - Utilize highway advisory radio, or HAR
  - Coordinate with 511
- Signage and Signalization
  - Provide real-time travel information
  - Use dynamic message signs (DMS), closed circuit TV (CCTV) and detectors to support lane operations
  - Provide better traffic signal coordination
- Closures
  - Utilize off-peak rolling road closures, weekend closures, directional closures, etc.
  - Provide contractor incentives/disincentives, i.e., lane rentals
- Work Zones
  - Monitor work zone safety
  - Utilize smart work zones

Innovative Contracting/Financing

- Alternative Financing
  - Use Grant Anticipation Revenue Vehicle (GARVEE) bonds
  - Charge for the use of right of way
  - Generate revenue through user fees on high occupancy vehicle/high occupancy toll (HOV/HOT) lanes
- Project Delivery
  - Consider public-private partnerships (PPP) - private equity or debt
  - Utilize design-build (D-B).
  - Consider construction manager (CM) at risk.
- Procurement
  - Use cost-plus-time (A-plus-B) bidding
  - Use cost-plus-time-plus-quality (A-plus-B-plus-Q, A-plus-B-plus-C)
  - Shortlist qualified contractors; use qualifications-based selection process.
- Contract Payment
  - Use incentives/disincentives for construction time
  - Consider incentives/disincentives such as:
    - Time-specific rewards
    - Lane rentals
    - Holidays
    - A five-day work week
    - Weather days
  - Include quality assurance/quality control (QA/QC) specifications and quality-based incentives
  - Provide no-excuse bonuses
- Warranties

  - Require a pavement warranty
  - Set up an advisory team/dispute review board to facilitate resolution of issues
- Alternative Insurance
  - Consider an owner-controlled insurance program, or OCIP
- Advanced Contract Packaging
  - Consider advance contracts for items such as utilities, right-of-way, ramps/overpasses, etc.
- Bonding/ performance securities
  - Letter of credit
  - Corporate/parent guarantee
  - Reduced bond (to owner exposure)

<u>Geotechnical Materials/Accelerated Testing</u>

- Subsurface Exploration
  - Consider subsurface explorations, seismic issues and lab testing
- Walls
  - Use mechanically stabilized earth (MSE) walls: two-stage, modular block, etc.
- Pavements
  - Rubblize existing pavement
  - Recycle existing material
- Alternative Materials
  - Stabilize sub grade with fly ash, lime, cement or other available additives
  - Consider flow able fill, foamed concrete and geofoam
  - Implement a geotech database
- Intelligent Compaction
  - Utilize intelligent compaction equipment
- Material Testing
  - Contractor test results for acceptance (e.g., earthwork, base, surfacing)
  - Change density testing from sand cones to nuclear gauge through streamlining calibration process
  - Use of proof rolling and reduced frequency of testing

<u>Public Relations</u>

- Team Integration
  - Establish a project team with representation from all areas
  - Begin coordination during the planning process and include it in every stage forward
  - Collaborate with the media and traffic teams
- Single Point Communication
  - Ensure that the communications office is the central point of contact/oversight for all communications efforts
- Additional Investment
  - Make sure that public outreach is a standing component in the construction budget. The teams recommended allocating up to 4-6% of the total project cost to public outreach
  - Dedicate a full-time communications specialist to the project
- Project Branding
  - Brand the project
  - Define campaign specifics
- Stakeholder Awareness
  - Identify project stakeholders
  - Identify the cultures and communities that will be affected
  - Target your message/develop a communications plan. Make sure to include businesses, community, government, media, residents, the tourism industry, special interest groups and the internal audience
- Performance Measurement

    - Do follow-up surveys to determine effectiveness of measures used and to adjust tactics as needed

Environment

- Master Planning
    - Establish a project development process or master plan that integrates engineering, environmental analysis, agency coordination and public involvement into a collaborative decision making process
- Context Sensitive Solutions
    - Focus on context sensitive solutions
- Comprehensive Scoping
    - Conduct a comprehensive scoping process
        - Define purpose and need
        - Obtain agency and public input
        - Establish performance measures that will support environmental streamlining and stewardship
    - Review safety and accident data
    - Document the project development process through comprehensive project files
- Advance Permitting
    - Address storm water management permitting issues during project development process

Roadway/Geometric Design

- Alternate Access
    - Movement or elimination the access
    - Manage access
    - Alternate interchange configurations (diamonds, single points, etc.)
- Alternate Geometrics
    - Lowering/raising profiles
    - Alternative weave patterns
    - Early widening
- Advance Roadwork
    - Alternate configurations to allow for early construction access

ROW/Utilities/Railroad Coordination

- Advance ROW Planning
    - Identify and acquire special properties
    - Have a relocation plan in place early
    - Advance ROW purchase
- Early Utility Location
    - Provide early identification and location of utilities
    - Avoid conflicts and relocations wherever possible
    - Conduct a consultant utility review as part of roadway design to ensure there are no known utility conflicts
    - Have major utilities at the design table/planning phase
- Common Utility Crossings
    - Build common ducts/DOT-owned conduit crossings
    - Consider level A Subsurface Utility Engineering (SUE) where appropriate
- Early Railroad Coordination
    - Coordinate regularly (daily, if needed) with the railroad

Long-Life Pavements/Maintenance

- Life-Cycle Design
    - Base design on best practices and life-cycle costs
    - Aim for minimal maintenance: no daytime lane closures for 50 years

- Performance Indicators
    - Use performance indicators as either initial construction standards or in a warranty contract for pavement rehabilitation
- Long-Life Materials
    - Consider the following pavement options:
        - Stone matrix asphalt, or SMA
        - Continuously reinforced concrete pavement, or CRCP
        - Polymer asphalt.
        - Composite pavement
        - Sub grade treatments/stabilization
- Maintenance Involvement
    - Communicate with maintenance personnel during design and construction

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Appendix D. Rapid Renewal Risk Categories and Risk Management Action Categories

Appendix D consists of three sections:

- Appendix D.1 Risk Checklist for Traditional Transportation Projects
- Appendix D.2 Summary Risk Checklist for Rapid Renewal Projects
- Appendix D.3 Rapid Renewal Risk Categories and Potential Risk Management Actions by Project Phase

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Appendix D.1. Risk Checklist for Traditional Transportation Projects

As shown, the items on this list do not form a formal risk register (i.e., this is not a comprehensive list of items for any particular project, and the listed items are *not* non-overlapping by intention). The list is only intended to serve as a supplemental "checklist" to identify items missed during brainstorming. Identified items then need to be redefined/recast to ensure a comprehensive, non-overlapping set of events in the risk register (adequately considering significant relationships (correlation, dependency) among items in the list, if any).

Some items shown are really "base uncertainty" (i.e., uncertainty within the base project/estimate assumptions), while the remainder are truly risk and opportunity events (i.e., uncertain conditions and events outside the base assumptions).

When identifying and quantifying risk, consider the issue of ownership/allocation (i.e., it's a risk to whom? And who pays?), impacts of insurance in capping costs, influence of "below-the-line" markups, correlation between cost and time impacts, etc.

Uncertainty in "Soft" Costs and / or Schedule (other than identified through other items, and *excluding additional costs that result from project delays*, which are accumulated directly and additionally through simulation). Fundamental question: Is the base estimate for each in terms of a percentage of construction cost? or a detailed line-item estimate?

- Design completion
- PS&E completion
- Administration costs (owner)
- Oversight costs (regulator)
- Construction management and construction inspection (CEI)
- Project management
- Design support during construction / construction engineering
- Mobilization
- Sales tax
- Financing, including interest costs
- Insurance
- Surety capacity and bonding
- Annual inflation rates (construction, right-of-way, engineering, other)
- Stipends
- Extended overheads from project delays (if not captured separately)

Contracting, Procurement, and Project Delivery

- Project delivery method (D/B, D/B/B, PPP), including uncertainty in ultimate method, and new or unique method to owner
- Single vs. multiple contracts (if not captured under market conditions)
- Construction market conditions (contractor pricing strategy/markup; cyclic market, and location within cycle at time of bid; number of viable bidders), including the potential for delay to the procurement process and/or re-bidding
- Significant increase in material, labor, or equipment costs (beyond what's included in inflation rates and market conditions)
- Delays procuring critical materials, labor, or specialized equipment
- Bid protests
- Claims related to clarity of bid and contract documents
- Errors and omissions
- Other issues related to unclear contract documents (identified during either procurement or later during construction)
- Other delays to contract procurement process (e.g., bonding and insurance issues)
- Owner approach to specifications (e.g., prescriptive versus performance-based)
- Incomplete or vague specifications

- Contractor non-performance (inefficiency if the impacts are not due to or captured by other risk items; default; bankruptcy)

Construction and Constructability (see also Geotech and Structures; there is some overlap in these two lists)

- Additional pavement resurfacing
- Additional geometry re-alignment
- Uncertainty in construction unit costs (e.g., earthwork)
- Uncertainty in construction quantities (e.g., bridges, walls)
- Inadequate staging areas identified for construction
- Dewatering issues during construction
- Issues related to tunnel construction procedures (see also tunneling under Geotech)
- Issues related to other construction procedures
- Uncertainty in planned construction sequencing / staging / phasing / construction duration
- Planned construction phasing doesn't work (need new plan)
- Maintenance of traffic (MOT) / work zone traffic control (WZTC) issues
    - Labor for assumed plan if plan is adequate
    - Proposed plan is not adequate
    - Issues related to detours
- Difficult or multiple contractor interfaces
- Uncertainty in structure demolition sequence and method
- Force Majeure during construction (acts of nature that impact construction, like earthquake, tornado, etc.)
- Safety issues (personnel, adjoining structures)
- Material reuse, removal, restoration
- Condition of existing structures (repair required?)
- Accidents/incidents during construction (traffic/collapse/crane toppling/slope failure/vandalism)
- Critical equipment failure
- Excessive scour or flooding
- New or unproven systems, processes, or materials
- Marine-construction issues
- Other difficult or specialized construction issues
- Tie-ins with existing facilities/roadways/structures/local access
- Failure prior to replacement (e.g., bridges)
- Additional temporary erosion and sediment control (TESC) costs
- Railroad conflicts (anticipated or unanticipated)
- Utility conflicts (anticipated or unanticipated)
- Work-window restrictions (e.g., fish windows, weather shut-down windows)
- Other third-party delays during construction

Design

- Uncertainty in, or risk or opportunity related to, the "base" design elements (e.g., due to early design, project definition, or development), including type, size, and location (TS&L) and unit prices and quantities. Consider related (i.e., correlated or dependent) impacts to design, ROW, environmental documentation, permitting, utilities, and construction. Consider relationships to other issues in this list (conditionality/correlation). Example items include:
    - horizontal alignment (e.g., geometry / grade)
    - vertical alignment (e.g., underground vs. surface vs. aerial)
    - bridges (superstructure and substructure)
    - retaining walls
    - earthwork
    - noise walls
    - other structures
    - stormwater collection and treatment
    - paving
    - right-of-way (e.g., full vs. partial takes; uncertain parcels/quantities)

    - maintenance of traffic / traffic control
    - Traffic Demand Management (TDM) / Intelligent Traffic Systems (ITS)
    - construction staging/phasing
    - electrical (systems, signals, illumination)
    - mechanical
- Design errors and omissions or errors in plans/specs/estimates (discovered during construction)
- Urban design and construction issues
- Changes in design standards (e.g., increased seismic criteria for structures)
- Design deviations (e.g., design speeds, vertical clearances, turn radii)
- Access deviations (e.g., FHWA)
- Additional aesthetics / context-sensitive solutions (CSS)
- Allowances for miscellaneous items (known pay items not yet itemized in the estimate)
- Floodplain issues

Environmental
- Uncertainty in appropriate environmental documentation (e.g., DCE vs. EA vs. EIS), and all the related consequential events (e.g., change in design, ROW, scope, and construction costs)
- Challenge to environmental documentation (e.g., resulting in delay in ROD)
- Delay in review and/or approval of environmental documentation
- Supplemental environmental documentation or re-evaluation required
- Challenge to Early-Action Mitigation Plan (Wetlands, Floodplain/Habitat)
- Additional habitat mitigation required, on- or off-site (e.g., wetlands, fish ladders, meandering; connectivity)
- Uncertain wetland mitigation (e.g., uncertain impacts, uncertain type of mitigation (replacement, enhancement, banking); different replacement ratio than assumed)
- Difficulty identifying and/or acquiring suitable wetland-mitigation site (including collecting required growing-season data)
- Biological Assessment consultation issues / delay
- New species listings (ESA)
- Encounter unanticipated listed species during construction
- Uncertain stormwater treatment standards or quantities
- Uncertain stormwater discharge criteria (e.g., Receiving body exemptions)
- Uncertain groundwater treatment standards or quantities
- Encounter unanticipated contaminated or hazardous materials (and possibly extent of liability for remediation)
- Encounter unanticipated contaminated groundwater (and possibly extent of liability for remediation)
- Additional noise mitigation required
- Additional view mitigation required
- Unanticipated Section 106 issues (archaeological, cultural, or historical finds) encountered during design or construction
- Known Section 106 issues different than anticipated
- Unanticipated 4(f) issues
- Known 4(f) issues different than anticipated
- Other Regulatory Issues (EIS, NEPA, etc.)

External Influences and Management (e.g., Political, Regulatory, Municipalities, Economic)
- Difficulty obtaining other agency approvals/agreements (higher-level, municipalities)
- Conflicts with other projects (municipalities, counties, state)
- Other predecessor projects not completed on time (delay current project)
- Coordination with other entities (e.g., Railroads)
- Coordination between multiple contractors on this project
- Force Majeure during design (e.g., earthquake causes existing facility to fail, requiring accelerated design/construction of new facility)
- Public opposition
- Political opposition

- Funding shortfall (and related delay or increased financing cost)
- Funding delay
- Legal challenges (other than environmental)
- Intergovernmental agreements and jurisdiction
- Labor issues (contract negotiations/strike)
- Tribal issues (e.g., fishing rights, TERO employment, etc.)
- Program management / executive oversight issues
- Project management issues / workload management
- Revenue issues (ridership; regulations/policies)
- Cash flow constraints
- Other significant constraints/milestones/”promises” to be met

Geotechnical and Structural

- Uncertainty in bridge or culvert design (including type/size/location (TS&L) – foundations and superstructure)
- Difficult bridge construction (e.g., transportation or erection of large components; other specialty construction; groundwater, adverse ground conditions; obstructions; scour; other foundation problems)
- Uncertainty in retaining wall design (including type, length, height – foundations and superstructure)
- Difficult retaining-wall construction (e.g., groundwater, adverse ground conditions; obstructions; other foundation problems)
- Slope stability issues – natural, man-made (cuts, embankments), etc.
- Liquefaction design issues
- Uncertainty in seismic design criteria
- Uncertainty in ground improvement design (e.g., what type, how much is required)
- Uncertainty in ground improvement performance (i.e., construction – need additional or different type of improvement)
- Damage to nearby structures during construction or as result of construction
- Tunneling-specific issues
    - Uncertain or early design (including uncertainty in tunneling method, lining, etc.)
    - TBM problems (e.g., TBM operator issues / inexperience; machine procurement; machine assembly, disassembly, and recover; machine maintenance; power-supply problems; drive rate/productivity (various causes, including obstructions or other poor ground conditions); drive misalignment; other problems)
    - Liner problems (e.g., damaged liner segments; bad gasket/seal resulting in leakage)
    - Problems with shaft or emergency exit construction
    - Problems with cross-passage excavation
    - Other tunnel construction problems
- Compatibility of new structures when placed adjacent to existing structures
- Other general geotechnical risk

Operations and Maintenance

- Uncertain annual costs for typical maintenance
- Additional resurfacing or re-decking cycle(s) required
- Additional significant (unplanned) maintenance required
- Uncertain O&M period (e.g., for P3 concessions)

Permitting

- Difficulty obtaining permit approval (by permit type; e.g., 401, 404, NPDES, USCG, shoreline) – manpower issues; incomplete or inadequate permit applications; or simple disagreement by approving agencies
- Uncertain permit requirements (current and in the future)
- Challenges to permits once issued (e.g., shoreline, 401, 404)
- Air quality permitting issues
- Non-compliance with permits (environmental or construction)

Right-of-Way / Real Estate

- Global right-of-way (ROW) problems (for widening, drainage, pipelines, detention, staging, etc.)
- Additional right-of-way required (e.g., plans change; inaccurate early estimates)
- Difficult or additional condemnation (either globally or for particular parcels)
- Additional relocation required (either globally or for particular parcels – business vs. residential)
- Additional demolition required (including unanticipated remediation) (either globally or for particular parcels)
- Accelerating pace of development in project corridor
- Changes in land use / demographics in project corridor
- Manpower shortages
- Process delays (e.g., ROW plan development by team; plan approval process)
- Planned ROW donations do not occur, or opportunity for additional donations
- Difficulty obtaining rights-of-entry
- Railroad ROW Problems
- Issues related to required easements (surface, subsurface)
- Other ROW issues

Scope Issues (other than identified through other items elsewhere in this list, such as design)

- Additional capacity required (e.g., lanes)
- Additional interchanges required (system-to-system or service)
- Additional local improvements required (e.g., additional paving or signals on local connections)
- Additional transit facility, park-and-ride, etc. required
- Other additional structures required (e.g., wildlife crossings)
- Scope reduction opportunity / Value Engineering
- Replace structures instead of retrofit existing (or vice-versa)
- Tolling facilities
- Managed lanes
- Note on scope changes: scope changes can occur during design and/or construction, and can be due to:
  - Incomplete design
  - Stakeholder influences leading to additional scope (e.g., aesthetics; political pressure)
  - Errors in design
  - Construction problems
  - Regulatory changes

Systems

- Software problems (technical, labor)
- Electrical-system problems (technical, labor)
- Mechanical-system problems (technical, labor)
- Problems with station finishes (technical, labor)
- Track-installation problems (technical, labor)
- Problems related to systems integration and testing

Traffic and Access Issues

- Uncertainty in traffic management costs (ITS, TDM)
- Access to site during construction
- Business or economic disruption mitigation

Utilities Issues

- Delay in completing utility agreements (for example, due to: disagreement over responsibility to move, disagreement over cost-sharing; delay in reviews and approvals by utility)
- Late changes to design delays utility planning (e.g., have to re-do utility design)
- Utility relocations to be completed by others (utility companies, municipalities) are not completed on time
- Encounter unexpected utilities during construction

- Damage utilities during construction (known or unknown)
- Utility integration with project and/or utility betterments not as planned
- Cost sharing with utilities not as planned

Vehicles

- Uncertainty in required number and/or type of vehicles
- Uncertainty in contracted price for vehicles (may include uncertainty in number/type of vehicles)
- Delay in vehicle delivery
- Cost increase due to change orders (for various reasons, perhaps detailed separately; separate from uncertainty in contract price)

Appendix D.2. Summary Risk Checklist for Rapid Renewal Projects

The lists below summarize *categories* or types of rapid renewal risks by project phase. The lists do not attempt to capture specific risks related to rapid renewal. Use these lists of risk categories as a quick 'check' to make sure no major types of risks were missed during initial risk brainstorming.

Because the lists below only address *categories* of risks, they do not constitute a proper risk register. To develop a risk register, the DOT must identify a comprehensive, non-overlapping set of *individual* (i.e., specific) risks and opportunities for the particular project being considered. More detail is provided in Appendix D.3 for each of the entries below.

Finally, *the DOT should remember to consider risks and opportunities for all aspects of a project* – not just for the rapid renewal elements covered specifically in this Guide.

Planning

- Inaccurate planning assumptions and projections
- Resources not available from all disciplines for advanced planning
- Advanced planning for rapid renewal projects not coordinated with transportation network
- Uncompleted or unfeasible rapid renewal project erode public trust
- Planning partners do not have resources to partner in advancing rapid renewal projects

Project Scoping (including project delivery and funding / financing)

- Project contains unrealistic scope considering budget and political landscape
- Master planning / integrated development process is inefficient or poorly implemented
- Owner not capable of managing the delivery method
- Delivery method not appropriate for the project
- Procurement protest pre-award
- Dispute post-award
- Market cannot support to selected delivery method / method restricts competition
- Other cost and/or schedule premium resulting from delivery method
- Cost premiums resulting from innovative payment structure
- Insufficient market interest in innovative payment processes to create competition
- Poor market conditions make securing financing difficult
- Enabling legislation not in place to allow alternative financing
- Changes in legislation before financial close (e.g., tolling, competing facilities) jeopardize alternative financing
- Other delay in funding process
- Actual revenues significantly less than anticipated (O&M)
- Surety market cannot support project's bond requirements
- Bonding capability of contractor(s) not adequate
- Lack of payment bond results in subcontractor protests or claims
- Contractor defaults

Environmental Process and Permits

- Different type of environmental documentation required
- Additional documentation required (but not a change in document type)
- Other delay to completion of environmental process related to attempted acceleration
- Approval / signatory organizations cannot accommodate streamlined processing / approval
- Review and approval process takes longer than anticipated for other reasons
- Challenge to environmental documentation once determination has been issued
- Development of permit application takes longer than anticipated
- Delay in permit review or approval
- Unanticipated or additional permits required
- Challenge to permits once issued
- Streamlined mitigation effort won't work (management issue)
- Streamlined mitigation effort won't work (technical issue)

Design and Construction (General Principles)

- Key design decisions are delayed
- Other key project-related decisions are delayed or changed
- Stakeholders not able (or willing) to support accelerated design process
- Encounter unanticipated changes in design standards
- Standardized designs not available or suitable
- Delay in approval of design exceptions, or denial of design exceptions
- Staffing for accelerated design not available
- Owning agency not staffed or structured for streamlined approvals
- Stakeholders unable or unwilling to accommodate streamlined approvals
- Delays to other activities delay the design's approval
- Mistakes in the design delay the design's approval
- Constructability review not allowed (policy)
- Constructability review not successful
- Constructability review successful, but leads to significant changes in design

Design and Construction (by Discipline)

- *Consider each of the following categories of rapid renewal risks and opportunities separately for each design discipline* and/or major project component (e.g., structures, geotechnical and earthwork, drainage and stormwater management, roadway, pavement, and ITS)
    - Innovative designs
        - Innovative and/or long-life designs not the right solution for the project
        - Innovative designs can work technically, but require design exceptions or have difficult permitting requirements
    - Alternative or long-life materials
        - Candidate alternative and/or long-life materials won't work (technical issues identified during design)
        - Delay in procuring candidate alternative and/or long-life materials
    - Rehabilitation
        - Rehabilitation not the best option (identified during design)
        - Problems with rehabilitation during construction
    - Pre-fabrication
        - Candidate pre-fabrication technique won't work (technical issues identified during design)
        - Delay in procuring pre-fabricated elements
        - Problems with pre-fabricated elements during construction
    - Rapid-replacement technologies
        - Candidate rapid-placement technique won't work (technical issues identified during design)
        - Delay in procuring rapid-replacement equipment and/or specialized labor
        - Problems with rapid-replacement technique during construction
- Maintenance of Traffic – full or directional closures
    - Planned closures and related detour routes are not allowed (political or management issue)
    - Planned closures and routes won't work (technical issue identified during design)
    - Planned closures and routes will work but are not most efficient (better plan identified later during design)
    - Implemented closure plan doesn't work (problem identified during construction)

Right-of-Way, Utilities, and Railroad

- Right-of-Way (ROW)
    - Late changes to the design cause delay in ROW planning
    - ROW plans not completed as planned for other reasons
    - Funding for accelerated or advance ROW acquisition delayed or reduced

    - Problems procuring critical (high-priority) parcels, such as
        - Challenge to possession-and-use
        - Condemnation required
        - Difficulties relocating tenants
        - Unanticipated contamination or utilities discovered
        - Additional demolition required
    - Delay to ROW certification (agency process delay)
- Utilities
    - Late changes to the design cause delay in utility planning
    - Utility agreements not reached as planned (from causes other than late design changes)
    - Encounter and/or damage utility during construction (if the owner's contractor performs the work)
    - Third party does not complete relocation as planned (if third party performs the work)
- Railroad
    - Late changes to the design cause delay in railroad planning
    - Railroad agreements not reached as planned (from causes other than late design changes)
    - Damage railroad facility during construction (if owner's contractor performs the work)
    - Railroad does not complete agreed railroad-related work as planned (if railroad performs the work)

Procurement (including Contracting Strategy)

- Litigation initiated by an interested party challenging the propriety of the alternative procurement process
- Public concern (and political pressure) resulting from the use of alternative procurement processes that heavily weight non-price factors
- Public reaction to alternative procurements that trade-off early accelerated completion with full road closures
- Limited competition arising from projects perceived as being created for large contractors
- Other problems procuring contract (e.g., bid protest, unclear documents, contractor default)
- Litigation initiated by an interested party challenging the propriety of the alternative contract packaging
- Public concern (and political pressure) resulting from the use of alternative contract packaging
- Expending funds in advance of full procurement (for advance procurement)

Operations and Maintenance (O&M)

- Required O&M effort greater than planned (more frequent, more extensive, or both)
- O&M contractor does not perform per contract requirements

Replacement

- Replacement required sooner than planned
- Replacement facility does not perform as intended

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Appendix D.3. Rapid Renewal Risk Categories and Potential Risk Management Actions by Project Phase

Appendix D.3 provides substantially more detail for each of the items identified in Appendix D.2. For each project phase, the following is provided in a separate table:

- General rapid renewal strategies that might be employed during that project phase.
- For each rapid renewal strategy, the table lists categories, or types, of risks and opportunities that might result from following a particular rapid renewal strategy. The categories of risks and opportunities were identified as "risks to the owner" and to the owner's rapid renewal objectives for the project (i.e., minimizing cost, minimizing schedule, minimizing disruption, and maximizing longevity).
- Potential risk-management actions to address the various categories of risks and opportunities.

The tables in Appendix D.3 therefore contain more background and detail on each risk category, including the corresponding rapid renewal strategy and example risks and risk management actions. The authors encourage DOTs to review the more-detailed documentation in Appendix D.3 to develop a better understanding for how each risk category was developed and what each category means.

The tables for each project phase include:

- Table D-1. Planning
- Table D-2. Project Scoping (including project delivery and funding / financing)
- Table D-3. Environmental Process and Permits
- Table D-4a. Design and Construction (General Principles)
- Table D-4b through D-4g. Design and Construction (by Discipline, such as Structures, Geotechnical, etc.)
    - Table D-4b. Structures
    - Table D-4c. Geotechnical and Earthwork
    - Table D-4d. Drainage and Stormwater Management
    - Table D-4e. Roadway, Geometrics, and ITS
    - Table D-4f. Pavement
    - Table D-4g. Maintenance of Traffic (MoT)
- Table D-5a. Right of Way
- Table D-5b. Utilities
- Table D-5c. Railroad
- Table D-6. Procurement (including Contracting Strategy)
- Table D-7. Operations and Maintenance
- Table D-8. Replacement

Notes for all Tables:

1. The Risk Categories are not intended to be specific risks, only general categories of potential issues that serve as prompts for identifying specific issues. Therefore, the listed categories cannot be taken together to form a proper risk register (i.e., they are not a comprehensive, non-overlapping list of risks and opportunities).
2. The Potential Risk-Management Actions are assumed to not already be part of the project plan. All actions should cost-effectively improve performance measures. The actions are not necessarily presented as one-to-one correspondence with risk categories because some actions might address more than one risk category.

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Table D-1. Project Phase: Planning

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Conduct programmatic / portfolio planning Examples: • Long range requirements, resources, and constraints • Short range requirements, resources, and constraints		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Focus internal planning efforts on rapid renewal projects as a priority over traditional projects • Create awareness with planning partners (e.g., metropolitan planning organizations, municipalities, etc.) of rapid renewal projects • Secure public awareness or “buy-in” for rapid renewal project early in planning • Early coordination and buy-in with local businesses that could be affected by closures and detours • Secure additional planning resources to monitor and update rapid renewal project approaches
	Inaccurate planning assumptions and projections Examples: • Inaccurate traffic projections • Inaccurate population growth projections • Intermodal transportation plans not coordinated or inaccurate	
Conduct early coordination – internal Examples: • Develop integrated team (technical disciplines, project development, finance, communications) • Prioritize planning studies on rapid renewal projects		

Table D-1. Project Phase: Planning

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Resources not available from all disciplines for advanced planning Examples: • Technical staff not available for research (e.g., right of way, utilities, etc.) • Technical staff not familiar with planning process (e.g., right of way, utilities, etc.)	
	Advanced planning for rapid renewal projects not coordinated with transportation network Examples: • Funding opportunities for alternative transportation modes makes advanced planning obsolete • Advancement of rapid renewal project creates strain on traditional planning areas	
Conduct early coordination – external Examples: • Develop stakeholder awareness • Gather political support • Establish single-point communication • Brand the project • Conduct public outreach / seek additional investment		
	Uncompleted or unfeasible rapid renewal project erode public trust Examples: • Funding for rapid renew project not available as “sold” to the public	

Table D-1. Project Phase: Planning

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Rapid renewal project identified in planning not feasible due to environmental constraints • Public opposition from small stakeholder groups successful in stopping project • Opposition from industry groups (e.g., trucking and freight stakeholder groups)	
	Planning partners do not have resources to partner in advancing rapid renewal projects Examples: • Metropolitan planning organizations do not have staff to advance rapid renewal project and still meet other commitments	

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Conduct early and comprehensive scoping Examples: • Obtain stakeholder input early • Develop and confirm purpose and need early • Develop and test viable alternatives early • Balance scope, budget and political goals of the project	**Project contains unrealistic scope considering budget and political landscape**	The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Conduct a thorough assessment of how much the agency is willing (or can afford) to spend on the project • Make an early decision on scope that is mandatory vs. discretionary, with due consideration for financing options and political/stakeholder concerns. • Determine plan for implementing what is determined to be discretionary scope • Consider multiple project phasing options early in the process so that the project can be staged
Employ master planning / integrated project development process Examples: • Integrate engineering, environmental analysis, agency coordination, public involvement into collaborative decision-making process	**Master planning / integrated development process is inefficient or poorly implemented**	Examples: • Conduct outreach within the agency to discuss how to best integrate functions • Early retention of any consultants who will be assisting agency's personnel • Consider using outside partnering consultant to assist in coordination efforts
Use innovative project delivery, including: • **Design/Build** • **Design/Build/Finance/ Operate/Maintain** • **CM at-risk** • **Public-Private Partnership (private**		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Secure enabling legislation early (applies to many) • Conduct outreach to the state Attorney General (AG) and obtain AG opinions

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
equity or debt) Examples: - Ensure authorizing legislation - Ensure agency has experienced staff - Develop project delivery selection methodology		for statutory areas that are unclear or evolving - Conduct broad training programs on alternative project delivery with staff - Utilize FHWA resources for training and education - Secure general engineering consultants with experience in innovative project delivery methods - Conduct outreach to other DOTs that have a history of success in implementing alternative delivery programs
	Owner not capable of managing the delivery method (could lead to delay in contracting; change in delivery method; etc.) For example, caused by: - Untrained internal resources - Management systems not established - Resources not available as needed - Lack of timely dispute resolution (e.g., from unclear documents; lack of experience)	- Implement training programs for all personnel involved in project delivery decisions - Develop programmatic approach for alternative delivery methods with policy statements and general guidelines prior to need for a specific project - Establish a specialized group within the agency to handle rapid renewal projects delivered through alternative project delivery methods - Use staff augmentation contracts to assist agency personnel in implementing the procurement and contracting of the project and assist in training - Develop comprehensive lessons learned from project experiences
	Delivery method not appropriate for the project (could lead to delay in contracting; change in delivery method; etc.).	See above. In addition: - Develop comprehensive process for

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	For example, caused by: • Method conflicts with owner goals • Project risk profile mismatched to delivery method • Stakeholders not aligned • Owner's goals change • No enabling legislation	project delivery selection and establishing project goals, with broad participation from interested agency departments • Integrate project delivery selection with risk registering process • Consider bringing key stakeholders into the training process and project delivery selection process
	Procurement protest pre-award (could lead to delay in contracting; change in delivery method; etc.) For example, caused by: • Insufficient history within owner organization with delivery method • Unfamiliarity of agency with evaluation of non-price factors • Unclear evaluation factors • Inappropriate discussions with proposers • Challenges to the legality of the statute allowing the delivery system	In addition to some of the items above (including training and lessons learned compilation): • Ensure that the team is supported by experienced individuals (internal or consultants) • Outreach to public to determine where the potential statutory challenges may lie • Develop a requirement in the procurement documents for any protests over the process (i.e., legality of the procurement) to be raised early rather than after any shortlist evaluations • Develop a comprehensive process for how communications with proposers will be handled
	Dispute post-award (could lead to delays and price increases) For example, caused by: • Inadequate scope definition • Ambiguous specifications • Overly active involvement of the agency in	In addition to the above: • Consider having a third party peer review of technical scoping documents to assess completeness, accuracy and whether they are overly prescriptive • Consider having a period of time

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	contractor's means and methods	immediately after award for contractor to assess project scope and determine whether there are any material problems with the RFP documents that could not have been determined during the proposal period • Develop an internal process and training for project personnel on how to review submittals
	Market cannot support selected delivery method and/or method restricts competition For example, caused by: • Contractors lack experience • Restrictions by agencies on ability of design professionals to participate on the contractor's team because of conflicts of interest	In addition to the above, particularly relative to legislative solutions and outreach: • Consider having a more liberal conflict of interest policy (see federal model) • Conduct regular meetings with contractor and consulting engineering associations to assess what is needed to obtain sufficient interest
	Other cost and/or schedule premium resulting from delivery method (aside from issues listed separately) For example: • Contractor perception of high risk • Contractor concern over whether the project is "real" given scope appearing to exceed budget	See above; In addition: • Have contracts with reasonable risk allocation • Ensure that the proposers understand that agency is taking steps to be a "good owner" in managing the process
Use innovative contract payment processes Examples: • Milestone construction-related payments • Availability payments for PPP projects		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Identify other agencies that have successfully used innovative payment terms • Investigate and implement best

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
• Incentives/disincentives • Warranty and O&M payment		practices • Consult with marketplace to evaluate what has worked well and what has not • Establish that contract payment process correlates with behavior changes expected from contracting teams
	Cost premiums resulting from payment structure For example: • Contractor unfamiliarity leads to pricing premiums • Contractor concerns over unreasonable risk (not getting paid)	In addition to the above: • Use outreach process to assess market interest in the alternative approach, particularly for innovative warranty, O&M or availability payments • Create balanced contracts that eliminate major uncertainty for contracting community • Determine financing costs (if any) to be incurred by the contractor in the innovative process • Assess the cost to benefit of using disincentives
	Insufficient market interest in innovative payment processes to create competition	In addition to the above: • Evaluate surety market to assess its concerns over the approach • Conduct regular meetings with contractor and consulting engineering associations to assess what is needed to obtain sufficient interest
Seek alternative financing Examples: • Grant Anticipation Revenue Vehicle (GARVEE) bonds • Generate revenue through user fees (e.g., HOV / HOT		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Secure enabling legislation early (applies to many), e.g., related to open road tolling (transponders vs. toll booths) and/or tolling enforcement.

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
lanes tolling)		• Retain an outside financial advisor to be integrally involved in the development of the project and financial modeling • Develop realistic revenue projections • Develop realistic scope, cost, schedule requirements • Develop financial terms early, including industry review • Re-package project (e.g., multiple, smaller projects) to improve market conditions • Obtain a detailed traffic and revenue study and financial model that can be used to assess the project and how the marketplace is likely to respond to the preferred financing approach • Assess the cost-to-benefit of using alternative financing, particularly in the event that financial close does not take place in a timely fashion

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Poor market conditions make securing financing difficult (reduced and/or delayed funding). Examples: • Difficult market • Market collapses • Proceeding on the assumption that there will be sufficient market interest to provide proposals on a revenue-negative project • Miscalculating the amount of agency-funds needed to make the project viable to the financing community	See above
	Enabling legislation not in place to allow alternative financing	In addition to the above: • Work with attorney general's office and state financing department to assess likelihood of passing such legislation • Consider lessons learned from jurisdictions where this has been used • Make early "go/-no-go" decision on project viability without alternative financing
	Changes in legislation before financial close (e.g., tolling, competing facilities) jeopardize alternative financing	• Ensure that RFP documents have mechanisms to address changes in law to provide assurances to financers that they are not evaluating a potential moving target • Ensure that there is a project contingency to fund changes in law • Conduct regular meetings with legislators to assess potential concerns and the likelihood of legislative changes
	Other delay in funding process Examples:	See above

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Approvals for grant funding or public loans (reduced and/or delayed funding) • Process complexity leads to delays • Revenue projections not strong enough to support/get required funding	
	Actual revenues significantly less than anticipated Examples: • Ability of concessionaire to live up to contract obligations • Bankruptcy of the concessionaire • For projects using availability payments, ability of agency to fund overruns • Impacts to O&M	In addition to the above: • Realistically determine whether the commercial deal is good for both sides • Use contracts that allow the agency to take over the project in event of financially distressed concessionaire • Ensure that the concessionaire has strong financial balance sheet • Develop a policy for how to establish and use reserves

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use alternative bonding or performance security Examples: • Letters of credit • Corporate guarantees		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Re-package the project (e.g., multiple, smaller projects with multiple contractors) to accommodate surety market or bonding capacity • Secure payment bond to protect subcontractors
	Surety market cannot support project's bond requirements Examples: • Contractual risks are too great • Duration of performance obligations are too long • Overall bond amounts are too great	In addition to the above: • Outreach to the surety market on the overall agency program as well as project specific terms and conditions • For projects in excess of $250 million, consider reducing bonding amounts • Evaluate legislative changes needed to have flexibility in bonding terms (including amount) • Use contracts that have reasonable risk allocation • Consider using a combination of bonds, letters of credit and guarantees on larger projects
	Bonding capability of contractor(s) not adequate Examples: • Project is considered too long in duration to tie up bonding capacity • Dollar value of project exceeds bonding limits	In addition to the above: • Outreach to the contracting community • Allow joint ventures • Consider using "staged" bonds, where warranty obligations are covered by a separate bond rather than the performance bond
	Lack of payment bond results in subcontractor protests or claims (subcontractors view that their	In addition to the above:

Table D-2. Project Phase: Project Scoping (including project delivery and funding / financing)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	payment rights are unprotected)	• Require payment bonds to be issued, even if the dollar value is less than the full contract value • Create trust fund obligations through legislation
	Contractor defaults (various degrees of severity)	In addition to the above: • Ensure that the contract has appropriate take-over language in the event of a default • Ensure that the performance security is stable and available • Provide notice to the surety of a problem • Develop payment provisions that do not allow the contractor to front-end load and be too far ahead of owner

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate the environmental documentation process Examples: • Leverage master planning (see Project Scoping) • Conduct early coordination (see Planning) • Identify documentation requirements early • Identify and avoid major impacts early (historical, cultural, archaeological)	Note: the individual risk categories (and their related examples, below) might apply to any or all of the renewal category examples (shown to the left).	
	Different type of documentation required Example causes or issues: • Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.), so more substantial documentation is required (e.g., EIS instead of EA) • Additional discipline studies are required • Additional (new) alternatives must be developed and documented • Documentation requirements change	The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Modify the project design to reduce the impacts that are triggering different type of documentation • Anticipate potential concerns with main alternatives, and develop additional alternatives early in process to address those concerns • Anticipate/plan for and/or start additional (targeted) discipline studies earlier to reduce impact to project schedule if they are later required • Develop alternate (or additional/more-detailed) documentation in parallel with presumed appropriate documentation to reduce impact to schedule if alternate documentation is later required

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Additional documentation required (but not a change in document type) Example causes or issues: • Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, uncertain impacts from new rapid-renewal methods, etc.) • Additional discipline studies are required (e.g., more-extensive cultural survey) • Additional (new) alternatives must be developed and documented	Similar to above
	Other delay to completion of environmental process related to attempted acceleration Example causes or issues: • Discipline studies take longer than planned in the accelerated schedule (e.g., gathering growing-season data) • Signatory agencies unable to accommodate accelerated process (e.g., consultation on Biological Assessment takes longer than planned; lack of staff to participate in accelerated process pre-approval; indecisive agency) • Stakeholders resistant to accelerated process (e.g., feel uncomfortable or "rushed" by the accelerated process)	• Early on, identify a quick-response team to address problems with the accelerated environmental process (might include actions listed below) • Early on, develop a contingency plan to accelerate discipline studies. For example: o Establish on-call contracts with discipline specialists who might be needed later o Identify additional staffing o Develop solutions for issues obtaining rights-of-entry for field visits • If not already done, provide staffing support for signatory agencies (and plan for it early so it's ready to go when needed) • If not already done, increase public and stakeholder outreach related to the accelerated process to ease concerns about the process

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Seek streamlined environmental approval process / approvals Examples: • Resolve appropriate environmental document type early • Seek streamlined Biological Assessment / consultation process • Provide staff to signatory agencies to expedite review		
	Approval / signatory organizations cannot accommodate streamlined processing / approval Example causes or issues: • Inadequate staffing or heavy workload • Incompatible process/procedures • Unresolved or unclear requirements • Unresolved disputes or agreements	• Early on, develop a contingency plan to mitigate problems with streamlined processing/approval. For example: o Identify a 'quick-response team' to address problems with the process o If not already done, provide staffing support for signatory agencies (and plan for it early so it's ready to go when needed) o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements • If not already done, increase public and stakeholder outreach related to the accelerated process to ease concerns about the process

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Review and approval process takes longer than anticipated for other reasons Example causes or issues: • Receive larger number or more-substantial comments (e.g., on draft document or to specific discipline reports) than anticipated	See all above
	Challenge to environmental documentation once determination has been issued Example causes or issues: • Challenge to determination by stakeholder or other third party, whether viable or frivolous	• Identify potential future sources of challenges and monitor (or perhaps even engage them positively) • Early on, develop a contingency plan to respond to a challenge if it occurs. For example: o Potentially take actions as outlined earlier for environmental documentation and process (above) o Identify on-call legal resources o Identify potential bargaining position (mitigation, design change, etc.), including securing relevant policy decisions/positions from leadership
Pursue accelerated environmental permitting Examples: • Develop permit applications coincident with design • Learn requirements early • Form multi-agency permitting teams (dispute resolution)		

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
• Provide staff to signatory agencies to expedite review		
	Development of permit application takes longer than anticipated Example causes or issues: • Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.) • Permit conditions different than anticipated (especially resulting from uncertainty in rapid-renewal element permitting) • Late changes to project design or environmental documentation	• Early on, develop a contingency plan to accelerate development of the permit application. For example: o Establish on-call contracts with discipline specialists who might be needed later o Identify additional staffing o Anticipate potential disputes over unclear requirements and work to avoid them • If not already done, provide staffing support for reviewing agencies (and plan for it early so it's ready to go when needed) • If not already done, increase public and stakeholder outreach related to the accelerated process to ease concerns about the process
	Delay in permit review or approval Example causes or issues: • Permitting agency uncomfortable with rapid-renewal elements • Stakeholders withhold support • Agency unable to manage or is not staffed for accelerated permitting process	• Early on, develop a contingency plan to mitigate problems with streamlined permit processing/approval. For example: o Identify a 'quick-response team' to address problems with the process o If not already done, provide staffing support for reviewing agencies (and plan for it early so it's ready to go when needed)

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
		o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Unanticipated or additional permits required Example causes or issues: • Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.) • Permit conditions different than anticipated (especially resulting from uncertainty in rapid-renewal element permitting)	See above
	Challenge to permits once issued Example causes or issues: • Stakeholders or opposition groups attempt to hold up project	• Identify potential future sources of challenges and monitor (or perhaps even engage them positively) • Early on, develop a contingency plan to respond to a challenge if it occurs. For example: o Potentially take actions as outlined earlier for permit development (above) o Identify on-call legal resources o Identify potential bargaining position (mitigation, design change, etc.), including securing relevant policy decisions/positions from leadership
Streamline mitigation planning and implementation Examples: • Utilize wetland banks • Leverage/improve existing mitigation sites (onsite or offsite), potentially including partnering with other		

Table D-3. Project Phase: Environmental Process

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
agencies • Proactively implement noise or view mitigation		
	Streamlined mitigation effort won't work (management issue) Example causes or issues: • Stakeholder or governing agency doesn't approve plan (e.g., doesn't acknowledge or believe that the plan will work; mitigation not in same drainage basin as impacts) • Unforeseen regulatory constraint • Unable to acquire required mitigation site (or unacceptable delay)	• Early on, develop a contingency plan to respond to a overcome resistance to the proposed mitigation plan if it occurs. For example: o Anticipate potential concerns with the proposed mitigation plan, and develop additional alternative mitigation concepts early in design to address those concerns o Identify potential bargaining position (different or more mitigation, design change, etc.), including securing relevant policy decisions/positions from leadership
	Streamlined mitigation effort won't work (technical issue) Example causes or issues: • Plan doesn't adequately mitigate impacts (e.g., need more or different mitigation) • Plan not feasible from a technical standpoint (e.g., can't sustain over time) • Wetland bank fails and can't supply project's mitigation	• Modify the design to reduce impacts • Anticipate potential technical issues with the proposed mitigation plan, and develop additional alternative mitigation concepts early in design to address those issues

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate the design process Examples: • Overlap design activities (make less sequential) • Involve stakeholders early • Learn requirements and constraints early • Resolve significant design decisions early • Equally develop and 'carry' multiple alternatives until selection of preferred alternative • Ensure adequate staffing • Employ design exceptions as strategy • Use standardized designs for repetitive items		
	Key design decisions are delayed Example causes or issues: • Technical – the current design has a significant technical problem • Management – the current design does not have management support • Political – the current design does not have political support or meet existing political commitments Note: this type of delay could result from (and be included under) other risk categories listed in this document. Don't double-count impacts.	• Early on, develop a contingency plan to accelerate design in the face of decision delays. For example: o Establish on-call contracts with discipline specialists who might be needed later o Identify additional staffing o Develop alternative design concepts and/or carry parallel design documentation to reduce impacts
	Other key project-related decisions are delayed or changed	Similar to above

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Example causes or issues: • Funding delayed • Purpose and need, project definition, and/or scope significantly modified late in design, requiring re-design • Project delivery method changed (which affects design documentation) Note: this type of delay could result from (and be included under) other risk categories listed in this document. Don't double-count impacts.	
	Stakeholders not able (or willing) to support accelerated design process Example causes or issues: • Not able to make internal decisions or provide input on accelerated schedule • Do not support current alternative	• Early on, develop a contingency plan to respond to and overcome potential inability to support or resistance to the proposed design. For example: o Anticipate potential concerns with the proposed design, and develop additional alternatives or concepts early in design to address those concerns o Identify potential bargaining position (design change, mitigation, etc.), including securing relevant policy decisions/positions from leadership o Provide staffing support to stakeholders to educate stakeholders on and/or help them evaluate the design
	Encounter unanticipated changes in design standards Example causes or issues:	• Reduce the likelihood of being 'surprised' by conducting frequent searches for potential design changes /

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Seismic (geotechnical, structural) • Hydraulic/stormwater • Environmental Note: could be covered separately under specific design disciplines.	stay in contact with issuing agencies • Reduce the impacts if a change occurs by evaluating impacts from potential standards changes early; potentially carry develop multiple design alternatives • Employ performance specifications to allow for contractor innovation
	Standardized designs not available or suitable Example causes or issues: • Not cost-effective or technically effective	• Modify design (or specs) to allow standardized designs (when feasible) • Develop standardized designs for repeatable elements (if possible)
	Delay in approval of design exceptions, or denial of design exceptions Example causes or issues: • Requested exceptions create too many adverse impacts • Requested exceptions not acceptable for other reasons (e.g., stakeholder concerns)	• Early on, develop a contingency plan to accelerate approval of design exceptions. For example: o Document how proposed design achieves objectives despite (or perhaps because of) proposed exceptions o Develop process for rapidly resolving any issues with approval authority • Early on, develop a contingency plan to mitigate impacts of denial of exceptions. For example: o Develop alternative design concepts and/or carry parallel design documentation to reduce impacts
	Staffing for accelerated design not available Example causes or issues:	• Early on, develop a contingency plan to accelerate design in the face of staffing

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions

	- Staffing re-directed to higher priorities
	- Key technical staff not available at critical times
		issues. For example (if not already done):
		  o Establish on-call contracts with discipline specialists who might be needed later
		  o Identify additional staffing
		- Employ performance specifications to allow for contractor innovation

Seek streamlined design approvals Examples: - Speed processing by providing staff support to approval authority - Coordinate early and often with approval authority		

	Owning agency not staffed or structured for streamlined approvals
	Example causes or issues:
	- Workload too great or right staff not available
	- Existing process doesn't accommodate accelerated approvals
		- Early on, develop a contingency plan to mitigate problems with streamlined processing/approval. For example:
		  o Identify a 'quick-response team' to address problems with the process
		  o Establish on-call contracts with discipline specialists who might be needed during approvals process
		  o Identify additional internal staffing and have 'on-hand'

	Stakeholders unable or unwilling to accommodate streamlined approvals Example causes or issues: - Not able to review or make internal	- Early on, develop a contingency plan to mitigate problems with streamlined processing/approval. For example: o Identify a 'quick-response team'

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	decisions/approvals on the streamlined schedule • Do not support submitted design	to address problems with the process o If not already done, provide staffing support for approving stakeholders (and plan for it early so it's ready to go when needed) o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements
	Delays to other activities delay the design's approval Example causes or issues: • Delay to environmental process • Delay to permitting Note: this type of delay could result from (and be included under) other risk categories listed in this document. Don't double-count impacts.	• Conduct early and frequent coordination with other disciplines, and assess potential impacts to design from delays to those activities • Elevate issues for higher (and hopefully more timely) resolution
	Mistakes in the design delay the design's approval Example causes or issues: • Mistakes resulting from accelerated pace of the design process (e.g., incomplete or inadequate checks and reviews)	• Conduct concept and design reviews (internal or external) early on to identify potential problems • Conduct early and frequent coordination with other disciplines to avoid miscommunication, misunderstanding, etc. • Have accelerated design approval process in place (if don't already) to mitigate delay
Hold industry constructability reviews early		

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Examples: • Engage non-bidding contractors to review and 'war game' construction phasing plan • Seek contractor opinion (non-conflicted) on potential new rapid-renewal construction techniques • Seek contractor opinion (non-conflicted) on other ways to accelerate construction (e.g., overlap activities)		
	Constructability review not allowed (policy) Example causes or issues: • Concerns about conflicts of interest • Other existing policy prohibits engaging contracting industry for this purpose	• Seek change in policy early on to allow reviews when needed
	Constructability review not successful Example causes or issues: • Unable to engage qualified contractors with no conflicts of interest • Feedback is biased or otherwise unreliable or unhelpful	• Early on, ensure have a viable pool of independent and available contractors (e.g., perhaps by using retired or out-of-town contractors)
	Constructability review successful, but leads to significant changes in design Example causes or issues: • Fatal flaw found, requiring re-design • Significant change in concept recommended	• Hold reviews early so that impact to design schedule is minimized • Be ready to make quick decisions on contractor recommendations (e.g., elevate and quickly resolve)

Table D-4a. Project Phase: Design and Construction (General Principles)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	and reviewed/accepted, leading to re-design	• Develop and carry alternative designs and/or construction phasing/staging plans throughout the design process (one might reflect contractor recommendations)

Table D-4b. Project Phase: Design and Construction - Structures

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use innovative and/or long-life designs		
	Innovative and long-life designs not the right solution Example causes or issues: • Inadequate funding • Adequate funding but innovative and long-life designs are not the most cost-effective approach • Innovative designs too “risky” (e.g., no demonstrated performance history; uncertain constructability) • Interim (short-term) solution more appropriate (e.g., adjacent or follow-on project will build permanent solution)	• Develop additional alternatives or concepts early in design to reduce delay if innovative or long-life designs don’t work out • Secure funding in advance for long-life designs • Gather performance information for innovative designs early (before selecting design) • Coordinate with adjacent projects early to better anticipate any interim solutions required from current project
Use alternative and/or long-life materials Examples: • High-performance steel • High-performance concrete • Lightweight aggregates • Fiber reinforcement		
	Candidate materials won’t work (technical issues identified during design) Example causes or issues: • Can’t get materials permitted • Planned materials not the best choice for desired structure (e.g., strength, stiffness, durability, cost) • Planned materials too “risky” (e.g., no	• Test materials and materials designs early on pilot section or parallel project of smaller scale • Develop additional alternatives or concepts early in design to reduce delay if candidate materials don’t work out • Gather performance information for

Table D-4b. Project Phase: Design and Construction - Structures

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	demonstrated performance history) - Other project conditions preclude the materials' application (e.g., too cold during construction)	candidate materials early (before selecting them for design) (i.e., evaluate feasibility early on)
	Delay in procuring candidate materials Example causes or issues: - Inadequate supply when needed (delay); for example, material supply source doesn't meet environmental requirements - Costs higher (other than because of limited supply) and/or benefits not as great as anticipated, so delay in decision to use the materials - Required expertise in using materials not available when needed	- Early on, identify material sources and evaluate potential availability (i.e., conduct feasibility study) - Have contractors guarantee supply in contract, or make provisions for schedule recovery or use of alternative, equivalent materials if material procurement is delayed
Re-use or rehabilitate existing components Examples: - Rehab columns and piers - Rehab bridge decks - Supplement existing foundations		
	Rehabilitation not the best option (identified during design) Example causes or issues: - Replacement turns out to be more technically viable o Improved compatibility with new structures o Difficulty performing rehabilitation o Rehabilitation does not provide desired performance	- In parallel, develop design for replacement/new structure (to reduce delay if rehabilitation turns out to not be the best option) - Gather/confirm technical and cost performance information for existing structures early in design, to help make early decisions on approach and funding

Table D-4b. Project Phase: Design and Construction - Structures

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Replacement turns out to be more cost-effective (e.g., due to limited amount of rehabilitation required)	
	Problems with rehabilitation during construction Example causes or issues: • Discover that more or different rehabilitation is required (e.g., selected technique won't deliver required performance) • Discover that rehabilitation won't work (e.g., structure is in worse condition than previously believed)	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur • Select contractor with demonstrated success in candidate rehabilitation methods • Ensure contract provisions allow for rapid and fair resolution of these issues
Pre-fabricate key elements Examples: • Full-depth decks • Partial-depth decks • Decks with girders • Decks with barriers • Retaining-wall panels • Noise-wall panels		
	Candidate pre-fabrication technique won't work (technical issues identified during design) Example causes or issues: • Transportation of pre-fabricated elements difficult or not possible • Inadequate site access (e.g., can't maneuver on-site) • Planned structure not suitable for construction via pre-fabricated elements • Other project conditions preclude the use of	• In parallel, develop design for alternative pre-fabrication or on-site fabrication (to reduce delay if pre-fabrication turns out to not be the best option) • Gather/confirm technical and cost performance information for pre-fabricating structures early in design, to help make early decisions on approach, procurement, and funding

Table D-4b. Project Phase: Design and Construction - Structures

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	pre-fabrication	• Employ performance specifications to allow for contractor innovation
	Delay in procuring pre-fabricated elements Example causes or issues: • Fabrication facility not available when needed • Problems with design (e.g., errors) or constructability discovered during fabrication process • Costs higher and/or benefits not as great as anticipated, so delay in decision to use the pre-fabricated elements	• Early on, identify fabricators and evaluate potential availability of required items (i.e., conduct feasibility study) • Have contractors guarantee availability and schedule of pre-fabricated items in contract, or make provisions for schedule recovery if procurement is delayed
	Problems with pre-fabricated elements during construction Example causes or issues: • Specialized construction equipment malfunctions or breaks down • Difficulty maneuvering pre-fabricated elements • Damage pre-fabricated elements during erection • Other construction-related accident	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur • Select contractor with demonstrated success in candidate pre-fabricated construction • Ensure contract provisions allow for rapid and fair resolution of these issues
Use rapid-placement/construction techniques Examples: • Longitudinal launching • Horizontal skidding • Self-propelled modular transporters (SPMTs) • Barges • Temporary structures		

Table D-4b. Project Phase: Design and Construction - Structures

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Candidate rapid-placement technique won't work (technical issues identified during design) Example causes or issues: • Inadequate access (e.g., can't get SPMTs into position) • Can't get technique permitted • Planned structure not suitable for construction via the technique • SPMTs will cross utilities that cannot be disrupted • Other project conditions preclude the technique's application	• In parallel, develop design for alternative rapid-replacement or accelerated traditional technique (to reduce delay if chosen rapid-replacement technique turns out to not be the best option) • Gather/confirm technical and cost performance information for the intended rapid-replacement technique early in design, to help make early decisions on approach, procurement, and funding • Coordinate with affected utilities early in the process and provide partnering facilitator if needed • Employ performance specifications to allow for contractor innovation
	Delay in procuring rapid-replacement equipment and/or specialized labor Example causes or issues: • Specialized equipment or labor not available when needed • Costs higher and/or benefits not as great as anticipated, so delay in decision to use the technique	• Early on, identify sources of relevant equipment and labor, and evaluate potential availability (i.e., conduct feasibility study) • Have contractors guarantee availability and schedule of specialized equipment items in contract, or make provisions for schedule recovery (e.g., alternative equipment; alternative construction method) if procurement is delayed
	Problems with rapid-replacement technique during construction Example causes or issues: • Specialized equipment malfunctions or breaks down	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs (using alternative construction techniques) and/or remedial measures

Table D-4b. Project Phase: Design and Construction - Structures

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	- Technique doesn't work as intended (various reasons) - Construction accident	(for selected technique) to reduce delay if problems occur - Select contractor with demonstrated success using the proposed rapid-placement technique - Ensure contract provisions allow for rapid and fair resolution of these issues - Conduct thorough survey of existing conditions, including independent peer review - Develop contingency plans for the case that technique does not work as intended

Table D-4c. Project Phase: Design and Construction – Geotechnical and Earthwork

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use innovative and long-life designs		
	Innovative and long-life designs not the right solution Example causes or issues: • Inadequate funding • Adequate funding but innovative and long-life designs not the most cost-effective approach • Innovative designs too “risky” (e.g., no demonstrated performance history; uncertain constructability) • Interim (short-term) solution more appropriate (e.g., follow-on project will build permanent solution)	• Develop additional alternatives or concepts early in design to reduce delay if innovative or long-life designs don’t work out • Secure funding in advance for long-life designs • Gather performance information for innovative designs early (before selecting design) • Coordinate with adjacent projects early to better anticipate any interim solutions required from current project
Use alternative and/or long-life materials Examples: • Flowable fill; foamed concrete; geofoam • Stabilize subgrade (e.g., with fly ash)		
	Candidate materials won’t work (technical issues identified during design) Example causes or issues: • Can’t get materials permitted • Planned materials not the best choice for desired geotechnical structure (e.g., strength, hydraulic conductivity, compressibility, durability, cost) • Planned materials too “risky” (e.g., no	• Test materials and materials designs early on pilot section or parallel project of smaller scale • Develop additional alternatives or concepts early in design to reduce delay if candidate materials don’t work out • Gather performance information for candidate materials early (before

Table D-4c. Project Phase: Design and Construction – Geotechnical and Earthwork

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	demonstrated performance history) • Other project conditions preclude the materials' application (e.g., too cold during construction)	selecting them for design) (i.e., evaluate feasibility early on) • Employ performance specifications to allow for contractor innovation
	Delay in procuring candidate materials Example causes or issues: • Inadequate supply when needed (delay); for example, material supply source doesn't meet environmental requirements • Costs higher (other than because of limited supply) and/or benefits not as great as anticipated, so delay in decision to use the materials • Required expertise in using materials not available when needed	• Early on, identify material sources and evaluate potential availability (i.e., conduct feasibility study) • Have contractors guarantee supply in contract, or make provisions for schedule recovery or use of alternative, equivalent materials if material procurement is delayed
Re-use or rehabilitate existing components Examples: • Supplement existing foundations (e.g., micropiles • Stabilize existing foundations (e.g., with ground support)		
	Rehabilitation not the best option (identified during design) Example causes or issues: • Replacement turns out to be more technically viable o Improved compatibility with new structures o Difficulty performing rehabilitation	• In parallel, develop design for replacement/new structure (to reduce delay if rehabilitation turns out to not be the best option) • Gather/confirm technical and cost performance information for existing structures early in design, to help make early decisions on approach and

Table D-4c. Project Phase: Design and Construction – Geotechnical and Earthwork

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	o Rehabilitation does not provide desired performance • Replacement turns out to be more cost-effective (e.g., due to limited amount of rehabilitation required)	funding
	Problems with rehabilitation during construction Example causes or issues: • Discover that more or different rehabilitation is required (e.g., selected technique won't deliver required performance) • Discover that rehabilitation won't work (e.g., foundation or structure is in worse condition than previously believed) • Construction accident	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur • Select contractor with demonstrated success in candidate rehabilitation methods • Ensure contract provisions allow for rapid and fair resolution of these issues
Pre-fabricate key elements		
	Candidate pre-fabrication technique won't work (technical issues identified during design) Example causes or issues: • Transportation of pre-fabricated elements difficult or not possible • Inadequate site access (e.g., can't maneuver on-site) • Planned geotechnical structure not suitable for construction via pre-fabricated elements • Other project conditions preclude the use of pre-fabrication	• In parallel, develop design for alternative pre-fabrication or on-site fabrication (to reduce delay if pre-fabrication turns out to not be the best option) • Gather/confirm technical and cost performance information for pre-fabricating geotechnical structures early in design, to help make early decisions on approach, procurement, and funding • Employ performance specifications to allow for contractor innovation
	Delay in procuring pre-fabricated elements Example causes or issues: • Fabrication facility not available when needed	• Early on, identify fabricators and evaluate potential availability of required items (i.e., conduct feasibility study)

Table D-4c. Project Phase: Design and Construction – Geotechnical and Earthwork

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Problems with design (e.g., errors) or constructability discovered during fabrication • Costs higher and/or benefits not as great as anticipated, so delay in decision to use the pre-fabricated elements	• Have contractors guarantee availability and schedule of pre-fabricated items in contract, or make provisions for schedule recovery if procurement is delayed
	Problems with pre-fabricated elements during construction Example causes or issues: • Specialized construction equipment malfunctions or breaks down • Difficulty maneuvering pre-fabricated elements • Damage pre-fabricated elements during construction • Other construction-related accident	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur • Select contractor with demonstrated success in candidate pre-fabricated construction • Ensure contract provisions allow for rapid and fair resolution of these issues

Table D-4c. Project Phase: Design and Construction – Geotechnical and Earthwork

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use rapid-placement/construction techniques Examples: • Top-down excavation support • Innovative ground improvement • Rapid-embankment consolidation / construction • Intelligent compaction equipment		
	Candidate rapid-placement technique won't work (technical issues identified during design) Example causes or issues: • Inadequate access (e.g., can't get specialized equipment into position) • Can't get technique permitted • Planned geotechnical structure not suitable for construction via the technique • Other project conditions preclude the technique's application	• In parallel, develop design for alternative rapid-replacement or accelerated traditional technique (to reduce delay if chosen rapid-replacement technique turns out to not be the best option) • Gather/confirm technical and cost performance information for the intended rapid-replacement technique early in design, to help make early decisions on approach, procurement, and funding
	Delay in procuring rapid-replacement equipment and/or specialized labor Example causes or issues: • Specialized equipment or labor not available when needed • Costs higher and/or benefits not as great as anticipated, so delay in decision to use the technique	• Early on, identify sources of relevant equipment and labor, and evaluate potential availability (i.e., conduct feasibility study) • Have contractors guarantee availability and schedule of specialized equipment items in contract, or make provisions for schedule recovery (e.g., alternative

Table D-4c. Project Phase: Design and Construction – Geotechnical and Earthwork

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
		equipment; alternative construction method) if procurement is delayed
	Problems with rapid-placement technique during construction Example causes or issues: • Specialized equipment malfunctions or breaks down • Technique doesn't work as intended (various reasons) • Construction accident	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs (using alternative construction techniques) and/or remedial measures (for selected technique) to reduce delay if problems occur • Select contractor with demonstrated success using the proposed rapid-placement technique • Ensure contract provisions allow for rapid and fair resolution of these issues

Table D-4d. Project Phase: Design and Construction – Drainage / Stormwater Management

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use innovative and long-life designs Examples: • Seek sustainable/natural solutions for treatment		• Work with interdisciplinary team to identify alternative locations and technologies to assist in drainage / stormwater management
	Innovative and/or long-life designs not the right solution Example causes or issues: • Innovative and long-life designs are not the most cost-effective or schedule appropriate approach • Innovative designs too "risky" (e.g., no demonstrated performance history; uncertain constructability) • Interim (short-term) solution more appropriate (e.g., adjacent or follow-on project will build permanent solution)	
Use alternative and/or long-life materials Examples: • Natural materials for conveyance, detention, and treatment structures/ponds • Utilize materials that allow for rapid installation and subsequent construction		

Table D-4d. Project Phase: Design and Construction – Drainage / Stormwater Management

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Candidate materials won't work (technical issues identified during design) Example causes or issues: • Can't get materials permitted • Planned materials will not work within project physical project constraints • Planned materials too "risky" (e.g., no demonstrated performance history)	• Test materials and materials designs early on pilot section or parallel project of smaller scale • Concurrently create a design with traditional material as a contingency • Develop contingency plans to achieve rapid construction via more traditional means (e.g., phased placement, alternative shifts, etc.) • Gather performance information for candidate materials early (before selecting them for design) (i.e., evaluate feasibility early on) • Employ performance specifications to allow for contractor innovation
	Delay in procuring candidate materials Example causes or issues: • Inadequate supply when needed (delay); for example, material supply source doesn't meet environmental requirements • Costs higher (other than because of limited supply) and/or benefits not as great as anticipated, so delay in decision to use the materials • Required expertise in using materials not available when needed	• Early on, identify material sources and evaluate potential availability (i.e., conduct feasibility study) • Have contractors guarantee supply in contract, or make provisions for schedule recovery or use of alternative, equivalent materials if material procurement is delayed
Re-use or rehabilitate existing components Examples: • Culverts • Tie into existing drainage system (outfalls, treatment)		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Conduct early testing of existing components • Explore designs that involve modifications to existing components

Table D-4d. Project Phase: Design and Construction – Drainage / Stormwater Management

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Rehabilitation not the best option (identified during design) Example causes or issues: • Replacement turns out to be more technically viable o Improved compatibility with new drainage facilities o Difficulty performing rehabilitation o Rehabilitation does not provide desired performance • Replacement turns out to be more cost-effective (e.g., due to limited amount of rehabilitation required)	• In parallel, develop design for replacement/new drainage facility (to reduce delay if rehabilitation turns out to not be the best option) • Gather/confirm technical and cost performance information for existing facility early in design, to help make early decisions on approach and funding
	Problems with rehabilitation during construction Example causes or issues: • Discover that more or different rehabilitation is required (e.g., selected technique won't deliver required performance) • Discover that rehabilitation won't work (e.g., existing drainage facility is in worse condition than previously believed) • Construction accident	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur • Select contractor with demonstrated success in candidate rehabilitation methods • Ensure contract provisions allow for rapid and fair resolution of these issues
Pre-fabricate key elements Examples: • Replacement culverts • Inlet and outlet structures		
	Candidate pre-fabrication technique won't work (technical issues identified during design) Example causes or issues:	• In parallel, develop design for alternative pre-fabrication or on-site fabrication (to reduce delay if pre-fabrication turns out to not be the best

Table D-4d. Project Phase: Design and Construction – Drainage / Stormwater Management

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Transportation of pre-fabricated elements difficult or not possible • Inadequate site access (e.g., can't maneuver on-site) • Other project conditions preclude the use of pre-fabrication	option)
	Delay in procuring pre-fabricated elements Example causes or issues: • Fabrication facility not available when needed • Problems with design (e.g., errors) or constructability discovered during fabrication process • Costs higher and/or benefits not as great as anticipated, so delay in decision to use the pre-fabricated elements	• Early on, identify fabricators and evaluate potential availability of required items (i.e., conduct feasibility study) • Have contractors guarantee availability and schedule of pre-fabricated items in contract, or make provisions for schedule recovery if procurement is delayed
	Problems with pre-fabricated elements during construction Example causes or issues: • Specialized construction equipment malfunctions or breaks down • Difficulty maneuvering pre-fabricated elements • Damage pre-fabricated elements during construction • Other construction-related accident	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur • Select contractor with demonstrated success in candidate pre-fabricated construction • Ensure contract provisions allow for rapid and fair resolution of these issues

Table D-4e. Project Phase: Design and Construction – Roadway, Geometrics, and ITS

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use innovative and long-life designs Examples: • Consider alternative alignment / geometrics • Provide alternative access		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Conduct early and thorough investigation of existing alignment / geometrics to optimize reuse and minimize disruption during construction • Study use of alternative technical solutions for ITS that may allow for reuse of existing infrastructure • Develop additional alternatives or concepts early in design to reduce delay if innovative or long-life designs don't work out • Secure funding in advance for long-life designs • Gather performance information for innovative designs early (before selecting design)
	Innovative designs require exemptions from FHWA or other agency Examples: • Alternative alignment does not meet current design standards • Innovative ITS design does not meet the approval of FHWA under current standards	
Use alternative and long-life equipment Examples: • Ensure compatibility with existing system		

Table D-4e. Project Phase: Design and Construction – Roadway, Geometrics, and ITS

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Candidate equipment won't work (technical issues identified during design) Example causes or issues: • Planned equipment not compatible with equipment in adjacent locations • Planned materials too "risky" (e.g., no demonstrated performance history)	
Re-use or rehabilitate existing components Examples: • Fiber backbone • Communications equipment		
	Testing of existing components is not reliable Examples: • Existing components cannot be accessed for testing • Adequate testing methods not available • Testing samples do not reflect the condition of the entire component	
	Existing component will not be compatible with new design or construction method Examples: • Impossible to integrate existing component with new design • Existing component will be damaged during construction	

Table D-4f. Project Phase: Design and Construction – Pavement

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use innovative and long-life designs Examples: • Conduct life-cycle analysis (e.g., asphalt vs. concrete) • Consider maintenance requirements • Establish performance indicators	**Innovative and long-life designs not the right solution** Example causes or issues: • Inadequate funding • Adequate funding but innovative and long-life designs not the most cost-effective approach • Innovative designs too "risky" (e.g., no demonstrated performance history; uncertain constructability) • Interim (short-term) solution more appropriate (e.g., follow-on project will build permanent solution)	• Develop additional alternatives or concepts early in design to reduce delay if innovative or long-life designs don't work out • Secure funding in advance for long-life designs • Gather performance information for innovative designs early (before selecting design) • Coordinate with adjacent projects early to better anticipate any interim solutions required from current project • Employ performance specifications to allow for contractor innovation
Use alternative and long-life materials Examples: • Stone matrix asphalt (SMA) • Continuously-reinforced concrete pavement (CRCP) • Polymer asphalt • Composite pavement • Sub-grade treatment/stabilization		
	Candidate materials won't work (technical issues identified during design) Example causes or issues: • Can't get materials permitted • Planned materials not the best choice for desired pavement performance (e.g., durability, cost)	• Test materials and materials designs early on pilot section or parallel project of smaller scale • Develop additional alternatives or concepts early in design to reduce delay if candidate materials don't work out

Table D-4f. Project Phase: Design and Construction – Pavement

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Planned materials too "risky" (e.g., no demonstrated performance history) • Other project conditions preclude the materials' application (e.g., too cold during construction)	• Gather performance information for candidate materials early (before selecting them for design) (i.e., evaluate feasibility early on) • Employ performance specifications to allow for contractor innovation
	Delay in procuring candidate materials Example causes or issues: • Inadequate supply when needed (delay); for example, material supply source doesn't meet environmental requirements • Costs higher (other than because of limited supply) and/or benefits not as great as anticipated, so delay in decision to use the materials • Required expertise in using materials not available when needed	• Early on, identify material sources and evaluate potential availability (i.e., conduct feasibility study) • Have contractors guarantee supply in contract, or make provisions for schedule recovery or use of alternative, equivalent materials if material procurement is delayed
Re-use or rehabilitate existing components Examples: • Rubblize / recycle existing pavement		
	Rehabilitation not the best option (identified during design) Example causes or issues: • Replacement turns out to be more technically viable o Improved compatibility with new or adjacent pavement sections o Difficulty performing rehabilitation o Rehabilitation does not provide	• In parallel, develop design for replacement pavement alternative (to reduce delay if rehabilitation turns out to not be the best option) • Gather/confirm technical and cost performance information for existing pavement early in design, to help make early decisions on approach and funding

Table D-4f. Project Phase: Design and Construction – Pavement

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	desired performance - Replacement turns out to be more cost-effective (e.g., due to limited amount of rehabilitation required)	
	Problems with rehabilitation during construction Example causes or issues: - Discover that more or different rehabilitation is required (e.g., selected technique won't deliver required performance) - Discover that rehabilitation won't work (e.g., pavement is in worse condition than previously believed) - Construction accident	- Either internally or through contractor: Try to anticipate potential problems in advance, and then develop alternative designs and/or remedial measures to reduce delay if problems occur - Select contractor with demonstrated success in candidate rehabilitation methods - Ensure contract provisions allow for rapid and fair resolution of these issues
Pre-fabricate key elements Examples: - Roadway panels (concrete, pre-stressed)		
	Candidate pre-fabrication technique won't work (technical issues identified during design) Example causes or issues: - Transportation of pre-fabricated elements difficult or not possible - Inadequate site access (e.g., can't maneuver on-site) - Planned pavement section not suitable for construction via pre-fabricated elements - Other project conditions preclude the use of pre-fabrication	- In parallel, develop design for alternative pre-fabrication or on-site fabrication (to reduce delay if pre-fabrication turns out to not be the best option) - Gather/confirm technical and cost performance information for pre-fabricating pavement sections/panels early in design, to help make early decisions on approach, procurement, and funding
	Delay in procuring pre-fabricated elements Example causes or issues:	- Early on, identify fabricators and evaluate potential availability of required

Table D-4f. Project Phase: Design and Construction – Pavement

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Fabrication facility not available when needed • Problems with design (e.g., errors) or constructability discovered during fabrication • Costs higher and/or benefits not as great as anticipated, so delay in decision to use the pre-fabricated elements	items (i.e., conduct feasibility study) • Have contractors guarantee availability and schedule of pre-fabricated items in contract, or make provisions for schedule recovery if procurement is delayed

Table D-4g. Project Phase: Design and Construction – Maintenance of Traffic (MOT)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
		The following potential risk-management actions could apply to a number of the risk categories in the column to the left: • Use performance-based specs • Use contractor incentives at key coordination points within contract and between contracts in a phased situation • Reduce traffic demand during closures. Examples: o Provide alternative modes o Provide additional alternate routes • Conduct early coordination with agencies and other stakeholders. Examples: o Presentation of case studies o Additional outreach o Early preparation of business case for closure • Seek early contractor involvement / constructability reviews • Conduct detailed (or earlier) traffic and/or safety analysis • Develop multiple alternatives early, including alternative staging or closures • Develop contingency plan for implemented closures

Table D-4g. Project Phase: Design and Construction – Maintenance of Traffic (MOT)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use innovative MOT strategies Examples: • Provide alternative modes • Provide alternative routes • Utilize creative closure strategies (incentive/disincentive; directional closures; total vs. partial closures) • Develop and 'carry' alternative MOT plans		
	Planned closures and related detour routes not allowed (management issue) Example causes or issues: • Local agency won't approve (various reasons) • Owning agency won't approve (various reasons) • Not viable/allowed by project delivery/contracting approach • Contractor won't reasonably bid the approach	
	Planned closures and related detour routes won't work (technical issue identified during design) Example causes or issues: • Unacceptable traffic capacity • Unacceptable safety impacts (to public or workers) • Unacceptable noise, dust, vibration, or other impacts to adjacent public	
	Planned closures and related routes are not the most efficient Example causes or issues:	

Table D-4g. Project Phase: Design and Construction – Maintenance of Traffic (MOT)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	• Another plan identified later which could work better (e.g., different or more closures; alternate routes instead of closures)	
	Implemented closure plan doesn't work (during construction) Example causes or issues: • Causes unacceptable traffic impacts • Creates unacceptable ancillary impacts (e.g., adjacent businesses)	
Test the MOT plan prior to construction Examples: • Simulate plan performance (e.g., using traffic models) • 'War game' the MOT plan with constructors (e.g., on a table-top project graphic, stepping through the construction staging/sequencing)	Similar to above.	

Table D-5a. Project Phase: Right-of-Way (ROW)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate ROW planning Examples: • Overlap ROW planning with project design and environmental activities • Coordinate early and often with design team • Carry multiple alternatives • Provide additional staff to support planning and appraisals • Approach sellers early with plans • Seek accelerated ROW funding • Seek streamlined ROW plan approval process		
	Late changes to the design cause delay in ROW planning Example causes or issues: • Change in design late in process cascades to ROW design changes (especially if ROW planning and design are overlapped), resulting in delay in agreements and/or ROW plan review/approval	• Early on, develop a contingency plan to accelerate ROW planning after late design changes. For example: o Develop and carry multiple design alternatives, and have corresponding ROW plans partially developed, to reduce impact if design changes o Coordinate early and often with design team o Early on, establish on-call contracts with real-estate appraisal specialists who might be needed later

Table D-5a. Project Phase: Right-of-Way (ROW)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	ROW plans not completed as planned (other than from design changes) Example causes or issues: • Delay in review and/or approval of plans. For example: o Design/planning schedule too aggressive o Inadequate staffing o Agency waiting for project funding or contractor NTP • Accelerating pace of development in project area triggers plan revision	• Early on, develop a contingency plan to mitigate problems reaching utility agreements. For example: o Identify a 'quick-response team' to address problems with the process o If not already done, establish a process to quickly resolve problems with the plans or clarify requirements
Accelerate ROW acquisition Examples: • Seek accelerated ROW funding • Conduct advance ROW acquisition / Prioritize parcels for acquisition (get what's needed to start construction first) • Ensure adequate staffing • Seek willing sellers (e.g., better offers) • Provide relocation assistance to displaced tenants • Conduct accelerated environmental remediation/clearance of select parcels		
	Funding for accelerated or advance ROW	Coordinate early and often with program

Table D-5a. Project Phase: Right-of-Way (ROW)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	acquisition delayed or reduced	management to ensure funding is approved and available when needed
	Problems procuring critical (high-priority) parcels Example causes or issues: • Challenge to possession and use, condemnation, or other seller action that delays DOT ability to occupy parcels and/or increases ROW cost • Delays relocating tenants offsite, such as: o Relocation effort larger than anticipated o No suitable replacement property/facility found o Legal challenge to relocation plan • Unanticipated contamination discovered, requiring remediation before site can be used • Delays demolishing structures on-site (other than from contamination issues) • Encounter unanticipated utilities on-site, requiring relocation before can use site • Other delays obtaining rights-of-entry • Staffing shortage (can't complete acquisition offers as planned)	• Early on, develop a contingency plan to mitigate problems with procurement of high-priority parcels. For example: o Identify a 'quick-response team' to address problems with the procurement process (e.g., see example causes at left) o Establish on-call contracts with ROW specialists, relocation specialists, environmental remediation contractors, and/or demolition contractors who might be needed during acquisition process (assumes accelerated acquisition is done in advance of main construction contract) o Identify additional internal staffing and have 'on-hand'
	Delays to ROW certification (agency process delay)	• Coordinate early and often with certifying authority to ensure process and requirements are understood • Identify additional internal staffing and have 'on-hand'

Table D-5b. Project Phase: Utilities

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate utility planning and agreements Examples: • Overlap utility planning with project design and environmental activities • Coordinate early and often with design team and utility companies • Carry multiple alternatives • Provide staff to support the utility's review/approval process • Develop common/shared utility crossings • Seek accelerated utility-plan approval process		
	Late changes to the design cause delay in utility planning Example causes or issues: • Change in design late in process cascades to utility design changes (especially if utility planning and design are overlapped), resulting in delay in agreements and/or design review/approval	• Early on, develop a contingency plan to accelerate utility planning after late design changes. For example: o Develop and carry multiple alternatives early in design, to reduce impact if design changes o Coordinate early and often with utility companies o Early on, establish on-call contracts with utility specialists who might be needed later • If not already done, provide staffing support for utility companies (and plan for it early so it's ready to go when

Table D-5b. Project Phase: Utilities

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
		needed)

Table D-5b. Project Phase: Utilities

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Utility agreements not reached as planned (other than from design changes) Example causes or issues: • Delay in review and/or approval of agreements – either by owner or utility. For example: o Design/planning schedule too aggressive o Inadequate staffing o Utility waiting for project funding or contractor NTP • Disagreement over the proposed terms of the agreement. For example: o Cost-sharing o Scope of the utility relocation o Work windows / closures o Responsibility for work o Questions related to the need for or legality of the planned relocation	• Early on, develop a contingency plan to mitigate problems reaching utility agreements. For example: o Identify a 'quick-response team' to address problems with the process o If not already done, provide staffing support for utilities (and plan for it early so it's ready to go when needed) o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements o Identify potential bargaining position (mitigation, design change, etc.), including securing relevant policy decisions/positions from leadership
Accelerate utility relocation Examples: • Provide incentive for utility to relocate on time • Cost sharing • Relocate critical utilities first (so can start construction)		
	Encounter and/or damage utility during construction (if owner's contractor performs the work) Example causes or issues: • Encounter previously unknown utility, perhaps	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop potential remedial measures to reduce delay if problems occur

Table D-5b. Project Phase: Utilities

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	due to accelerated relocation schedule (e.g., utility-location effort was inadequate; 'potholing' not conducted so could accelerate schedule) • Damage existing utility even though knew it was there	• If not already done, have contractor confirm utility locations • Ensure contract provisions allow for rapid and fair resolution of these issues
	Third party does not complete agreed relocation as planned (if third party performs the work) Example causes or issues: • Third party (e.g., utility company or municipality) too busy with other work (i.e., does not prioritize this relocation effort) • Other delay to third-party design, review/approval, or sub-contracting effort • Funding delay • Third party simply "drags its feet" for other reasons	• Early on, develop a contingency plan to mitigate delays in third-party utility relocations. For example: o Identify a 'quick-response team' to address problems o If not already done, provide staffing support for utilities (and plan for it early so it's ready to go when needed) o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements o Identify potential bargaining position (mitigation, design change, additional funding, etc.), including securing relevant policy decisions/positions from leadership

Table D-5c. Project Phase: Railroad

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate railroad planning and agreements Examples: • Overlap railroad planning with project design and environmental activities • Coordinate early and often with design team and railroad representative • Carry multiple alternatives • Provide staff to support the railroad's review/approval process • Propose mitigation to speed agreements		

Table D-5c. Project Phase: Railroad

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Late changes to the design cause delay in railroad planning Example causes or issues: • Change in design late in process cascades to railroad-related design changes (especially if railroad planning and design are overlapped), resulting in delay in agreements and/or design review/approval	• Early on, develop a contingency plan to accelerate railroad planning after late design changes. For example: o Develop and carry multiple alternatives early in design, to reduce impact if design changes o Coordinate early and often with railroad companies o Early on, establish on-call contracts with railroad specialists who might be needed later o If not already done, provide staffing support for railroad companies (plan for it early so it's ready to go when needed)
	Railroad agreements not reached as planned (other than from design changes) Example causes or issues: • Delay in review and/or approval of agreements – either by owner or railroad. For example: o Design/planning schedule too aggressive o Inadequate staffing o Railroad company waiting for project funding or contractor NTP • Disagreement over the proposed terms of the agreement. For example: o Cost-sharing o Scope of the work to be done on, over, under, or adjacent to railroad property or at crossings	• Early on, develop a contingency plan to mitigate problems reaching railroad agreements. For example: o Identify a 'quick-response team' to address problems with the process o If not already done, provide staffing support for railroads (and plan for it early so it's ready to go when needed) o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements o Identify potential bargaining position (mitigation, design change, etc.), including

Table D-5c. Project Phase: Railroad

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	o Work windows / closures o Responsibility for work o Questions related to the need for or legality of the planned work	securing relevant policy decisions/positions from leadership

Table D-5c. Project Phase: Railroad

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate railroad-related construction Examples: • Provide incentive for railroad to provide longer or more frequent work windows • Cost sharing • Complete critical railroad-related construction first (so can start general construction)		
	Damage railroad facility during construction (if owner's contractor performs the work) Example causes or issues: • Foul or block the track (i.e., railroad can't operate during necessary windows) • Damage railroad crossing structure (bridge) • Damage other railroad infrastructure (e.g., signals, switches, crossings)	• Either internally or through contractor: Try to anticipate potential problems in advance, and then develop potential remedial measures to solve the problems • If not already done, have contractor confirm locations of key rail infrastructure • Ensure contractor has a plan that safeguards railroad infrastructure • Ensure contract provisions allow for rapid and fair resolution of these issues
	Railroad does not complete agreed railroad-related work as planned (if railroad performs the work) Example causes or issues: • Railroad too busy with other work (i.e., does not prioritize this effort) • Other delay to railroad-driven design, review/approval, or sub-contracting effort	• Early on, develop a contingency plan to mitigate delays in railroad-conducted work. For example: o Identify a 'quick-response team' to address problems o If not already done, provide staffing support for railroads (and plan for it early so it's

Table D-5c. Project Phase: Railroad

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	- Funding delay - Railroad simply “drags its feet” for other reasons	ready to go when needed) o If not already done, establish a process to quickly resolve differences/disputes or clarify requirements o Identify potential bargaining position (mitigation, design change, additional funding, etc.), including securing relevant policy decisions/positions from leadership

Table D-6. Project Phase: Procurement and Contracting Strategy

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Use alternative procurement method Examples: • Cost-plus-time (A+B) bidding • Cost-plus-time-plus-quality (A+B+Q) bidding • Shortlist qualified contractors and then use qualifications-based selection process • Unsolicited proposals, followed by sole source negotiations		Note that many of the same risks and risk management actions that were identified in Table 2, “Project Scoping,” relative to Innovative Project Delivery methods, are applicable to this category as well. Specific attention is brought to the following actions, each of which applies to the risks discussed to the left: Examples: • Develop a procurement plan that meets the goals of the overall project and stakeholders, and in particular focus on what the goals are in using an alternative procurement and contracting approach • Ensure that the team is supported by experienced individuals (internal or consultants) • Early retention of any consultants who will be assisting agency’s personnel • Secure enabling legislation early to allow alternative procurement approaches to work • Conduct outreach to the state attorney general and obtain AG opinions for statutory areas that are unclear or evolving • Conduct broad training programs on procurement and contracting innovations with staff • Conduct outreach to other DOTs that have a history of success in implementing alternative procurement and contracting programs.

Table D-6. Project Phase: Procurement and Contracting Strategy

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
		• Consider bringing key stakeholders into the training process for the implementation of the procurement approach • Outreach to public to determine where the potential statutory challenges may lie
	Litigation initiated by an interested party challenging the propriety of the alternative procurement process Example causes or issues: • Challenges to the ability of a state to select construction projects on something other than full, open competitive bidding • Challenges as to the reasonableness of the selection factors	In addition to the above: • Create a team that develops a formal procurement and contracting plan that is reasonable, logical and objective • Outreach to legislators who are concerned about alternative procurement practices • Ensure that the Attorney General's office is cognizant of potential issues and prepared to act quickly to address any challenges
	Public concern (and political pressure) resulting from the use of procurement processes that heavily weight non-price factors Example causes or issues: • Perceived conflict of interest when a design-builder is first selected to perform preliminary engineering and then has sole source negotiation rights for final design and construction • Perception that contracts awarded on qualifications basis are "sweetheart" contracts and the result of cronyism.	In addition to the above: • Outreach to the public to make the procurement process transparent and to explain the rationale and public benefit behind the procurement choice • Use of independent outside consultants to evaluate pricing of the contracting teams • Use of escrowed bid documents to obtain access to the documents • Use open book negotiation process • Require contractor (design-builder) to certify the currency, completeness and accuracy of its open book submissions • Consider, where applicable, the use of

Table D-6. Project Phase: Procurement and Contracting Strategy

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
		construction management at risk contracting principles, where the bulk of the work is competitively subcontracted to third parties, and with prime contractor being responsible to manage such work and interfaces.
	Public reaction to procurements that trade-off early accelerated completion with full road closures	In addition to the above: • Developing a comprehensive outreach program to explain the benefits of this system • Determining and widely disseminating maintenance of traffic plans that minimize disruption
	Limited competition arising from projects perceived as being created for large contractors	In addition to the above: • Assess whether the project can be broken down into alternative contract packaging (see below) • Require proposers to submit a subcontracting plan that demonstrates how it will use small businesses and have this as a significant selection factor
	Other problems procuring contract Example causes or issues: • Bid protest • Unclear contract documents or language resulting in claims, whether credible or not. This could be a problem during contract procurement, during construction, or both. • Contractor default (most likely during construction)	In addition to the above: • Pre-qualify contractors • Short-list a minimum of three contractors • Ask contractors' association to provide feedback on draft contract documents (e.g., Request for Proposal) • Set reasonable minimum bonding requirements
Use alternative contract	See above	In addition to the above:

Table D-6. Project Phase: Procurement and Contracting Strategy

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
packaging Examples: • Larger number of smaller contracts • Use of allowances for work that is not sufficiently designed at the time of bid or is to be undertaken far in the future and that will be performed by smaller contractors		• Conduct a thorough evaluation as to the goals and detriments of alternative contract packaging • Develop an outreach program for the smaller contractors and DBEs • Consider lessons learned from other agencies that have used allowance-type of contracting arrangements
Employ advance procurement Examples: • Early procurement of long-lead items • Advance earthwork / embankment construction contracts • Advance remediation of contaminated sites		In addition to the above: • Ensuring that the project delivery, procurement and risk management plans are fully aligned • Integrating early procurement of components into a qualifications-based selection process for the prime contractor
	Expending funds in advance of full procurement	See above, particularly as it relates to understanding how the plans integrate
Use delayed-start provision in contract Examples: • Purchase of construction ROW to allow for prefabrication of elements • Allow contractor to revise designs prior to beginning work to minimize traffic impact	**Perception of delayed start will erode internal or external confidence in rapid renewal goals**	In addition to the above: • Educate stakeholders in need for delayed start • Align incentives and disincentives with start of mainline work rather than start of contract

Table D-6. Project Phase: Procurement and Contracting Strategy

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
• Allow contractor to do off-line work that will not impede traffic		
	Mobilization costs are higher and at risk if contractor defaults	In addition to the above: • Use best-value procurement to ensure that a solvent and experienced contractor is selected • Monitor work and payment closely

Table D- 7. Project Phase: Operations and Maintenance (O&M)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Consider private O&M Contractor		
	Required O&M effort greater than planned (either more frequently, more extensive, or both) Example causes or issues: • Quality of constructed facility not as anticipated or required • Extreme seasonal weather impacts • Traffic demand greater than anticipated, or mix of vehicle types not as anticipated	• Ensure adequate contractual provisions (e.g., warranty) in contract with constructor • Ensure adequate quality control and assurance during construction of facility (to minimize risk of poorly-constructed facility) • Conduct uncertainty-based traffic modeling for project's projected lifetime
	O&M contractor does not perform per contract Example causes or issues: • Performs O&M tasks when required, but not to technical standards • Fails to perform O&M tasks per requirements (regardless of how specified)	• Ensure adequate contractual provisions (e.g., performance bond) in contract with O&M contractor • Develop contingency plan in advance to quickly mobilize agency O&M resources if needed

Table D-8. Project Phase: Replacement

Rapid-Renewal Category	Related Risk or Opportunity Categories	Potential Risk-Management Actions
	Replacement required sooner than planned Example causes or issues: • Demand increases faster than anticipated, requiring additional capacity • Poor design, materials, and/or construction quality	• Conduct uncertainty-based demand modeling during design (consider uncertainties and risks that could affect modeling results) • Ensure adequate contractual provisions (e.g., warranty) in contract with constructor • Ensure adequate quality control and assurance during construction of facility (to minimize risk of poorly-constructed facility) • Delay replacement with additional maintenance (develop contingency plan in advance for funding and resources)
	Replacement does not perform as intended (e.g., inadequate capacity; poor construction)	

Appendix E. Simplified Risk Management Overview, Forms and Template

An MS PowerPoint overview presentation of the risk management process, and a set of forms and a complementary MS Excel workbook template, are provided to help conduct risk management on relatively simple rapid renewal projects, per the process described in this *Guide*.

The overview is intended to be presented by the risk facilitator at the beginning of a risk management workshop to adequately familiarize the participants with the risk management process that will be used throughout that workshop. The overview is presented in annotated form in this appendix, and in animated form on the CD – because it should be modified for specific applications (e.g., identifying the DOT involved), the source file is also contained on the CD.

The forms and template specifically consider the key relevant performance objectives (i.e., construction cost, schedule and disruption, plus post-construction longevity) and project delivery methods (traditional design-bid-build and non-traditional design-build). However, these forms and template can also be applied to non-rapid renewal projects, and can consider a reduced set of project performance objectives for those projects.

The forms include the following, copies of which are attached:

- Summary Project Base Description
- Risk Identification (Brainstorming)
- Risk Register
- Rating Category Definition
- Unmitigated Risk Factor Assessment
- Risk Reduction Action Evaluation
- Risk Reduction Implementation Plan

Although the forms can also be used to document the results of calculations (as described in this *Guide*), these calculations are separate and must be done outside the forms.

A simple template (a Microsoft Excel workbook) has been developed to enter the data directly, and then automatically carry out the appropriate calculations (as described in this *Guide*). This template consists of fourteen (14) macro-free linked worksheets in a single workbook, highlighting user inputs while hiding and protecting other parts to prevent confusion, mistakes, and inadvertent misuse. A User's Guide for this template has been developed, documenting and explaining the various worksheets, and is attached. The template is provided on the CD.

E.1 Overview Presentation

An overview is intended to be presented by the risk facilitator at the beginning of a risk management workshop to adequately familiarize the participants with the risk management process that will be used throughout that workshop. The overview is presented in annotated form in this appendix, and in animated form on the CD – because it should be modified for specific applications (e.g., identifying the DOT involved), the source file is also contained on the CD.

<insert Workshop Intro rev003.pdf>

<DOT>

Simplified
Risk Management Planning
for <Project>

<facilitator>

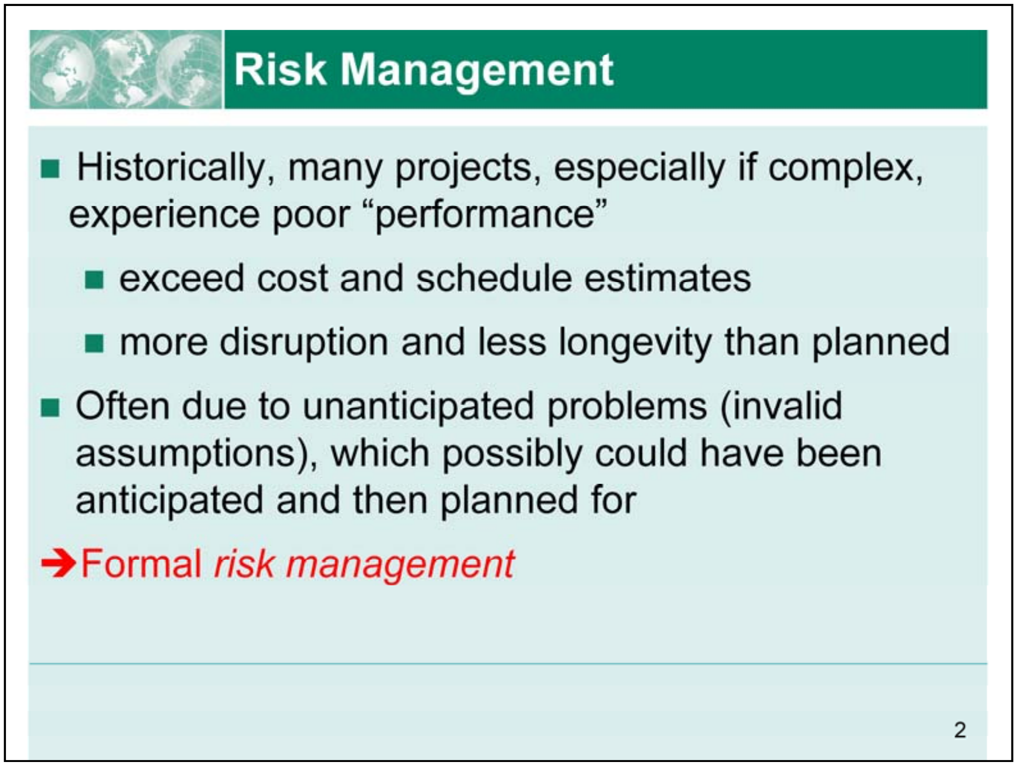
<date>

A Risk Management Process Overview presentation, which should take about 30 minutes, has been developed for the risk facilitator to present at the beginning of the workshop. This presentation will allow the workshop participants to become adequately familiarized with the risk management process that will be followed throughout the workshop. It can be easily modified for specific applications (e.g., changing DOT, project name, facilitator name, and workshop date, and possibly putting a project plan as background, on the title slide).

This version of the presentation is for one specific but common scope of risk management (i.e., development of cost-effective, proactive, individual risk reduction plans for a relatively significant project that is moderately large and complex, but not too large or complex, and that has alternatives). The scope does not include (and thus this presentation does not address) quantifying the uncertainty in project performance (e.g., to establish budget/milestone/contingency).

The risk management process addressed in this presentation requires a two-day workshop with two concurrent groups of project staff and independent subject matter experts, and thus two facilitators, at times.

The presentation might need to be modified more extensively for a different risk management scope, e.g., larger or more complex project, smaller and simpler project, quantification of uncertainty in project performance (e.g., to establish budget/milestone/contingency). Other relatively simple potential stylistic changes of the presentation by the facilitator include: a) turning off animation (e.g., to speed it up); and b) putting the agenda at the end of the presentation (instead of near the beginning).

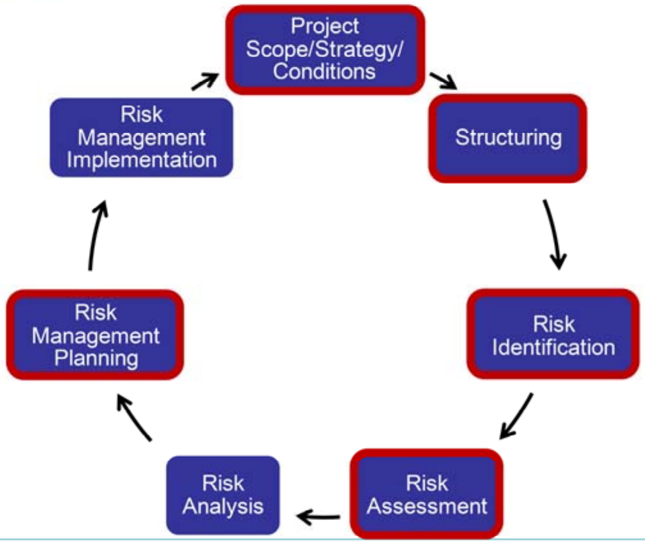


Risk Management

- Historically, many projects, especially if complex, experience poor “performance”
  - exceed cost and schedule estimates
  - more disruption and less longevity than planned
- Often due to unanticipated problems (invalid assumptions), which possibly could have been anticipated and then planned for

➔Formal *risk management*

Risk Management Process



Project Scope/Strategy/ Conditions

Structuring

Risk Identification

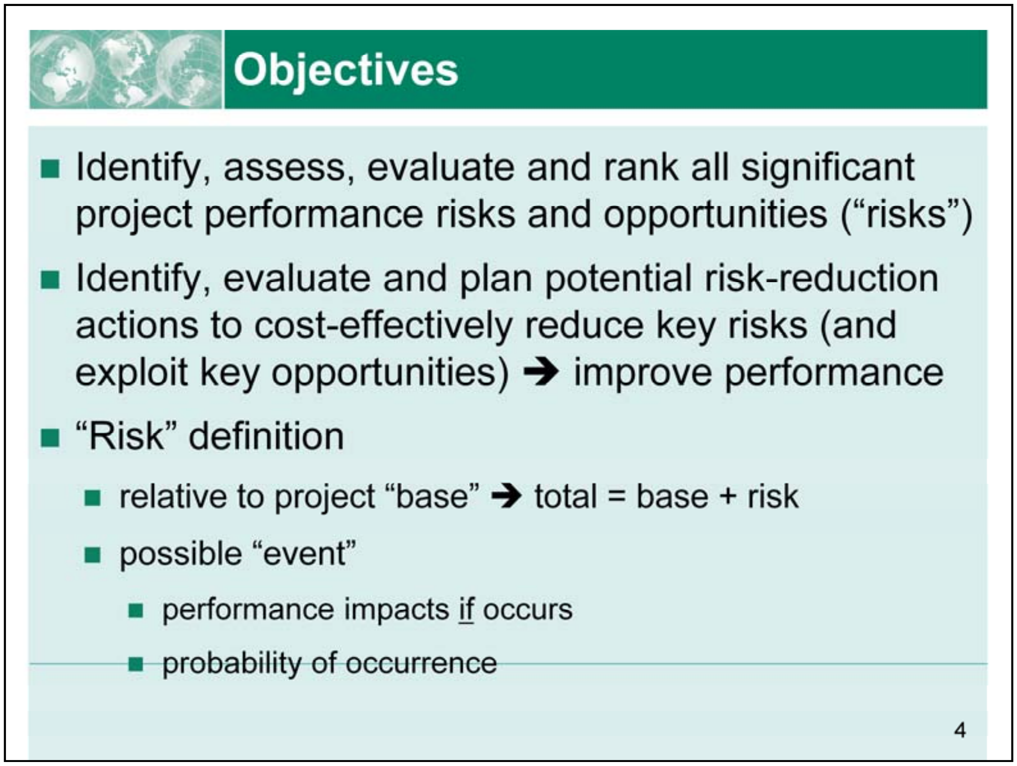
Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

Ref. *Guide for the Process of Managing Risk on Rapid Renewal Projects*



Objectives

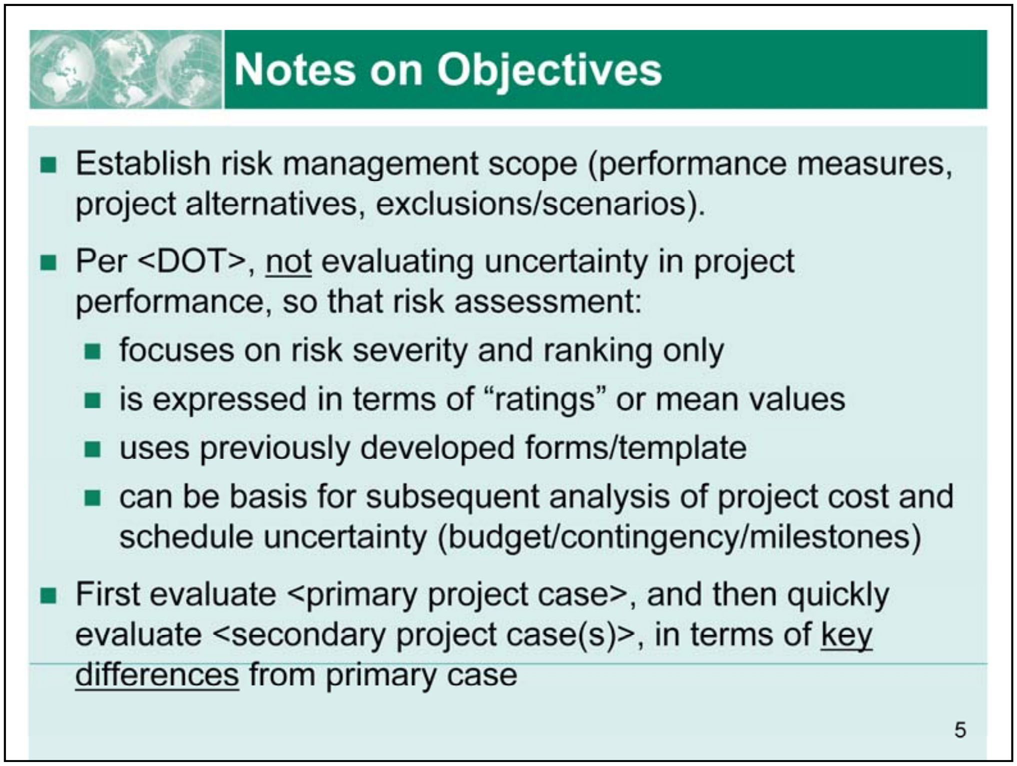
- Identify, assess, evaluate and rank all significant project performance risks and opportunities (“risks”)
- Identify, evaluate and plan potential risk-reduction actions to cost-effectively reduce key risks (and exploit key opportunities) ➔ improve performance
- “Risk” definition
  - relative to project “base” ➔ total = base + risk
  - possible “event”
    - performance impacts if occurs
    - probability of occurrence

Risks are potential losses (worse performance), and opportunities are potential improvements (better performance. Collectively, risks and opportunities are termed “risks”, with opportunities simply negative risks.

Project performance measures includes: escalated cost through construction, schedule through construction, disruption through construction, and post-construction longevity (which combines, via “tradeoffs”, cost and disruption associated with operations and ultimately replacement, and the schedule of replacement). These various project performance measures can be combined (via “tradeoffs”) into one overall project performance measure.

Performance impacts, e.g., additional cost to particular project activity.

Probability = chance.



Notes on Objectives

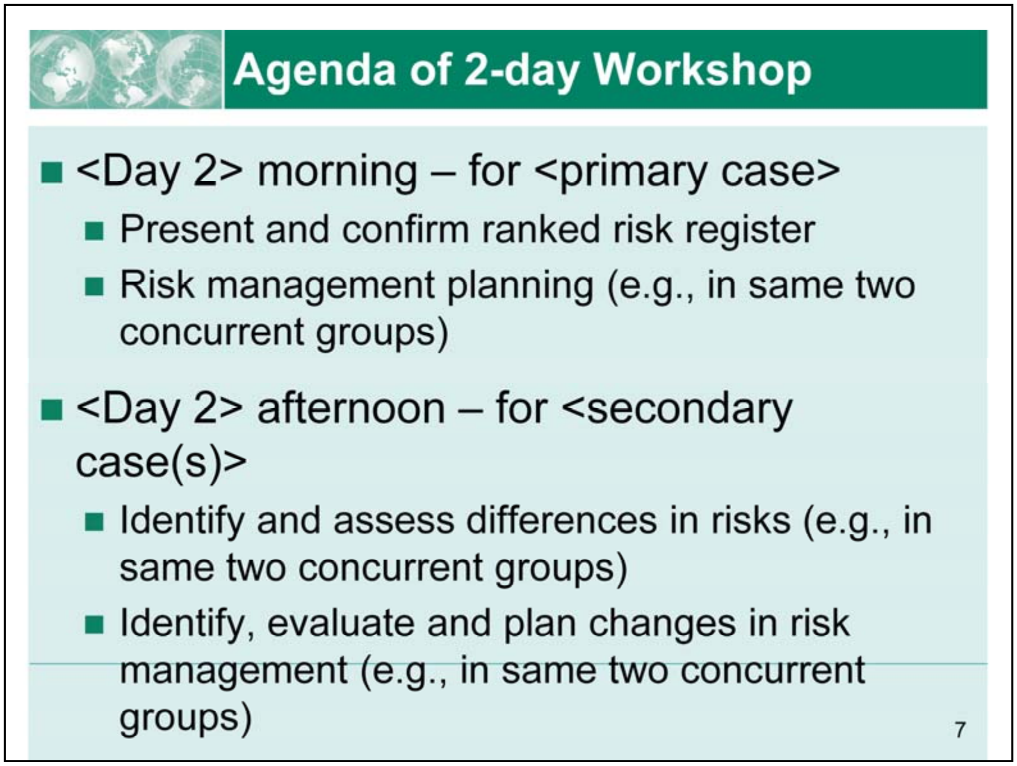
- Establish risk management scope (performance measures, project alternatives, exclusions/scenarios).
- Per <DOT>, not evaluating uncertainty in project performance, so that risk assessment:
  - focuses on risk severity and ranking only
  - is expressed in terms of “ratings” or mean values
  - uses previously developed forms/template
  - can be basis for subsequent analysis of project cost and schedule uncertainty (budget/contingency/milestones)
- First evaluate <primary project case>, and then quickly evaluate <secondary project case(s)>, in terms of key differences from primary case

Forms have been developed to guide and document information/assessments. These forms have been “automated” in an MS Excel workbook template, that also automatically conducts the required calculations using that information/assessments.

Although not evaluating the uncertainty in project performance (e.g., to establish budget/milestones/contingency), the information developed here can be refined/expanded for such use.

Agenda of 2-day Workshop

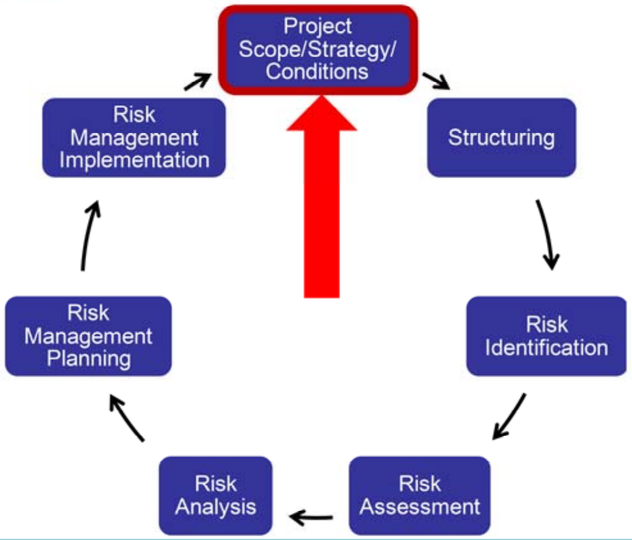
- <Day 1> morning – for <primary case>
  - ✓ Risk management planning overview/scope
  - Project overview (scope, strategy, conditions)
  - Structuring for risk management
  - Risk identification (“brainstorming”, risk register)
- <Day 1> afternoon – for <primary case>
  - Risk assessment (e.g., in two concurrent groups)
    - Funding/policy, planning/scoping, environmental, right-of-way/utilities/railroad, contracting
    - Design (prelim/final), construction, O&M, replacement



Agenda of 2-day Workshop

- <Day 2> morning – for <primary case>
  - Present and confirm ranked risk register
  - Risk management planning (e.g., in same two concurrent groups)
- <Day 2> afternoon – for <secondary case(s)>
  - Identify and assess differences in risks (e.g., in same two concurrent groups)
  - Identify, evaluate and plan changes in risk management (e.g., in same two concurrent groups)

Risk Management Process



Project Scope/Strategy/ Conditions

Structuring

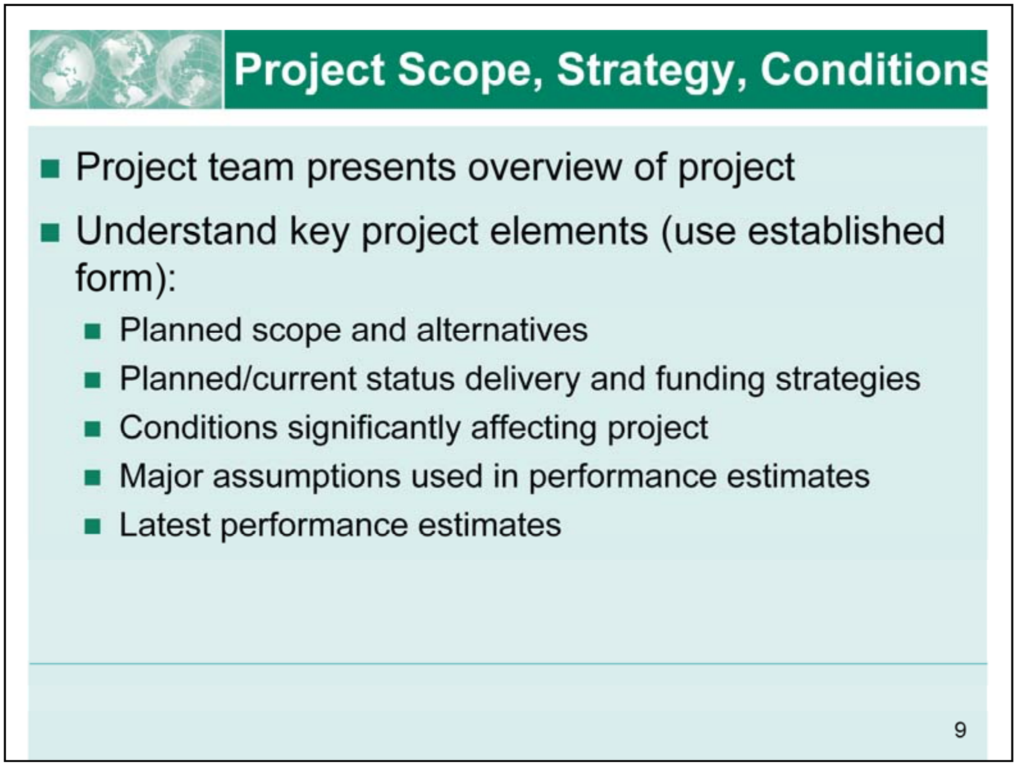
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



Project Scope, Strategy, Conditions

- Project team presents overview of project
- Understand key project elements (use established form):
  - Planned scope and alternatives
  - Planned/current status delivery and funding strategies
  - Conditions significantly affecting project
  - Major assumptions used in performance estimates
  - Latest performance estimates

Key project elements include:

- Planned scope and all alternatives (focusing on their differences)
- Planned delivery (including contract packaging, phasing) and funding strategies, and their current status
- Conditions significantly affecting project (e.g., stakeholders)
- Major assumptions used in performance estimates (e.g., normal market conditions, as well as policy issues such as “value” of any other considered performance measures, e.g., disruption)
- Latest performance estimates (e.g., re schedule, cost, disruption)

An established form is used to ensure that all the relevant information is provided.

Risk Management Process

Project Scope/Strategy/ Conditions

Structuring

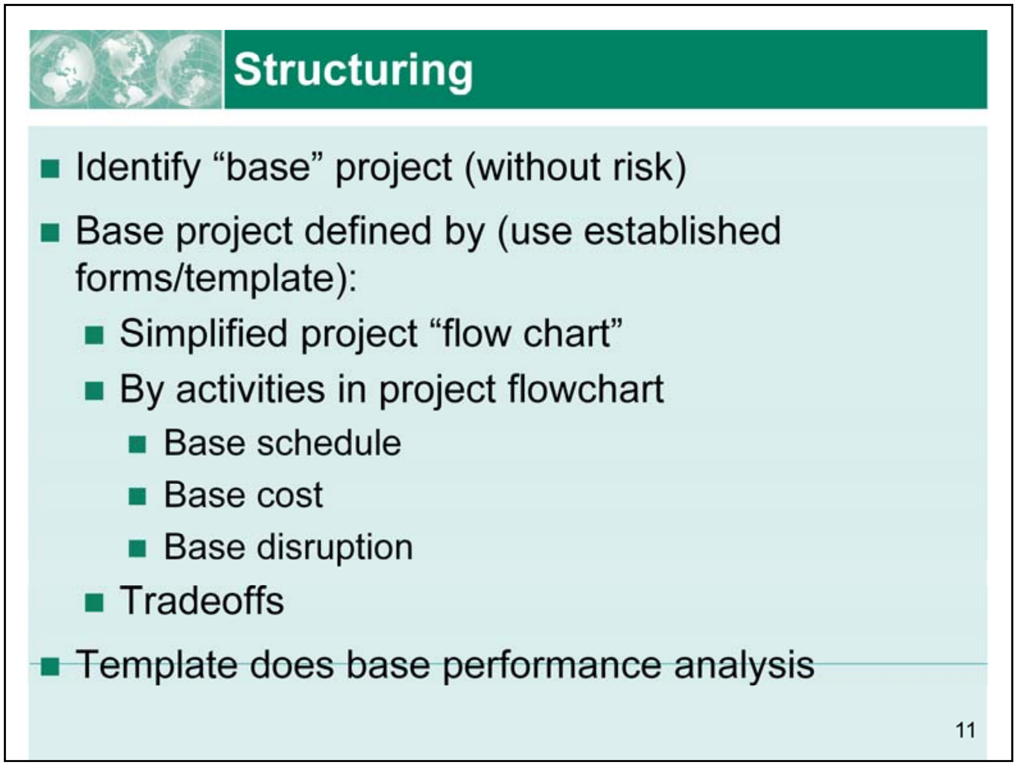
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



Structuring

- Identify "base" project (without risk)
- Base project defined by (use established forms/template):
  - Simplified project "flow chart"
  - By activities in project flowchart
    - Base schedule
    - Base cost
    - Base disruption
  - Tradeoffs
- Template does base performance analysis

Base project is "abstracted" in terms of:

- Simplified "flow chart" (major activities and logic)
- Base schedule (activity durations/lags/milestone)
- Base cost (activity unescalated costs, plus extended OH rates and escalation rates)
- Base disruption (activity lost person-hours)
- Tradeoffs (disruption value, longevity value, schedule value, etc)

Structuring

Standard simplified “flow chart” (on form) for risk identification and assessment for D/B/B or D/B

Traditional Design/Bid/Build (D/B/B)

Time ➔

Planning ___mo $___M, ___Mhrs

Scoping ___mo $___M, ___Mhrs

Enviro Proc, Prelim Design ___mo $___M, ___Mhrs

Enviro Permits ___mo $___M, ___Mhrs

Final Design ___mo $___M, ___Mhrs

ROW, Util, RR ___mo $___M, ___Mhrs

Procurement ___mo $___M, ___Mhrs

Construction ___mo $___M, ___Mhrs

Operations ___mo $___M, ___Mhrs

Replacement ___mo $___M, ___Mhrs

① ② ③ ④ ⑤ <E>

__/__/__ __/__/__ __/__/__

Notes: 1,2,3 = funding
4 = project delivery
5 = replacement
Enviro Proc = Environmental Process
Util, RR = Utilities, Railroad

Notes: <x> = lag
E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR

Duration 24 mo.

Cost $100 million

Disruption 1 M-hr

Assumes one contract package

Similar flowchart for D/B.

If quantifying performance uncertainty, would need more-detailed flow chart.

Risk Management Process

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

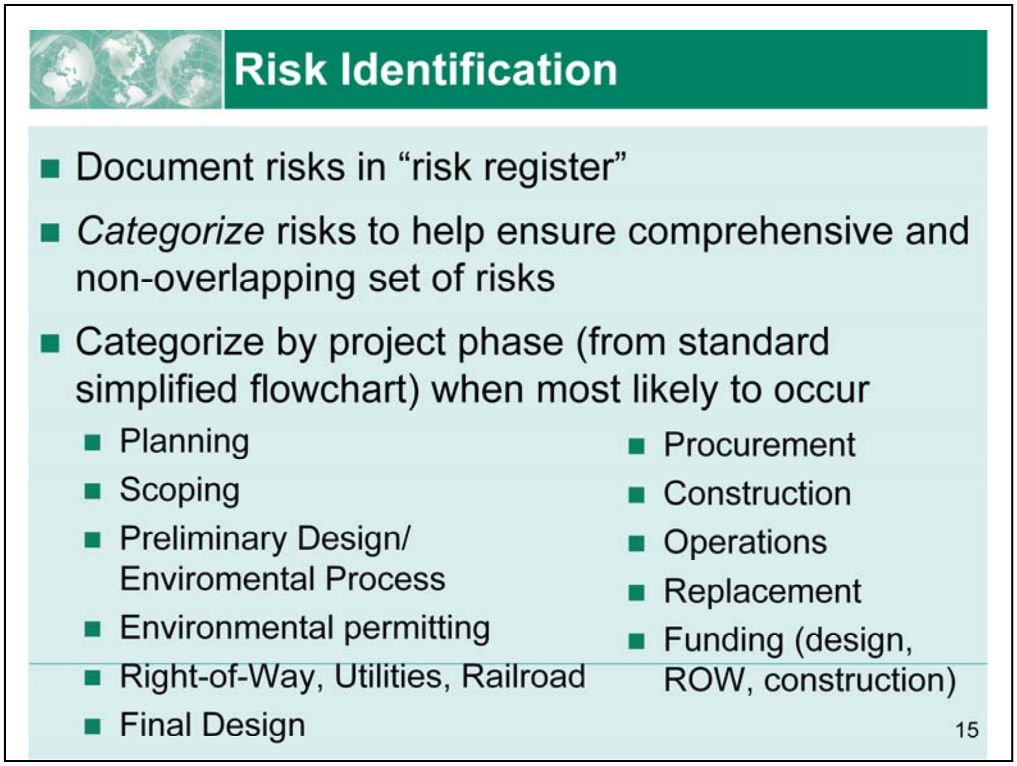
Risk Analysis

Risk Management Planning

Risk Management Implementation

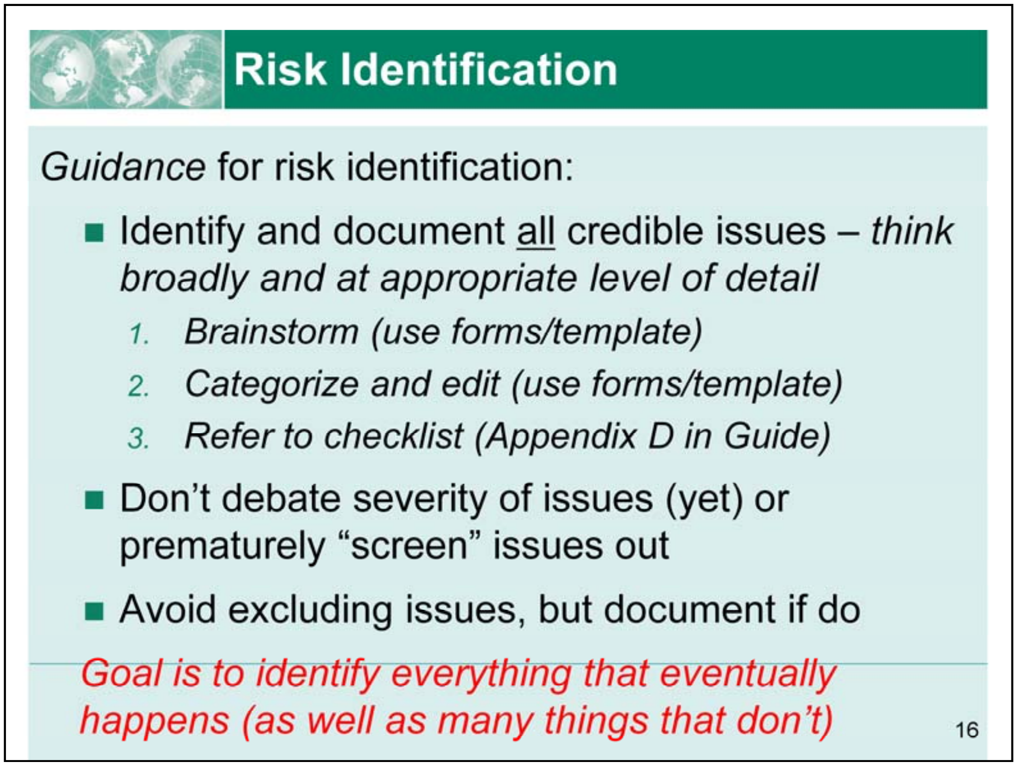
Risk Identification

Identify, document, and categorize comprehensive and non-overlapping set of risks (including opportunities) to project's performance
e.g., delay in ROW



Risk Identification

- Document risks in “risk register”
- *Categorize* risks to help ensure comprehensive and non-overlapping set of risks
- Categorize by project phase (from standard simplified flowchart) when most likely to occur
  - Planning
  - Scoping
  - Preliminary Design/ Enviromental Process
  - Environmental permitting
  - Right-of-Way, Utilities, Railroad
  - Final Design
  - Procurement
  - Construction
  - Operations
  - Replacement
  - Funding (design, ROW, construction)



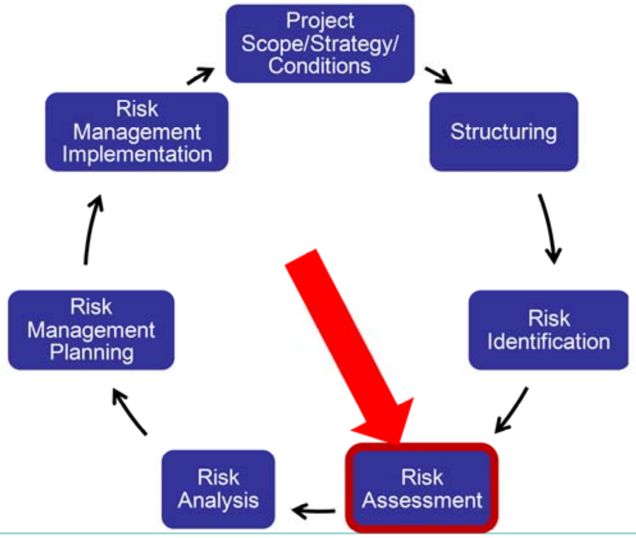
Risk Identification

Guidance for risk identification:

- Identify and document <u>all</u> credible issues – *think broadly and at appropriate level of detail*
    1. *Brainstorm (use forms/template)*
    2. *Categorize and edit (use forms/template)*
    3. *Refer to checklist (Appendix D in Guide)*
- Don't debate severity of issues (yet) or prematurely "screen" issues out
- Avoid excluding issues, but document if do

Goal is to identify everything that eventually happens (as well as many things that don't)

Risk Management Process



Project Scope/Strategy/ Conditions

Structuring

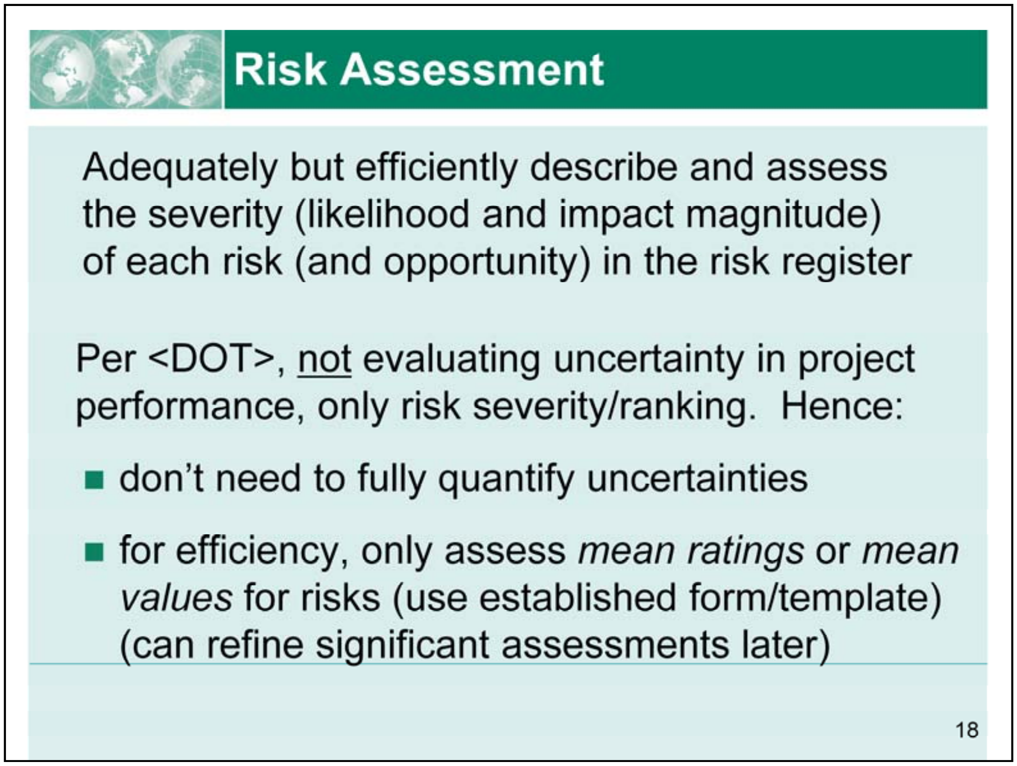
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

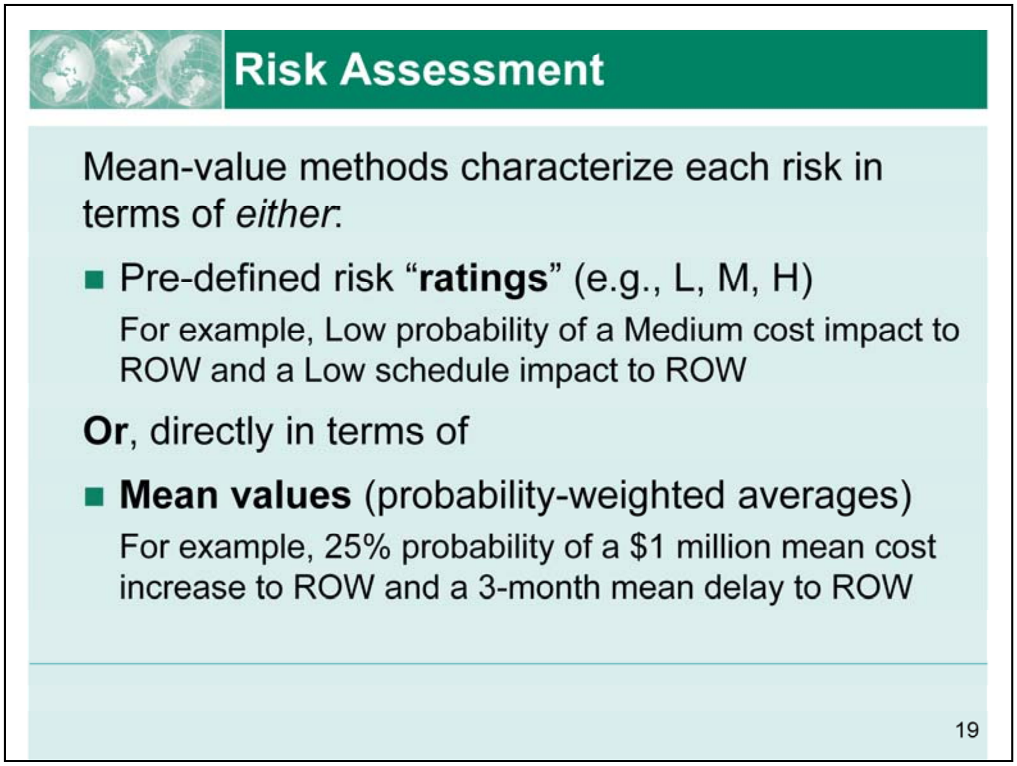


Risk Assessment

Adequately but efficiently describe and assess the severity (likelihood and impact magnitude) of each risk (and opportunity) in the risk register

Per <DOT>, not evaluating uncertainty in project performance, only risk severity/ranking. Hence:

- don’t need to fully quantify uncertainties
- for efficiency, only assess *mean ratings* or *mean values* for risks (use established form/template) (can refine significant assessments later)



Risk Assessment

Mean-value methods characterize each risk in terms of *either*:

- Pre-defined risk "**ratings**" (e.g., L, M, H)

  For example, Low probability of a Medium cost impact to ROW and a Low schedule impact to ROW

Or, directly in terms of

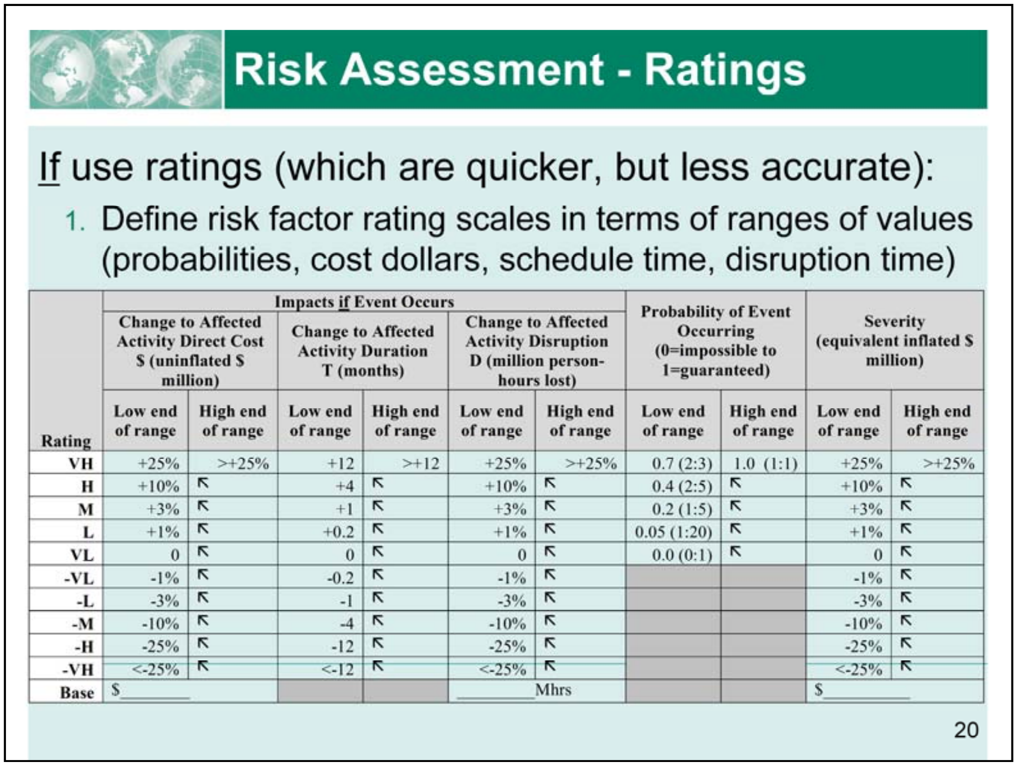
- **Mean values** (probability-weighted averages)

  For example, 25% probability of a $1 million mean cost increase to ROW and a 3-month mean delay to ROW

The group decides which approach (between ratings and values) to use and can mix approaches (i.e., use ratings for some risk factors, and use mean values on others).

Cost impact is marked up, but does not include extended OHs or escalation, which are dealt with separately and automtically.

Impacts are assigned to a particular activity.



Risk Assessment - Ratings

<u>If</u> use ratings (which are quicker, but less accurate):

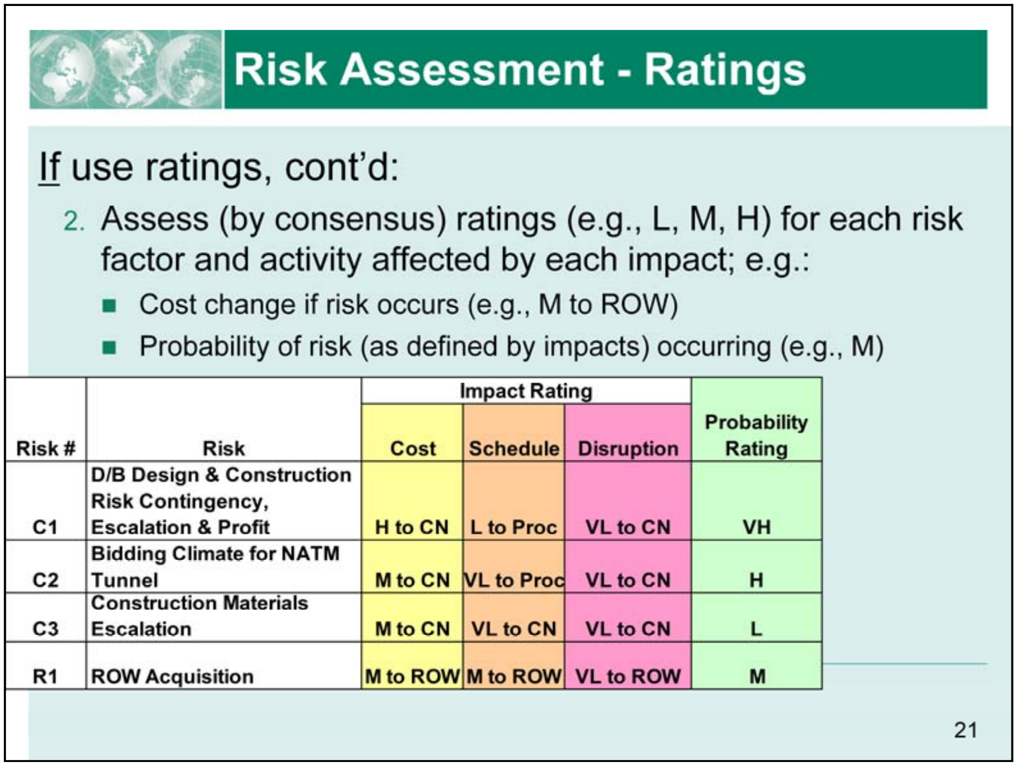
1. Define risk factor rating scales in terms of ranges of values (probabilities, cost dollars, schedule time, disruption time)

	Impacts *if* Event Occurs						Probability of Event Occurring (0=impossible to 1=guaranteed)		Severity (equivalent inflated $ million)	
	Change to Affected Activity Direct Cost $ (uninflated $ million)		Change to Affected Activity Duration T (months)		Change to Affected Activity Disruption D (million person-hours lost)					
Rating	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**
VH	+25%	>+25%	+12	>+12	+25%	>+25%	0.7 (2:3)	1.0 (1:1)	+25%	>+25%
H	+10%	↖	+4	↖	+10%	↖	0.4 (2:5)	↖	+10%	↖
M	+3%	↖	+1	↖	+3%	↖	0.2 (1:5)	↖	+3%	↖
L	+1%	↖	+0.2	↖	+1%	↖	0.05 (1:20)	↖	+1%	↖
VL	0	↖	0	↖	0	↖	0.0 (0:1)	↖	0	↖
-VL	-1%	↖	-0.2	↖	-1%	↖			-1%	↖
-L	-3%	↖	-1	↖	-3%	↖			-3%	↖
-M	-10%	↖	-4	↖	-10%	↖			-10%	↖
-H	-25%	↖	-12	↖	-25%	↖			-25%	↖
-VH	<-25%	↖	<-12	↖	<-25%	↖			<-25%	↖
Base	$________				________Mhrs				$__________	

Can express values directly (e.g., default values are shown for probability of event occurring) or as % of base value (e.g., default values are shown for direct cost as % of total uninflated base cost through construction, for disruption as % of total base disruption through construction, and for severity as % of combined project performance).

Default values (shown) can be over-ridden (either ranges or base).

High end of one range is same as low end of next higher range (as indicated by arrows), and does not need to be repeated.

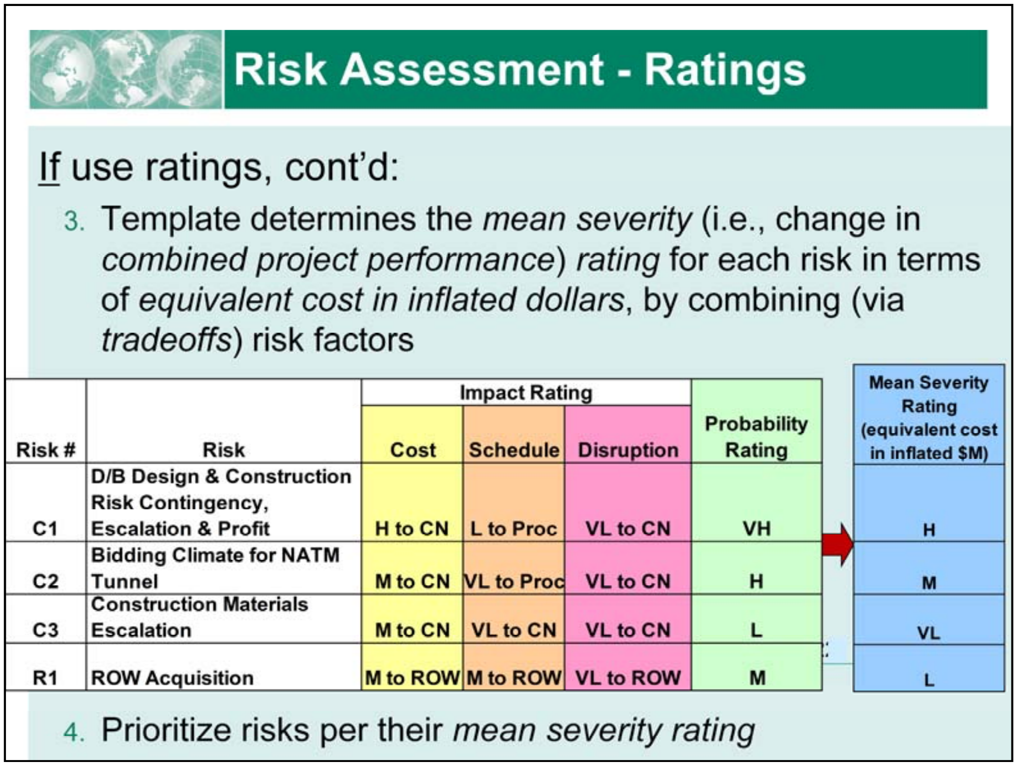


Risk Assessment - Ratings

If use ratings, cont'd:

2. Assess (by consensus) ratings (e.g., L, M, H) for each risk factor and activity affected by each impact; e.g.:
   - Cost change if risk occurs (e.g., M to ROW)
   - Probability of risk (as defined by impacts) occurring (e.g., M)

		Impact Rating			
Risk #	**Risk**	**Cost**	**Schedule**	**Disruption**	**Probability Rating**
C1	D/B Design & Construction Risk Contingency, Escalation & Profit	H to CN	L to Proc	VL to CN	VH
C2	Bidding Climate for NATM Tunnel	M to CN	VL to Proc	VL to CN	H
C3	Construction Materials Escalation	M to CN	VL to CN	VL to CN	L
R1	ROW Acquisition	M to ROW	M to ROW	VL to ROW	M



Risk Assessment - Ratings

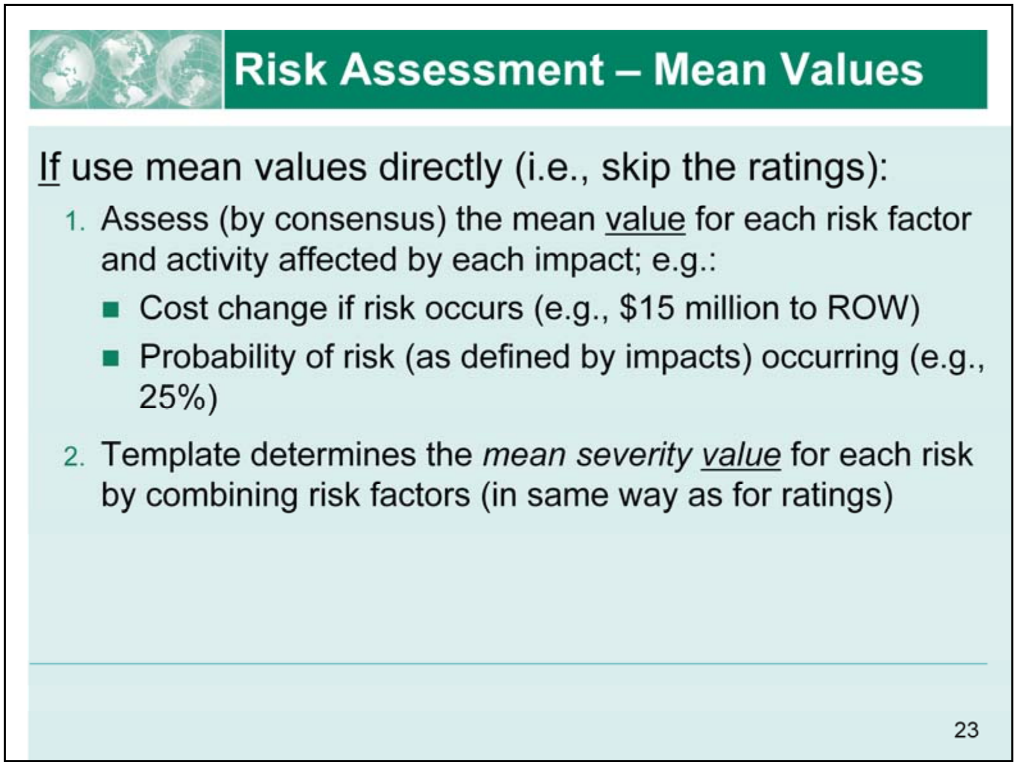
If use ratings, cont'd:

3. Template determines the *mean severity* (i.e., change in *combined project performance*) *rating* for each risk in terms of *equivalent cost in inflated dollars*, by combining (via *tradeoffs*) risk factors

Risk #	Risk	Impact Rating			Probability Rating	Mean Severity Rating (equivalent cost in inflated $M)
		Cost	Schedule	Disruption		
C1	D/B Design & Construction Risk Contingency, Escalation & Profit	H to CN	L to Proc	VL to CN	VH	H
C2	Bidding Climate for NATM Tunnel	M to CN	VL to Proc	VL to CN	H	M
C3	Construction Materials Escalation	M to CN	VL to CN	VL to CN	L	VL
R1	ROW Acquisition	M to ROW	M to ROW	VL to ROW	M	L

4. Prioritize risks per their *mean severity rating*

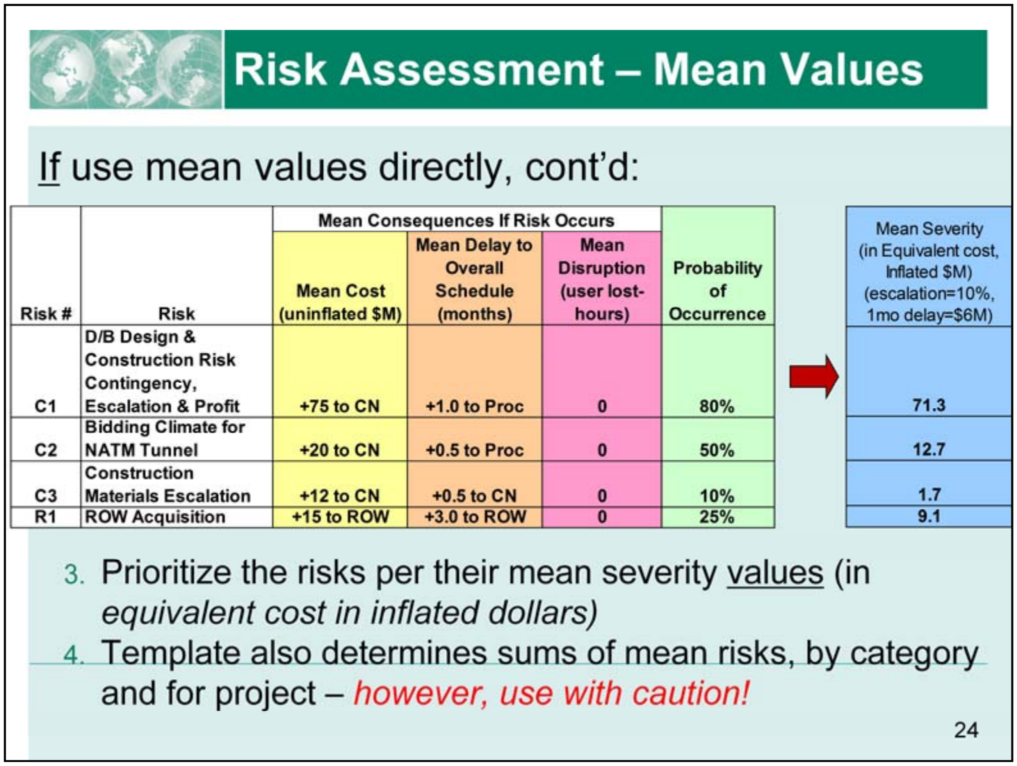
Severity equals the change in combined project performance, which appropriately combines probability and, by activity, direct uninflated cost change, schedule change, and disruption change, also considering inflation, cost of schedule delay (incl. extended overheads and additional inflation) and tradeoffs (value of disruption, value of schedule, value of longevity, etc.)



Risk Assessment – Mean Values

If use mean values directly (i.e., skip the ratings):

1. Assess (by consensus) the mean value for each risk factor and activity affected by each impact; e.g.:
   - Cost change if risk occurs (e.g., $15 million to ROW)
   - Probability of risk (as defined by impacts) occurring (e.g., 25%)
2. Template determines the *mean severity value* for each risk by combining risk factors (in same way as for ratings)



Risk Assessment – Mean Values

If use mean values directly, cont'd:

Risk #	Risk	Mean Consequences If Risk Occurs			Probability of Occurrence	Mean Severity (in Equivalent cost, Inflated $M) (escalation=10%, 1mo delay=$6M)
		Mean Cost (uninflated $M)	Mean Delay to Overall Schedule (months)	Mean Disruption (user lost-hours)		
C1	D/B Design & Construction Risk Contingency, Escalation & Profit	+75 to CN	+1.0 to Proc	0	80%	71.3
C2	Bidding Climate for NATM Tunnel	+20 to CN	+0.5 to Proc	0	50%	12.7
C3	Construction Materials Escalation	+12 to CN	+0.5 to CN	0	10%	1.7
R1	ROW Acquisition	+15 to ROW	+3.0 to ROW	0	25%	9.1

3. Prioritize the risks per their mean severity values (in *equivalent cost in inflated dollars)*
4. Template also determines sums of mean risks, by category and for project – *however, use with caution!*

If set of risks is comprehensive/non-overlapping, then template determines approx mean total performance and mean risk performance by summing over those risks. However, this would not be adequate for establishing budget/milestone/contingency, because it does not consider the uncertainty

For example, for R1 (no disruption):

0.25 * 1.10 * ($15.0M + 3.0 mo * $6.0M/mo) = $9.1M

where:

Probability of risk occurrence = 0.25

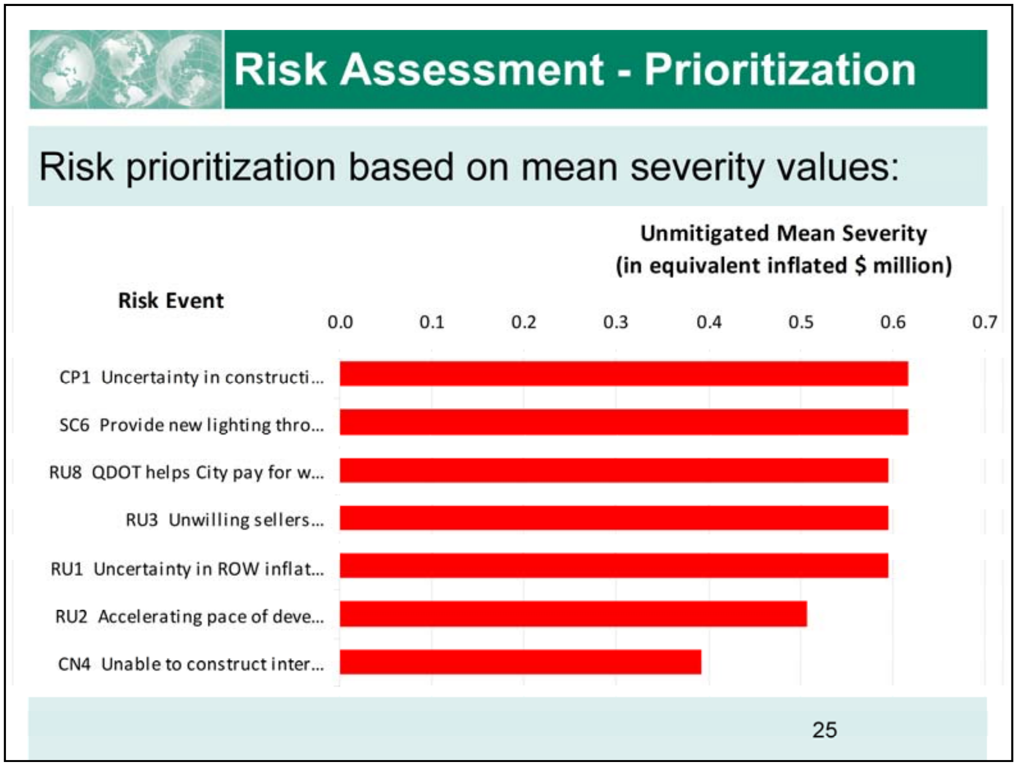
Mean escalation factor[1] = 1.10

Mean uninflated cost impact if risk occurs = $15.0M

Mean delay if risk occurs = 3.0 mo

Mean uninflated cost per month of delay (including mean increased extended OH and increased escalation of remainder of project cost due to delay, and additional "value" of delay, such as loss of service)[1] = $6.0M/mo

Note: [1] this is done in a more sophisticated way in the template



Risk Assessment - Prioritization

Risk prioritization based on mean severity values:

Note: this is for different example than shown on previous slides.

Risk Assessment

For efficiency, assess risks by category / project phase in two concurrent groups, e.g.:

- Group 1
  - Funding and policy
  - Planning and scoping
  - Environmental process and permitting
  - Right-of-way, utilities, railroad
  - Contract procurement
- Group 2
  - Design (preliminary and final)
  - Construction
  - O&M
  - Replacement

Risk Management Process

Project Scope/Strategy/ Conditions

Structuring

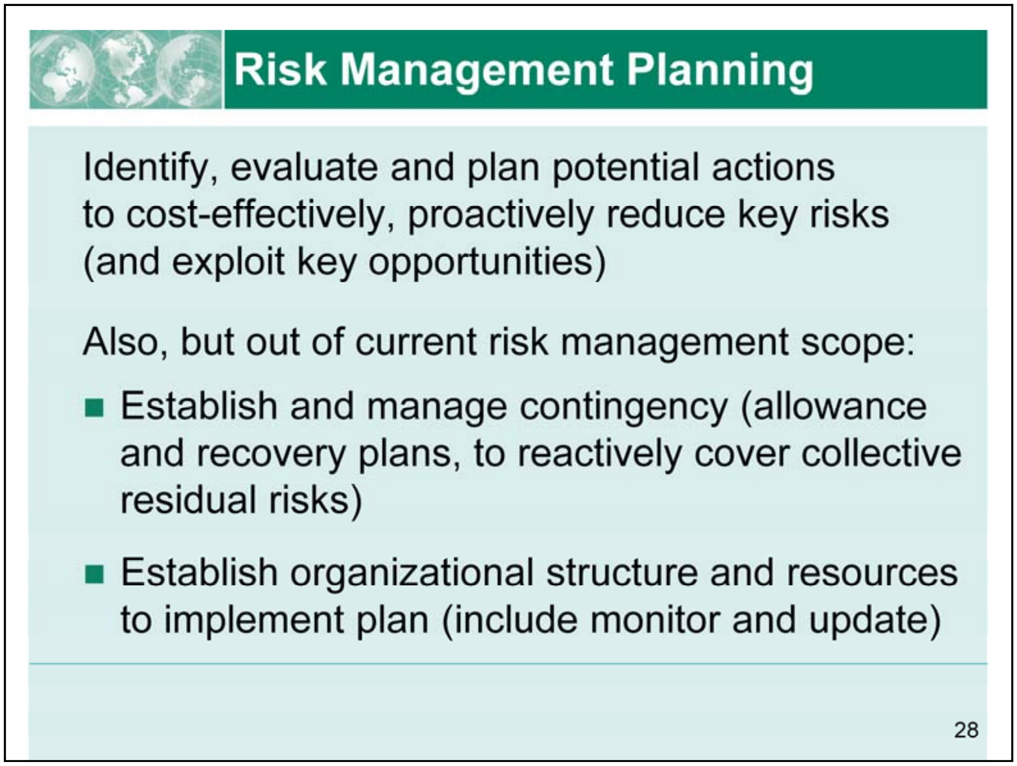
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



Risk Management Planning

Identify, evaluate and plan potential actions to cost-effectively, proactively reduce key risks (and exploit key opportunities)

Also, but out of current risk management scope:

- Establish and manage contingency (allowance and recovery plans, to reactively cover collective residual risks)
- Establish organizational structure and resources to implement plan (include monitor and update)

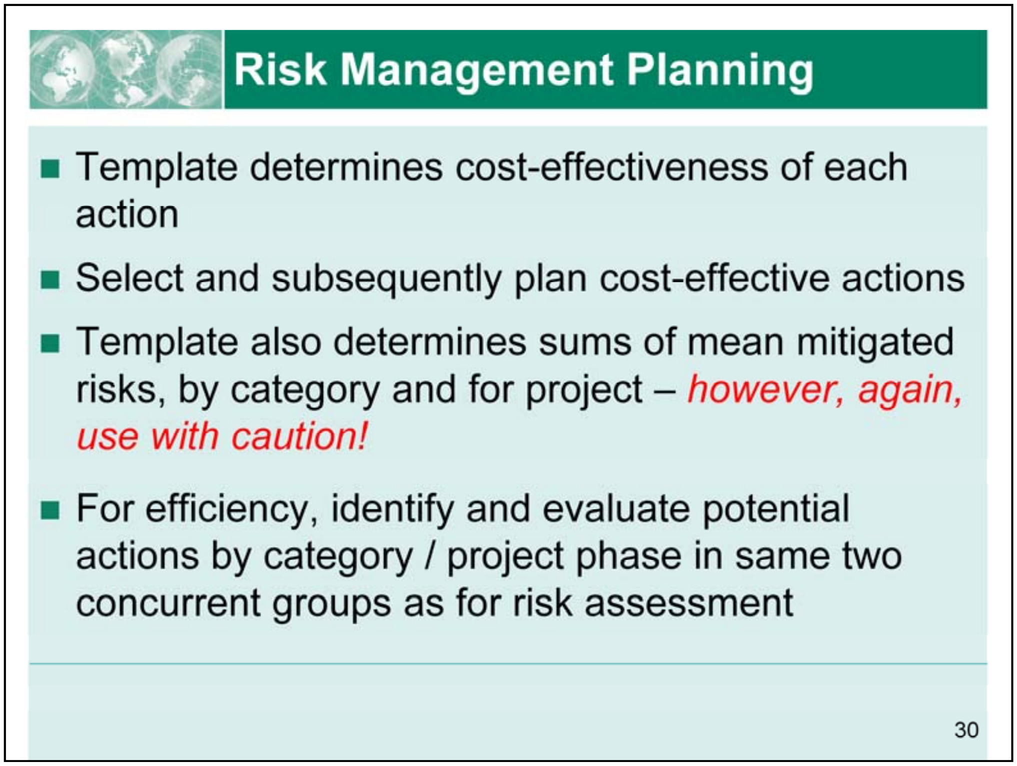
Contingency includes:

- Allowance, e.g., contingency fund or float (by phase), and protocols for managing it
- Recovery plans, e.g., scope deferral or schedule acceleration (by phase)

Determination of contingency allowance (by phase) should be done by quantitative risk analysis to determine the uncertainty in project performance (e.g., cost to complete from each phase) in conjunction with a specified level of confidence (target percentile), which is a DOT policy issue.

Risk Management Planning

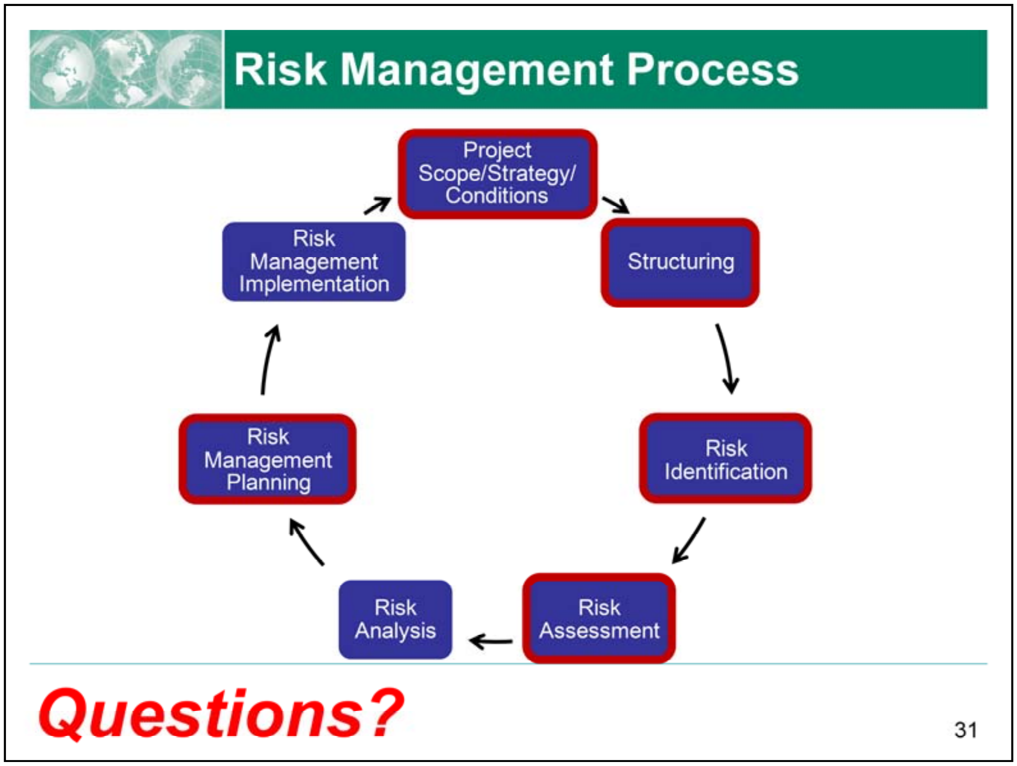
- Start with high-priority risks (and opportunities)
  e.g., ROW delay
- Identify potential, *specific* actions to reduce (exploit)
  e.g., advance ROW acquisition
- Assess implementation impacts for each action
  e.g., additional $1.0M to ROW
- Assess effectiveness of each action, in terms of its mean *changes to* one or more risk factors:
  - Schedule, cost and/or disruption impact if risk occurs
    e.g., reduce schedule impact to ROW in ½, from +3 to +1.5 months
  - Probability of occurrence
    e.g., reduce in ½, from 25% to 12.5%



Risk Management Planning

- Template determines cost-effectiveness of each action
- Select and subsequently plan cost-effective actions
- Template also determines sums of mean mitigated risks, by category and for project – *however, again, use with caution!*
- For efficiency, identify and evaluate potential actions by category / project phase in same two concurrent groups as for risk assessment

In the same ways as for risk assessment, if set of risks is comprehensive /non-overlapping, then template determines approx mean total performance and mean risk performance after mitigation by summing over those risks. However, again, this would not be adequate for establishing budget/milestone/contingency, because it does not consider the uncertainty.



Risk Management Process

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

Questions?

E.2 Forms

A set of forms has been developed to help conduct risk management on relatively simple rapid renewal projects, per the process described in this *Guide*. These forms specifically consider the key relevant performance objectives (i.e., construction cost, schedule and disruption, plus post-construction longevity) and project delivery methods (traditional design-bid-build and non-traditional design-build). However, these forms can also be applied to non-rapid renewal projects, and can consider a reduced set of project performance objectives for those projects.

The forms include the following, copies of which are attached:

- Summary Project Base Description
- Risk Identification (Brainstorming)
- Risk Register
- Rating Category Definition
- Unmitigated Risk Factor Assessment
- Risk Reduction Action Evaluation
- Risk Reduction Implementation Plan

Although the forms can also be used to document the results of calculations (as described in this *Guide*), these calculations are separate and must be done outside the forms.

<insert set of forms>

Summary Project Description

Brief Project Description:

<insert>

Project Scope, Strategy/Status, and Key Conditions and Assumptions (identify):

- Detailed scope (including alternatives): <insert>
- Funding: <insert>
- Design:
  - Design level: <insert>
  - Structural: <insert>
  - Geotechnical: <insert>
  - Drainage: <insert>
  - Pavement: <insert>
  - Systems (including lighting and ITS)
  - Design deviations: <insert>
- Environmental:
  - Environmental documentation: <insert>
  - Wetlands: <insert>
  - Streams: <insert>
  - ESA: <insert>
  - Floodplain: <insert>
  - Stormwater: <insert>
  - Contaminated/hazardous waste: <insert>
  - Section 106: <insert>
  - 4(f): <insert>
  - Permitting (incl 404): <insert>
- Right of way and other agreements
  - Right-of-Way: <insert>
  - Utilities: <insert>
  - Railroad: <insert>
  - Other stakeholders: <insert>
- Procurement:
  - Delivery method: <insert>
  - Contract packaging: <insert>
  - Market (general and specialty): <insert>
- Construction:
  - Construction access/restrictions (including seasonal, events, shifts/hours): <insert>
  - Maintenance of traffic/business: <insert>
  - Construction phasing: <insert>
- Post-construction ("longevity"):
  - O&M: <insert>
  - Replacement: <insert>

Project Schedule (delivery, O&M, replacement – abstracted on next sheet):

<summarize major activities/milestones, including discussion of basis and bias/conservatism>

Project Cost Estimate (delivery, O&M, replacement – abstracted on next sheet):

<summarize major elements and costs, including discussion of basis and bias/conservatism, escalation, NPV for long term, disruption cost, and schedule and longevity value>

Project Disruption Estimate (delivery, O&M, replacement – abstracted on next sheet):

<summarize major elements and disruption, including discussion of basis and bias/conservatism>

Project Tradeoffs (disruption, schedule, longevity):

<summarize policy values for combining performance measures>

Project Performance Analysis:

<summarize project schedule, cost (including inflation), disruption, longevity, and combined performance>

Project Schematics (Scope and Flowchart, customized or simplified – see next sheet):

<insert>

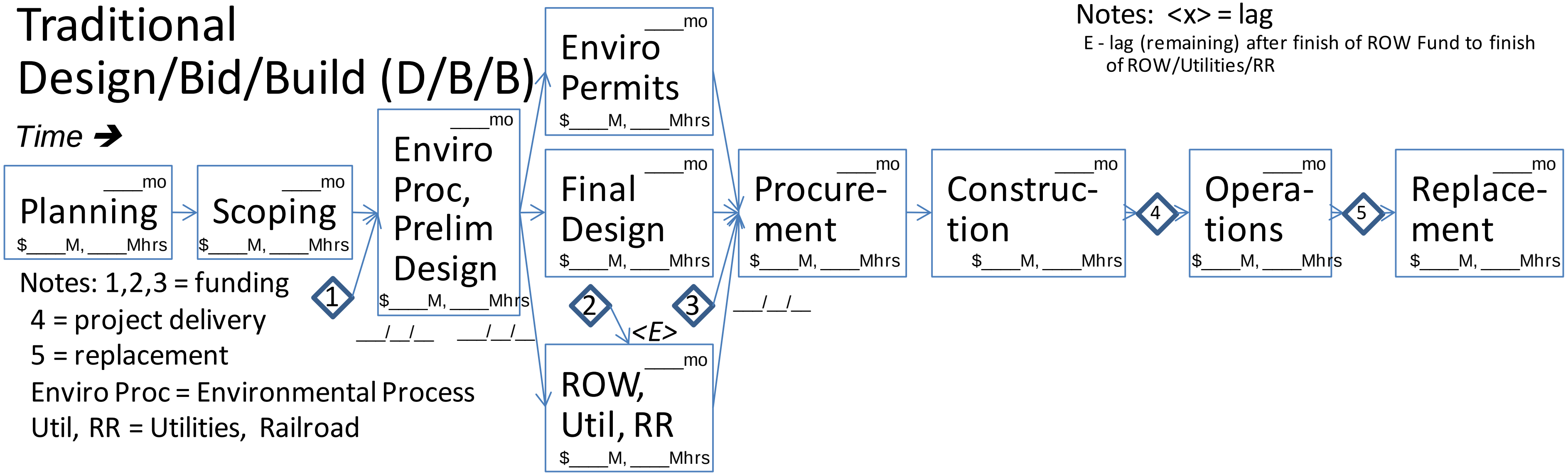
Project Base – Uses simplified "standard" flowcharts, which are really applicable to either traditional single phase/contract design/bid/build procurement or single phase/contract design/build procurement. A more detailed, custom flowchart would be needed for better schedule analysis (especially for multi-phase/contract procurement) and for quantitative risk analysis. Fill in the appropriate flowchart for the selected project delivery method, and fill in the other factors noted above.

Current Date/Status: ___________________________

Base Schedule: Flowchart depicts sequence of major project activities (left-to-right, per precedent arrows). Fill in remaining activity durations/lags/funding milestone dates directly in each activity box.

Base Cost: Fill in activity mean uninflated costs ($million) directly in each activity box, and following inflation factors: inflation start date _______; engineering inflation rate[1] ___%/yr, ROW inflation rate[1] ___%/yr, construction inflation rate[1] ___%/yr;
(note: [1] mean average rate from escalation start date through end of that phase)
Base Disruption: Fill in activity mean disruptions (million lost-hrs) in each activity box, disruption value NPV$____/hr;
Schedule Target Date: ________; **Schedule Value:** NPV$___million/mo; **Net Discount Rate**: ___%/yr;
Longevity Value: NPV$___/longevity$;
Extended OH Rates[2]: preCN uninflated $___million/mo, CN (incl penalty) uninflated $___million/mo
(note: [2] mean average rate during each phase, equal to specific fraction of average "burn" rates during each phase)

Traditional Design/Bid/Build (D/B/B)



Notes: <x> = lag
E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR

Notes: 1,2,3 = funding
4 = project delivery
5 = replacement
Enviro Proc = Environmental Process
Util, RR = Utilities, Railroad

Project Base – Uses simplified "standard" flowcharts, which are really applicable to either traditional single phase/contract design/bid/build procurement or single phase/contract design/build procurement. A more detailed, custom flowchart would be needed for better schedule analysis (especially for multi-phase/contract procurement) and for quantitative risk analysis. Fill in the appropriate flowchart for the selected project delivery method, and fill in the other factors noted above.

Current Date/Status: ___________________________

Base Schedule: Flowchart depicts sequence of major project activities (left-to-right, per precedent arrows). Fill in remaining activity durations/lags/funding milestone dates directly in each activity box.

Base Cost: Fill in activity mean uninflated costs ($million) directly in each activity box, and following inflation factors: inflation start date ________; engineering inflation rate[1] ___%/yr, ROW inflation rate[1] ___%/yr, construction inflation rate[1] ___%/yr;
(note: [1] mean average rate from escalation start date through end of that phase)

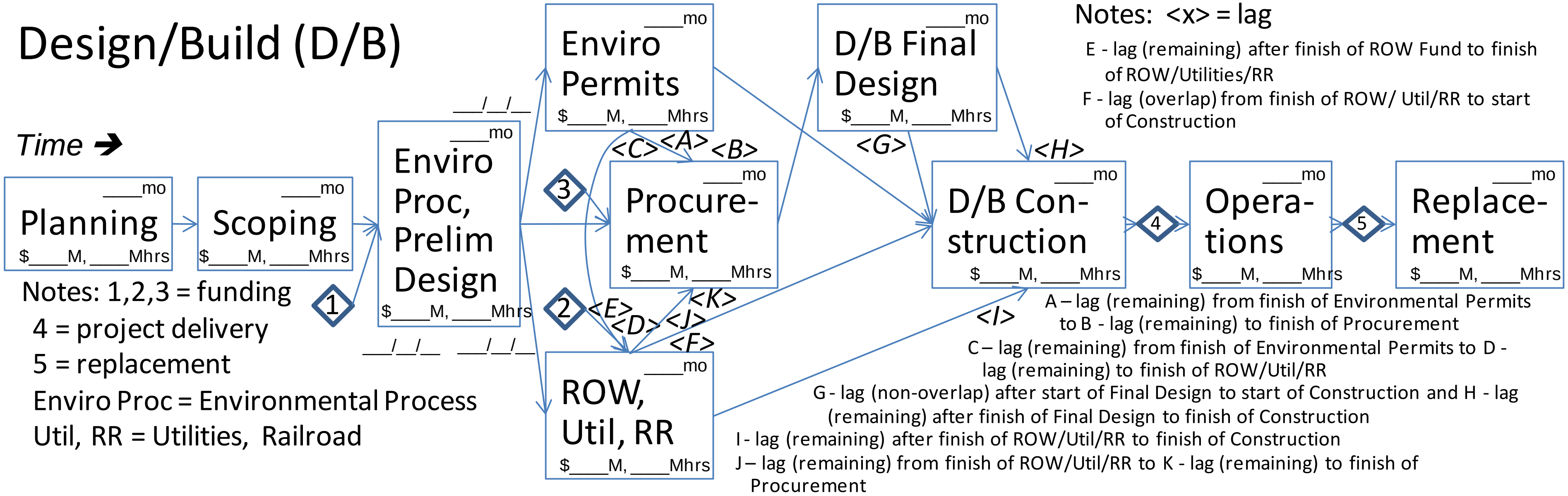
Base Disruption: Fill in activity mean disruptions (million lost-hrs) in each activity box, disruption value NPV$____/hr;

Schedule Target Date: _________; **Schedule Value:** NPV$___million/mo; **Net Discount Rate**: ___%/yr;

Longevity Value: NPV$___/longevity$;

Extended OH Rates[2]: preCN uninflated $___million/mo, CN (incl penalty) uninflated $___million/mo
(note: [2] mean average rate during each phase, equal to specific fraction of average "burn" rates during each phase)

Design/Build (D/B)



Notes: 1,2,3 = funding
4 = project delivery
5 = replacement
Enviro Proc = Environmental Process
Util, RR = Utilities, Railroad

Notes: <x> = lag
E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR
F - lag (overlap) from finish of ROW/ Util/RR to start of Construction

A – lag (remaining) from finish of Environmental Permits to B - lag (remaining) to finish of Procurement
C – lag (remaining) from finish of Environmental Permits to D - lag (remaining) to finish of ROW/Util/RR
G - lag (non-overlap) after start of Final Design to start of Construction and H - lag (remaining) after finish of Final Design to finish of Construction
I - lag (remaining) after finish of ROW/Util/RR to finish of Construction
J – lag (remaining) from finish of ROW/Util/RR to K - lag (remaining) to finish of Procurement

Activity (master list)	**Base Cost (unesc$M)**	**Base Disruption (M-hrs)**	**Base Duration (months)**	**Lag Label**	**Lag (mos)**	**Base Early Start Date**	**Base Early End Date**	**Float (months)**	**Base Cost (esc$M)**
Planning				A					
Scoping				B					
Design Funding									
Prelim Design/Env Proc				C					
Environmental Permits				D					
ROW/Util/RR Funding				E					
ROW/Util/RR				F					
Final Design				G					
Construction Funding									
Procurement				H					
Construction				I					
subtotal									
Operations				J					
Replacement				K					
subtotal				**←longevity (NPV$M)**					
Total				**←combined ($M)**					

Risk Identification (Brainstorming)

Item#	Risk or Opportunity (add rows as needed	Activity[1] (Circle One)	Description (possible non-"base" scenario(s) – causes and consequences)
EXAMPLE Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur. [2] Pr Dsn/Env Pr = preliminary design and environmental process			
100	*Landowner(s) unwilling to sell parcel <xxx>*	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding	*Additional right-of-way needed for project, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.*
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	

Risk Identification (Brainstorming)

Item#	**Risk or Opportunity (add rows as needed**	**Activity[1] (Circle One)**	**Description (possible non-“base” scenario(s) – causes and consequences)**
EXAMPLE Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur. [2] Pr Dsn/Env Pr = preliminary design and environmental process			
100	*Landowner(s) unwilling to sell parcel <xxx>*	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding	*Additional right-of-way needed for project, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.*
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	
		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	

Risk Register

Item	Risk or Opportunity (by category) (add lines with labels as needed)	Initial Item#	Description (possible non-“base” scenario(s) – causes and consequences)
PL	***Planning Risks***		
PL1			
PL2			
PL3			
SC	***Scoping Risks***		
SC1			
SC2			
SC3			
SC4			
PD	***Prelim Design / Enviro Process Risks***		
PD1			
PD2			
PD3			
PD4			
PD5			
PD6			
EP	***Environmental Permits Risks***		
EP1			
EP2			
EP3			
RU	***ROW/Utility/RR/etc Risks***		
RU1			
RU2			
RU3			
RU4			
FD	***Final Design Risks***		
FD1			
FD2			
FD3			
FD4			

Risk Register

Item	Risk or Opportunity (by category) (add lines with labels as needed)	Initial Item#	Description (possible non-“base” scenario(s) – causes and consequences)
CP	***Procurement Risks***		
CP1			
CP2			
CP3			
CP4			
CP5			
CN	***Construction Risks***		
CN1			
CN2			
CN3			
CN4			
CN5			
CN6			
CN7			
CN8			
CN9			
CN10			
OM	***Operations Risks***		
OM1			
OM2			
OM3			
RP	***Replacement Risks***		
RP1			
RP2			
RP3			
FN	***Funding Risks***		
FN1			
FN2			
FN3			

Note: Transfer risks from Risk ID Form (brainstorming) to appropriate category. Edit to be comprehensive/non-overlapping. See checklists.

Rating Category Definition

	Impacts if Event Occurs						Probability of Event Occurring (0=impossible to 1=guaranteed)		Severity (equivalent inflated $ million)	
	Change to Affected Activity Direct Cost $ (uninflated $ million)		Change to Affected Activity Duration T (months)		Change to Affected Activity Disruption D (million person-hours lost)					
Rating	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**	**Low end of range**	**High end of range**
VH	+25%	>+25%	+12	>+12	+25%	>+25%	0.7 (2:3)	1.0 (1:1)	+25%	>+25%
H	+10%	↖	+4	↖	+10%	↖	0.4 (2:5)	↖	+10%	↖
M	+3%	↖	+1	↖	+3%	↖	0.2 (1:5)	↖	+3%	↖
L	+1%	↖	+0.2	↖	+1%	↖	0.05 (1:20)	↖	+1%	↖
VL	0	↖	0	↖	0	↖	0.0 (0:1)	↖	0	↖
-VL	-1%	↖	-0.2	↖	-1%	↖			-1%	↖
-L	-3%	↖	-1	↖	-3%	↖			-3%	↖
-M	-10%	↖	-4	↖	-10%	↖			-10%	↖
-H	-25%	↖	-12	↖	-25%	↖			-25%	↖
-VH	<-25%	↖	<-12	↖	<-25%	↖			<-25%	↖
Base	$________				_________Mhrs				$__________	

Note: Can express values directly (e.g., default values are shown for probability of event occurring) or as % of base value (e.g., default values are shown for direct cost as % of total uninflated base cost through construction, for disruption as % of total base disruption through construction, and for severity as % of combined project performance. High end of one range is same as low end of next higher range (as indicated by arrows), and does not need to be repeated. Default values can be over-ridden.

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Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur) (*ratings as defined by range categories –defaults shown)						Calculated[1]	
			Mean Direct Cost Change $ to Activity (uninflated $M, or rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, or rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, or rating*)	Activity D Affected (circle)	Severity (equivalent inflated $M, or rating*)	Rank
EXAMPLE (showing mean values and ratings) Note: [1]Considers extended OHs, inflation, and values of schedule and disruption [2] Pr Dsn/Env Pr = preliminary design and environmental process										
RUi	Landowner(s) unwilling to sell parcel <xxx>	0.5 VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+$0.5M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo + – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+$0.3M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%)	1
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	

Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur) (*ratings as defined by range categories –defaults shown)						Calculated[1]	
			Mean Direct Cost Change $ to Activity (uninflated $M, or rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, or rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, or rating*)	Activity D Affected (circle)	Severity (equivalent inflated $M, or rating*)	Rank
EXAMPLE (showing mean values and ratings) Note: [1]Considers extended OHs, inflation, and values of schedule and disruption [2] Pr Dsn/Env Pr = preliminary design and environmental process										
R01	Landowner(s) unwilling to sell parcel <xxx>	0.5 VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+$0.5M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo + – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] – M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+$0.3M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%)	1
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	

Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)	Response Strategy (Circle)	Potential Risk Reduction Action (see checklist) (add rows as needed)	Implementation ([1]mean value or ratings – default ranges shown)						Effectiveness (value or rating)[3]				Calculated[1] Net Equiv Cost Savings (equiv infl $M)	Adopted
				Cost $ (uninfl $M)[1]	Affected $ Activity (Circle)	Delay T (months)[1]	Affected T Activity (Circle)	Disruption D (M man-hrs)[1]	Affected D Activity (Circle)	Probability (0.0 to 1.0)	Impacts (if occurs)				
											$ (un-infl $)	T (mos)	D (hr)		
EXAMPLE (showing mean values and ratings) Note: [1]Considers extended OHs, escalation, and values of schedule and disruption. [3]Residual value X_R = unmitigated value X_0 * (1 – effectiveness E_X); e.g., X_R=0 if E_X=100% [2] Pr Dsn/Env Pr = preliminary design/environmental process															
1	RUi. Landowners unwilling to sell parcel <xxx>	[✓ Avoid] Mitigate Transfer Accept	RUi(1). The team will design around areas where right of way may be an issue.	$0.1	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement [✓ Construction] Operations Replacement Funding 1,2,3	1.0	Planning Scoping [✓ Pr Dsn/Env Pr[2]] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	0	Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	1.0	NA	NA	NA	$0.2	✓
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) [✓ VL] (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) [✓ L] (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Pr Dsn/Env Pr[2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	

Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	**Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)**	**Response Strategy (Circle)**	**Potential Risk Reduction Action (see checklist) (add rows as needed)**	**Implementation (^{1}mean value or ratings – default ranges shown)**						**Effectiveness (value or rating)^3**				**Calculated^1 Net Equiv Cost Savings (equiv infl $M)**	**Adopted**
				Cost $ (uninfl $M)^1	**Affected $ Activity (Circle)**	**Delay T (months)^1**	**Affected T Activity (Circle)**	**Disruption D (M man-hrs)^1**	**Affected D Activity (Circle)**	**Probability (0.0 to 1.0)**	**Impacts (if occurs)**				
											$ (un-infl $)	**T (mos)**	**D (hr)**		
EXAMPLE (showing mean values and ratings) *Note: ^{1}Considers extended OHs, escalation, and values of schedule and disruption. ^{3}Residual value X_R = unmitigated value X_0 * (1 – effectiveness E_X); e.g., X_R=0 if E_X=100%* ^{2} Pr Dsn/Env Pr = preliminary design/environmental process															
1	RUi. Landowners unwilling to sell parcel <xxx>	[✓ Avoid] Mitigate Transfer Accept	RUi(1). The team will design around areas where right of way may be an issue.	$0.1 VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) [✓ VL] (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement [✓ Construction] Operations Replacement Funding 1,2,3	1.0 VH (>1yr) H (4mo-1yr) M (1mo-4mo) [✓ L] (1wk-1mo) VL (<1wk) 0	Planning Scoping [✓ Pr Dsn/Env Pr^2] Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	1.0 Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	NA +-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	NA +-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	NA +-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	$0.2 + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	✓
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
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		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Pr Dsn/Env Pr^2 Enviro Permits ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
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Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	RUi(1). The team will design around areas where right of way may be an issue, specifically at parcel <xxx>.	Design lead, in conjunction with right-of-way lead	By end of preliminary design	Need to get approval for design deviations.

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	RUi(1). The team will design around areas where right of way may be an issue, specifically at parcel <xxx>.	Design lead, in conjunction with right-of-way lead	By end of preliminary design	Need to get approval for design deviations.

E.3 Template

A template has been developed to help conduct risk management on relatively simple rapid renewal projects, per the process described in this *Guide*. This template specifically considers the key relevant performance objectives (i.e., construction cost, schedule and disruption, plus post-construction longevity) and project delivery methods (traditional design-bid-build and non-traditional design-build). However, this template can also be applied to non-rapid renewal projects, and can consider a reduced set of project performance objectives for those projects.

The template (a Microsoft Excel workbook) has been developed to enter the data directly, and then automatically carry out the appropriate calculations (as described in this *Guide*). This template consists of fourteen (14) macro-free linked worksheets in a single workbook, highlighting user inputs while hiding and protecting other parts to prevent confusion, mistakes, and inadvertent misuse. A User's Guide for this template has been developed, documenting and explaining the various worksheets, and is attached. The template is provided on the CD.

<insert Risk Management Planning Template User’s Guide ver003.doc, which in turn requires other inserts>

User's Guide for Microsoft Excel Workbook Template for Conducting Simplified Risk Management Planning for Rapid Renewal Projects

(<Risk Management Planning Template (Beta 30June2010b)> per SHRP2 R09 "*Guide for the Process of Managing Risk on Rapid Renewal Projects*" and related training materials)

Contents

1. Introduction

1.1 Purpose and Objectives

- Facilitate conducting simplified risk management planning (in terms of proactive risk reduction, but not contingency or recovery management) for relatively simple rapid renewal projects.
- Optimize key rapid renewal project performance objectives (measures):
    - Minimize project schedule, in terms of project construction completion (operations start) date;
    - Minimize project cost, in terms of total inflated cost (through construction);
    - Minimize project "disruption", in terms of total user impacts (through construction); and
    - Maximize project "longevity", in terms of combination of schedule, cost and disruption post construction (i.e., considering operations and replacement).
- Optimize by minimizing combined project performance, in terms of combination of project schedule (through construction), inflated project cost (through construction), project disruption (through construction) and project longevity (post-construction).

1.2 Background and Limitations

- Ref. SHRP2 R09 "*Guide for the Process of Managing Risk on Rapid Renewal Projects*" ("*Guide*") and related training materials – more discussion and examples are provided in *Guide*.
- Does not evaluate the uncertainty (or range) in project performance, only mean values. Such mean values (by themselves) would not be sufficient to establish budgets or milestones.
- Template was developed by Golder Associates Inc. (Golder) for its own use. This is a Beta version (dated 30June2010), and as such is still under development and might contain some "bugs" - please contact Golder if bugs are discovered so that they can be fixed in future versions. Golder provides this version solely as a courtesy, but does not warrant that the results are correct and cannot warrant that either the user-specified inputs are appropriate or the results will be interpreted correctly by the user, both of which are outside of Golder's control. In using this template, a user acknowledges that they do so at their own risk, and that Golder has no liability for such use.

1.3 General Guidance

- Project performance components are separated (ref Ch 2 in the *Guide*):
    - "Activities" (pieces of project) versus "project" (combination of all activities).
    - "Base" (without risk or contingency/float) versus "risk" (complementary to "base", which is intended to be covered by contingency/float), where "risk" includes opportunities (i.e., simply negative risks). "Total" is the combination of "base" and "risk".
    - "Unmitigated" (before additional risk reduction actions) versus "mitigated" (with additional risk reduction actions)
    - "Mean" (probability-weighted average value) versus "uncertainty/range" (likelihoods of various possible values). This template does not include assessment and determination

    of full uncertainty/range, only mean values (which by themselves would not be sufficient for establishing budgets and milestones)

- Proactive risk reduction process (ref Ch 2 in the *Guide*):
    - Unmitigated (before additional risk reduction actions)
        - Unmitigated "base" assessment and performance analysis
        - Unmitigated "risks" identification and assessments
        - Unmitigated "total" performance analysis
    - Mitigated (with additional risk reduction actions)
        - Mitigation identification (focusing on key risks), implementation and effectiveness assessments, cost-effectiveness evaluation, and subsequent selection
        - Mitigated "total" performance analysis
- Microsoft Excel workbook template developed to document (similar to forms in the *Guide*) and automatically conduct analyses (as described in the *Guide*)
    - Load/save – load/open the template in Excel and then save under a specific project name. Periodically resave the renamed template during use.
    - Template is Microsoft Excel workbook with following linked spreadsheets:
        - Instructions
        - <1. "Base" Project Info>
        - <2a.Initial Risks (Brainstorm)>
        - <2b.Risks by Category>
        - <3a.Rating Scales>
        - <3b.Unmitigated Risk Assess>
        - <4a.Unmitigated Risk Results>
        - <4b.Unmitigated Risk Ranking>
        - <4c.Unmitig. Risk Ranking Plots>
        - <5a.Risk Reduction Evaluation>
        - <5b.Risk Reduction Plan>
        - <6a.Mitigated Risk Assess>
        - <6b.Mitigated Risk Results>
        - <6c.Mitigated Risk Ranking>
        - <6d.Mitigated Risk Ranking Plots>
    - Input – required inputs (of which some are drop down boxes) for each spreadsheet are highlighted (in yellow shading), with other cells protected from being changed. User can reformat specific rows (e.g., autoheight or hide if not unused) or columns (e.g., change width) if needed (for long descriptions and for printing) – note: must not hide first and last rows of any section, so that hidden rows in between can subsequently be unhidden if needed.
    - Output – outputs for each spreadsheet are automatically generated . Template is protected (and most calculations are hidden) to prevent inadvertent changes that could introduce errors in outputs. Print area for each spreadsheet in workbook is pre-set, so

that user simply needs to "print" worksheet or entire workbook. However, user can reformat specific rows (e.g., autoheight or hide if not used) or columns (e.g., change width) if needed (for long descriptions).

1.4 Organization

- This User's Guide (in the following chapters) describes the specific input (where needed) and associated output in each spreadsheet for the following basic components of the template (which mirror the proactive risk reduction process described above):

  Ch 2. "Base" Project Information and Performance Analysis: <1.Base Project Info>
  Ch 3. Unmitigated Risk Identification and Assessment: <2a.Initial Risks (Brainstorm)>, <2b.Risks by Category>, <3a.Rating Scales>, and <3b.Unmitigated Risk Assess>
  Ch 4. Unmitigated Performance (Risk) Analysis: <4a.Unmitigated Risk Results>, <4b.Unmitigated Risk Ranking>, and <4c.Unmitig. Risk Ranking Plots>
  Ch 5. Risk Reduction Planning: <5a.Risk Reduction Evaluation> and <5b.Risk Reduction Plan>
  Ch 6. Mitigated Performance (Risk) Analysis: <6a.Mitigated Risk Assess>, <6b.Mitigated Risk Results>, <6c.Mitigated Risk Ranking> and <6d.Mitigated Risk Ranking Plots>

- Instructions are also provided as a separate spreadsheet at the beginning of the workbook (see Fig 1), and these instructions are repeated in each spreadsheet in the workbook. An example of a filled-in template for a specific project is provided in the *Guide*.

Workbook Instructions Golder Associates©

Limitations : This protected MS Excel workbook was developed by Golder Associates Inc. (Golder) for its own use, as a companion to the "Guide for the Process of Managing Risks on Rapid Renewal Projects" and related training materials developed by Golder under NAS/TRB SHRP2 research project R09; these materials include a separate "User's Manual" for this template to which a user is referred. This is a Beta version (dated 30June2010), and as such is still under development and might contain some "bugs" - please contact Golder (broberds@golder.com) if bugs are discovered so that they can be fixed in future versions. Golder provides this version solely as a courtesy, but does not warrant that the results are correct and cannot warrant that either the user-specified inputs are appropriate or the results will be interpreted correctly by the user, both of which are outside of Golder's control. In using this template, a user acknowledges that they do so at their own risk, and that Golder has no liability for such use.

Proceed through worksheets in following order (see cautions about making changes in previous sheets):

<1. "Base" Project Info>	Enter significant (simplified) project cost, schedule, disruption and "value" information per template, and specify whether traditional DBB or DB project delivery - automatically generates a simple cost-loaded schedule with escalation, default extended OH rates (which can be revised), measure of longevity (NPV of O&M and replacement cost and disruption), and "combined" project performance measure (cost, schedule and disruption through construction, and post construction longevity). The risks will subsequently be defined relative to this "base", and might need to be redefined if the "base" changes. Similarly, the risk management (reduction) actions might need to be re-evaluated anc the Risk Management (Reduction) Plan changed if the "base" changes.
<2a.Initial Risks (Brainstorm)>	Enter all risks and opportunities identified through brainstorming, and specify which project activity each is most likely to occur during (and very unlikely to occur after), and a more detailed description of each (as needed). At this time, only the nature of the event, and not its severity, are described - severity (expressed in terms of risk factors) will be described in <3b.Unmitigated Risk Assess>.
<2b.Risks by Category>	Risks (and their detailed descriptions) from <2a.Initial Risks> are automatically carried over and listed in appropriate "category" (i.e., the project activity during which the risk is most likely to occur, and after which it is very unlikely to occur). However, add new risks (based on provided check list) and/or edit initial risks (including the detailed description) in this sheet to ensure comprehensive and non-overlapping set. Once a risk is edited in this sheet, the tie to <2a.Initial Risks> is broken. Hence, do not go back to change risks in <2a.Initial Risks>, because they will not necessarily be carried over to this sheet. Can add/edit risks until start <5a.Risk Reduction Evaluation>, however cannot move risks after start <3b.Unmitigated Risk Assess> (because would cause assessments in <3b.Unmitigated Risk Assess> to incorrectly address wrong risk), and editing risks after starting <3b.Unmitigated Risk Assess> might require reassessment of that risk.
<3a.Rating Scales>	If using mean ratings (instead of mean values) in <3b.Unmitigated Risk Assess>, confirm or revise the default rating-scale information for each factor (not needed if using mean values)before doing any assessments in <3b.Unmitigated Risk Assess>. Changes after starting <3b.Unmitigated Risk Assess> might require reassessment of risks.
<3b.Unmitigated Risk Assess>	Risks from <2b.Risks by Category> are automatically carried over, although the detailed description is not - any edits to risk register must be made in <2b. Risks by Category>, which could affect <3b. Unmitigated Risk Assess>. Enter mean rating (per <3a.Rating Scales>)or mean value for each risk factor, assuming no additional risk management. The unmitigated mean severity is determined for each risk automatically. If the set of risks is comprehensive and non-overlapping, approximate mean values for unmitigated collective risk are also determined automatically. Can revise assessments until start <5a.Risk Reduction Evaluation>. Changes to assessments after starting <5a.Risk Reduction Evaluation>, e.g., updates, might require redoing <5a.Risk Reduction Evaluation> and <5b.Risk Reduction Plan>, because the effectiveness might change.
<4a.Unmitigated Risk Results>	The unmitigated collective risks (from <3b. Unmitigated Risk Assess>) are determined automatically and combined with the base factors (from <1.Base Project Info>) to automatically determine approximate mean values of unmitigated total project performance.
<4b.Unmitigated Risk Ranking>	The ranking of the identified risks and opportunities (based on their unmitigated mean severity from <3b.Unmitigated Risk Assess>) is automatically determined.
<4c.Unmitig. Risk Ranking Plots>	The ranking of the identified risks and opportunities (based on their unmitigated mean severity, from <4b.Unmitigated Risk Ranking>) is automatically plotted.
<5a.Risk Reduction Evaluation>	Initially (premitigated/pre-updated) ranked risks and opportunities from <4b.Unmitigated Risk Ranking> must be manually carried over (the current rankings are shown in this sheet); once entered, their properties will be automatically carried over. Enter the candidate actions for each critical risk (both immediate and contractual, first from brainstorming and then from provided check list), and enter the cost-effectiveness factors for each. The cost-effectiveness of each candidate will be automatically determined. Select the most cost-effective action for each risk, with the default being "no action". The assessments can be revised until start <5b.Risk Reduction Plan>; changes after starting <5b.Risk Reduction Plan> might change the ranking of the actions.
<5b.Risk Reduction Plan>	The selected (most cost-effective) set of actions to address the set of risks from <5a.Risk Reduction Evaluation> must be manually carried over (the currently selected actions are shown in this sheet, listed in rank order based on cost-effectiveness); once entered, their properties will be automatically carried over. Add implementation details.
<6a.Mitigated Risk Assess>	The risks and their unmitigated factors are automatically carried over from <3b.Unmitigated Risk Assess>, and combined with the assessed effectiveness of the selected risk reduction actions (from <5b.Risk Reduction Plan>), to automatically determine the mitigated mean severity for each risk. If the set of risks is comprehensive and non-overlapping, approximate mean values for mitigated collective risk are also determined automatically.
<6b.Mitigated Risk Results>	The residual collective risks for the Risk Reduction Plan (from <5b.Risk Reduction Plan>) are determined automatically and combined with the initial base factors (from <1.Base Project Info>), the unmitigated risk factors (from <3b.Unmitigated Risk Assess>), and risk management factors (from <5a.Risk Reduction Evaluation>) to automatically determine approximate mean values of mitigated total project performance.
<6c.Mitigated Risk Ranking>	The ranking of the identified risks and opportunities (based on their mitigated mean severity from <6a.Mitigated Risk Assess>) is automatically determined.
<6d.Mitigated Risk Ranking Plots>	The ranking of the identified risks and opportunities (based on their mitigated mean severity, from <6c.Mitigated Risk Ranking>) is automatically plotted.

Yellow-shaded cells are input cells; all others are protected and/or hidden to prevent inadvertent changes, which could produce misleading results

Comments : Additional information is provided in spreadsheets through embedded comments, denoted by small red triangle in upper right corner of a cell and exposed when mouse moves over that cell.

Printing : Only relevant information is printed for each spreadsheet (print area is pre-set). However, can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows. Generally, only need to print latest spreadsheet (relevant info from previous spreadsheets is generally incorporated), but can print entire workbook if desired for complete report.

Figure 1. <Instructions>

2. "Base" Project Information and Performance Analysis: <1.Base Project Info>

- ref.Ch 4 in the *Guide*
- spreadsheet <1.Base Project Info> - see Fig 2

2.1 Inputs

In spreadsheet <1.Base Project Info> (see Fig 2):

- Enter <project name> and select <project delivery method, either Traditional Design/Bid/Build (D/B/B) or Design/Build (D/B), from drop down box> - each project delivery method subsequently references a different simplified flowchart, as shown in Fig 2, which is carried throughout the rest of the analysis. Each project is divided into the following activities (regardless of project delivery method, which only affects the sequence of these activities):
    - Planning
    - Scoping
    - Design funding
    - Preliminary design/environmental process
    - Environmental permits
    - ROW/utility/RR funding
    - ROW/utilities/RR
    - Final design
    - Construction funding
    - Procurement
    - Construction
    - Operations
    - Replacement
- Enter project "base" schedule factors:
    - <mean durations in months or mean milestone dates> for each activity in relevant simplified flowchart (note: funding activities are expressed as milestones, whereas the other activities are expressed as durations)
    - <lags, in months> for specific activities, depending on which flowchart is relevant
        - Traditional DBB, which tends to be linear/sequential
            - E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR
        - Design-Build, which tends to overlap/accelerate
            - A – lag (remaining) from finish of Environmental Permits to B - lag (remaining) to finish of Procurement
            - C – lag (remaining) from finish of Environmental Permits to D - lag (remaining) to finish of ROW/Util/RR
            - E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR
            - F - lag (overlap) from finish of ROW/Util/RR to start of Construction

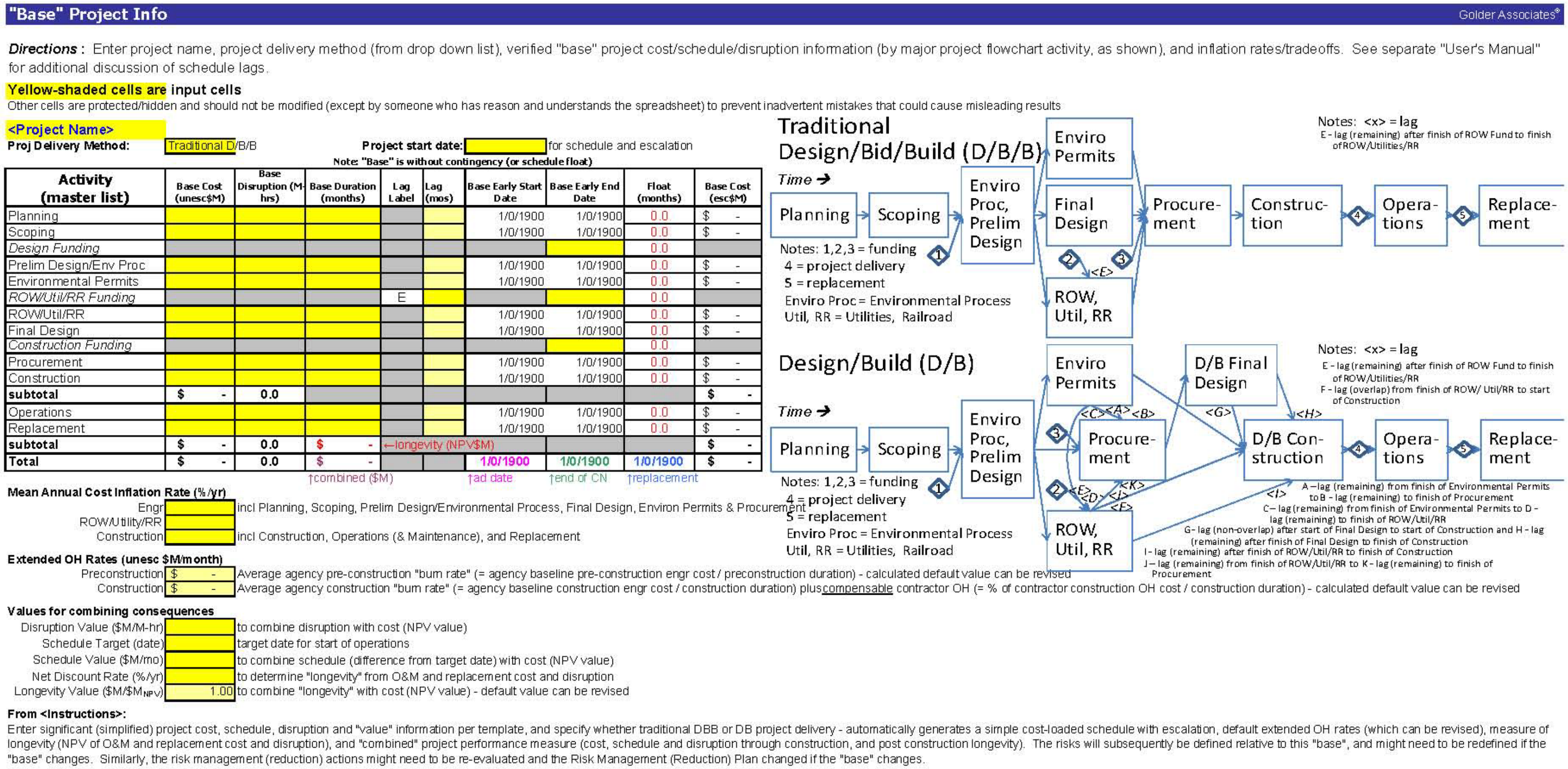
        - G - lag (non-overlap) after start of Final Design to start of Construction and H - lag (remaining) after finish of Final Design to finish of Construction
        - I - lag (remaining) after finish of ROW/Util/RR to finish of Construction
        - J – lag (remaining) from finish of ROW/Util/RR to K - lag (remaining) to finish of Procurement
- Enter <project "base" cost factors, in mean uninflated $million> for each activity in relevant simplified flowchart
- Enter <project "base" disruption factors, in mean million lost-hours> for each activity in relevant simplified flowchart
- Enter <inflation rates, in mean average %/yr from reference start date through mid-point of relevant activities in relevant simplified flowchart> for following activities (note: operations and replacement are covered separately under longevity tradeoffs):
    - Engineering (including planning, scoping, prelim design/environmental process, environmental permits, final design, and procurement)
    - ROW/utility/RR
    - Construction
- Enter <extended OH rates, in mean average uninflated $ per month critical path delay> or accept default values (if default value not over-ridden) for following phases:
    - Pre-construction (default value = average agency pre-construction "burn rate" = agency baseline pre-construction engr cost / preconstruction duration)
    - Construction (default value = average agency construction "burn rate" [= agency baseline construction engr cost / construction duration] plus compensable contractor OH [= 5% of contractor construction cost / construction duration])
- Enter "tradeoffs" to determine longevity and severity:
    - Enter <disruption value, in terms of mean average current uninflated $ per lost-hour, to determine user costs>
    - Enter <schedule target, in terms of planned construction completion date> and <schedule value, in terms of current uninflated $million per month change in construction completion date>.
    - Enter <net post-construction discount rate, in terms of %/yr, to determine NPV of longevity at end of construction> and <longevity value, in terms of YOE$ per NPV$, to determine equivalent inflated cost of longevity> or accept default value of 1.0 (if default value not over-ridden).

2.2 Outputs

In spreadsheet <1.Base Project Info> (see Fig 2):

- the project delivery method (and relevant project flowchart) and the associated "base" factor assessments (i.e., regarding cost, schedule, disruption, inflation, extended OHs and tradeoffs) for the project are documented.
- The "base" project performance is automatically determined:

- Project “base” schedule, in terms of mean early start and end dates and float (in months) for each activity in relevant simplified flowchart, and key project “base” mean milestone dates (i.e., for advertisement, end of construction, and replacement)
- Project “base” cost, in terms of both mean uninflated and inflated $million, through construction and post construction
- Project “base” disruption, in terms of mean million lost-hours, through construction and post construction
- Project “base” longevity (i.e., combination via specified tradeoffs of mean post construction schedule, cost and disruption), in terms of mean NPV$million at end of construction
- Project “base” combined performance (i.e., combination via specified tradeoffs of mean schedule, cost, and disruption through construction, and mean longevity), in terms of mean equivalent inflated $million.



"Base" Project Info

Golder Associates®

Directions **:** Enter project name, project delivery method (from drop down list), verified "base" project cost/schedule/disruption information (by major project flowchart activity, as shown), and inflation rates/tradeoffs. See separate "User's Manual" for additional discussion of schedule lags.

Yellow-shaded cells are input cells

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results

<Project Name>

Proj Delivery Method: Traditional D/B/B

Project start date: for schedule and escalation

Note: "Base" is without contingency (or schedule float)

Activity (master list)	**Base Cost (unesc$M)**	**Base Disruption (M-hrs)**	**Base Duration (months)**	**Lag Label**	**Lag (mos)**	**Base Early Start Date**	**Base Early End Date**	**Float (months)**	**Base Cost (esc$M)**
Planning						1/0/1900	1/0/1900	0.0	$ -
Scoping						1/0/1900	1/0/1900	0.0	$ -
Design Funding								0.0	
Prelim Design/Env Proc						1/0/1900	1/0/1900	0.0	$ -
Environmental Permits						1/0/1900	1/0/1900	0.0	$ -
ROW/Util/RR Funding				E				0.0	
ROW/Util/RR						1/0/1900	1/0/1900	0.0	$ -
Final Design						1/0/1900	1/0/1900	0.0	$ -
Construction Funding								0.0	
Procurement						1/0/1900	1/0/1900	0.0	$ -
Construction						1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**							**$ -**
Operations						1/0/1900	1/0/1900	0.0	$ -
Replacement						1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**	**$ -**	←longevity (NPV$M)					**$ -**
Total	**$ -**	**0.0**	**$ -**			**1/0/1900**	**1/0/1900**	**1/0/1900**	**$ -**

↑combined ($M) ↑ad date ↑end of CN ↑replacement

Mean Annual Cost Inflation Rate (%/yr)

Engr — incl Planning, Scoping, Prelim Design/Environmental Process, Final Design, Environ Permits & Procurement

ROW/Utility/RR

Construction — incl Construction, Operations (& Maintenance), and Replacement

Extended OH Rates (unesc $M/month)

Preconstruction $ - Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / preconstruction duration) - calculated default value can be revised

Construction $ - Average agency construction "burn rate" (= agency baseline construction engr cost / construction duration) plus compensable contractor OH (= % of contractor construction OH cost / construction duration) - calculated default value can be revised

Values for combining consequences

Disruption Value ($M/M-hr)		to combine disruption with cost (NPV value)
Schedule Target (date)		target date for start of operations
Schedule Value ($M/mo)		to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)		to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	1.00	to combine "longevity" with cost (NPV value) - default value can be revised

From <Instructions>:

Enter significant (simplified) project cost, schedule, disruption and "value" information per template, and specify whether traditional DBB or DB project delivery - automatically generates a simple cost-loaded schedule with escalation, default extended OH rates (which can be revised), measure of longevity (NPV of O&M and replacement cost and disruption), and "combined" project performance measure (cost, schedule and disruption through construction, and post construction longevity). The risks will subsequently be defined relative to this "base", and might need to be redefined if the "base" changes. Similarly, the risk management (reduction) actions might need to be re-evaluated and the Risk Management (Reduction) Plan changed if the "base" changes.

Notes: 1,2,3 = funding
4 = project delivery
5 = replacement
Enviro Proc = Environmental Process
Util, RR = Utilities, Railroad

Notes: <x> = lag
E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR

Notes: 1,2,3 = funding
4 = project delivery
5 = replacement
Enviro Proc = Environmental Process
Util, RR = Utilities, Railroad

Notes: <x> = lag
E - lag (remaining) after finish of ROW Fund to finish of ROW/Utilities/RR
F - lag (overlap) from finish of ROW/ Util/RR to start of Construction

A – lag (remaining) from finish of Environmental Permits to B - lag (remaining) to finish of Procurement
C – lag (remaining) from finish of Environmental Permits to D - lag (remaining) to finish of ROW/Util/RR
G - lag (non-overlap) after start of Final Design to start of Construction and H - lag (remaining) after finish of Final Design to finish of Construction
I - lag (remaining) after finish of ROW/Util/RR to finish of Construction
J – lag (remaining) from finish of ROW/Util/RR to K - lag (remaining) to finish of Procurement

Figure 2. <1.Base Project Info>

3. Unmitigated Risk Identification and Assessment: <2a.Initial Risks (Brainstorm)>, <2b.Risks by Category>, <3a.Rating Scales>, and <3b.Unmitigated Risk Assess>

- ref.Ch 5 and Ch 6 in the *Guide*
- spreadsheets <2a.Initial Risks (Brainstorm)> - see Fig 3, <2b.Risks by Category> - see Fig 4, <3a.Rating Scales> - see Fig 5, and <3b.Unmitigated Risk Assess> - see Fig 6

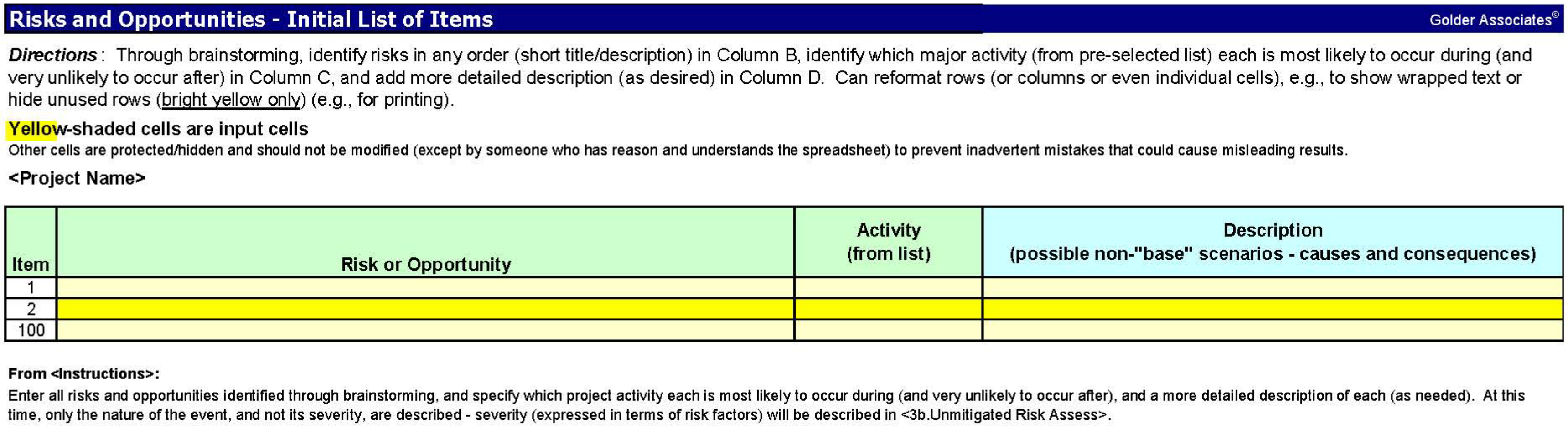
3.1 Inputs

- In <2a.Initial Risks (Brainstorm)> (see Fig 3), enter <descriptive title> and <description> for each risk (up to 100, identified through brainstorming, considering current plans without additional risk management) in random order, and then enter their "category" (select <flowchart activity, from drop-down box> during which they are most likely to occur and unlikely to occur after). Unused rows (except the last) can be hidden.
- In <2b.Risks by Category> (see Fig 4), edit categorized risks, which have been automatically carried over from <2a.Initial Risks (Brainstorm)>, e.g., by comparing with checklist in the *Guide*, to ensure comprehensive and non-overlapping set in each category (up to maximum number per category, e.g., 15 for most categories, 20 for Procurement, 25 for Construction and 10 for Funding). Can edit < descriptive title> and/or <description>, either by simply typing over or by first copying and pasting special (values) – however, such editing breaks the link with <2a.Initial Risks (Brainstorm)>. Can also add risks by simply typing < descriptive title> and <description>, over-riding the equations that carries them over from <2a.Initial Risks (Brainstorm)>. Similarly, can delete risks by simply deleting < descriptive title> and <description>, although unless replaced there will be a gap in the risk numbering. All changes in <descriptive title> and/or <description> must be made in this sheet; these are carried forward throughout the rest of the workbook (by item #, e.g., PL1).
- In <3b.Unmitigated Risk Assess> (see Fig 6), for each risk (which have been automatically carried over from <2b.Risks by Category>), enter risk factor assessments (either <mean values> or <ratings, from drop-down box>, per pre-defined rating scales in <3a.Rating Scales> - see Fig 5, and <affected activity, from drop-down box>) before any additional risk management:
    - Unmitigated probability of that risk event occurring
    - Unmitigated mean cost impact (and affected project activity) if that risk event occurs, in terms of uninflated $million
    - Unmitigated mean schedule impact (and affected project activity) if that risk event occurs, in terms of months delay in affected activity (regardless of whether it is on critical path)
    - Unmitigated mean disruption impact (and affected project activity) if that risk event occurs, in terms of million lost-hours.
- In <3a.Rating Scales> (see Fig 5), if rating scales are used in <3b.Unmitigated Risk Assess> (see Fig 6), enter <value> in appropriate units for each unique range end point. For cost impact, disruption impact and severity, default values are tied (as specified percentages) to "base" costs,

"base" disruption and "base" severity (actually combined performance), either from <1.Base Project Info> (see Fig 2) or over-ridden; however, these can be over-ridden by simply typing in specific values (although this breaks the link to those base values). Common default values are also provided for schedule impacts and probabilities; these default values can also be over-ridden by simply typing in specific values.

3.2 Outputs

- In <2b.Risks by Category> (see Fig 4), the risks (by category) are documented. Unused rows (except first and last in each category) can be hidden.
- In <3b.Unmitigated Risk Assess> (see Fig 6):
    - the unmitigated risk factor assessments (either in mean values or ratings, per pre-defined rating scales in <3a.Rating Scales> - see Fig 5) for each identified risk are documented
    - the unmitigated mean change in combined project performance or "severity" (mean values or ratings, per pre-defined rating scales in <3a.Rating Scales> - see Fig 5, in terms of equivalent inflated $million) is automatically determined for each identified risk (ratings are used if any of the risk factors are expressed as ratings), and the identified risks are ranked on that basis
    - the sums (over all risks) of the mean performance measures (e.g., direct cost) are also determined automatically for each category, as well as over all categories. Note: although informative, these sums would not be adequate to establish budgets/milestones/contingencies
    - unused rows (except first and last in each category) can be hidden.



Risks and Opportunities - Initial List of Items

Golder Associates©

Directions : Through brainstorming, identify risks in any order (short title/description) in Column B, identify which major activity (from pre-selected list) each is most likely to occur during (and very unlikely to occur after) in Column C, and add more detailed description (as desired) in Column D. Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

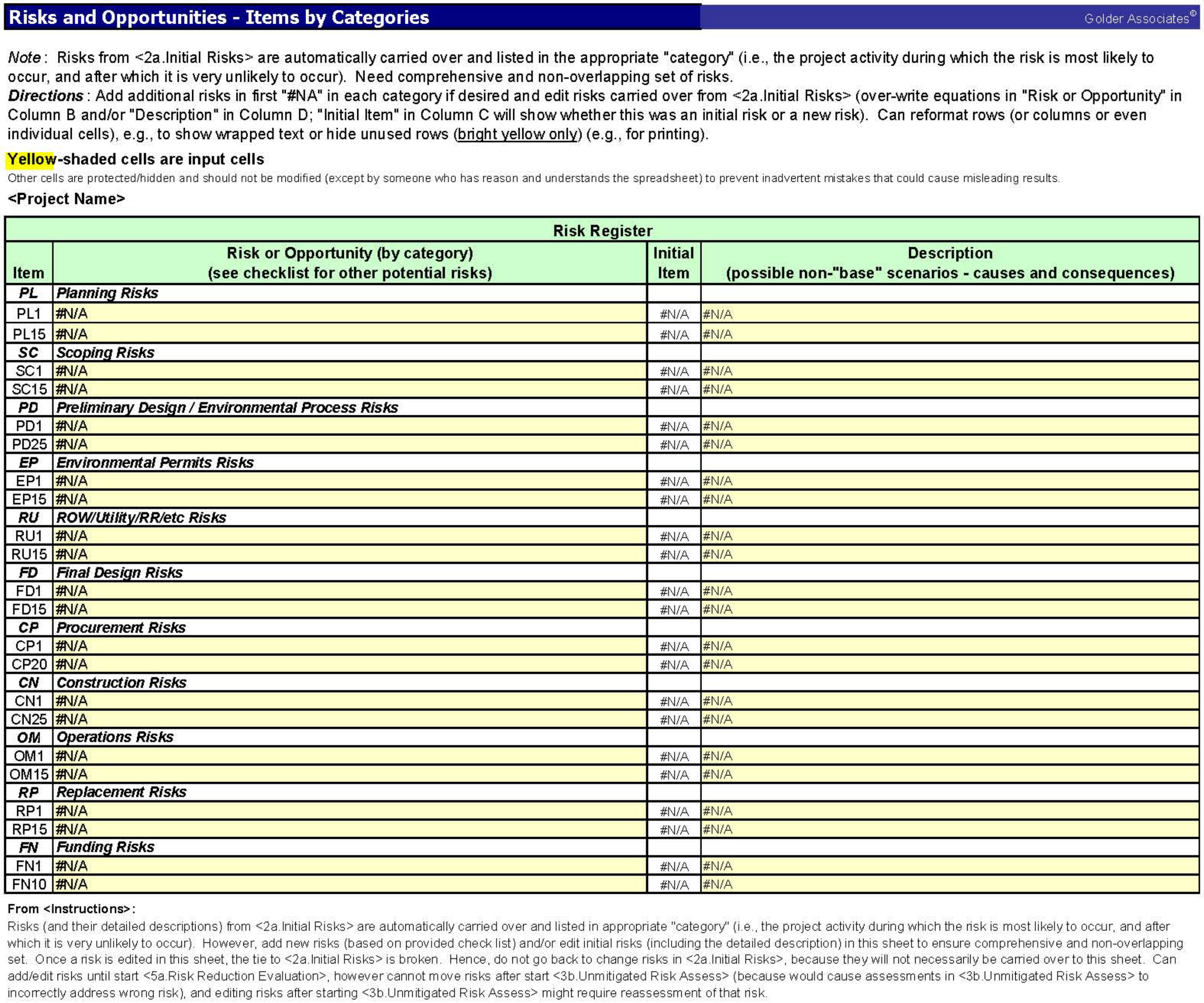
<Project Name>

Item	Risk or Opportunity	Activity (from list)	Description (possible non-"base" scenarios - causes and consequences)
1			
2			
100			

From <Instructions>:

Enter all risks and opportunities identified through brainstorming, and specify which project activity each is most likely to occur during (and very unlikely to occur after), and a more detailed description of each (as needed). At this time, only the nature of the event, and not its severity, are described - severity (expressed in terms of risk factors) will be described in <3b.Unmitigated Risk Assess>.

Figure 3. <2a.Initial Risks (Brainstorm)> (showing only first two and last risk items)



Risks and Opportunities - Items by Categories Golder Associates®

Note : Risks from <2a.Initial Risks> are automatically carried over and listed in the appropriate "category" (i.e., the project activity during which the risk is most likely to occur, and after which it is very unlikely to occur). Need comprehensive and non-overlapping set of risks.

Directions : Add additional risks in first "#NA" in each category if desired and edit risks carried over from <2a.Initial Risks> (over-write equations in "Risk or Opportunity" in Column B and/or "Description" in Column D; "Initial Item" in Column C will show whether this was an initial risk or a new risk). Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

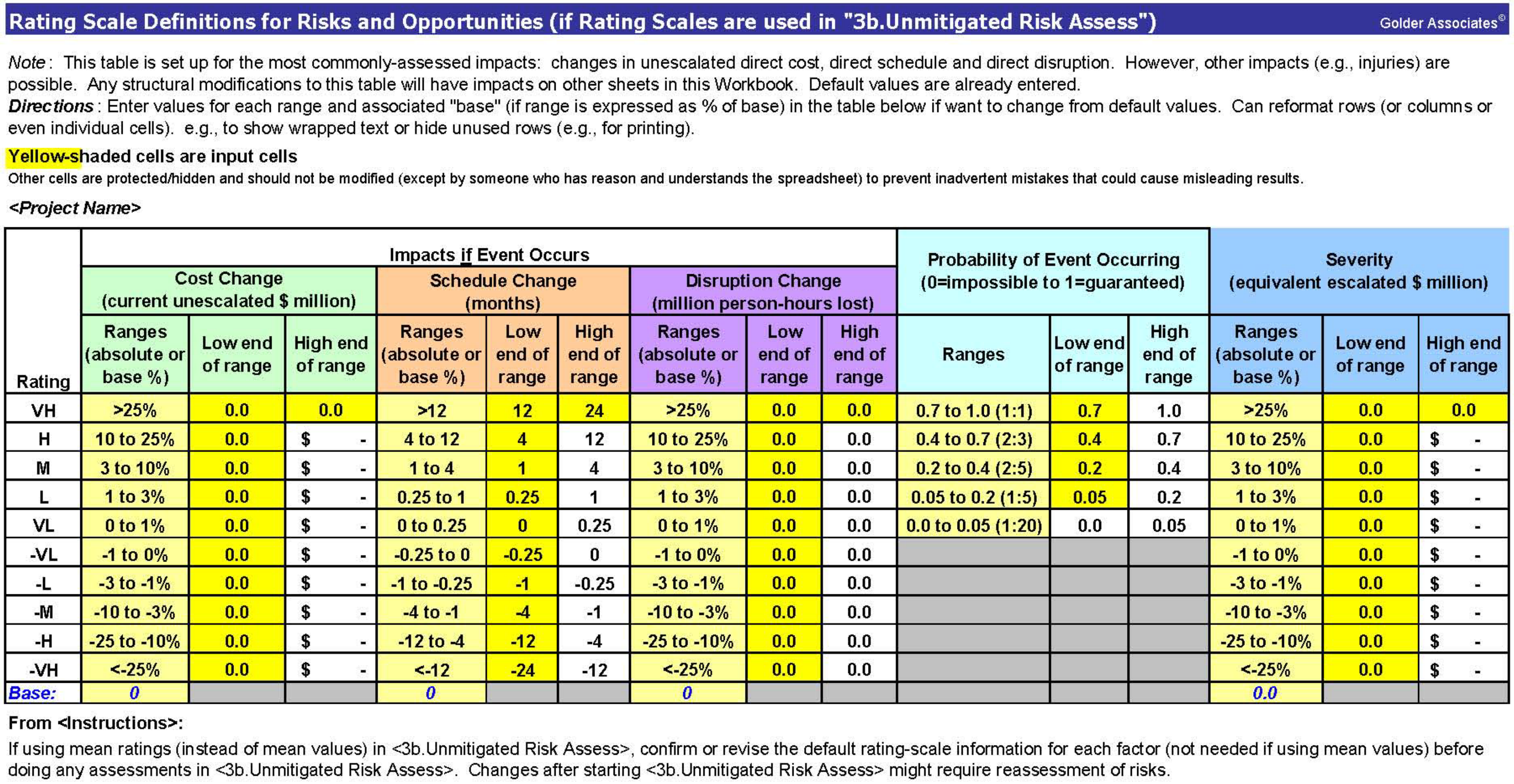
<Project Name>

Risk Register			
Item	**Risk or Opportunity (by category) (see checklist for other potential risks)**	**Initial Item**	**Description (possible non-"base" scenarios - causes and consequences)**
PL	***Planning Risks***		
PL1	#N/A	#N/A	#N/A
PL15	#N/A	#N/A	#N/A
SC	***Scoping Risks***		
SC1	#N/A	#N/A	#N/A
SC15	#N/A	#N/A	#N/A
PD	***Preliminary Design / Environmental Process Risks***		
PD1	#N/A	#N/A	#N/A
PD25	#N/A	#N/A	#N/A
EP	***Environmental Permits Risks***		
EP1	#N/A	#N/A	#N/A
EP15	#N/A	#N/A	#N/A
RU	***ROW/Utility/RR/etc Risks***		
RU1	#N/A	#N/A	#N/A
RU15	#N/A	#N/A	#N/A
FD	***Final Design Risks***		
FD1	#N/A	#N/A	#N/A
FD15	#N/A	#N/A	#N/A
CP	***Procurement Risks***		
CP1	#N/A	#N/A	#N/A
CP20	#N/A	#N/A	#N/A
CN	***Construction Risks***		
CN1	#N/A	#N/A	#N/A
CN25	#N/A	#N/A	#N/A
OM	***Operations Risks***		
OM1	#N/A	#N/A	#N/A
OM15	#N/A	#N/A	#N/A
RP	***Replacement Risks***		
RP1	#N/A	#N/A	#N/A
RP15	#N/A	#N/A	#N/A
FN	***Funding Risks***		
FN1	#N/A	#N/A	#N/A
FN10	#N/A	#N/A	#N/A

From <Instructions>:

Risks (and their detailed descriptions) from <2a.Initial Risks> are automatically carried over and listed in appropriate "category" (i.e., the project activity during which the risk is most likely to occur, and after which it is very unlikely to occur). However, add new risks (based on provided check list) and/or edit initial risks (including the detailed description) in this sheet to ensure comprehensive and non-overlapping set. Once a risk is edited in this sheet, the tie to <2a.Initial Risks> is broken. Hence, do not go back to change risks in <2a.Initial Risks>, because they will not necessarily be carried over to this sheet. Can add/edit risks until start <5a.Risk Reduction Evaluation>, however cannot move risks after start <3b.Unmitigated Risk Assess> (because would cause assessments in <3b.Unmitigated Risk Assess> to incorrectly address wrong risk), and editing risks after starting <3b.Unmitigated Risk Assess> might require reassessment of that risk.

Figure 4. <2b.Risks by Category> (showing only first and last risk items in each category)



Rating Scale Definitions for Risks and Opportunities (if Rating Scales are used in "3b.Unmitigated Risk Assess")

Golder Associates©

Note: This table is set up for the most commonly-assessed impacts: changes in unescalated direct cost, direct schedule and direct disruption. However, other impacts (e.g., injuries) are possible. Any structural modifications to this table will have impacts on other sheets in this Workbook. Default values are already entered.

Directions: Enter values for each range and associated "base" (if range is expressed as % of base) in the table below if want to change from default values. Can reformat rows (or columns or even individual cells). e.g., to show wrapped text or hide unused rows (e.g., for printing).

Yellow-shaded cells are input cells

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

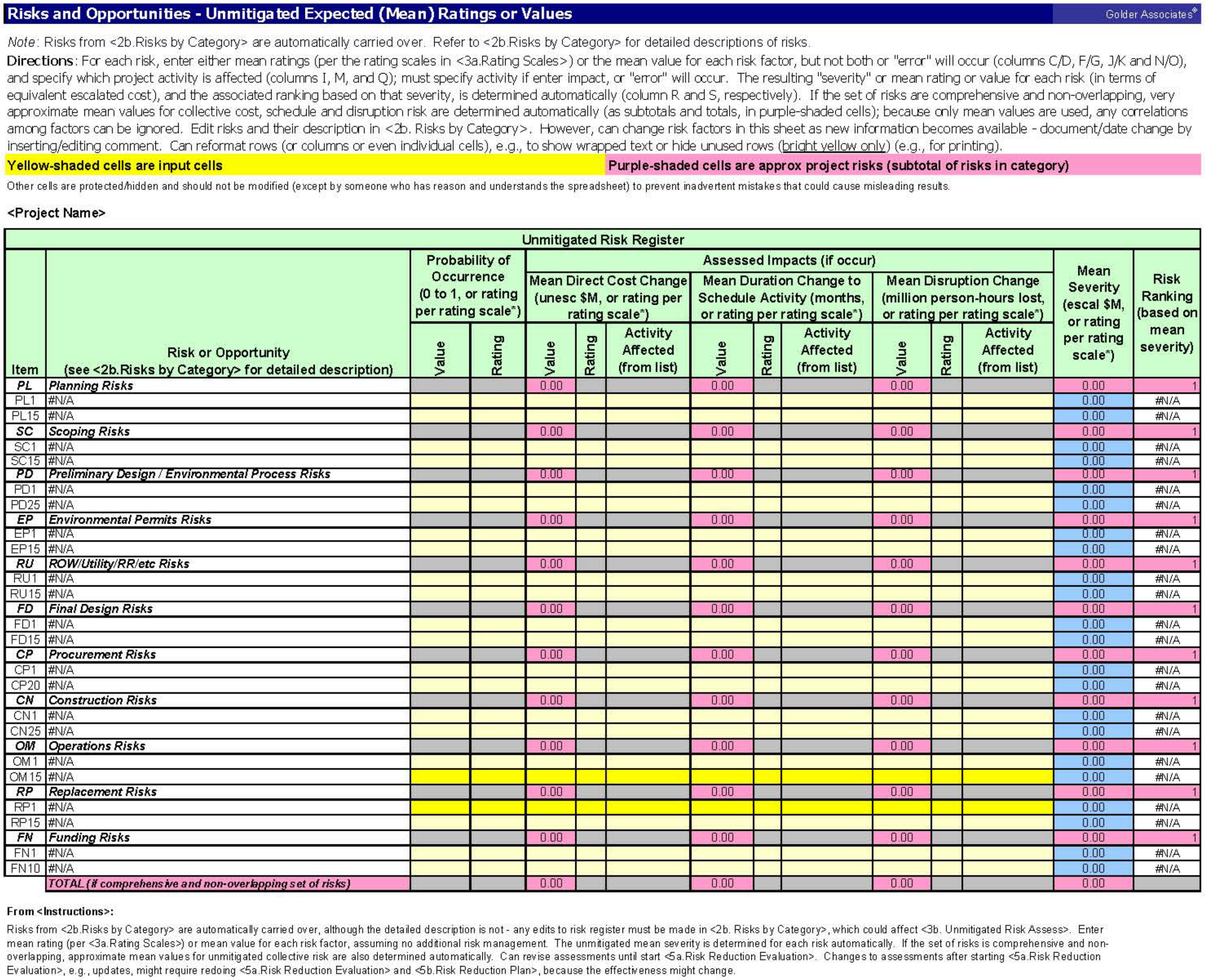
<Project Name>

	Impacts if Event Occurs									Probability of Event Occurring (0=impossible to 1=guaranteed)			Severity (equivalent escalated $ million)		
	Cost Change (current unescalated $ million)			Schedule Change (months)			Disruption Change (million person-hours lost)								
Rating	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range
VH	>25%	0.0	0.0	>12	12	24	>25%	0.0	0.0	0.7 to 1.0 (1:1)	0.7	1.0	>25%	0.0	0.0
H	10 to 25%	0.0	$ -	4 to 12	4	12	10 to 25%	0.0	0.0	0.4 to 0.7 (2:3)	0.4	0.7	10 to 25%	0.0	$ -
M	3 to 10%	0.0	$ -	1 to 4	1	4	3 to 10%	0.0	0.0	0.2 to 0.4 (2:5)	0.2	0.4	3 to 10%	0.0	$ -
L	1 to 3%	0.0	$ -	0.25 to 1	0.25	1	1 to 3%	0.0	0.0	0.05 to 0.2 (1:5)	0.05	0.2	1 to 3%	0.0	$ -
VL	0 to 1%	0.0	$ -	0 to 0.25	0	0.25	0 to 1%	0.0	0.0	0.0 to 0.05 (1:20)	0.0	0.05	0 to 1%	0.0	$ -
-VL	-1 to 0%	0.0	$ -	-0.25 to 0	-0.25	0	-1 to 0%	0.0	0.0				-1 to 0%	0.0	$ -
-L	-3 to -1%	0.0	$ -	-1 to -0.25	-1	-0.25	-3 to -1%	0.0	0.0				-3 to -1%	0.0	$ -
-M	-10 to -3%	0.0	$ -	-4 to -1	-4	-1	-10 to -3%	0.0	0.0				-10 to -3%	0.0	$ -
-H	-25 to -10%	0.0	$ -	-12 to -4	-12	-4	-25 to -10%	0.0	0.0				-25 to -10%	0.0	$ -
-VH	<-25%	0.0	$ -	<-12	-24	-12	<-25%	0.0	0.0				<-25%	0.0	$ -
Base:	*0*			*0*			*0*						*0.0*		

From <Instructions>:

If using mean ratings (instead of mean values) in <3b.Unmitigated Risk Assess>, confirm or revise the default rating-scale information for each factor (not needed if using mean values) before doing any assessments in <3b.Unmitigated Risk Assess>. Changes after starting <3b.Unmitigated Risk Assess> might require reassessment of risks.

Figure 5. <3a.Rating Scales>



Risks and Opportunities - Unmitigated Expected (Mean) Ratings or Values Golder Associates®

Note: Risks from <2b.Risks by Category> are automatically carried over. Refer to <2b.Risks by Category> for detailed descriptions of risks.

Directions: For each risk, enter either mean ratings (per the rating scales in <3a.Rating Scales>) or the mean value for each risk factor, but not both or "error" will occur (columns C/D, F/G, J/K and N/O), and specify which project activity is affected (columns I, M, and Q); must specify activity if enter impact, or "error" will occur. The resulting "severity" or mean rating or value for each risk (in terms of equivalent escalated cost), and the associated ranking based on that severity, is determined automatically (column R and S, respectively). If the set of risks are comprehensive and non-overlapping, very approximate mean values for collective cost, schedule and disruption risk are determined automatically (as subtotals and totals, in purple-shaded cells); because only mean values are used, any correlations among factors can be ignored. Edit risks and their description in <2b. Risks by Category>. However, can change risk factors in this sheet as new information becomes available - document/date change by inserting/editing comment. Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells **Purple-shaded cells are approx project risks (subtotal of risks in category)**

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

<Project Name>

Unmitigated Risk Register														
		Probability of Occurrence (0 to 1, or rating per rating scale*)		Assessed Impacts (if occur)									Mean Severity (escal $M, or rating per rating scale*)	Risk Ranking (based on mean severity)
				Mean Direct Cost Change (unesc $M, or rating per rating scale*)			Mean Duration Change to Schedule Activity (months, or rating per rating scale*)			Mean Disruption Change (million person-hours lost, or rating per rating scale*)				
Item	Risk or Opportunity (see <2b.Risks by Category> for detailed description)	Value	Rating	Value	Rating	Activity Affected (from list)	Value	Rating	Activity Affected (from list)	Value	Rating	Activity Affected (from list)		
PL	***Planning Risks***			0.00			0.00			0.00			0.00	1
PL1	#N/A												0.00	#N/A
PL15	#N/A												0.00	#N/A
SC	***Scoping Risks***			0.00			0.00			0.00			0.00	1
SC1	#N/A												0.00	#N/A
SC15	#N/A												0.00	#N/A
PD	***Preliminary Design / Environmental Process Risks***			0.00			0.00			0.00			0.00	1
PD1	#N/A												0.00	#N/A
PD25	#N/A												0.00	#N/A
EP	***Environmental Permits Risks***			0.00			0.00			0.00			0.00	1
EP1	#N/A												0.00	#N/A
EP15	#N/A												0.00	#N/A
RU	***ROW/Utility/RR/etc Risks***			0.00			0.00			0.00			0.00	1
RU1	#N/A												0.00	#N/A
RU15	#N/A												0.00	#N/A
FD	***Final Design Risks***			0.00			0.00			0.00			0.00	1
FD1	#N/A												0.00	#N/A
FD15	#N/A												0.00	#N/A
CP	***Procurement Risks***			0.00			0.00			0.00			0.00	1
CP1	#N/A												0.00	#N/A
CP20	#N/A												0.00	#N/A
CN	***Construction Risks***			0.00			0.00			0.00			0.00	1
CN1	#N/A												0.00	#N/A
CN25	#N/A												0.00	#N/A
OM	***Operations Risks***			0.00			0.00			0.00			0.00	1
OM1	#N/A												0.00	#N/A
OM15	#N/A												0.00	#N/A
RP	***Replacement Risks***			0.00			0.00			0.00			0.00	1
RP1	#N/A												0.00	#N/A
RP15	#N/A												0.00	#N/A
FN	***Funding Risks***			0.00			0.00			0.00			0.00	1
FN1	#N/A												0.00	#N/A
FN10	#N/A												0.00	#N/A
	TOTAL (if comprehensive and non-overlapping set of risks)			0.00			0.00			0.00			0.00	

From <Instructions>:

Risks from <2b.Risks by Category> are automatically carried over, although the detailed description is not - any edits to risk register must be made in <2b. Risks by Category>, which could affect <3b. Unmitigated Risk Assess>. Enter mean rating (per <3a.Rating Scales>) or mean value for each risk factor, assuming no additional risk management. The unmitigated mean severity is determined for each risk automatically. If the set of risks is comprehensive and non-overlapping, approximate mean values for unmitigated collective risk are also determined automatically. Can revise assessments until start <5a.Risk Reduction Evaluation>. Changes to assessments after starting <5a.Risk Reduction Evaluation>, e.g., updates, might require redoing <5a.Risk Reduction Evaluation> and <5b.Risk Reduction Plan>, because the effectiveness might change.

Figure 6. <3b.Unmitigated Risk Assess> (showing only first and last risk items in each category)

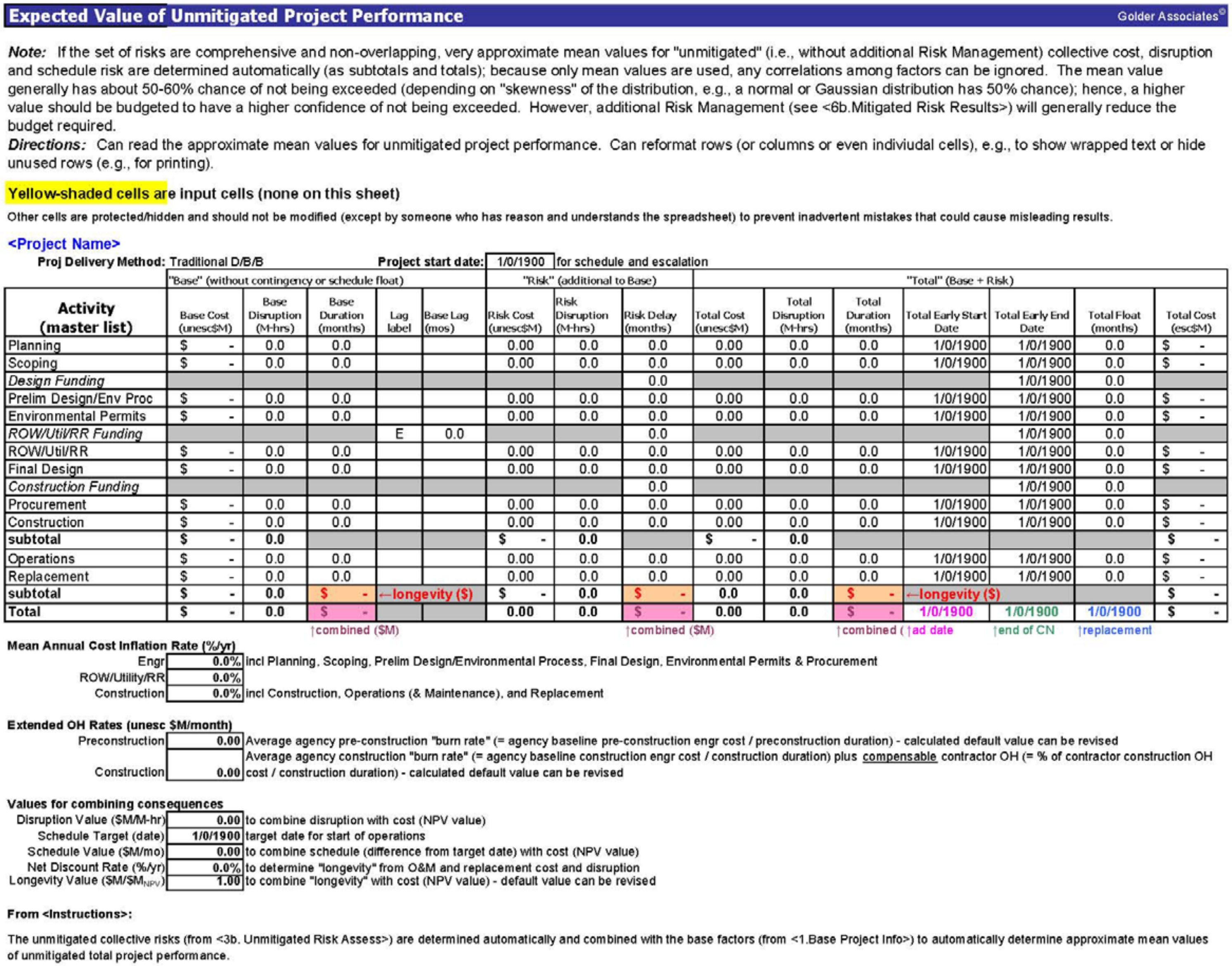
4. Unmitigated Risk Analysis: <4a.Unmitigated Risk Results>, <4b.Unmitigated Risk Ranking>, and <4c.Unmitig. Risk Ranking Plots>

- ref.Ch 6 and Ch 7 in the *Guide*
- spreadsheets <4a.Unmitigated Risk Results> - see Fig 7, <4b.Unmitigated Risk Ranking> - see Fig 8, and <4c.Unmitig. Risk Ranking Plots> - see Fig 9

No inputs, only following outputs:

- In <4b.Unmitigated Risk Ranking> (see Fig 8), the unmitigated identified risks are automatically presented in rank order (based on mean severity from <3b.Unmitigated Risk Assess> - see Fig 6), separately for risks and for opportunities. Unused rows (except the last) can be hidden.
- In <4c.Unmitig. Risk Ranking Plots> (see Fig 9), the top 20 unmitigated identified risks are automatically plotted in rank order (based on mean severity from <3b.Unmitigated Risk Assess> - see Fig 6), separately for risks and for opportunities
- In <4a.Unmitigated Risk Results> (see Fig 7), the unmitigated mean project performance is automatically determined (based on the unmitigated risk factor assessments in <3b.Unmitigated Risk Assess> - see Fig 6 and on the "base" factor assessments in <1.Base Project Info> - see Fig 2) in similar terms as for the "base" mean project performance (in <1.Base Project Info> - see Fig 2):
    - Project unmitigated "total" schedule, in terms of mean early start and end dates and float (in months) for each activity in relevant simplified flowchart, and key project unmitigated "total" mean milestone dates (i.e., for advertisement, end of construction, and replacement)
    - Project unmitigated "total" cost, in terms of both mean uninflated and inflated $million, through construction and post construction
    - Project unmitigated "total" disruption, in terms of mean million lost-hours, through construction and post construction
    - Project unmitigated "total" longevity (i.e., combination via specified tradeoffs of mean post construction schedule, cost and disruption), in terms of mean NPV$million at end of construction
    - Project unmitigated "total" combined performance (i.e., combination via specified tradeoffs of mean schedule, cost, and disruption through construction, and mean longevity), in terms of mean equivalent inflated $million

  Note: Mean total project performance is very approximate, depending on whether the risk register is comprehensive and non-overlapping, and should not be used to establish budgets/ milestones / contingencies.



Expected Value of Unmitigated Project Performance Golder Associates©

Note: If the set of risks are comprehensive and non-overlapping, very approximate mean values for "unmitigated" (i.e., without additional Risk Management) collective cost, disruption and schedule risk are determined automatically (as subtotals and totals); because only mean values are used, any correlations among factors can be ignored. The mean value generally has about 50-60% chance of not being exceeded (depending on "skewness" of the distribution, e.g., a normal or Gaussian distribution has 50% chance); hence, a higher value should be budgeted to have a higher confidence of not being exceeded. However, additional Risk Management (see <6b.Mitigated Risk Results>) will generally reduce the budget required.

Directions: Can read the approximate mean values for unmitigated project performance. Can reformat rows (or columns or even indiviudal cells), e.g., to show wrapped text or hide unused rows (e.g., for printing).

Yellow-shaded cells are input cells (none on this sheet)

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

<Project Name>

Proj Delivery Method: Traditional D/B/B **Project start date:** 1/0/1900 for schedule and escalation

	"Base" (without contingency or schedule float)					"Risk" (additional to Base)			"Total" (Base + Risk)						
Activity (master list)	Base Cost (unesc$M)	Base Disruption (M-hrs)	Base Duration (months)	Lag label	Base Lag (mos)	Risk Cost (unesc$M)	Risk Disruption (M-hrs)	Risk Delay (months)	Total Cost (unesc$M)	Total Disruption (M-hrs)	Total Duration (months)	Total Early Start Date	Total Early End Date	Total Float (months)	Total Cost (esc$M)
Planning	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Scoping	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Design Funding								0.0					1/0/1900	0.0	
Prelim Design/Env Proc	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Environmental Permits	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
ROW/Util/RR Funding				E	0.0			0.0					1/0/1900	0.0	
ROW/Util/RR	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Final Design	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction Funding								0.0					1/0/1900	0.0	
Procurement	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**				**$ -**	**0.0**		**$ -**	**0.0**					**$ -**
Operations	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Replacement	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**	**$ -**	**←longevity ($)**		**$ -**	**0.0**	**$ -**	**0.0**	**0.0**	**$ -**	**←longevity ($)**			**$ -**
Total	**$ -**	**0.0**	**$ -**			**0.00**	**0.0**	**$ -**	**0.00**	**0.0**	**$ -**	**1/0/1900**	**1/0/1900**	**1/0/1900**	**$ -**
			↑combined ($M)					↑combined ($M)			↑combined (	↑ad date	↑end of CN	↑replacement	

Mean Annual Cost Inflation Rate (%/yr)

Engr	**0.0%**	incl Planning, Scoping, Prelim Design/Environmental Process, Final Design, Environmental Permits & Procurement
ROW/Utility/RR	**0.0%**	
Construction	**0.0%**	incl Construction, Operations (& Maintenance), and Replacement

Extended OH Rates (unesc $M/month)

Preconstruction	**0.00**	Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / preconstruction duration) - calculated default value can be revised
Construction	**0.00**	Average agency construction "burn rate" (= agency baseline construction engr cost / construction duration) plus <u>compensable</u> contractor OH (= % of contractor construction OH cost / construction duration) - calculated default value can be revised

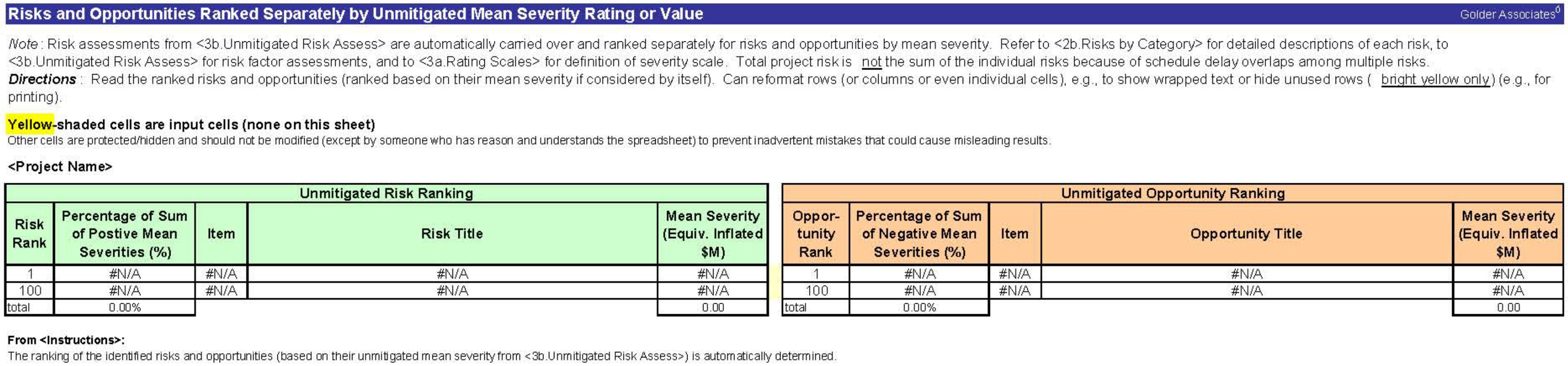
Values for combining consequences

Disruption Value ($M/M-hr)	**0.00**	to combine disruption with cost (NPV value)
Schedule Target (date)	**1/0/1900**	target date for start of operations
Schedule Value ($M/mo)	**0.00**	to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)	**0.0%**	to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	**1.00**	to combine "longevity" with cost (NPV value) - default value can be revised

From <Instructions>:

The unmitigated collective risks (from <3b. Unmitigated Risk Assess>) are determined automatically and combined with the base factors (from <1.Base Project Info>) to automatically determine approximate mean values of unmitigated total project performance.

Figure 7. <4a.Unmitigated Risk Results>



Risks and Opportunities Ranked Separately by Unmitigated Mean Severity Rating or Value Golder Associates^{0}

Note : Risk assessments from <3b.Unmitigated Risk Assess> are automatically carried over and ranked separately for risks and opportunities by mean severity. Refer to <2b.Risks by Category> for detailed descriptions of each risk, to <3b.Unmitigated Risk Assess> for risk factor assessments, and to <3a.Rating Scales> for definition of severity scale. Total project risk is not the sum of the individual risks because of schedule delay overlaps among multiple risks.
Directions : Read the ranked risks and opportunities (ranked based on their mean severity if considered by itself). Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells (none on this sheet)
Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

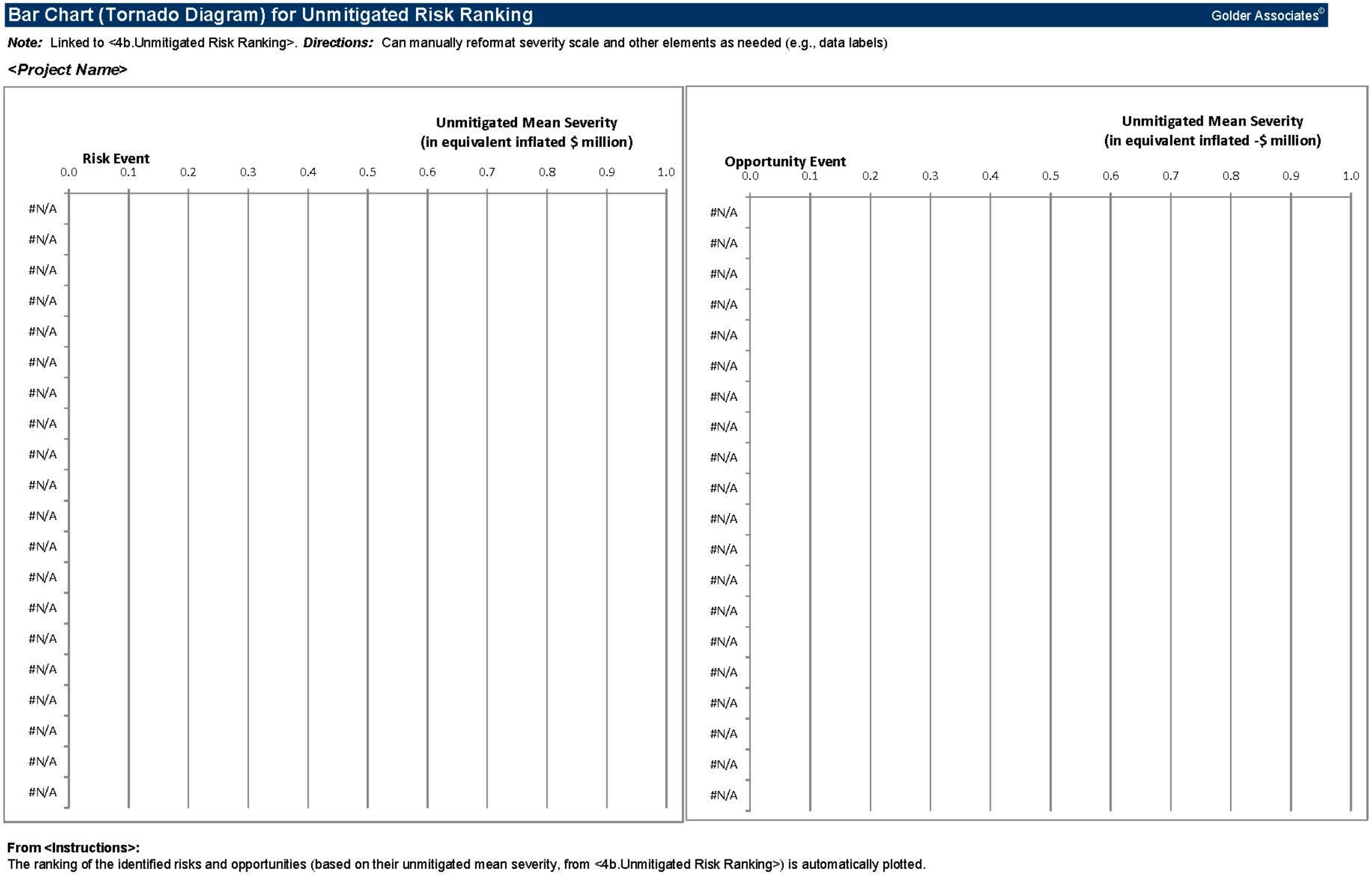
<Project Name>

Unmitigated Risk Ranking				
Risk Rank	**Percentage of Sum of Postive Mean Severities (%)**	**Item**	**Risk Title**	**Mean Severity (Equiv. Inflated $M)**
1	#N/A	#N/A	#N/A	#N/A
100	#N/A	#N/A	#N/A	#N/A
total	0.00%			0.00

Unmitigated Opportunity Ranking				
Oppor-tunity Rank	**Percentage of Sum of Negative Mean Severities (%)**	**Item**	**Opportunity Title**	**Mean Severity (Equiv. Inflated $M)**
1	#N/A	#N/A	#N/A	#N/A
100	#N/A	#N/A	#N/A	#N/A
total	0.00%			0.00

From <Instructions>:
The ranking of the identified risks and opportunities (based on their unmitigated mean severity from <3b.Unmitigated Risk Assess>) is automatically determined.

Figure 8. <4b.Unmitigated Risk Ranking> (showing only first and last ranked risk items)



Bar Chart (Tornado Diagram) for Unmitigated Risk Ranking Golder Associates©

Note: Linked to <4b.Unmitigated Risk Ranking>. ***Directions:*** Can manually reformat severity scale and other elements as needed (e.g., data labels)

<Project Name>

From <Instructions>:
The ranking of the identified risks and opportunities (based on their unmitigated mean severity, from <4b.Unmitigated Risk Ranking>) is automatically plotted.

Figure 9. <4c.Unmitig. Risk Ranking Plots>

5. Risk Reduction Planning: <5a.Risk Reduction Evaluation> and <5b.Risk Reduction Plan>

- ref.Ch 8 and Ch 9 in the *Guide*
- spreadsheets <5a.Risk Reduction Evaluation> - see Fig 10 and <5b.Risk Reduction Plan> - see Fig 11

5.1 Inputs

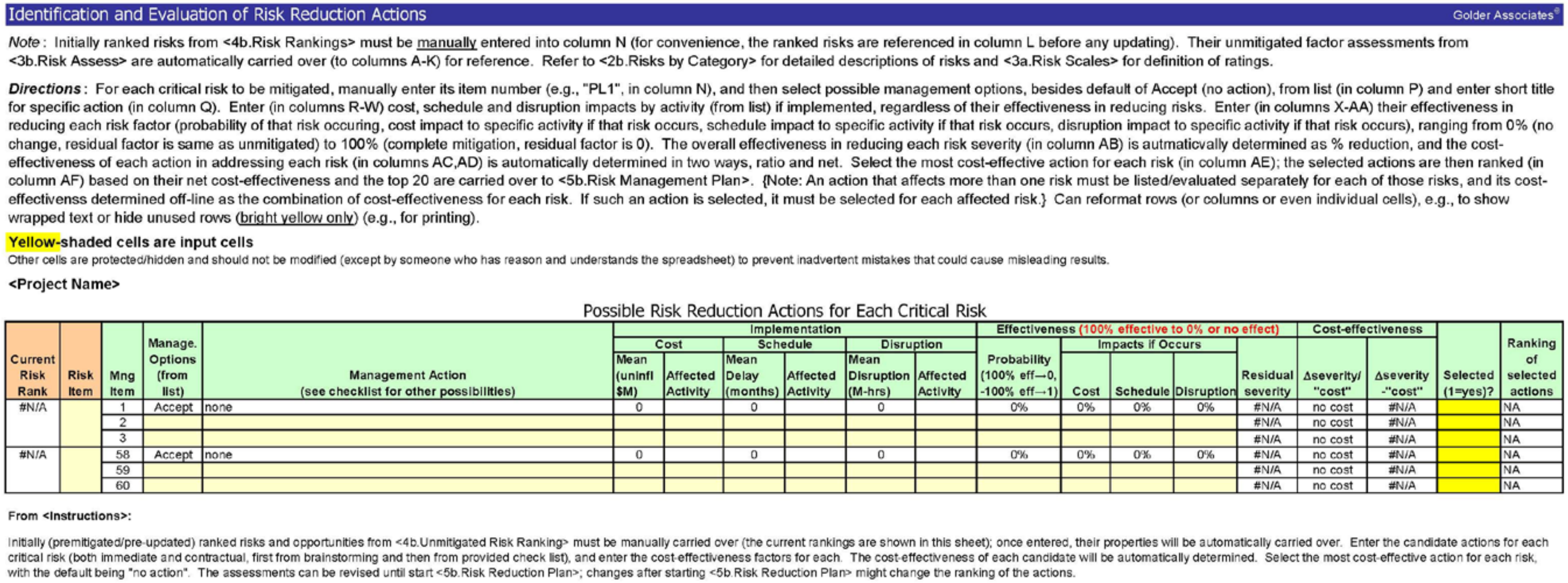
- In <5a.Risk Reduction Evaluation> (see Fig 10)
    - Enter <key risk item#>, which have been automatically carried over in rank order from <4b.Unmitigated Risk Ranking> (see Fig 8).
    - Enter <potential risk reduction actions> that have been identified for each critical risk, and categorize (select <action category>, i.e., avoid, mitigate, transfer or accept, from drop-down box)
    - Enter risk reduction factor assessments for each listed risk reduction action (except for "no action"):
        - Implementation – note: if an action addresses more than one risk, allocate its implementation impacts to the affected risks
            - <mean uninflated <u>cost</u> to implement, in terms of uninflated $million> and <affected activity, from drop-down box>
            - <mean <u>delay</u> to implement, in terms of months> and <affected activity, from drop-down box>
            - <mean <u>disruption</u> to implement, in terms of million lost-hours> and <affected activity, from drop-down box>
        - Effectiveness (note: for reference, the unmitigated risk factor assessments for each critical risk have been carried over from <3b.Unmitigated Risk Assess> - see Fig 6)
            - <mean effectiveness, in %, in reducing risk (or increasing opportunity, for which use negative %) <u>probability</u> if implemented; note: +100% effectiveness reduces probability of risk to 0, whereas -100% effectiveness increases probability of opportunity to 1, and 0% effectiveness means no change>
            - <mean effectiveness, in %, in reducing risk (or increasing opportunity, for which use negative %) <u>cost impact</u> if implemented; note: +100% effectiveness reduces risk impact to 0, whereas -100% effectiveness doubles impact of opportunity, and 0% effectiveness means no change>
            - < mean effectiveness, in %, in reducing risk (or increasing opportunity, for which use negative %) <u>delay</u> if implemented; note: +100% effectiveness reduces risk impact to 0, whereas -100% effectiveness doubles impact of opportunity, and 0% effectiveness means no change>

        - < mean effectiveness, in %, in reducing risk (or increasing opportunity, for which use negative %) disruption impact if implemented; note: 100% effectiveness reduces risk impact to 0, whereas -100% effectiveness doubles impact of opportunity, and 0% effectiveness means no change>>
    - Select (enter <1>) risk reduction actions (based on their cost-effectiveness – see output) – note: if an action that addresses more than one risk is selected, it must be selected for all affected risks
- In <5b.Risk Reduction Plan> (see Fig 11), enter <selected risk reduction action #> (based on info carried over from <5a.Risk Reduction Evaluation> - see Fig 10) and then enter implementation plan logistics for that action:
    - <name of person responsible for implementing that action>
    - <schedule/milestone date for completing that action>
    - <comments regarding implementing that action>.

5.2 Outputs

- In <5a.Risk Reduction Evaluation> (see Fig 10):
    - the potential risk reduction actions identified for each critical risk are documented – note: an action that affects more than one risk must be entered separately for each affected risk
    - the risk reduction factor assessments (in mean values) for each identified potential risk reduction action for each critical risk are documented
    - the effectiveness of each identified potential risk reduction action is automatically determined, in terms of mean % effectiveness in reducing each risk (or increasing opportunity) severity
    - the cost-effectiveness of each identified potential risk reduction action is automatically determined, both in terms of mean ratio (i.e., mean change in risk severity over mean change in combined performance for implementation) and mean net (i.e., mean change in risk severity minus mean change in combined performance for implementation, in equivalent inflated $million) – note: if an action affects more than one risk, the cost-effectiveness of that action is the combination of the cost-effectiveness in addressing each risk
    - the selection of risk reduction actions (presumably based on their cost-effectiveness) is documented, and the selected actions are automatically ranked based on their cost-effectiveness (i.e., mean net) in addressing each risk separately – note: if an action that addresses more than one risk is selected, it must be selected for all affected risks
    - unused rows (except fist and last) can be hidden.
- in <5b.Risk Reduction Plan> - see Fig 11):

  - the selected proactive risk reduction actions are presented (in rank order of their cost-effectiveness) and summarized (in terms of their implementation and effectiveness factor assessments and their resulting cost-effectiveness)
  - the implementation plan (i.e., responsibility, schedule/milestone and comments) for each selected risk reduction action is documented
  - unused rows (except fist and last) can be hidden.



Identification and Evaluation of Risk Reduction Actions

Note: Initially ranked risks from <4b.Risk Rankings> must be manually entered into column N (for convenience, the ranked risks are referenced in column L before any updating). Their unmitigated factor assessments from <3b.Risk Assess> are automatically carried over (to columns A-K) for reference. Refer to <2b.Risks by Category> for detailed descriptions of risks and <3a.Risk Scales> for definition of ratings.

Directions: For each critical risk to be mitigated, manually enter its item number (e.g., "PL1", in column N), and then select possible management options, besides default of Accept (no action), from list (in column P) and enter short title for specific action (in column Q). Enter (in columns R-W) cost, schedule and disruption impacts by activity (from list) if implemented, regardless of their effectiveness in reducing risks. Enter (in columns X-AA) their effectiveness in reducing each risk factor (probability of that risk occuring, cost impact to specific activity if that risk occurs, schedule impact to specific activity if that risk occurs, disruption impact to specific activity if that risk occurs), ranging from 0% (no change, residual factor is same as unmitigated) to 100% (complete mitigation, residual factor is 0). The overall effectiveness in reducing each risk severity (in column AB) is autmaticvally determined as % reduction, and the cost-effectiveness of each action in addressing each risk (in columns AC,AD) is automatically determined in two ways, ratio and net. Select the most cost-effective action for each risk (in column AE); the selected actions are then ranked (in column AF) based on their net cost-effectiveness and the top 20 are carried over to <5b.Risk Management Plan>. {Note: An action that affects more than one risk must be listed/evaluated separately for each of those risks, and its cost-effectivenss determined off-line as the combination of cost-effectiveness for each risk. If such an action is selected, it must be selected for each affected risk.} Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

<Project Name>

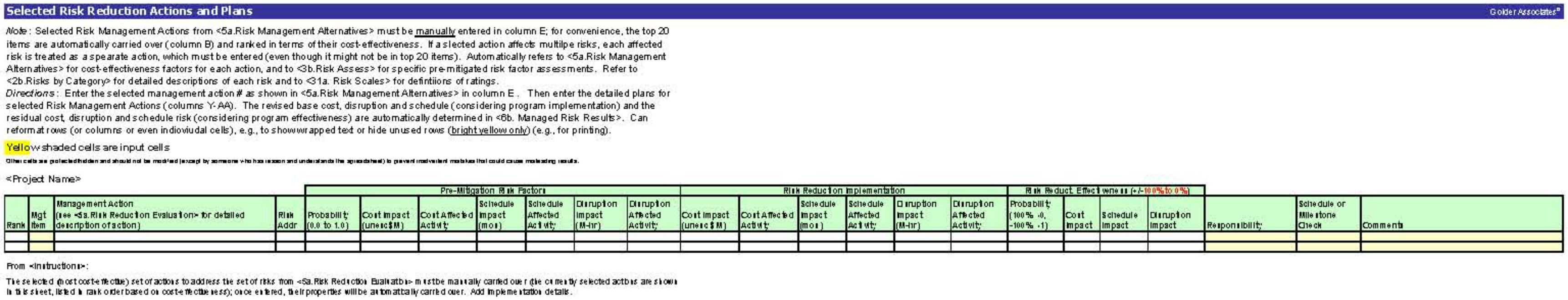
Possible Risk Reduction Actions for Each Critical Risk

					Implementation						Effectiveness (100% effective to 0% or no effect)					Cost-effectiveness			
					Cost		Schedule		Disruption			Impacts if Occurs							
Current Risk Rank	Risk Item	Mng Item	Manage. Options (from list)	Management Action (see checklist for other possibilities)	Mean (uninfl $M)	Affected Activity	Mean Delay (months)	Affected Activity	Mean Disruption (M-hrs)	Affected Activity	Probability (100% eff→0, -100% eff→1)	Cost	Schedule	Disruption	Residual severity	Δseverity/ "cost"	Δseverity -"cost"	Selected (1=yes)?	Ranking of selected actions
#N/A		1	Accept	none	0		0		0		0%	0%	0%	0%	#N/A	no cost	#N/A		NA
		2													#N/A	no cost	#N/A		NA
		3													#N/A	no cost	#N/A		NA
#N/A		58	Accept	none	0		0		0		0%	0%	0%	0%	#N/A	no cost	#N/A		NA
		59													#N/A	no cost	#N/A		NA
		60													#N/A	no cost	#N/A		NA

From <Instructions>:

Initially (premitigated/pre-updated) ranked risks and opportunities from <4b.Unmitigated Risk Ranking> must be manually carried over (the current rankings are shown in this sheet); once entered, their properties will be automatically carried over. Enter the candidate actions for each critical risk (both immediate and contractual, first from brainstorming and then from provided check list), and enter the cost-effectiveness factors for each. The cost-effectiveness of each candidate will be automatically determined. Select the most cost-effective action for each risk, with the default being "no action". The assessments can be revised until start <5b.Risk Reduction Plan>; changes after starting <5b.Risk Reduction Plan> might change the ranking of the actions.

Figure 10. <5a.Risk Reduction Evaluation> (showing only first and last risk items)



Selected Risk Reduction Actions and Plans

Note: Selected Risk Management Actions from <5a.Risk Management Alternatives> must be manually entered in column E; for convenience, the top 20 items are automatically carried over (column B) and ranked in terms of their cost-effectiveness. If a slected action affects multilpe risks, each affected risk is treated as a spearate action, which must be entered (even though it might not be in top 20 items). Automatically refers to <5a.Risk Management Alternatives> for cost-effectiveness factors for each action, and to <3b.Risk Assess> for specific pre-mitigated risk factor assessments. Refer to <2b.Risks by Category> for detailed descriptions of each risk and to <31a. Risk Scales> for defintiions of ratings.
Directions: Enter the selected management action # as shown in <5a.Risk Management Alternatives> in column E. Then enter the detailed plans for selected Risk Management Actions (columns Y-AA). The revised base cost, disruption and schedule (considering program implementation) and the residual cost, disruption and schedule risk (considering program effectiveness) are automatically determined in <6b. Managed Risk Results>. Can reformat rows (or columns or even indioviudal cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow shaded cells are input cells

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

<Project Name>

				Pre-Mitigation Risk Factors							Risk Reduction Implementation						Risk Reduct. Effectiveness (+/-100% to 0%)						
Rank	Mgt Item	Management Action (see <5a.Risk Reduction Evaluation> for detailed description of action)	Risk Addr	Probability (0.0 to 1.0)	Cost Impact (unesc $M)	Cost Affected Activity	Schedule Impact (mos)	Schedule Affected Activity	Disruption Impact (M-hr)	Disruption Affected Activity	Cost Impact (unesc $M)	Cost Affected Activity	Schedule Impact (mos)	Schedule Affected Activity	Disruption Impact (M-hr)	Disruption Affected Activity	Probability (100% -0, -100% -1)	Cost Impact	Schedule Impact	Disruption Impact	Responsibility	Schedule or Milestone Check	Comments

From <Instructions>:

The selected (most cost-effective) set of actions to address the set of risks from <5a.Risk Reduction Evaluation> must be manually carried over (the currently selected actions are shown in this sheet, listed in rank order based on cost-effectiveness); once entered, their properties will be automatically carried over. Add implementation details.

Figure 11. <5b.Risk Reduction Plan> (showing only first and last selected risk reduction actions)

6. Mitigated Risk Analysis: <6a.Mitigated Risk Assess>, <6b.Mitigated Risk Results>, <6c.Mitigated Risk Ranking> and <6d.Mitigated Risk Ranking Plots>

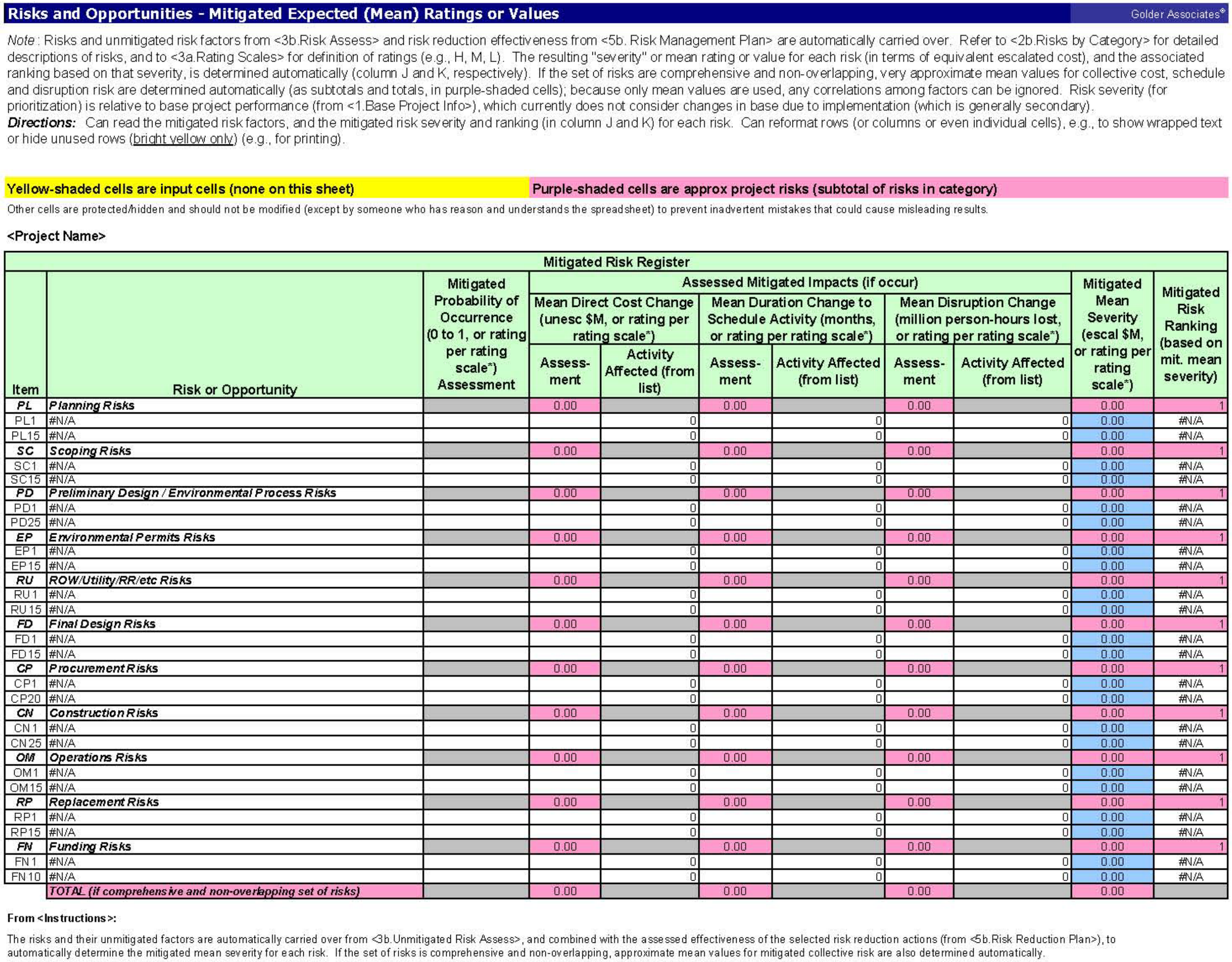
- ref.Ch 6, Ch 7 and Ch 8 in the *Guide*
- spreadsheets <6a.Mitigated Risk Assess> - see Fig 12, <6b.Mitigated Risk Results> - see Fig 13, <6c.Mitigated Risk Ranking> - see Fig 14 and <6d.Mitigated Risk Ranking Plots>- see Fig 15

No inputs, only following outputs:

- In <6a.Mitigated Risk Assess> (see Fig 12), in the same way as in <3b.Unmitigated Risk Assess> (see Fig 6):
    - the mitigated risk factor assessments (either in mean values or ratings, per pre-defined rating scales in <3a.Rating Scales> - see Fig 5) are summarized
    - the mitigated mean severity (mean values or ratings, per pre-defined rating scales in <3a.Rating Scales> - see Fig 5, in terms of equivalent inflated $million) is automatically determined for each risk (ratings are used if any of the risk factors are expressed as ratings), and the risks are ranked on that basis
    - unused rows (except fist and last in each category) can be hidden.
- In <6c.Mitigated Risk Ranking> (see Fig 14), in the same way as in <4b.Unmitigated Risk Ranking> (see Fig 8), the mitigated risks are automatically presented in rank order (based on mean severity from <6a.Mitigated Risk Assess> (see Fig 12), separately for risks and for opportunities. Unused rows (except the last) can be hidden.
- In <6d.Mitigated Risk Ranking Plots> (see Fig 15), in the same way as in <4c.Unmitig. Risk Ranking Plots> (see Fig 9), the top 20 mitigated risks are automatically plotted in rank order (based on mean severity from <6a.Mitigated Risk Assess> (see Fig 12), separately for risks and for opportunities
- In <6b.Mitigated Risk Results> (see Fig 13), the mitigated mean project performance is automatically determined (based on the mitigated risk factor assessments in <6a.Mitigated Risk Assess> - see Fig 12 and on the "base" factor assessments in <1.Base Project Info> - see Fig 2) in similar terms as for the "base" mean project performance (in <1.Base Project Info> - see Fig 2) and the unmitigated mean project performance (in 4a.Unmitigated Risk Results> - see Fig 7):
    - Project mitigated "total" schedule, in terms of mean early start and end dates and float (in months) for each activity in relevant simplified flowchart, and mean key project mitigated "total" milestone dates (i.e., for advertisement, end of construction, and replacement)
    - Project mitigated "total" cost, in terms of both mean uninflated and inflated $million, through construction and post construction
    - Project mitigated "total" disruption, in terms of mean million lost-hours, through construction and post construction

  - Project mitigated "total" longevity (i.e., combination via specified tradeoffs of mean post construction schedule, cost and disruption), in terms of mean NPV$million at end of construction
  - Project mitigated "total" combined performance (i.e., combination via specified tradeoffs of mean schedule, cost, and disruption through construction, and mean longevity), in terms of mean equivalent inflated $million

Note: Same as for <4a. Unmitigated Risk Results>, mean total project performance is very approximate, depending on whether the risk register is comprehensive and non-overlapping, and should not be used to establish budgets/ milestones / contingencies.



Risks and Opportunities - Mitigated Expected (Mean) Ratings or Values Golder Associates®

Note: Risks and unmitigated risk factors from <3b.Risk Assess> and risk reduction effectiveness from <5b. Risk Management Plan> are automatically carried over. Refer to <2b.Risks by Category> for detailed descriptions of risks, and to <3a.Rating Scales> for definition of ratings (e.g., H, M, L). The resulting "severity" or mean rating or value for each risk (in terms of equivalent escalated cost), and the associated ranking based on that severity, is determined automatically (column J and K, respectively). If the set of risks are comprehensive and non-overlapping, very approximate mean values for collective cost, schedule and disruption risk are determined automatically (as subtotals and totals, in purple-shaded cells); because only mean values are used, any correlations among factors can be ignored. Risk severity (for prioritization) is relative to base project performance (from <1.Base Project Info>), which currently does not consider changes in base due to implementation (which is generally secondary).
Directions: Can read the mitigated risk factors, and the mitigated risk severity and ranking (in column J and K) for each risk. Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells (none on this sheet) **Purple-shaded cells are approx project risks (subtotal of risks in category)**

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

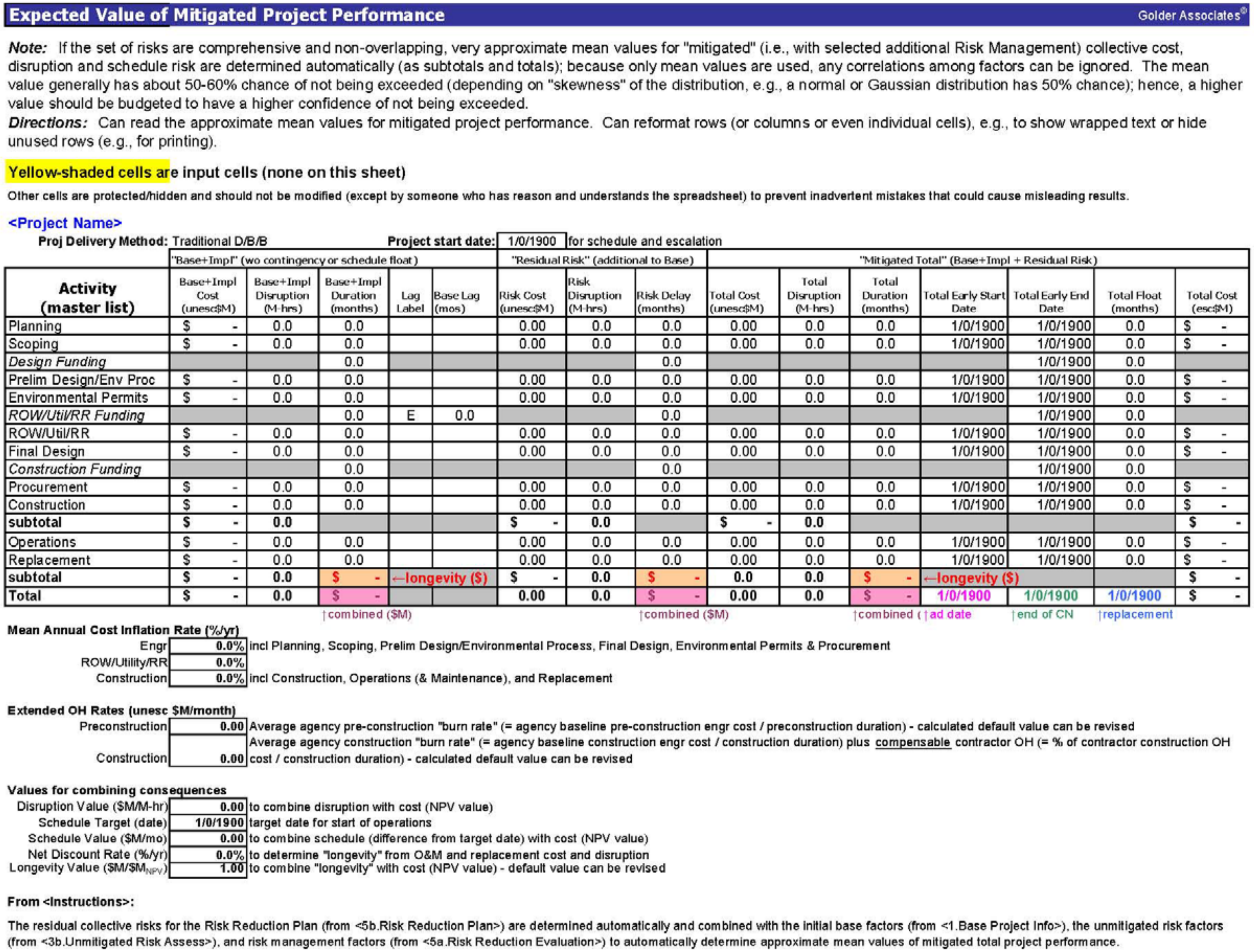
<Project Name>

Mitigated Risk Register										
		Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Assessed Mitigated Impacts (if occur)						Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
			Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)			
Item	Risk or Opportunity		Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
PL	***Planning Risks***		0.00		0.00		0.00		0.00	1
PL1	#N/A			0		0		0	0.00	#N/A
PL15	#N/A			0		0		0	0.00	#N/A
SC	***Scoping Risks***		0.00		0.00		0.00		0.00	1
SC1	#N/A			0		0		0	0.00	#N/A
SC15	#N/A			0		0		0	0.00	#N/A
PD	***Preliminary Design / Environmental Process Risks***		0.00		0.00		0.00		0.00	1
PD1	#N/A			0		0		0	0.00	#N/A
PD25	#N/A			0		0		0	0.00	#N/A
EP	***Environmental Permits Risks***		0.00		0.00		0.00		0.00	1
EP1	#N/A			0		0		0	0.00	#N/A
EP15	#N/A			0		0		0	0.00	#N/A
RU	***ROW/Utility/RR/etc Risks***		0.00		0.00		0.00		0.00	1
RU1	#N/A			0		0		0	0.00	#N/A
RU15	#N/A			0		0		0	0.00	#N/A
FD	***Final Design Risks***		0.00		0.00		0.00		0.00	1
FD1	#N/A			0		0		0	0.00	#N/A
FD15	#N/A			0		0		0	0.00	#N/A
CP	***Procurement Risks***		0.00		0.00		0.00		0.00	1
CP1	#N/A			0		0		0	0.00	#N/A
CP20	#N/A			0		0		0	0.00	#N/A
CN	***Construction Risks***		0.00		0.00		0.00		0.00	1
CN1	#N/A			0		0		0	0.00	#N/A
CN25	#N/A			0		0		0	0.00	#N/A
OM	***Operations Risks***		0.00		0.00		0.00		0.00	1
OM1	#N/A			0		0		0	0.00	#N/A
OM15	#N/A			0		0		0	0.00	#N/A
RP	***Replacement Risks***		0.00		0.00		0.00		0.00	1
RP1	#N/A			0		0		0	0.00	#N/A
RP15	#N/A			0		0		0	0.00	#N/A
FN	***Funding Risks***		0.00		0.00		0.00		0.00	1
FN1	#N/A			0		0		0	0.00	#N/A
FN10	#N/A			0		0		0	0.00	#N/A
	TOTAL (if comprehensive and non-overlapping set of risks)		0.00		0.00		0.00		0.00	

From <Instructions>:

The risks and their unmitigated factors are automatically carried over from <3b.Unmitigated Risk Assess>, and combined with the assessed effectiveness of the selected risk reduction actions (from <5b.Risk Reduction Plan>), to automatically determine the mitigated mean severity for each risk. If the set of risks is comprehensive and non-overlapping, approximate mean values for mitigated collective risk are also determined automatically.

Figure 12. <6a.Mitigated Risk Assess> (showing only first and last risk items in each category)



Expected Value of Mitigated Project Performance Golder Associates®

Note: If the set of risks are comprehensive and non-overlapping, very approximate mean values for "mitigated" (i.e., with selected additional Risk Management) collective cost, disruption and schedule risk are determined automatically (as subtotals and totals); because only mean values are used, any correlations among factors can be ignored. The mean value generally has about 50-60% chance of not being exceeded (depending on "skewness" of the distribution, e.g., a normal or Gaussian distribution has 50% chance); hence, a higher value should be budgeted to have a higher confidence of not being exceeded.

Directions: Can read the approximate mean values for mitigated project performance. Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (e.g., for printing).

Yellow-shaded cells are input cells (none on this sheet)

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

<Project Name>

Proj Delivery Method: Traditional D/B/B **Project start date:** 1/0/1900 for schedule and escalation

	"Base+Impl" (wo contingency or schedule float)					"Residual Risk" (additional to Base)			"Mitigated Total" (Base+Impl + Residual Risk)						
Activity (master list)	Base+Impl Cost (unesc$M)	Base+Impl Disruption (M-hrs)	Base+Impl Duration (months)	Lag Label	Base Lag (mos)	Risk Cost (unesc$M)	Risk Disruption (M-hrs)	Risk Delay (months)	Total Cost (unesc$M)	Total Disruption (M-hrs)	Total Duration (months)	Total Early Start Date	Total Early End Date	Total Float (months)	Total Cost (esc$M)
Planning	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Scoping	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Design Funding			0.0					0.0					1/0/1900	0.0	
Prelim Design/Env Proc	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Environmental Permits	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
ROW/Util/RR Funding			0.0	E	0.0			0.0					1/0/1900	0.0	
ROW/Util/RR	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Final Design	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction Funding			0.0					0.0					1/0/1900	0.0	
Procurement	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**				**$ -**	**0.0**		**$ -**	**0.0**					**$ -**
Operations	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Replacement	$ -	0.0	0.0			0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**	**$ -**	**←longevity ($)**		**$ -**	**0.0**	**$ -**	**0.0**	**0.0**	**$ -**	**←longevity ($)**			**$ -**
Total	**$ -**	**0.0**	**$ -**			**0.00**	**0.0**	**$ -**	**0.00**	**0.0**	**$ -**	**1/0/1900**	**1/0/1900**	**1/0/1900**	**$ -**
			↑combined ($M)					↑combined ($M)			↑combined (	↑ad date	↑end of CN	↑replacement	

Mean Annual Cost Inflation Rate (%/yr)

Engr	0.0%	incl Planning, Scoping, Prelim Design/Environmental Process, Final Design, Environmental Permits & Procurement
ROW/Utility/RR	0.0%	
Construction	0.0%	incl Construction, Operations (& Maintenance), and Replacement

Extended OH Rates (unesc $M/month)

Preconstruction	0.00	Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / preconstruction duration) - calculated default value can be revised
Construction	0.00	Average agency construction "burn rate" (= agency baseline construction engr cost / construction duration) plus compensable contractor OH (= % of contractor construction OH cost / construction duration) - calculated default value can be revised

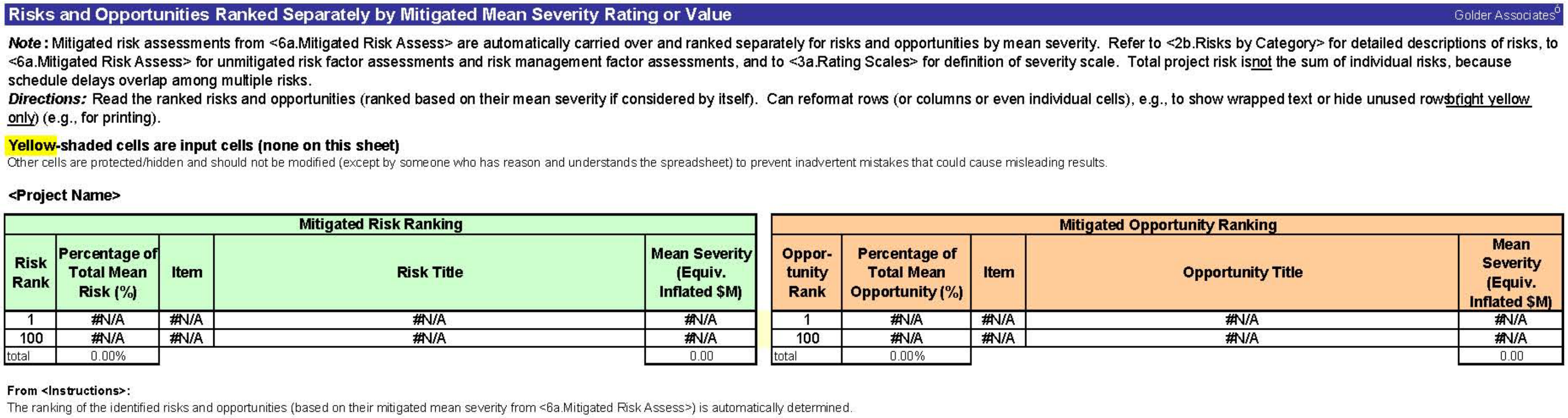
Values for combining consequences

Disruption Value ($M/M-hr)	0.00	to combine disruption with cost (NPV value)
Schedule Target (date)	1/0/1900	target date for start of operations
Schedule Value ($M/mo)	0.00	to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)	0.0%	to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	1.00	to combine "longevity" with cost (NPV value) - default value can be revised

From <Instructions>:

The residual collective risks for the Risk Reduction Plan (from <5b.Risk Reduction Plan>) are determined automatically and combined with the initial base factors (from <1.Base Project Info>), the unmitigated risk factors (from <3b.Unmitigated Risk Assess>), and risk management factors (from <5a.Risk Reduction Evaluation>) to automatically determine approximate mean values of mitigated total project performance.

Figure 13. <6b.Mitigated Risk Results>



Risks and Opportunities Ranked Separately by Mitigated Mean Severity Rating or Value Golder Associates©

***Note*:** Mitigated risk assessments from <6a.Mitigated Risk Assess> are automatically carried over and ranked separately for risks and opportunities by mean severity. Refer to <2b.Risks by Category> for detailed descriptions of risks, to <6a.Mitigated Risk Assess> for unmitigated risk factor assessments and risk management factor assessments, and to <3a.Rating Scales> for definition of severity scale. Total project risk is not the sum of individual risks, because schedule delays overlap among multiple risks.

Directions: Read the ranked risks and opportunities (ranked based on their mean severity if considered by itself). Can reformat rows (or columns or even individual cells), e.g., to show wrapped text or hide unused rows (bright yellow only) (e.g., for printing).

Yellow-shaded cells are input cells (none on this sheet)

Other cells are protected/hidden and should not be modified (except by someone who has reason and understands the spreadsheet) to prevent inadvertent mistakes that could cause misleading results.

<Project Name>

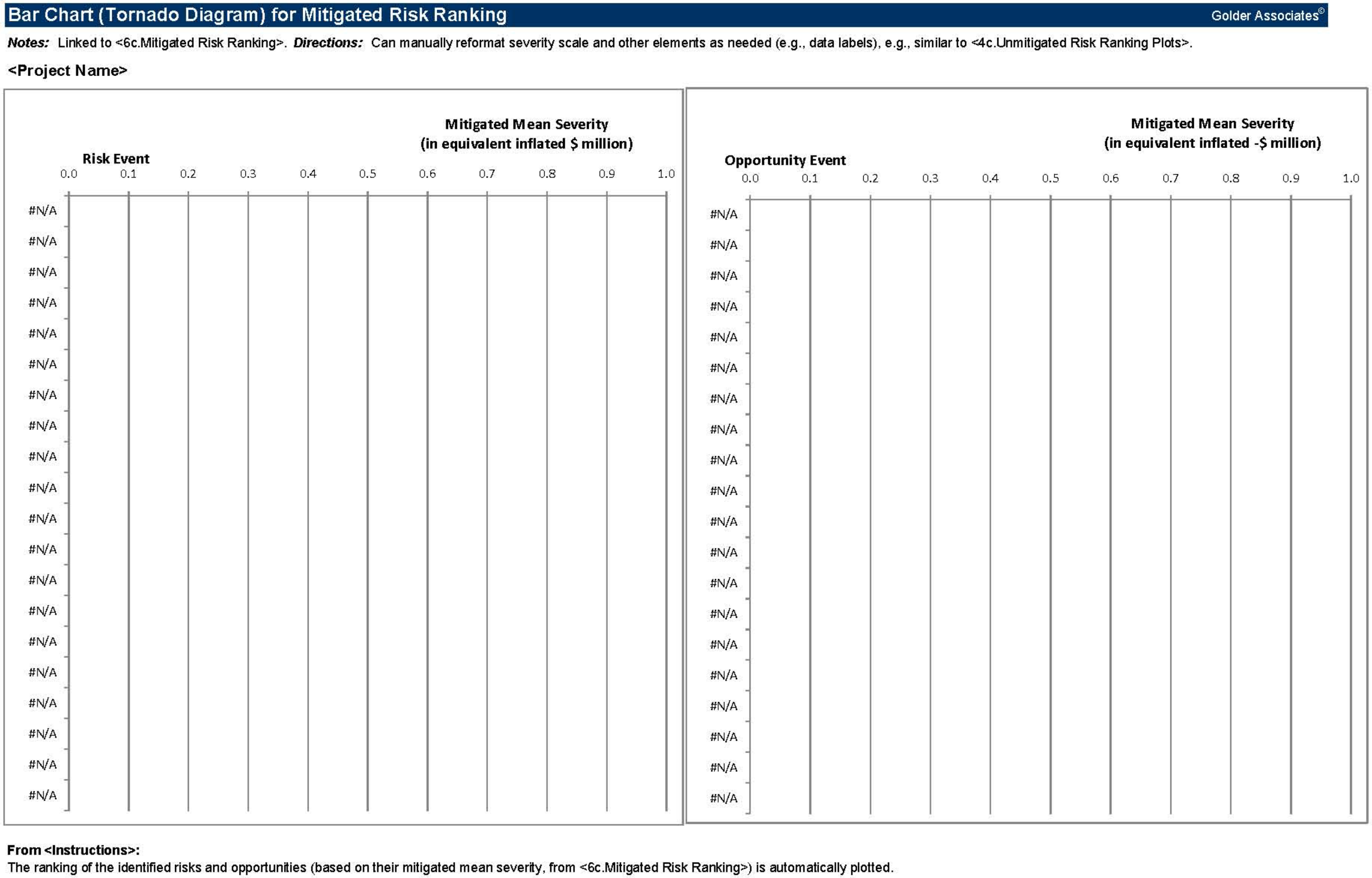
Mitigated Risk Ranking				
Risk Rank	**Percentage of Total Mean Risk (%)**	**Item**	**Risk Title**	**Mean Severity (Equiv. Inflated $M)**
1	#N/A	#N/A	#N/A	#N/A
100	#N/A	#N/A	#N/A	#N/A
total	0.00%			0.00

Mitigated Opportunity Ranking				
Oppor-tunity Rank	**Percentage of Total Mean Opportunity (%)**	**Item**	**Opportunity Title**	**Mean Severity (Equiv. Inflated $M)**
1	#N/A	#N/A	#N/A	#N/A
100	#N/A	#N/A	#N/A	#N/A
total	0.00%			0.00

From <Instructions>:

The ranking of the identified risks and opportunities (based on their mitigated mean severity from <6a.Mitigated Risk Assess>) is automatically determined.

Figure 14. <6c.Mitigated Risk Ranking> (showing only first and last ranked risk items)



Bar Chart (Tornado Diagram) for Mitigated Risk Ranking Golder Associates©

Notes: Linked to <6c.Mitigated Risk Ranking>. ***Directions:*** Can manually reformat severity scale and other elements as needed (e.g., data labels), e.g., similar to <4c.Unmitigated Risk Ranking Plots>.

<Project Name>

From <Instructions>:

The ranking of the identified risks and opportunities (based on their mitigated mean severity, from <6c.Mitigated Risk Ranking>) is automatically plotted.

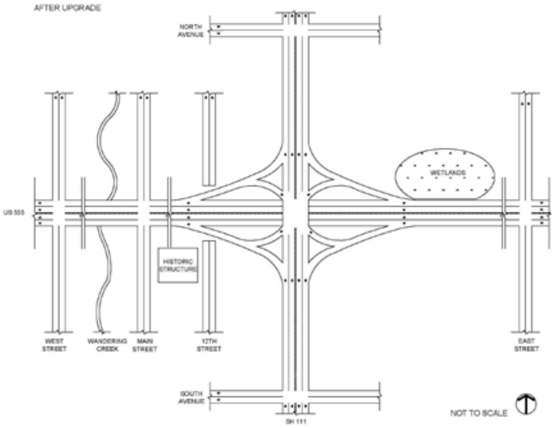
Figure 15. <6d.Mitigated Risk Ranking Plots>

Appendix – Printout of Template (Blank Workbook)

<insert printout of blank workbook: SHRP2 R09 Rapid Renewal Risk Management Planning Template (Beta 30June2010b).pdf>

Risk Management Plan

for US 555 / SH 111 Project



for
QDOT

by

Golder Associates

15 Feb 2010

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No tables

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EXECUTIVE SUMMARY

QDOT is planning to reconstruct and expand segments of two existing (intersecting) highways, US 555 and SH 111, through a rapidly-developing suburban area. QDOT wants to minimize cost, schedule and disruption through construction, and maximize longevity after construction. To help achieve these objectives, QDOT will use design/build project delivery, as well as encourage accelerated construction methods.

In order to further improve and control ultimate project performance where innovative methods are being used, QDOT conducted formal risk management, as described in the "Guide for Managing Risks for Rapid Renewal Projects" (TRB, 2010). Such risk management involves appropriately anticipating and planning for potential problems (risks), as well as opportunities (negative risks), and is documented in this project *Risk Management Plan*.

This *Risk Management Plan* consists of the following elements:

- Description of the project
- Identification of current risks, and assessment of their factors
- Analysis of project performance, and ranking of risks in terms of their contribution to this project performance
- Identification of ways to proactively reduce significant individual risks, and evaluation of their cost-effectiveness
- Selection, planning and implementation of cost-effective ways to proactively reduce significant individual risks
- Establishment and management of cost and schedule contingency to cover (to a high level of confidence) remaining risks throughout the project
- Establishment and management of "recovery" plans (in case contingencies are insufficient)
- Establishment of organizational structure and resources to successfully implement the *Risk Management Plan*.

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1.0 INTRODUCTION

1.1 Purpose and Objectives

The primary purpose of this *Risk Management Plan* is to provide appropriate plans (and adequate justification of those plans) for improving and controlling “performance” (i.e., cost, schedule, disruption, and longevity) of the project, by focusing on controlling project risks (both individually and collectively).

Quantification of the uncertainty in project performance, e.g., to help establish budgets, milestones, and contingencies at QDOT-specified confidence levels, is not currently part of the scope of this *Risk Management Plan*, but could be added later (e.g., by addendum).

1.2 Approach

The approach taken in developing this plan is adopted from “Guide for Managing Risks for Rapid Renewal Projects” (TRB, 2010). This approach consists of the following steps, as documented in this plan:

- Project Description (Section 2) - Develop an adequate understanding of the project (as documented in a specific format) and its likely “base” (without “risk”) performance (i.e., regarding schedule, cost, and disruption through construction, and post-construction longevity). As part of this, develop a simple but adequate cost- and disruption-loaded project schedule.
- Pre-Mitigation Risk Identification and Assessment (Section 3) – Develop a comprehensive and non-over-lapping set of project performance risks, which are possible events that, if they occur, can change project performance, and categorize the list by when during project development the risks would occur. For each of the risks, adequately assess the factors defining those risks, including the likely impacts (e.g., change in unescalated cost to a particular project activity) if the risk occurs, and the likelihood of the event (as defined by those impacts) occurring.
- Pre-Mitigation Risk Analysis (Section 4) – Determine likely project performance, including the risks, and especially the relative significance of the various risks in affecting that performance (“sensitivity”), before any additional mitigation.
- Risk Reduction Planning (Section 5) – Identify possible actions to proactively reduce individual risks, focusing on the most significant risks, and evaluate their cost-effectiveness. Select and adequately plan (i.e., assign responsibility and resources) the set of cost-effective actions.
- Post-Mitigation Risk Analysis (Section 6) – Determine likely project performance, including the risks, and especially the relative significance of the various risks in affecting that performance (“sensitivity”), considering additional mitigation.
- Contingency Management (Section 7) – Establish contingency requirements (cost and schedule allowances) for the various phases of project development, based on likely project performance considering collectively the residual risks for each phase if the risk reduction plans are adopted and implemented. Also establish adequate procedures for how those contingencies will be controlled.
- Recovery Planning (Section 8) – Establish plans for what to do if contingencies turn out to be insufficient (e.g., defer scope through contract options) during various phases of project development. Also establish adequate procedures for how those plans will be triggered.

- *Risk Management Plan* Implementation (Section 9) – Identify the organizational structure and resources required to successfully implement this *Risk Management Plan*.

Each of the above steps is briefly discussed in the following sections, with details presented in attachments (including the filled-in template in Attachment I).

2.0 PROJECT DESCRIPTION

2.1 Project Summary

QDOT is planning to reconstruct and expand segments of two existing (intersecting) highways, US 555 and SH 111, through a rapidly-developing suburban area. The existing highways are nearly 40 years old, have increasingly inadequate capacity, and are expensive to maintain. These facilities are the only viable east-west (US 555) and north-south (SH 111) routes for commercial traffic for several miles in either direction. Therefore, it is imperative that the necessary improvements be made quickly and with minimal disruption. QDOT would also like to minimize construction costs and future repair cycles and maintenance requirements, as well as eventual replacement issues.

To help achieve these objectives, QDOT plans to encourage contractor innovation through the use of performance-based specifications and incentives, and to procure with an innovative project delivery method (i.e., design-build or D/B). It is expected that accelerated bridge construction techniques, minimally disruptive MOT, and innovative pavement design, among other rapid renewal elements, will be considered for this project.

A detailed project description, including major assumptions and conditions, is presented in Attachment A.

2.2 Base Project Schedule

As presented in Attachment B (Table B-3), for the assumptions outlined above, the “base” project schedule (without risk) was developed from QDOT’s latest project schedule, using a standard simplified project flowchart for D/B with base durations, lags, and milestones for the various activities. QDOT’s project schedule was first reviewed and “de-biased”, removing any float. In general terms of overall pre-construction and construction schedules, the base project schedule (before risk and opportunity) is 18 months from present time to reach contractor NTP, then 17 months for D/B design and construction, with a target completion date of 01 November 2012. The project team is also assuming a 50-year time to replacement (which takes two years).

2.3 Base Project Cost

As presented in Attachment B (Tables B-1 and B-3), for the assumptions outlined above, the “base” project cost (without risk) was developed from QDOT’s latest cost estimate and allocated to the activities in the D/B standard simplified project flowchart, to create a simple cost-loaded schedule. QDOT’s project cost estimate was first reviewed and de-biased, removing any contingency. The base total project cost (through delivery, without contingency) is approximately $16.4 million in current (uninflated) dollars. By major project component or phase, the base costs (in current uninflated dollars) are approximately as follows:

- For capital project delivery:
    - $1.2 million for QDOT pre-construction effort (including preliminary design, contract procurement, environmental documentation, and permitting)
    - $2.0 million for right-of-way acquisition
    - $1.0 million for utility relocations,
    - $11.9 million for D/B design and construction plus QDOT contract administration
- For post-construction:
    - Operations & maintenance costs average about $0.5 million per year

  - Replacement costs are about the same as the current project delivery costs ($16 million).

On average, mean Inflation is about 3.0% per year for engineering, 3.0% per year for ROW and 3.0% per year for construction. Mean extended overheads (i.e., delay costs) associated with schedule delays are about $0.10 million per month for pre-construction and about $0.23 million per month during construction, based on average "burn rates".

2.4 Base Project Disruption

As presented in Attachment B (Tables B-2 and B-3), for the assumptions outlined above, QDOT estimates its total disruption (through replacement) at about 2.8 million hours (M-hr). By major project component or phase, the mean disruptions are determined (considering how much of that phase experiences disruption, how many people are affected during disruption, and their impact) approximately as follows:

- Utility relocation: 0.2 M-hr
- Construction: 0.5 M-hr
- Operations & maintenance: 1.4 M-hr
- Replacement: 0.7 M-hr

2.5 Tradeoffs

As presented in Attachment B (Table B-3), QDOT has established the following "tradeoffs" for combining performance (cost, disruption, schedule, and longevity):

- The "value" (or user costs) of disruption (in terms of how much QDOT is willing to pay now to avoid disruption) is about $10 per person-hour.
- The "value" of the planned completion date (in terms of how much QDOT is willing to pay now to prevent delay) is about $0.1 million per month.
- The "value" of longevity (in terms of how much QDOT is willing to pay now to prevent discounted longevity costs) is about $1.00 per NPV$.
- The net long-term (during operations and replacement) discount rate (for determining longevity NPV$) is about 5.0% per year.

2.6 Base Project Performance Analysis

As presented in Attachment B (Table B-3), the following mean base project performance measures were determined (using an MS Excel template) based on the D/B standard simplified project flowchart (Figure 2-1) using mean input values (as discussed above):

- Mean base project schedule (start and end dates, float)
- Mean base project cost (both uninflated and inflated) through construction
- Mean base project disruption through construction
- Mean base project "longevity" (combined measure of post-construction project cost, schedule and disruption)
- Mean combined project performance (combined measure of cost, schedule, and disruption through construction, and post-construction longevity, for subsequently determining "severity" of risks)

It should be noted that the mean base performance produced by quantitative risk analysis might differ from that produced by the template for several reasons: a) the quantitative risk analysis is typically done in more detail; and b) the means of the input ranges used in quantitative risk analysis might differ from the directly assessed mean inputs used in the template.

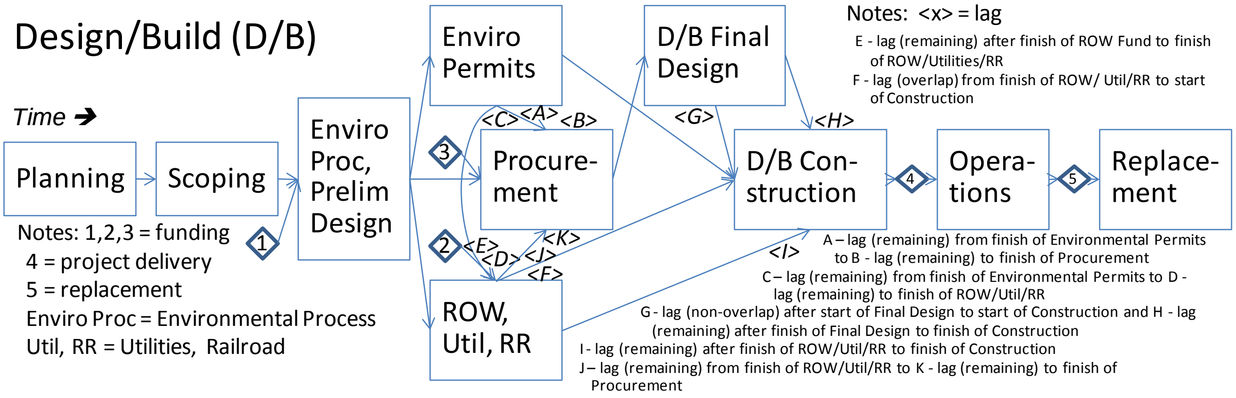

Figure 2-1. Standard Simplified D/B Flowchart for QDOT's US 555 / SH 111 Mean-Value Risk Assessment

3.0 RISK IDENTIFICATION AND ASSESSMENT – BEFORE MITIGATION

3.1 Assumptions and Exclusions

Assumptions are necessary for any analysis, and the results of the analysis must clearly state the assumptions on which they are based. Risk assessments attempt to include all relevant issues so that the results are as inclusive and robust as possible (i.e., the results will "stand the test of time"). The more risks that are excluded, the more "constrained" or "conditional" the results are. However, in many cases an owner has good reason to exclude particular issues from the analysis. The major assumptions for (and exclusions from) this risk assessment are shown in the bulleted items below. All results presented in this report are conditional on these assumptions being true (unless noted specifically).

- Uncertainty in the timing or availability in funding (e.g., cash-flow constraints or contractor financing) was excluded. These issues could be addressed with separate model scenarios.
- "Project-cancelling" risks were excluded (e.g., significant change in purpose and need).

In other words, the question being addressed is, "How much will the project cost and how long will it take if it is funded and completed as currently planned?"

3.2 Risk Register – Before Mitigation

In a facilitated environment, the project team and project-independent subject matter experts identified a comprehensive, non-overlapping set of risks and opportunities relative to the project "base", first by brainstorming and then by categorizing/editing/adding. These risks to project cost, schedule, and disruption were documented in the "risk register".

Each risk and opportunity is defined by several "risk factors":

- the cost, duration, and/or disruption changes to specific flow chart activities (i.e., the "impact scenario") if the risk occurs; and
- the probability of occurrence (as defined by the impact scenario), recognizing that the chance that the risk event does not occur (i.e., no impacts) equals 1.0 minus the probability of occurrence.

The group (by consensus) characterized each of these risk factors in a "mean-value" (i.e., probability-weighted average) sense, via either mean values (e.g., in dollars and months) or pre-defined mean risk ratings (e.g., H, M, L). These factor assessments were also documented in the risk register.

The full risk register (before mitigation) and associated risk-factor rating scales are presented in Attachment C:

- Table C-1 presents the risk-factor rating scale definitions (from the Microsoft Excel template); and
- Table C-2 presents the risk register, in terms of a categorized list of risks (from the Microsoft Excel template) that has been edited and added to so that the list is comprehensive and non-overlapping, and their mean-value or mean rating factor assessments before additional mitigation (from the Microsoft Excel template).

Note that a mean-rating or mean-value risk assessment approach (as used here) provides single mean values/ratings of project performance, essentially ignoring uncertainties and correlations among those uncertainties. To formally address such uncertainties and correlations, and produce ranges (probability distributions) rather than single mean values, a quantitative risk analysis should be conducted.

4.0 RISK ASSESSMENT RESULTS – BEFORE MITIGATION

The base performance factors (as summarized in Chapter 2) and the risk factors before mitigation (as summarized in Chapter 3) were appropriately combined (using the MS Excel template) to determine the following:

- Approximate mean values of base+risk project performance before any additional mitigation, including:
  - Project schedule (duration, start and end dates, and float by activity, and key milestone dates)
  - Project cost (unescalated and escalated, by activity and collectively
  - Project disruption (by activity and collectively)
  - Project longevity (combination via tradeoffs of post-construction schedule, cost and disruption)
  - Project combined performance (combination via tradeoffs of escalated project cost, schedule and disruption through construction, and longevity).
- Mean "severity" of each risk, in terms of its contribution to mean combined project performance before any additional mitigation, and ranking of risks on that basis. Severity is an expression of how much QDOT would logically be willing to pay (on average, for various reasons) to eliminate that risk.

These results are presented in Attachment D:

- Unmitigated base+risk project performance is presented in Table D-1. However, these mean values of project performance are very approximate (for various reasons) and should be used with caution. More accurate results would require quantitative risk analysis, which is currently outside the scope of this *Risk Management Plan*.
- The top risks are presented in rank order of mean severity, both in tabular form (Table D-2) and graphically (Figure D-1). The mean severity and ranking of all risks are presented in Attachment I.

5.0 RISK REDUCTION PLANNING

In a facilitated environment, the project team and project-independent subject matter experts:

- First identified possible ways to reduce the significant risks (and exploit the significant opportunities), as discussed in Chapter 4; and
- Then, assessed (by consensus) the various factors that define the cost-effectiveness of each action in reducing risks (or exploiting opportunities) and thereby improving project performance. These factors include:
    - Mean changes in the base factors (cost, schedule and disruption by activity) associated with implementing the action (regardless of effectiveness), e.g., action A will cost about $1.0M to implement, and
    - Mean changes in the risk factors (cost, schedule, and disruption impacts by activity, and probability of occurrence) as a result of that action, e.g., action A will reduce the probability of risk R occurring by about 1/2.

These actions, and their assessed factors, were documented in the “risk reduction plan”.

The cost-effectiveness of each action was then determined (in terms of its net change in combined project performance) by appropriately combining the above information (along with tradeoffs, using the MS Excel template). Cost-effective actions were then selected and plans developed for them, including responsibility and schedule for completion.

The risk reduction plan is presented in Attachment E:

- The possible risk reduction actions for the highest ranking risks are identified in Table E-1.
- The assessed cost-effectiveness factors for each action are documented in Table E-1.
- The calculated (using the MS Excel template) cost-effectiveness of each action is presented in Table E-2.
- The selected cost-effective set of actions, and plans for implementing them, are presented in Table E-3.
- The calculated (using the MS Excel template) mitigated Risk Register (in terms of mean value/ratings) for the selected set of actions is presented in Table E-4.

6.0 RISK ASSESSMENT RESULTS – AFTER MITIGATION

The base performance factors (as summarized in Chapter 2) and the mitigation implementation and risk factors after mitigation (as summarized in Chapter 5) were appropriately combined (using the MS Excel template) to determine the following:

- Approximate mean values of base+risk project performance considering additional mitigation, including:
    - Project schedule (duration, start and end dates, and float by activity, and key milestone dates)
    - Project cost (unescalated and escalated, by activity and collectively
    - Project disruption (by activity and collectively)
    - Project longevity (combination via tradeoffs of post-construction schedule, cost and disruption)
    - Project combined performance (combination via tradeoffs of escalated project cost, schedule and disruption through construction, and longevity).
- Mean “severity” of each risk, in terms of its contribution to mean combined project performance considering additional mitigation, and ranking of risks on that basis. Severity is an expression of how much QDOT would logically be willing to pay (on average, for various reasons) to eliminate that risk.

These results are presented in Attachment F:

- Mitigated base+risk project performance is presented in Table F-1. However, these mean values of project performance are very approximate (for various reasons) and should be used with caution. More accurate results would require quantitative risk analysis, which is currently outside the scope of this *Risk Management Plan*.
- The top risks are presented in rank order of mean severity, both in tabular form (Table F-2) and graphically (Figure F-1). The mean severity and ranking of all risks are presented in Attachment I.

7.0 CONTINGENCY MANAGEMENT

Contingency funds and float are needed on top of the base cost and schedule, respectively, to adequately cover (with appropriate confidence) the risks that actually occur during a project. Cleary, such contingencies generally cannot be based on worst-possible-case assumptions, because that would usually be unaffordable (e.g., commit too much money and time, possibly starving other projects). Instead, a “reasonable” level of confidence is needed, appropriately reflecting the “pain” of exceeding available contingency, i.e., the more pain involved, the higher the confidence level should be. In the past, cost contingencies have often been based strictly on judgment (with industry guidance), as a percentage of the project cost; however, such empirically-derived contingencies have often proven to be inadequate, although occasionally they prove to be excessive. Often, there is no explicit schedule contingency, resulting in missed milestones.

The amount of cost and schedule contingency needed for each phase would ideally be developed by quantitative risk analysis, in which the uncertainty in project cost and schedule would be determined and the values associated with a specified confidence level (which would be a QDOT policy issue) could be identified. In the absence of such analyses, ,judgment must be used. Hence, the contingency required for this project through each project phase was identified in a facilitated workshop with the project team and project-independent subject matter experts, considering the risks for each phase (see Attachment G).

Specific protocol has been established for managing contingency expenditures and release (see Attachment G).

8.0 RECOVERY

Various actions can be taken throughout project development if contingency becomes insufficient. For example, if remaining schedule contingency has become (or is becoming) insufficient to cover the remaining risks, work can sometimes be accelerated (albeit at a premium price) by working more or longer workshifts or critical path scope can be deferred (e.g., through contract options). As another example, if remaining cost contingency has become (or is becoming) insufficient, then generally either additional funds must be obtained (e.g., from program reserve) or some scope must be deferred (e.g., through contract options).

The amount of recovery needed for each phase would ideally be developed in the same way as contingency should be, i.e., by quantitative risk analysis. In the absence of such analyses, judgment must be used. Hence, the recovery required for this project through each project phase was identified in the same facilitated workshop with the project team and project-independent subject matter experts as for establishing contingency, considering the risks for each phase (see Attachment H). The recovery actions (and their approximate net recovery value) that are available and that satisfy the requirements for this project through each project phase were identified in a facilitated workshop with the project team and project-independent subject matter experts (see Attachment H).

Specific protocol has been established for implementing the recovery plans (see Attachment H).

9.0 IMPLEMENTATION

In order to successfully implement this *Risk Management Plan*, and thereby realize improved project performance, the following is required:

- DOT commitment to the *Risk Management Plan*.
- Designated Project Risk Manager, with adequate authority and resources to carry out this *Risk Management Plan* to:
    - monitor and periodically update the *Risk Register*, i.e., regarding changes in risk factors and in associated results
    - monitor and periodically update this *Risk Management Plan*, i.e., regarding:
        - status/progress and results of selected risk reduction actions, and possible redirection,
        - adequacy of remaining contingency, and recommendations regarding contingency management and implementation of recovery plans
        - status/adequacy of recovery plans

  Monitoring is typically done via short interviews with select project staff (e.g., as part of weekly or monthly project progress meetings), whereas updating requires additional effort (e.g., short workshop).
- Adequate information systems to support implementation of his *Risk Management Plan*, e.g., regarding gathering, interpreting and distributing relevant information

10.0 CONCLUSIONS

A suitable *Risk Management Plan* has been defensibly developed for the QDOT US 555 / SH 111 project to improve and control project performance (i.e., schedule, cost and disruption through construction and post-construction longevity). This plan consists of three main elements:

- A program of actions intended to proactively and cost-effectively reduce the significant project risks, where the risks were meaningfully evaluated in terms of their "severity" with respect to the project's combined performance (combination via tradeoffs of schedule, cost and disruption through construction and post-construction longevity).
- Establishment and management of cost and schedule contingency throughout project development to cover the remaining risks (collectively) with a high level of confidence.
- Establishment and management of recovery plans throughout project development in case the remaining contingency is insufficient.

In addition, the requirements for successfully implementing this *Risk Management Plan* have been identified, e.g., organizational structure and resources.

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ATTACHMENT A. PROJECT DESCRIPTION

QDOT is planning to reconstruct and expand segments of two existing (intersecting) highways, US 555 and SH 111, through a rapidly-developing suburban area (see Figure A-1). The existing highways are nearly 40 years old, have increasingly inadequate capacity, and are expensive to maintain. These facilities are the only viable east-west (US 555) and north-south (SH 111) routes for commercial traffic for several miles in either direction. Therefore, it is imperative that the necessary improvements be made quickly and with minimal disruption. QDOT would also like to minimize construction costs and future repair cycles and maintenance requirements, as well as eventual replacement issues. To help achieve these objectives, QDOT plans to encourage contractor innovation through the use of performance-based specifications and incentives, and to procure with an innovative project delivery method (i.e., design-build or D/B). It is expected that accelerated bridge construction techniques, minimally disruptive MOT, and innovative pavement design, among other rapid renewal elements, will be considered for this project.

- Detailed scope (including alternatives):
  - **Upgrade** the existing unlimited-access, two-lane **US 555 into a limited-access, four-lane highway**. This includes reconstruction of the existing roadway section.
    - The limits of the upgrade are still not established, but the current assumption is from just west of West Street (1 mile west of SH 111) to just east of East Street (1 mile east of SH 111), including signalized intersections at each street.
    - US 555 will have four 11-foot lanes and no shoulders. A concrete median barrier will separate eastbound and westbound lanes. Concrete pavement is assumed for longevity; however, QDOT is open to innovative designs (e.g., composite pavement) from the contractor. QDOT currently assumes that FHWA will approve a design exception / deviation to build the facility with 11 ft lanes and no shoulders.
    - QDOT anticipates that US 555 will be widened to the north of the existing facility where possible because right-of-way is more readily available to the north. Even with no shoulders as assumed, and if the roadway embankment is supported by retaining walls as assumed, widening to the north will impact a 10- to 15-foot-wide strip of existing Class III wetlands along the east half of the upgrade. The cost estimate assumes this alternative.
  - **Upgrade** the existing unlimited-access, two-lane **SH 111 into a limited-access, four-lane highway**. This includes reconstruction of the existing roadway section.
    - The limits of improvement for SH 111 are from just north of North Avenue (1/2 mile north of interchange) to just south of South Avenue (1/2 mile south of interchange), including signalized intersections at each avenue.
    - SH 111 will also have four 11-foot lanes and no shoulders. A concrete median barrier will separate northbound and southbound lanes. Concrete pavement is assumed for longevity; however, QDOT is open to innovative designs from the contractor. QDOT currently assumes that FHWA will approve a design exception / deviation to build the facility with 11 ft lanes and no shoulders.
    - QDOT envisions that the contractor could propose one of two major alternatives to accomplish this upgrade while meeting its objectives for the project:
      - Rebuild on existing alignment: Build a detour for SH 111 around the existing facility, switch traffic onto the detour, then rapidly construct the approach embankments, abutment, and the new bridge (overpass) using accelerated bridge construction (ABC) techniques on the existing alignment, then switch traffic back onto the new facility on the original alignment and demolish the detour. This alternative is most likely and is assumed in QDOT's current cost estimate. Or,
      - Split / shift alignment: Instead of widening on the existing alignment, re-align (and perhaps separate northbound and southbound) around the existing alignment. This would allow rapid construction of approach embankments and bridge structures out of traffic and would keep traffic on the existing facility in the meantime. However, this approach would require more right-of-way (with greater business impacts) and is therefore not favored by QDOT. The City in particular is opposed to this alternative, as

are at least two known public groups. Note that this alternative likely would not require ABC techniques.

  - **Convert** the at-grade **intersection of US 555 and SH 111 into a grade-separated interchange**.
    - QDOT anticipates that SH 111 will be carried over the top of US 555.
    - The type of interchange has not been finalized (the interchange design will be a function of the selected alignment for SH 111 as mentioned previously). QDOT plans to issue performance-based specifications to enable contractor innovation, but currently assumes (and estimates) the following consistent with building on the existing alignment:
      - Single-point urban interchange (SPUI). The existing right-of-way will accommodate this design, but this design might not provide the most operational benefit. Hence, other interchange designs might be feasible.
      - The structure type for the interchange has not been finalized, but the current assumption is a two-span, pre-cast concrete-girder structure. QDOT anticipates that the contractor will propose some sort of accelerated bridge construction (ABC) to complete the abutment and bridge construction more rapidly than with traditional methods.
      - The design currently assumes drilled-shaft foundations for the structural piers. However, potentially poor soil conditions might require ground improvement as well.
      - No on-site fill material is available for construction of the approach embankments, which are assumed to be retained fill to minimize ROW impacts.
  - **Re-align the arterial (Main Street) intersection** to be perpendicular with US 555 (from its current significant skew). Re-alignment of Main Street will require new right-of-way near the at-grade and signalized intersection. In addition, realigning Main Street will impact several old structures. The baseline assumption is that these structures do not contain any asbestos and are not eligible for listing on the National Historic Register. The existing intersection of SH 555 with 12th Street will be removed (i.e., there will be no access to SH 555 from 12th Street).
- Funding: The project is fully funded at this time. Federal funding is involved.
- Design:
  - Design level: The project is in preliminary engineering (<10% design). If Design/Build (D/B) delivery method is chosen, QDOT would complete preliminary design (to 30% design) before turning the project over to the D/B contractor.
  - Structural: See above.
  - Geotechnical: See above.
  - Drainage: See below.
  - Pavement: See above.
  - Systems
    - Lighting: The design currently assumes new lighting only in the interchange area. However, there is some push for new lighting throughout the project (most of this area is currently lit, but some of the lighting would have to be moved during the widening).
    - ITS: ITS upgrades will be completed separately (in the future) as part of a corridor-wide upgrade.
  - Design deviations: See above.
- Environmental:
  - Environmental documentation: The team is conducting an Environmental Assessment (EA) based on the assumption of non-significant right-of-way, wetland, and potential historic impacts (note: because QDOT does not know what alignment/alternative the contractor will propose, it is assuming conservative impacts). Field studies are underway. The plan is to complete the draft EA prior to issuing the Request for Proposal (RFP) for D/B, and to have the EA finalized before issuing a Notice to Proceed (NTP) for D/B.
  - Wetlands: See above.
  - Streams: US 555 crosses Wandering Creek half a mile west of Main Street. The existing crossing is a small box culvert that is still serviceable and QDOT is not planning to replace it because QDOT believes it can be extended. However, the state fisheries agency has required QDOT to replace similar culverts with new larger culverts on recent projects.
  - ESA: No known issues. Currently, no listed fish species are believed to inhabit Wandering Creek this far upstream.

  - Floodplain: None.
  - Stormwater: The project assumes curb-and-gutter stormwater-runoff collection, with assumed conveyance to the City's existing combined stormwater/sanitary sewer system. The City has indicated that it might ask the project to pay for some upgrades to its system in exchange for the increased load, but this cost has not been included in the estimate. See also notes under "Utilities".
  - Contaminated/hazardous waste: There could be some unanticipated contaminated soil or groundwater (likely hydrocarbons) in the interchange area. The estimate includes a small allowance for remediation of this material if exposed through foundation excavation. QDOT has not yet decided whether it will accept the risk of additional contamination, or allocate this risk to the contractor.
  - Section 106: Potential historical buildings – see above.
  - 4(f): No known issues.
  - Permitting: A USACE 404 permit is required for the planned wetland impacts. The base assumes this will be an Individual permit, but if the design can be modified, wetland impacts could be less than anticipated and a Nationwide 404 permit might suffice. QDOT will secure the necessary 404 permit before issuing NTP to the D/B contractor.
- Right-of-Way and other agreements:
  - Right-of-Way: As described above. The area is quickly developing within project limits, with development happening more rapidly near the US 555 / SH 111 interchange. The cost estimate is based on today's estimated property values, but this might be insufficient to cover the increased values from planned developments.
  - Utilities: A number of utilities (e.g., City water and sewer, electric power, telecommunications fiber optic, and natural gas lines) are believed to cross the project, primarily beneath the proposed interchange. QDOT currently assumes (and estimates) that these utilities will be relocated at the utilities' expense. These relocations would occur in advance of construction and QDOT assumes that the utilities will relocate their lines in a timely manner. However, utility coordination is just getting started, and:
    - There is some indication that the telecommunication utility may seek a cost-sharing arrangement since it just completed the fiber-optic upgrade.
    - The City does not have money to relocate its water and sewer lines and might not be able to relocate in the time needed by the project. It is possible that the City will try to negotiate (with QDOT) a combined solution for relocation of the water and sewer lines and use of the sewer system by QDOT.
  - Railroad: None.
  - Other stakeholders: FHWA, the City, business owners, developers, travelling public, and residents.
- Procurement:
  - Delivery method: The project delivery method has not been selected, but the current assumption is a single Design/Build (D/B) contract to facilitate contractor innovation and to improve QDOT's chances of meeting its objectives for the project. QDOT might also employ contractor incentives to reward shortened construction schedule and minimized user impacts during construction (note: incentives are not included in the cost estimate; there is significant resistance by some within QDOT to using incentives with D/B procurement).
  - Contract packaging: See above.
  - Market (general and specialty): Current market conditions are uncertain. Because of the type and size of the project, and other projects currently underway or being bid, as well as the local contractor situation, QDOT anticipates four "good" proposals in response to its RFP, which could enhance competition. However, the successful proposals for two other recent QDOT Design/Build projects in this region bid higher costs than QDOT's internal estimates.
- Construction:
  - Construction access/restrictions (including seasonal, events, and workshifts): There are no significant restrictions along mainline US 555 and SH 111. Construction access and staging areas are good.

  - Maintenance of traffic: To maintain mobility and minimize "user costs" (disruption) during construction, capacity equivalent to two lanes of US 555 and two lanes on SH 111 should be maintained during construction. However, QDOT anticipates that the contractor could propose alternatives, such as directional or full closures over short durations, to complete construction while minimizing disruption to the travelling public and minimizing construction schedule.
  - Construction phasing: This has not been worked out in detail (QDOT does not know how the D/B contractor will build the project), but it is assumed that the interchange and roadway work can proceed simultaneously. QDOT hopes that the structures construction schedule can be minimized through use of ABC.
- Post-Construction ("Longevity"):
  - O&M: O&M for this roadway is expected to be typical, primarily involving periodic repaving (e.g., every ten years) and system (e.g., drainage system) maintenance as required. Such work can generally be done with limited lane closures and thus little disruption.
  - Replacement: Replacement of this roadway (especially structures) is anticipated to be required after about 50 years. Such replacement is expected to be very similar (in terms of activities and effort, and thus cost, schedule and disruption) to the current project, i.e., there are no elements that would be especially difficult to replace.

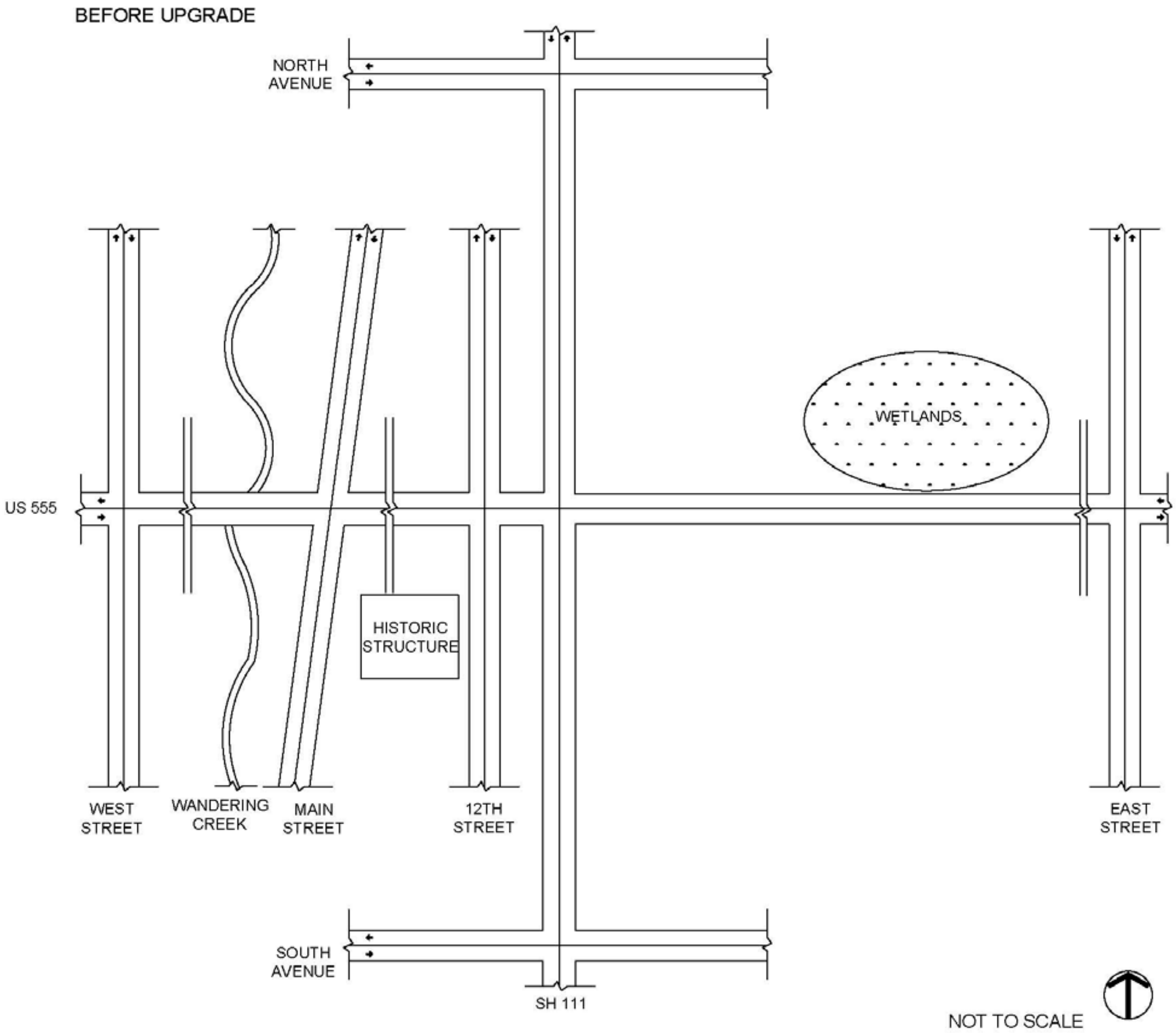


Figure A-1. QDOT US 555 / SH 111 Project Schematic: a) Before Upgrade

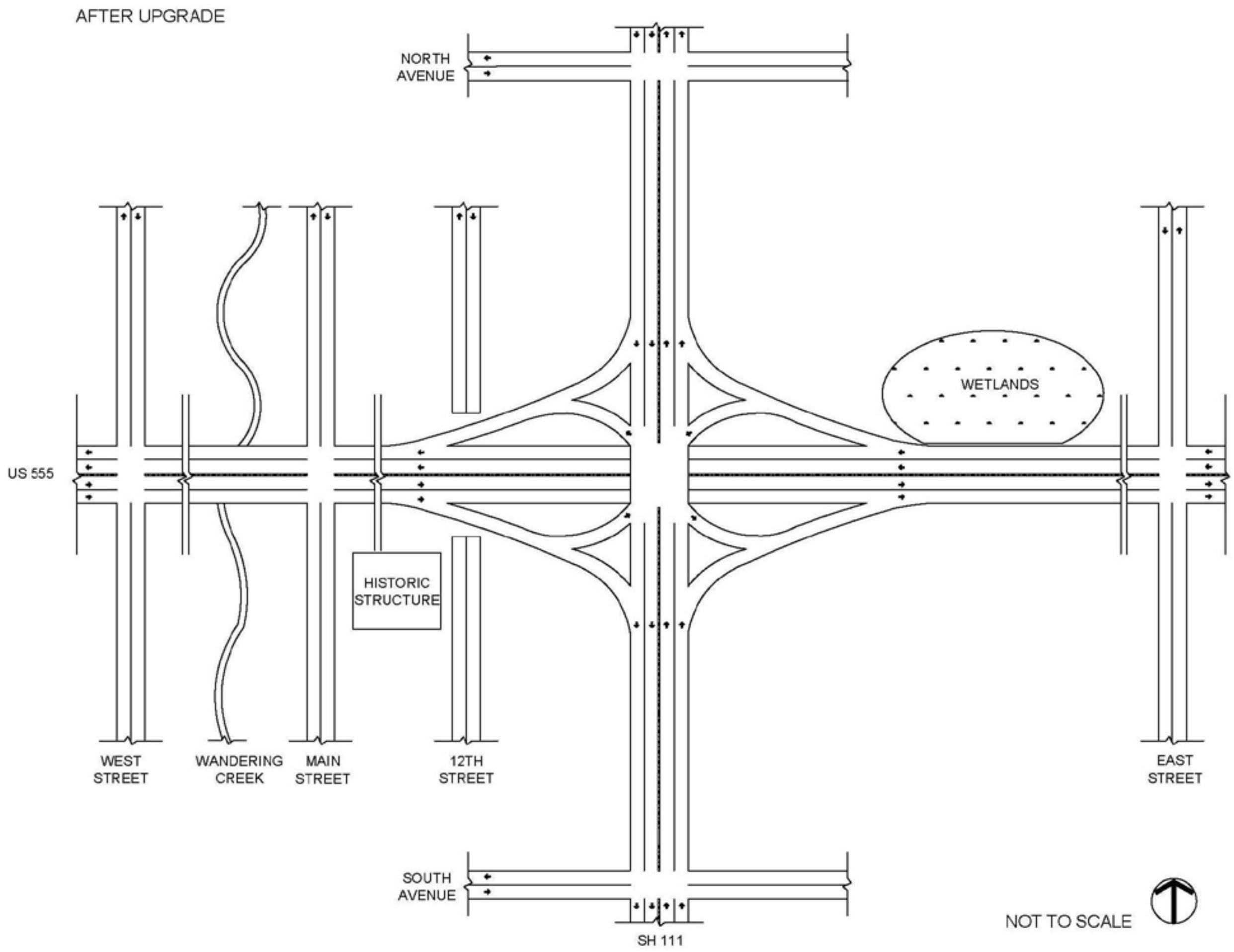


Figure A-1. QDOT US 555 / SH 111 Project Schematic: b) After Upgrade

ATTACHMENT B. BASE PROJECT PERFORMANCE

Project performance of interest generally consists primarily of:

- Schedule (especially through construction)
- Cost (both unescalated and escalated, especially through construction)
- Disruption (especially through construction)
- Longevity (combination of schedule, cost and disruption after construction)

Such performance is a combination of "base" (without risk) and "risk" components. This attachment discusses the base component; the risk component is discussed in Attachment C. The base component is typically derived from project team estimates (e.g., of schedule, cost, disruption, etc.), which are reviewed and possibly revised to remove any bias (e.g., conservatism) and stripped of any other contingency (which will be replaced by the "risk" component). However, only performance through construction is focused on for now.

Project Schedule Estimate

The current project schedule estimate consists of the following key elements (as of 01 Dec 2009):

- Remaining prelim design / environmental process - 12 months long
- Environmental permitting – 6 months long, starts after prelim design / environmental process is done
- ROW/utilities/RR – 12 months long
    - starts after prelim design / environmental process is done
    - can't finish until environmental permitting is done and ROW funding is available,
- Procurement - 6 months long
    - starts after prelim design / environmental process is done and construction funding is available
    - can't finish until environmental permitting is done and ROW/utilities/RR is at least half done (6 months left, i.e., QDOT is prioritizing ROW acquisition to get key parcels before issuing NTP to contractor; hence, procurement can finish when only half the ROW acquisition remains)
- D/B design – 6 months long, starts after procurement is done
- D/B construction – 16 months long
    - starts after environmental permitting is done and at least 1 month after start of D/B design and with no more than 6 months remaining of ROW/util/RR
    - can't finish until at least 6 months after end of D/B design and at least 10 months after end of ROW/utility/RR
- Operations – 50 yrs long, starts after construction done
- Replacement – 2 yrs long, start after operations done

Project Cost Estimate

The current project cost estimate (through construction) is shown in Table B-1. For post-construction, operations & maintenance costs average about $0.5 million per year and replacement costs are about the same as the current project delivery costs ($16 million), all in 2009$..

Project Disruption Estimate

The current project disruption estimate is shown in Table B-2.

Base Project Performance

The various inputs for the standard simplified D/B flowchart for this project (see Figure 2-1) are summarized in Table B-3, in which they are used to calculate mean project performance (by activity and collectively): cost (unescalated and escalated), schedule (milestone dates), disruption, and longevity (post construction cost, schedule and disruption), as well as combined performance. However, as previously noted, only performance through construction has been focused on for now.

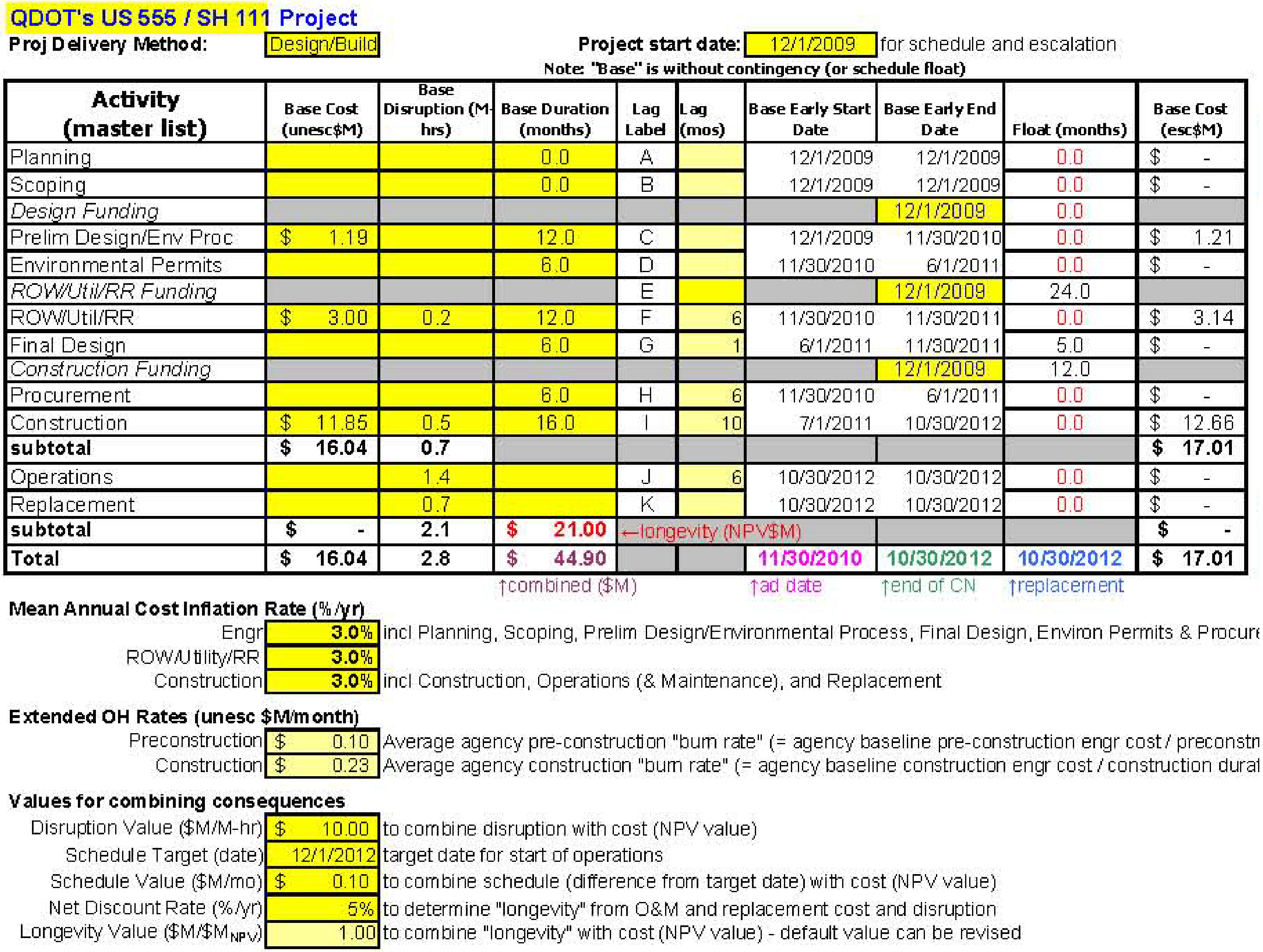
Table B-1. Project Cost Estimate (through construction only)

Quantity	Unit of Measure	Unit cost	Description of Work Items	Cost (2009 $)
			CONSTRUCTION	
			PREPARATION	
21	Acre	$4,800.00	Clearing and Grubbing	$99,360
26,397	S.Y.	$8.40	Removing Cement Conc. Pavement	$221,735
26,397	S.Y.	$4.80	Removing Asphalt Conc. Pavement	$126,706
			GRADING	
33,393	C.Y.	$9.60	Roadway Excavation Incl. Haul	$320,573
27,960	C.Y.	$4.20	Common Borrow incl. Haul	$117,432
3,107	C.Y.	$14.40	Gravel Borrow Incl. Haul	$44,741
31,067	C.Y.	$1.20	Embankment Compaction	$37,280
			DRAINAGE	
42	Each	$2,160.00	Grate Inlet Type 1 or 2	$90,720
6	Each	$3,600.00	Drop Inlet Type 1	$21,600
21,120	L.F.	$78.00	Plain St. Culv. Pipe 0.109 In. Thick 36 In. Diam.	$1,647,360
50	L.F.	$1,800.00	St. Stru. Pipe Arch 8 Gauge 20 Ft. 0 In. Span	$89,100
			STRUCTURE	
3,972	S.F.	$145.00	Bridge No. (easy bridge)	$575,940
			SURFACING	
27,047	Ton	$12.00	Crushed Surfacing Base Course	$324,564
			CEMENT CONC. PAVEMENT	
16,696	C.Y.	$110.00	Cement Conc. Pavement	$1,836,560
882	S.Y.	$146.00	Bridge Approach Slab	$128,772
			ASPHALT CONCRETE PAVEMENT	
1,100	Ton	$36.00	Miscellaneous Asphalt Conc. Pavement	$39,600
			EROSION CONTROL AND PLANTING	
2	Acre	$2,400.00	Seeding, Fertilizing and Mulching	$4,800
1	EST.	$85,000.00	Temporary Water Pollution/Erosion Control	$85,000
1,564	C.Y.	$13.20	Topsoil Type B	$20,645
1	EST.	$150,000.00	Miscellaneous Landscaping	
			TRAFFIC	
15,840	L.F.	$120.00	Special Conc. Barrier Type 5	$1,900,800
8	Each	$14,400.00	Permanent Impact Attenuator	$115,200
214,000	L.F.	$0.12	Paint Line	$25,680
1	L.S.	$24,000.00	Permanent Signing	$24,000
			OTHER ITEMS	
4,000	L.F.	$18.00	Temporary Barrier Glare Screen	$72,000
1	EST.	$12,000.00	Roadside Cleanup	$12,000
1	EST.	$6,000.00	Trimming and Cleanup	$6,000
			CONSTRUCTION SUBTOTAL "A" (before Mob, Traffic Control and Other Misc. Items)	$7,988,167
1	L.S.	$399,408.36	Mobilization	$399,408
1	L.S.	$587,130.29	Traffic Control (at 7% of subtotal A + Mob)	$587,130
1	EST.	$1,006,509.07	Other Miscellaneous Items (12% of subtotal A + Mob)	$1,006,509
			CONSTRUCTION SUBTOTAL "B" (including Mob, Traffic Control and Other Misc. Items)	$9,981,215
			DESIGN-BUILDER DESIGN FEES (10% of "B")	$998,121
			DESIGN-BUILD CONSTRUCTION TOTAL "C"	$10,979,336
			CONSTRUCTION ADMINSTRATION (8% of "C")	$878,347
			AGENCY DESIGN, ENV, PERMITTING, AND PROCUREMENT (10% of "C" + C. Admin) (includes previous costs of $200,000)	$1,185,768
			RIGHT OF WAY	$2,000,000
			UTILITY RELOCATIONS	$1,000,000
			PROJECT SUBTOTAL "D" (Before Contingency)	$16,043,452

Table B-2. Project Disruption Estimate (including post-construction)

Activity	Duration of Activity (months)	% of Activity Duration Affected	People Affected/ Day	Delay/ person	Disruption (million-hours)
Utilities	12	10%	10,000	½ hr	0.2
Construction	16	20%	10,000	½ hr	0.5
Operations	600	1%	15,000	½ hr	1.4
Replacement	24	10%	20,000	½ hr	0.7

Table B-3. Base Project Performance (from template – see Attachment I; see Figure 2-1 for project flowchart; through construction only)



QDOT's US 555 / SH 111 Project

Proj Delivery Method: Design/Build **Project start date:** 12/1/2009 for schedule and escalation

Note: "Base" is without contingency (or schedule float)

Activity (master list)	Base Cost (unesc$M)	Base Disruption (M-hrs)	Base Duration (months)	Lag Label	Lag (mos)	Base Early Start Date	Base Early End Date	Float (months)	Base Cost (esc$M)
Planning			0.0	A		12/1/2009	12/1/2009	0.0	$ -
Scoping			0.0	B		12/1/2009	12/1/2009	0.0	$ -
Design Funding							12/1/2009	0.0	
Prelim Design/Env Proc	$ 1.19		12.0	C		12/1/2009	11/30/2010	0.0	$ 1.21
Environmental Permits			6.0	D		11/30/2010	6/1/2011	0.0	$ -
ROW/Util/RR Funding				E			12/1/2009	24.0	
ROW/Util/RR	$ 3.00	0.2	12.0	F	6	11/30/2010	11/30/2011	0.0	$ 3.14
Final Design			6.0	G	1	6/1/2011	11/30/2011	5.0	$ -
Construction Funding							12/1/2009	12.0	
Procurement			6.0	H	6	11/30/2010	6/1/2011	0.0	$ -
Construction	$ 11.85	0.5	16.0	I	10	7/1/2011	10/30/2012	0.0	$ 12.66
subtotal	**$ 16.04**	**0.7**							**$ 17.01**
Operations		1.4		J	6	10/30/2012	10/30/2012	0.0	$ -
Replacement		0.7		K		10/30/2012	10/30/2012	0.0	$ -
subtotal	**$ -**	**2.1**	**$ 21.00**	←longevity (NPV$M)					**$ -**
Total	**$ 16.04**	**2.8**	**$ 44.90**			**11/30/2010**	**10/30/2012**	**10/30/2012**	**$ 17.01**
			↑combined ($M)			↑ad date	↑end of CN	↑replacement	

Mean Annual Cost Inflation Rate (%/yr)

Engr	3.0%	incl Planning, Scoping, Prelim Design/Environmental Process, Final Design, Environ Permits & Procure
ROW/Utility/RR	3.0%	
Construction	3.0%	incl Construction, Operations (& Maintenance), and Replacement

Extended OH Rates (unesc $M/month)

Preconstruction	$ 0.10	Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / preconstn
Construction	$ 0.23	Average agency construction "burn rate" (= agency baseline construction engr cost / construction durat

Values for combining consequences

Disruption Value ($M/M-hr)	$ 10.00	to combine disruption with cost (NPV value)
Schedule Target (date)	12/1/2012	target date for start of operations
Schedule Value ($M/mo)	$ 0.10	to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)	5%	to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	1.00	to combine "longevity" with cost (NPV value) - default value can be revised

ATTACHMENT C. UNMITIGATED RISK REGISTER

The Risk Register for the project (as described in Attachments A and B) was developed (by consensus) by a facilitated group of project team and project-independent subject matter experts, as follows:

- Risks were first brainstormed and then categorized, edited, and added to create a comprehensive and non-overlappng set (see Table C-2 for the resulting set, and see the template in Attachment I for initial steps). As previously noted, only performance (and thus risks) through construction has been focused on for now.
- The factors that define risks (i.e., impacts and probability of occurrence) before any additional mitigation ("unmitigated") were then assessed for each of the risks in terms of mean value/ratings (see Table C-1 for rating "scale" definitions for assessments, and Table C-2 for the assessments for each risk, and see the template in Attachment I for a summary of those assessments)

Table C-1. Risk-Factor Rating Scale Definitions (from template – see Attachment I)

QDOT's US 555 / SH 111 Project

	Impacts if Event Occurs									Probability of Event Occurring (0=impossible to 1=guaranteed)			Severity (equivalent escalated $ million)		
	Cost Change (current unescalated $ million)			Schedule Change (months)			Disruption Change (million person-hours lost)								
Rating	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range
VH	>25%	4.0	8.0	>12	12	24	>25%	0.2	0.4	0.7 to 1.0 (1:1)	0.7	1.0	>25%	4.0	8.0
H	10 to 25%	1.6	$ 4.00	4 to 12	4	12	10 to 25%	0.1	0.2	0.4 to 0.7 (2:3)	0.4	0.7	10 to 25%	1.6	$ 4.00
M	3 to 10%	0.5	$ 1.60	1 to 4	1	4	3 to 10%	0.0	0.1	0.2 to 0.4 (2:5)	0.2	0.4	3 to 10%	0.5	$ 1.60
L	1 to 3%	0.2	$ 0.50	0.25 to 1	0.25	1	1 to 3%	0.0	0.0	0.05 to 0.2 (1:5)	0.05	0.2	1 to 3%	0.2	$ 0.50
VL	0 to 1%	0.0	$ 0.20	0 to 0.25	0	0.25	0 to 1%	0.0	0.0	0.0 to 0.05 (1:20)	0.0	0.05	0 to 1%	0.0	$ 0.20
-VL	-1 to 0%	-0.2	$ -	-0.25 to 0	-0.25	0	-1 to 0%	0.0	0.0				-1 to 0%	-0.2	$ -
-L	-3 to -1%	-0.5	$ (0.20)	-1 to -0.25	-1	-0.25	-3 to -1%	0.0	0.0				-3 to -1%	-0.5	$ (0.20)
-M	-10 to -3%	-1.6	$ (0.50)	-4 to -1	-4	-1	-10 to -3%	-0.1	0.0				-10 to -3%	-1.6	$ (0.50)
-H	-25 to -10%	-4.0	$ (1.60)	-12 to -4	-12	-4	-25 to -10%	-0.2	-0.1				-25 to -10%	-4.0	$ (1.60)
-VH	<-25%	-8.0	$ (4.00)	<-12	-24	-12	<-25%	-0.4	-0.2				<-25%	-8.0	$ (4.00)
Base:	*16.04*			*35*			*0.7*						*16.0*		

Table C-2. Unmitigated Risk Register for Mean-Value / Rating Assessment (see Table C-1 for rating scale definitions; for risks through construction only)

Item	Risk or Opportunity	IF Conducting only a Qualitative Risk Assessment (enter either Mean Ratings per scale or Mean Values)			
		Probability of Occurrence (%)	**Cost Change to Activity (current $million)**	**Schedule Change to Activity (months)**	**Disruption Change to Activity (million person-hrs lost)**
	Planning				
PL1 Excluded	**Project funding delayed or reduced** The project is currently funded for an amount that QDOT feels is adequate. However, if additional funding is required (i.e., if costs increase for various reasons), might be a delay in obtaining the additional funding. However, QDOT's objective is to evaluate the project's risk assuming funding is available without delay. Hence, QDOT wants to *exclude* uncertainty in funding at this time (but might later treat that uncertainty by defining separate "model scenarios" to evaluate the impact of various potential funding delays). Otherwise, *exclude* the risk that funding is cancelled or substantially reduced (so that scope reduction is required, which would lead to a "different" project).				
PL2	**Opposition to removing access to US 555 from 12th Street** Several businesses rely on this access and might protest or challenge the removal of the access. However, removal of that access is necessary for the project. Hence, this design decision is unlikely to be reversed. However, some mitigation might be required as compensation.	L	+VL to D/B Construction	0	0
PL3 Elsewhere	**Opposition to "splitting" alignment of SH 111 in the interchange area** The City does not like this alternative. This issue is captured as a factor influencing the probability that this split will occur – see risk D2.				
PL4 Minor	**Other stakeholder issues not captured separately**				

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
	Scoping				
SC1 Minor	**Change in East-West project limits** Project might be required (either for political or operational reasons) to improve longer or shorter stretch of US 555 than assumed in the base estimate. The project team and QDOT believe this is unlikely because funding is not available for such a significant change, and the need is not clear (for the project to perform as desired).				
S2C Minor	**Change in North-South project limits** Project might be required (either for political or operational reasons) to improve longer or shorter stretch of SH 111 than assumed in the base estimate. Similar to discussion for S1.				
SC3	**Additional local improvements required** For example: • More improvements on Main Street away from US 555 • More improvements on North and/or South Avenues away from SH 111 • More improvements on West and/or East Streets away from US 555 Schedule impacts are design-related.	M	+L to D/B Construction	+L to Prelim Design	0
SC4 Minor	**Increased aesthetics for US 555 / SH 111 interchange** For example, “gateway” appearance, decorative lighting, etc. The project already includes reasonable aesthetics, and a significant ‘gateway’ theme is well outside the project’s budget. The City would therefore have to pay for such improvements, which it is unlikely to be able to afford.				

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
SC5	**Replace culvert over Wandering Creek** Base assumes that the state fisheries agency will allow widening this culvert, especially since no listed fish species are believed to live this far up Wandering Creek. The fisheries agency has, however, required replacement of similar culverts on nearby projects.	M	+L to D/B Construction	0	0
SC6	**Provide new lighting throughout project** Base assumes new lighting only in the interchange area. The team increasingly believes that new lighting will be required throughout (mainly because they will have to relocate existing lighting to widen the roadway anyway).	H	+M To D/B Construction	0	0
SC7 Minor	**ITS added to this project** Unlikely – not funded and the system-wide ITS development is lagging this project.				
	Preliminary Design and Environmental Process For all relevant risks in this category, the following conditions apply: Each risk includes all related / correlated design, environmental, right-of-way, and construction impacts. Impacts shown are in addition to any assessed base uncertainties.				
PD1	**Shift alignment of US 555 at east end of project** This would reduce wetland impacts by shifting alignment to the south. However, there is some resistance (City) to shifting the alignment this way because of the number of business displacements it would cause. It could also cause a problem with geometry at the intersection of East Street. The group therefore thinks that this is unlikely to occur. If it did, however, the impacts would include reduced wetland impacts, increased right-of-way costs (mostly due to additional demolition and business relocations), additional design time. The change in construction cost would be minimal.	VL	+M to ROW, Utilities, Railroads	+M to ROW, Utilities, Railroads	0

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
PD2 Minor	**Split alignment of SH 111 at US 555 interchange** Instead of widening on existing alignment; would allow for more rapid construction but requires additional ROW. Benefits (reduced construction duration) probably don't outweigh the detriments (additional ROW; less efficient traffic flow; re-design). The City and at least two public groups do not like this alternative. Therefore, it is unlikely to occur.				
PD3	**Change in configuration of SH 111 / US 555 interchange** QDOT's preliminary design (SPUI) is one of several viable alternatives, and it is expected that the contractor could propose a suitable alternative. It is uncertain how much such a change might cost relative to the currently-assumed alternative (could be more, could be less), but QDOT won't accept a design that is significantly more expensive. Includes potential change in structure and foundation type/size, but assumes that an appropriate accelerated bridge construction technique will be used.	0	0 (could be a significant increase or decrease with equal likelihood; hence, on average, no change)	0	0
PD4	**Ground improvement required in interchange area** QDOT HQ design is also concerned that a recent change to the seismic design criteria (which is still being evaluated) might require localized ground improvement to mitigate for liquefaction potential. The project team thinks this is unlikely, but could have significant impacts if it occurs.	L	+M to D/B Construction	+L to D/B Construction	0
PD5	**Shoulders required on US 555** For example, if FHWA or QDOT HQ Design both don't approve the no-shoulder exception/deviation. The project team is reasonably confident that this design exception will be approved based on recent, similar approvals for other nearby projects.	VL	+H to D/B Construction	+M to D/B Construction	0

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
	However, if shoulders are required, the impacts are significant: additional right-of-way would be required, construction costs would increase, the draft EA might have to be modified (wetland impacts would increase), and design time (prior to RFP) would increase.				
PD6	**Shoulders required on SH 111** For example, if QDOT HQ Design doesn't approve the no-shoulder exception/deviation. Similar to the discussion and assessments for risk D5. For the quantitative risk analysis: Risk D6 is correlated to risk D5. If risk D5 does not occur (shoulders not required on US 555), then it is likely that shoulders won't be required on this facility either. If risk D5 does occur, then shoulders will likely be required for SH 111 as well.	VL	+H to D/B Construction	+M to D/B Construction	0
PD7 Minor	**Additional cost for signalized intersections** Excludes any change in the number of intersections that is captured separately in risks related to project limits (i.e., risks S1 and S2).				
PD8	**Change in pavement section and/or type** The base assumes concrete pavement to provide longevity (one of the project's goals). QDOT is therefore most likely to specify a concrete pavement. Asphalt pavement might be selected to provide compatibility with existing pavement (beyond the project limits) and to save initial cost. However, QDOT considers maximizing longevity (including life-cycle costs) a higher priority than saving initial capital cost.	M	-M to D/B Construction	0	0

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
PD9 Minor	**Rehabilitate instead of reconstruct existing roadway (e.g., overlay instead)** See *Guide* Appendix C, Appendix D, or Table D-4f. Existing roadway is 20 years old; might not be cost effective to rehabilitate when have to build new lanes anyway. In addition, rehab is not as likely to meet the project objective of maximizing longevity of the facility. Note: for the quantitative risk analysis, this risk is correlated to risk D8 (impacts are a function of the outcome of that risk).				
PD10 Minor	**Change in stormwater design standards** The design incorporates the latest standards, which are only two years old. Hence, it is unlikely that new standards will emerge in this project's timeframe.				
PD11	**Cannot use City sewer system for project runoff (or City charges for use)** The City might deny use or charge QDOT for various upgrades to the system to accommodate stormwater runoff from this project. The project team and QDOT management are "almost certain" that the City will ultimately allow use of the City's system (the City needs this project, and the additional load on the sewer system is not substantial), but will most likely ask for money to help upgrade its system. QDOT would probably capitulate as this is the best option from a cost and time perspective. This cost would occur during the project's "utility relocations" phase. This issue is correlated with the likely request by the City to help pay for a water and sewer-line relocation (see risk U2 under utilities risks). For the quantitative risk analysis, the group assesses that if risk U2 occurs (i.e., QDOT decides to help pay for relocation), then this risk is much less likely to occur.	M	+M to ROW, Utilities, Railroads	+L to ROW, Utilities, Railroads	0

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		Probability of Occurrence (%)	**Cost Change to Activity (current $million)**	**Schedule Change to Activity (months)**	**Disruption Change to Activity (million person-hrs lost)**
PD12	**Structures impacted by Main Street realignment are eligible for Historic Register** Can reasonably capture the range of credible possibilities with the following set of potential (mutually-exclusive) scenarios / outcomes: A. Not historic structures (base assumption) B. Historic structures, but no significant impact to project cost or schedule (e.g., document, then acquire) C. Historic structures, creating significant impact to project cost or schedule (e.g., have to relocate structures; structures are contaminated; or have to shift project alignment to avoid)	L	+M to ROW, Utilities, Railroads	+M to ROW, Utilities, Railroads	0
PD13	**Change in environmental documentation** Only treat this issue here if not captured separately by specific triggers / issues elsewhere (e.g., design changes). Base assumes an EA, but an EIS might be required if impacts are greater than assumed. Can reasonably capture the range of credible possibilities with the following set of potential (mutually-exclusive) scenarios / outcomes: A. Complete EA as planned (base assumption) B. Complete EA with additional effort, but with no significant changes to the project C. EIS required, but with no significant changes to the project **D.** EIS required, resulting in significant change to the project design, right-of-way, and/or construction	L	+M to Prelim Design / Environmental Process	+H to Prelim Design / Environmental Process	0
PD14	**Delays completing environmental documentation** From various causes if not already captured separately (i.e., significant design changes; change in type of environmental documentation, risk E2). For example: • Additional impacts identified • Process delays (internal or external reviews, comments, and/or approvals)	M	No direct cost (schedule-related only)	+M to Prelim Design / Environmental Process	0

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
PD15	**Encounter unanticipated contamination in interchange area** If encountered, likely to be hydrocarbon-based soil and/or groundwater contamination.	M	+VL to D/B Construction	0	0
PD16	**Additional wetland mitigation required for planned alignment** Additional mitigation could be required for various reasons. For example: • Change in mitigation requirements (ratios, buffers) • Change in wetland classification • Impacts different than assumed (i.e., underestimated originally) (this could happen for the current or shifted alignment) Note: for the quantitative risk analysis, this risk is partially a function of any potential shift in alignment at the east end of the project (risk D1). If risk D1 occurs and the 'base' wetland impacts are reduced, the probability of this risk is reduced.	M	+L to D/B Construction	0	0
	Environmental Permits				
EP1 Minor	**Challenge to environmental determination or permits** For any reason not captured elsewhere. Could come from organized public groups for various reasons. However, very unlikely for the base project (chances could increase for some alternatives like shifting the alignment at the east end of the project, but these impacts are captured in those risks).				
EP2	**Delay obtaining the 404 permit** Either from internal or USACE process delays (review, approval) or deficiencies in QDOT's application. Note that this risk is assumed to be approximately independent of risks D1 and E6 (delay issues could occur regardless of the outcomes from those risks).	L	No direct costs (schedule-related only)	+M to Environmental Permits	0

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		Probability of Occurrence (%)	**Cost Change to Activity (current $million)**	**Schedule Change to Activity (months)**	**Disruption Change to Activity (million person-hrs lost)**
	Right-of-Way				
RU1	**Uncertainty in ROW inflation rate** Regionally; before considering the localized effects of accelerating development, which is captured separately. Despite a sag in the economy, property prices have held steady, and appear to even be increasing slightly. However, this could change (e.g., if this area is lagging the economy). Over the short term of this project, local indicators and the ROW professionals anticipate an average increase of approximately 3%/year in the area.	H	+M to ROW, Utilities, Railroads	0	0
RU2	**Accelerating pace of development in interchange area** Beyond the regional ROW inflation rate captured in R1. Several new developments are planned in the area, and at least one could be implemented before this project is let. The impact to this project would be increased acquisition and perhaps relocation costs compared to what is currently assumed in the estimate.	M	+M to ROW, Utilities, Railroads	+M to ROW, Utilities, Railroads	0
RU3	**Unwilling sellers** Note: base cost excludes condemnation costs/allowance. This risk is separate from risk R2. Particularly in the US 555 / SH 111 interchange area, property owners might not want to relocate, leading to increased cost to acquire ROW (e.g., have to go through condemnation). Note that condemnation does not normally extend the right-of-way acquisition timeframe, because QDOT can usually quickly gain possession-and-use of condemned properties.	H	+M to ROW, Utilities, Railroads	0	0

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RU4 In R2	**Additional relocation or demolition required** Excludes additional relocation or demolition that might be required to accommodate changes in design or scope, which are captured as part of those separate risks. Excludes contamination, which is captured separately. For example, multi-tenant properties could be complex to relocate. The group assesses that this potential additional cost and time was captured in risk R2.				
RU5 Minor	**Additional ROW required for planned project** Excludes additional ROW that might be required for changes in design or scope, which are captured as part of those separate risks. For example, initial estimates for required ROW for the assumed design were incorrect or incomplete. The group assesses that the potential significant changes were captured as part of other risks.				
RU6	**Other delays to ROW planning** For reasons not captured as part of other specific risks. For example, late changes in design result in changes in ROW plans, or internal QDOT delays to ROW plan development.	M	No direct costs (schedule-related only)	+L to ROW, Utilities, Railroads	0
	Utilities				
RU7	**Telecom utility wants a cost-sharing agreement** The Telecom's presence in the project right-of-way pre-dates QDOT's, so QDOT cannot force relocation. The Telecom just recently replaced its fiber optic backbone, so not likely to replace without some sort of cost sharing (or, at least, replace within the timeframe needed by this project).	M	+L To ROW, Utilities, Railroads	0	0

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
RU8	**QDOT helps City pay for water and sewer-line relocation** See *Guide* Appendix C (rapid renewal strategies / methods). To help maintain project schedule, QDOT might help pay for the sewer-line relocation. This "risk" is therefore really a project / policy decision within QDOT's control. This decision comes at a monetary cost but avoids schedule delay (as reflected to the right). Note that for the quantitative risk analysis, the outcome of this risk affects the likelihood of occurrence for risk PD11.	H	+M To ROW, Utilities, Railroads	0	0
RU9 Minor	**Other utility relocations not completed on time** For issues not captured separately in other risks. For various reasons, including delayed negotiations, design, or relocation work itself.				
RU10 Minor	**Damage existing utility or encounter unanticipated utility during construction** Possible, but the time impacts are quickly mitigated. The cost impact would be the D/B contractor's responsibility.				
	Contracting and Procurement				
CP1	**Uncertainty in construction-cost inflation rate** Excludes contracting market conditions and material-supply issues, which are captured separately in risks CP2 and CP3. This issue includes uncertainty in the general regional and national trends in construction-industry cost changes over time (general inflation), with reasonable adjustment for this region.	H	+M to D/B Construction	0	0
CP2	**Uncertain Design/Build contracting market conditions at time of bid** See *Guide*, Appendix D-2 or Table D-6.	25% (note: team felt ratings	+10% of base construction	+1 to Procurement	0

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	Separate from general construction inflation and material-supply issues, which are captured in risks CP1 and CP3, respectively. This issue includes uncertainty in pricing strategy and other contractor competition factors. QDOT expects four proposals/bids, which could improve competition. However, recent experience for similar projects is that bids are coming in above QDOT's Engineer's Estimates. Can reasonably capture the range of credible possibilities with the following set of potential (mutually-exclusive) scenarios / outcomes: A. Market conditions are favorable (competitive), and bids come in below the base estimate B. Market conditions are similar to assumed in the estimate (minimal change from base) C. Market conditions are not competitive, so bids are higher than the base but still acceptable (below threshold for canceling the procurement) D. Market is not competitive, and no acceptable bids are received – requires re-bidding and perhaps repackaging to get acceptable bids.	were insufficient to describe this risk)	cost to D/B Construction		
CP3 Elsewhere	**Material-supply issues** Various local factors could affect the availability of materials for this project. For example: • Cannot locate an appropriate fill source • Fill source is farther away than assumed • Aggregate prices higher than anticipated • Steel prices higher than anticipated • Cement prices higher than anticipated The group believes that all of these issues are captured in either risk CP1 or CP2.				

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CP4 Minor	**Change in project delivery method** See *Guide* Appendix D-2 or Table 4-6. Contract other than through the assumed single Design/Build contract. Only treat here if not already captured under the market conditions risk (CP2). It is unlikely that QDOT will change to a traditional delivery method (e.g., Design/Bid/Build) given the rapid renewal-type objectives for this project. Other delivery alternatives are unlikely, either because enabling legislation does not exist or QDOT does not have adequate experience with those delivery methods.				
CP5 Minor	**Accelerate pre-construction activities to reach NTP sooner** See *Guide* Appendix C, Appendix D-2 or Table D-3. If not captured separately under Design, Environmental, and/or ROW risk categories. To reach NTP more quickly, QDOT could adopt a more-aggressive pre-construction strategy. For example: • Moving to NTP before permitting is complete. • Could seek streamlined environmental process or design-approval process (see *Guide*, Appendix D-2 or Table D-3). However, it might be too late to implement these for this project (would have been better to plan for this in advance of starting work on the project). The group believes that a more-aggressive permitting vs. NTP strategy is possible, but introduces its own risks (i.e., if NTP is issued before the environmental permits are complete, the contractor could have grounds for				

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	significant claims if permit conditions change relative to the RFP). Hence, it is unlikely for QDOT to pursue this strategy.				
CP6 Minor	**Use incentives to accelerate D/B construction** See *Guide*, Appendix D-2 or Tables D-2 and D-6. The team believes that QDOT is unlikely to apply additional incentives – use of D/B delivery method and performance-based specs should provide adequate flexibility and incentive for the contractor to complete the project within QDOT's desired timeframe.				
CP7	**Issues with D/B design or submittals** For example: • Internal QDOT or FHWA delays reviewing and approving submissions • Errors or omissions in D/B submissions	M	No direct cost (schedule-related only)	+M to D/B Design	0
CP8	**Other problems with D/B contract procurement** See *Guide*, Appendix D-2 or Tables D-2 and D-6. Aside from issues captured separately (e.g., as part of market conditions risk). Note: project-cancelling issues are excluded; most of the remaining identified issues were assessed to be low likelihood and relatively low impact for this project. Hence, the group combined them into one 'larger' issue and assessed their combined potential impacts. Even so, the group believes that a significant problem is unlikely (especially given QDOT's reasonable history for such procurements). If something did occur, the most-likely impact to schedule would be during D/B procurement.	L	No direct cost (schedule-related only)	+L to Procurement	0

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
	For example: • Bid protest (pre-award or post-award) • Unclear contract documents • Contractor default • Bonding or insurance issues • QDOT unfamiliarity with D/B contracting • Approach to specifications (e.g., performance-based specs)				
	Construction				
CN1	**D/B construction phasing significantly different than assumed** Excludes specific changes to schedule and phasing related to changes in design, etc. that are captured under other risks. The base schedule is not believed to be overly optimistic or aggressive. It's impossible to know at this point how the D/B will actually construct the project, so the actual schedule and phasing could be significantly different than currently assumed.	25% (note: team felt ratings were insufficient to describe this risk)	No direct cost (schedule-related only)	-2 to D/B Construction	-0.1 to D/B Construction
CN2	**Additional Maintenance of Traffic required** See *Guide*, Appendix D-2 or Table D-4g. Either because the original plan doesn't work and needs to be modified, or the plan works but simply needs to be augmented.	H	+L to D/B Construction	+VL to D/B Construction	+M to D/B Construction
CN3	**Problems with planned accelerated bridge construction (ABC) technique** QDOT assumes the contractor will employ ABC (regardless of the structure type selected for the interchange; hence, this issue is approximately independent of risk D3). The performance of this planned rapid renewal method (accelerated bridge construction) is difficult to predict because the method the contractor will use is not known, and many ABC techniques are still evolving.	H	+L to D/B Construction	+L to D/B Construction	+L to D/B Construction

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	Potential problems include (see *Guide*, Appendix D-2 or Table D-4b): • Selected technology doesn't work as planned (technical issue) • Delays procuring technology *Note that this risk does not apply if the SH 111 alignment is split at the interchange (construction is out of traffic; ABC is not employed).*				
CN4	**Unable to construct interchange embankments as rapidly as assumed** Base assumes rapid construction techniques for the approach embankments of the SH 111 overcrossing at the interchange with US 555. The performance of this planned rapid renewal method (rapid embankment construction) is difficult to predict for the following reasons (see *Guide*, Appendix D-2 or Table D-4c): • Uncertainty in subsurface conditions (soft soils are suspected); • Uncertainty in what method the contractor will choose; and • Uncertainty in performance of the selected method for actual subsurface conditions (e.g., method doesn't perform as intended). It is therefore unclear at this point how much benefit will be achieved relative to traditional embankment construction. If the method doesn't work, remedial measures will be needed to accelerate embankment construction, but with some loss of time.	M	+L to D/B Construction	+M to D/B Construction	+L to D/B Construction
CN5	**Difficult foundation installation** Separate from ground-improvement issues. Information is limited in the interchange area (additional geotechnical investigation is scheduled for later). However, anecdotal information indicates that near-surface ground conditions are poor enough to require deep foundations (assumed in the base).	L	+L to D/B Construction	+L to D/B Construction	+VL to D/B Construction

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		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
	Could encounter obstructions, have difficulty obtaining design capacity for various reasons, etc.				
CN6 Minor	**Severe weather event significantly impacts construction** This refers to specific, individual events, like earthquake or flood, during construction. Could result in either delay or significant damage. Very low likelihood of significant impact in this geographic location.				
CN7	**Colder-than-usual winter** Usually, construction work can proceed year-round in some manner (the base schedule accounts for this). However, an extreme winter could result in perhaps a one-month delay.	L	No direct cost (schedule-related only)	+VL to D/B Construction	+VL to D/B Construction
CN8 Minor	**Significant accident during construction** Low likelihood. If occurs, time impact is likely to be minimal and cost impacts could be covered by D/B insurance.				
CN9	**Limited construction staging area in vicinity of interchange** Either QDOT or the contractor will likely have to find a suitable staging area, but it might not be close to the interchange, which could increase contractor costs.	M	+VL to D/B Construction	0	0
CN10 Minor	**Fish window in Wandering Creek** Currently, no listed species are believed to inhabit Wandering Creek near US 555. Hence, in-water work windows are assumed to not apply. Even if a window did apply, however, the contractor should easily be able to stage culvert work to accommodate a window.				
CN11 Minor	**Non-compliance with permits during construction** Low likelihood of any significant non-compliance. Even if it does occur, low likelihood of significant cost impact (contractor's) or schedule impact (QDOT's schedule, but contractor financially responsible).				

Item	Risk or Opportunity	IF Conducting only a Qualitative Risk Assessment (enter either Mean Ratings per scale or Mean Values)			
		Probability of Occurrence (%)	Cost Change to Activity (current $million)	Schedule Change to Activity (months)	Disruption Change to Activity (million person-hrs lost)
CN12	**Extended overheads as a function of project delays** Pre-construction (QDOT staff): $100k / month of delay Construction: • QDOT staff: $100k / month of delay • Contractor: For compensable delays, $250k / month of delay (modeled as $125k / month of total delay, assuming 50% of delays are compensable)	Not treated as a separate, explicit risk (results from other risks)			
	Minor and Unidentified Risks and Opportunities Aggregate effect of items labeled “Minor” above. “Major” means the items quantified above (i.e., all items other than those labeled “Minor” above)				
	Aggregate Minor Risks	H	+L	+L	+L
	Aggregate Minor Opportunities	H	-L	-L	-L
	Unidentified Risks	H	+L	+L	+L
	Unidentified Opportunities	H	-L	-L	-L

Notes:

1. All cost impacts are assessed in current terms. Cost escalation is handled automatically through the simulation model, appropriately considering uncertainty in inflation rates and the affected project activities.
2. Except for “soft cost” uncertainties that are addressed separately, and unless noted otherwise, all cost impacts in this table are “fully loaded” with appropriate markups. Potential markups include items that may be treated as a percentage of the construction subtotal in the cost estimate, such as sales tax, mobilization, construction engineering, design, and allowances for miscellaneous items.

ATTACHMENT D. UNMITIGATED MEAN-VALUE PROJECT PERFORMANCE

The various base and unmitigated risk factors (as described in Attachments B and C) were used to calculate (using the MS Excel template – see Attachment I) approximate mean unmitigated project performance (by activity and collectively), including cost (unescalated and escalated), schedule (milestone dates), disruption, and longevity (post construction cost, schedule and disruption), as well as combined performance (see Table D-1). The mean “severity” of each risk was also determined (using the MS Excel template) in terms of its approximate contribution to the mean combined performance, and the risks were then sorted by their mean severity (see Table D-2 and Figure D-1). As previously noted, only performance through construction has been focused on for now.

Table D-1. Approximate Mean Unmitigated Base+Risk Project Performance (from template – see Attachment I; through construction only)

QDOT's US 555 / SH 111 Project

Proj Delivery Method: Design/Build **Project start date:** 12/1/2009 for schedule and escalation

	"Base" (without contingency or schedule float)					"Risk" (additional to Base)			"Total" (Base + Risk)						
Activity (master list)	Base Cost (unesc$M)	Base Disruption (M-hrs)	Base Duration (months)	Lag label	Base Lag (mos)	Risk Cost (unesc$M)	Risk Disruption (M-hrs)	Risk Delay (months)	Total Cost (unesc$M)	Total Disruption (M-hrs)	Total Duration (months)	Total Early Start Date	Total Early End Date	Total Float (months)	Total Cost (esc$M)
Planning	$ -	0.0	0.0	A	0.0	0.00	0.0	0.0	0.00	0.0	0.0	12/1/2009	12/1/2009	0.0	$ -
Scoping	$ -	0.0	0.0	B	0.0	0.00	0.0	0.0	0.00	0.0	0.0	12/1/2009	12/1/2009	0.0	$ -
Design Funding								0.0					12/1/2009	0.0	
Prelim Design/Env Proc	$ 1.19	0.0	12.0	C	0.0	0.13	0.0	1.4	1.32	0.0	13.4	12/1/2009	1/13/2011	0.0	$ 1.34
Environmental Permits	$ -	0.0	6.0	D	0.0	0.00	0.0	0.3	0.00	0.0	6.3	1/13/2011	7/23/2011	0.9	$ 0.00
ROW/Util/RR Funding				E	0.0			0.0					12/1/2009	26.6	
ROW/Util/RR	$ 3.00	0.2	12.0	F	6.0	2.62	0.0	1.2	5.62	0.2	13.2	1/13/2011	2/17/2012	0.0	$ 5.91
Final Design	$ -	0.0	6.0	G	1.0	0.00	0.0	0.8	0.00	0.0	6.8	8/19/2011	3/11/2012	5.1	$ -
Construction Funding								0.0					12/1/2009	14.3	
Procurement	$ -	0.0	6.0	H	6.0	0.26	0.0	0.3	0.26	0.0	6.3	1/13/2011	8/19/2011	0.0	$ 0.27
Construction	$ 11.85	0.5	16.0	I	10.0	2.51	0.0	0.8	14.36	0.5	16.8	9/18/2011	2/10/2013	0.0	$ 15.46
subtotal	**$ 16.04**	**0.7**				**$ 5.53**	**0.0**		**$ 21.57**	**0.7**					**$ 22.98**
Operations	$ -	1.4	0.0	J	6.0	0.00	0.0	0.0	0.00	1.4	0.0	2/10/2013	2/10/2013	0.0	$ -
Replacement	$ -	0.7	0.0	K	0.0	0.00	0.0	0.0	0.00	0.7	0.0	2/10/2013	2/10/2013	0.0	$ -
subtotal	**$ -**	**2.1**	**$ 21.00**	**←longevity ($)**		**$ -**	**0.0**	**$ -**	**0.0**	**2.1**	**$ 21.00**	**←longevity ($)**			**$ -**
Total	**$ 16.04**	**2.8**	**$ 44.90**			**5.53**	**0.0**	**$ 6.34**	**21.57**	**2.8**	**$ 51.24**	**1/13/2011**	**2/10/2013**	**2/10/2013**	**$ 22.98**
			↑combined ($M)					↑combined ($M)			↑combined (	↑ad date	↑end of CN	↑replacement	

Mean Annual Cost Inflation Rate (%/yr)

Engr	**3.0%**	incl Planning, Scoping, Prelim Design/Environmental Process, Final Design, Environmental Permits & Procurement
ROW/Utility/RR	**3.0%**	
Construction	**3.0%**	incl Construction, Operations (& Maintenance), and Replacement

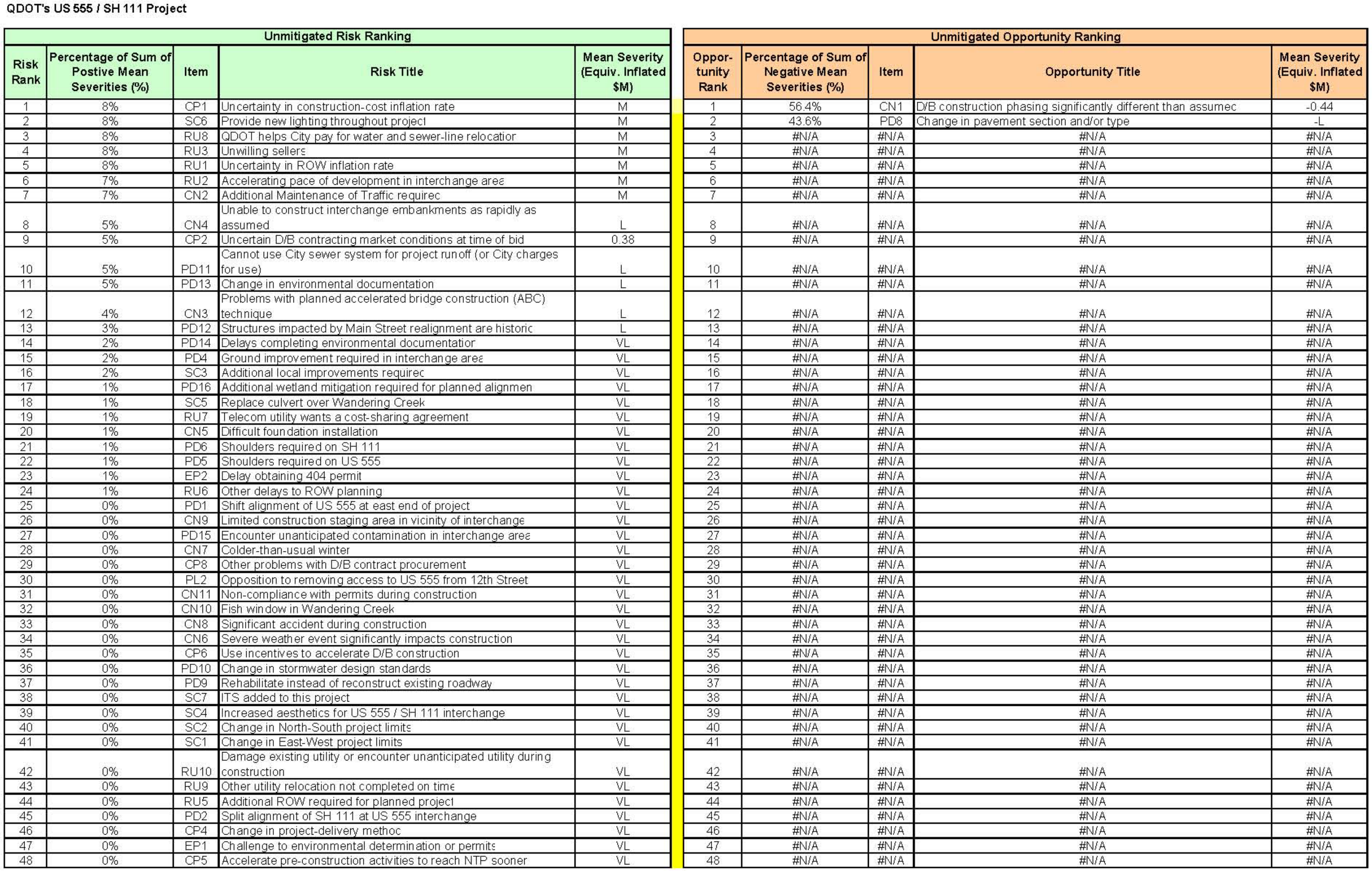
Extended OH Rates (unesc $M/month)

Preconstruction	**0.10**	Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / preconstruction duration) - calculated default value can be revised
Construction	**0.23**	Average agency construction "burn rate" (= agency baseline construction engr cost / construction duration) plus <u>compensable</u> contractor OH (= % of contractor construction OH cost / construction duration) - calculated default value can be revised

Values for combining consequences

Disruption Value ($M/M-hr)	**10.00**	to combine disruption with cost (NPV value)
Schedule Target (date)	**12/1/2012**	target date for start of operations
Schedule Value ($M/mo)	**0.10**	to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)	**5.0%**	to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	**1.00**	to combine "longevity" with cost (NPV value) - default value can be revised

Table D-2. Unmitigated Risk Ranking (from template – see Attachment I; for risks and performance through construction only)

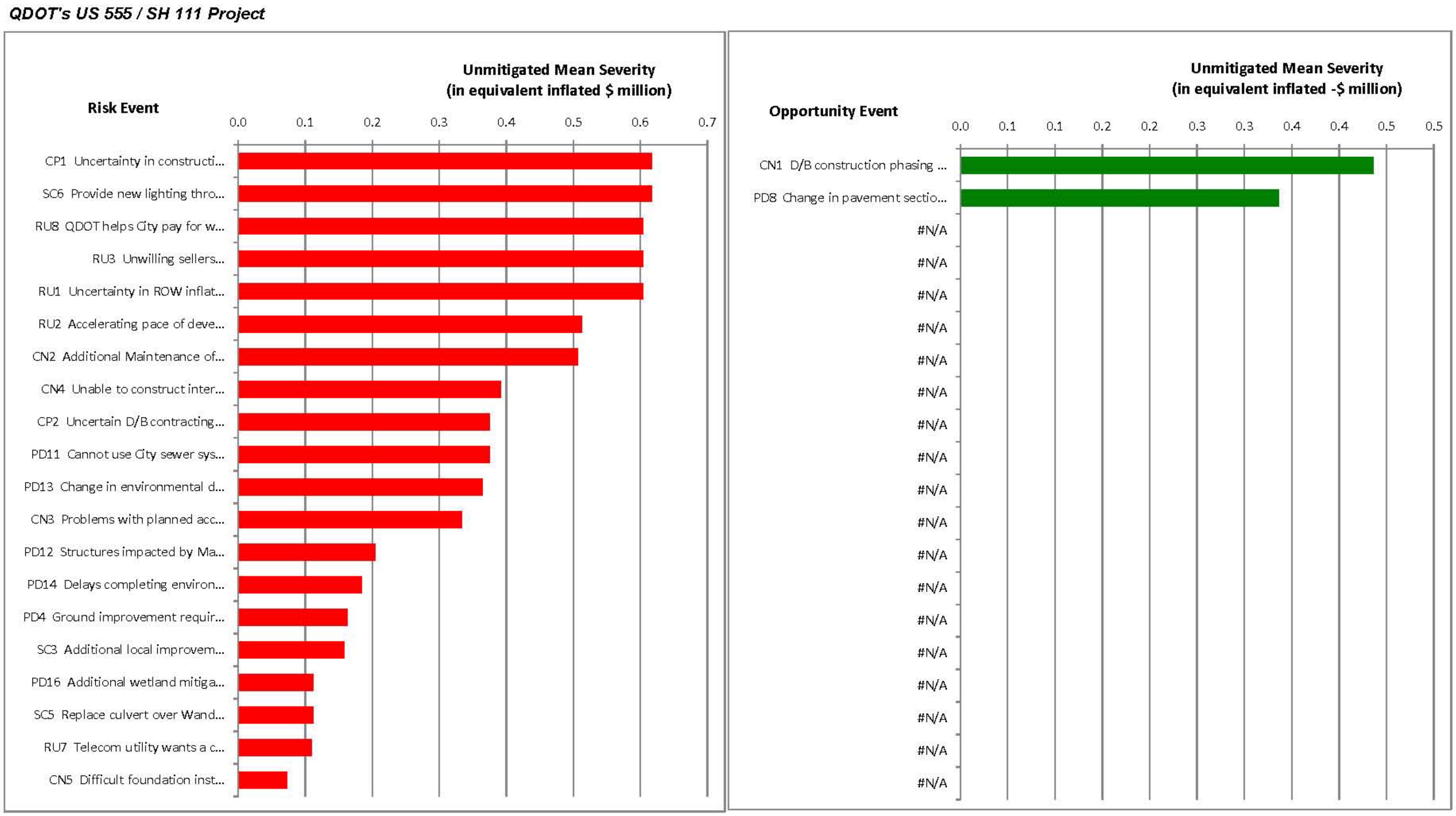


QDOT's US 555 / SH 111 Project

Unmitigated Risk Ranking				
Risk Rank	**Percentage of Sum of Postive Mean Severities (%)**	**Item**	**Risk Title**	**Mean Severity (Equiv. Inflated $M)**
1	8%	CP1	Uncertainty in construction-cost inflation rate	M
2	8%	SC6	Provide new lighting throughout projeci	M
3	8%	RU8	QDOT helps City pay for water and sewer-line relocatior	M
4	8%	RU3	Unwilling sellers	M
5	8%	RU1	Uncertainty in ROW inflation rate	M
6	7%	RU2	Accelerating pace of development in interchange area	M
7	7%	CN2	Additional Maintenance of Traffic requirec	M
8	5%	CN4	Unable to construct interchange embankments as rapidly as assumed	L
9	5%	CP2	Uncertain D/B contracting market conditions at time of bid	0.38
10	5%	PD11	Cannot use City sewer system for project runoff (or City charges for use)	L
11	5%	PD13	Change in environmental documentation	L
12	4%	CN3	Problems with planned accelerated bridge construction (ABC) technique	L
13	3%	PD12	Structures impacted by Main Street realignment are historic	L
14	2%	PD14	Delays completing environmental documentatior	VL
15	2%	PD4	Ground improvement required in interchange area	VL
16	2%	SC3	Additional local improvements requirec	VL
17	1%	PD16	Additional wetland mitigation required for planned alignmen	VL
18	1%	SC5	Replace culvert over Wandering Creek	VL
19	1%	RU7	Telecom utility wants a cost-sharing agreement	VL
20	1%	CN5	Difficult foundation installation	VL
21	1%	PD6	Shoulders required on SH 111	VL
22	1%	PD5	Shoulders required on US 555	VL
23	1%	EP2	Delay obtaining 404 permit	VL
24	1%	RU6	Other delays to ROW planning	VL
25	0%	PD1	Shift alignment of US 555 at east end of project	VL
26	0%	CN9	Limited construction staging area in vicinity of interchange	VL
27	0%	PD15	Encounter unanticipated contamination in interchange area	VL
28	0%	CN7	Colder-than-usual winter	VL
29	0%	CP8	Other problems with D/B contract procurement	VL
30	0%	PL2	Opposition to removing access to US 555 from 12th Street	VL
31	0%	CN11	Non-compliance with permits during construction	VL
32	0%	CN10	Fish window in Wandering Creek	VL
33	0%	CN8	Significant accident during construction	VL
34	0%	CN6	Severe weather event significantly impacts construction	VL
35	0%	CP6	Use incentives to accelerate D/B construction	VL
36	0%	PD10	Change in stormwater design standards	VL
37	0%	PD9	Rehabilitate instead of reconstruct existing roadway	VL
38	0%	SC7	ITS added to this project	VL
39	0%	SC4	Increased aesthetics for US 555 / SH 111 interchange	VL
40	0%	SC2	Change in North-South project limits	VL
41	0%	SC1	Change in East-West project limits	VL
42	0%	RU10	Damage existing utility or encounter unanticipated utility during construction	VL
43	0%	RU9	Other utility relocation not completed on time	VL
44	0%	RU5	Additional ROW required for planned projeci	VL
45	0%	PD2	Split alignment of SH 111 at US 555 interchange	VL
46	0%	CP4	Change in project-delivery methoc	VL
47	0%	EP1	Challenge to environmental determination or permits	VL
48	0%	CP5	Accelerate pre-construction activities to reach NTP sooner	VL

Unmitigated Opportunity Ranking				
Oppor-tunity Rank	**Percentage of Sum of Negative Mean Severities (%)**	**Item**	**Opportunity Title**	**Mean Severity (Equiv. Inflated $M)**
1	56.4%	CN1	D/B construction phasing significantly different than assumec	-0.44
2	43.6%	PD8	Change in pavement section and/or type	-L
3	#N/A	#N/A	#N/A	#N/A
4	#N/A	#N/A	#N/A	#N/A
5	#N/A	#N/A	#N/A	#N/A
6	#N/A	#N/A	#N/A	#N/A
7	#N/A	#N/A	#N/A	#N/A
8	#N/A	#N/A	#N/A	#N/A
9	#N/A	#N/A	#N/A	#N/A
10	#N/A	#N/A	#N/A	#N/A
11	#N/A	#N/A	#N/A	#N/A
12	#N/A	#N/A	#N/A	#N/A
13	#N/A	#N/A	#N/A	#N/A
14	#N/A	#N/A	#N/A	#N/A
15	#N/A	#N/A	#N/A	#N/A
16	#N/A	#N/A	#N/A	#N/A
17	#N/A	#N/A	#N/A	#N/A
18	#N/A	#N/A	#N/A	#N/A
19	#N/A	#N/A	#N/A	#N/A
20	#N/A	#N/A	#N/A	#N/A
21	#N/A	#N/A	#N/A	#N/A
22	#N/A	#N/A	#N/A	#N/A
23	#N/A	#N/A	#N/A	#N/A
24	#N/A	#N/A	#N/A	#N/A
25	#N/A	#N/A	#N/A	#N/A
26	#N/A	#N/A	#N/A	#N/A
27	#N/A	#N/A	#N/A	#N/A
28	#N/A	#N/A	#N/A	#N/A
29	#N/A	#N/A	#N/A	#N/A
30	#N/A	#N/A	#N/A	#N/A
31	#N/A	#N/A	#N/A	#N/A
32	#N/A	#N/A	#N/A	#N/A
33	#N/A	#N/A	#N/A	#N/A
34	#N/A	#N/A	#N/A	#N/A
35	#N/A	#N/A	#N/A	#N/A
36	#N/A	#N/A	#N/A	#N/A
37	#N/A	#N/A	#N/A	#N/A
38	#N/A	#N/A	#N/A	#N/A
39	#N/A	#N/A	#N/A	#N/A
40	#N/A	#N/A	#N/A	#N/A
41	#N/A	#N/A	#N/A	#N/A
42	#N/A	#N/A	#N/A	#N/A
43	#N/A	#N/A	#N/A	#N/A
44	#N/A	#N/A	#N/A	#N/A
45	#N/A	#N/A	#N/A	#N/A
46	#N/A	#N/A	#N/A	#N/A
47	#N/A	#N/A	#N/A	#N/A
48	#N/A	#N/A	#N/A	#N/A

Figure D-1. Unmitigated Risk Ranking (from template – see Attachment I; for risks and performance through construction only)



ATTACHMENT E. RISK REDUCTION PLAN

The plan for proactively reducing individual risks (as identified, described, assessed, evaluated and finally ranked in Attachments C and D) for the project was developed as follows:

- Identified possible risk reduction actions for the highest ranking risks (see Table E-1)
- Assessed the cost-effectiveness factors for each action (see Table E-1)
- Determined (using the MS Excel template – see Attachment I) the cost-effectiveness of each action (see Table E-2)
- Selected a cost-effective set of actions (see Table E-2), and planned them (see Table E-3)
- Determined (using the MS Excel template – see Attachment I) the mitigated Risk Register (mean value/ratings) for that set of actions (see Table E-4).

As previously noted, only performance (and thus risks) through construction has been focused on for now.

Table E-1. Detailed Identification of Risk Reduction Actions (for risks and performance through construction only), and Cost-Effectiveness Assessment

Notes: Risks are ranked in terms of their mean-value severity, and only risks with mean severity rating of "Low" or higher are shown.

Risk	**Risk or Opportunity Addressed** (see Risk Register for description)	**Potential Risk Management Actions** (Proactive actions: Mitigate, Avoid, Allocate)	**Cost to Implement Actions (impacts to affected activity)**			**Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)**			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
CP1	**Uncertainty in Construction-Cost Inflation Rate**	This is a true uncertainty and given the large-scale factors controlling it, the project team is unable to mitigate this factor.	-	-	-	-	-	-	-
SC6	**Provide new lighting throughout project**	1. Modify the project's design to avoid relocating existing lighting outside the interchange. However, this creates new risks (e.g., extra design time; additional ROW requirements; maintaining old lighting). This is not seen as a viable action at this point. 2. Accept that new lighting might be required, and optimize lighting design to minimize cost impact if it does occur. However, the savings would likely not be significant. 3. Negotiate a cost-sharing agreement with the City for the new continuous lighting, since QDOT's standards don't really require it. This action will not reduce the likelihood of the risk, but could reduce the cost to QDOT.	-	Minor (can work within existing schedule)	-	-	Reduce by 50% (say from M to L)	-	-

Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
RU8	**QDOT helps City pay for water and sewer-line relocation**	This “risk” is really a project / policy decision to be made by QDOT. In that light, this is really a way to accelerate project delivery (i.e., the action is a rapid renewal method, belonging to the “additional investment” strategy; see *Guide*, Appendix C). QDOT should be able to somewhat reduce risk PD11 if it helps the City pay for the relocation. Hence, the impacts to risks RU8 and PD11 are related: • The “cost” of this risk management action shows up under risk RU8 in terms of an *increased* probability of occurrence (i.e., an increased probability of helping the City). • The “benefit” of this action shows up under risk PD11 as *reduced* probability of occurrence (i.e., a reduced probability that the City will deny use of its system). *The impacts to both RU8 and PD11 will have to be considered together to determine if this decision / action is cost-effective*.	-	-	-	Increase by 70% (say from H to VH)	-	-	-

Risk	**Risk or Opportunity Addressed** (see Risk Register for description)	**Potential Risk Management Actions** (Proactive actions: Mitigate, Avoid, Allocate)	**Cost to Implement Actions (impacts to affected activity)**			**Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)**			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
RU3	**Unwilling sellers**	QDOT's principal risk from unwilling sellers is increased right-of-way acquisition cost. Hence, QDOT could take the following actions to reduce this risk (see *Guide*, Table D-5a): 1. Review the design to see if can "tweak" it to avoid any of these properties. This has already been done once, and the project team does not believe there is much room for improvement under the current design concept. 2. <u>Make reasonable, early offers</u>: conduct thorough research on the values of these properties, and present reasonable offers to the property owners. Do this early to provide more time to reach negotiated settlements (and therefore avoid court proceedings). This action would likely reduce the probability of cost increase, but not the magnitude of a cost increase if it occurs.	0.05 to ROW	-	-	Reduce by 50% (say from H to M)	-	-	-
RU1	**Uncertainty in Right-of-Way Inflation Rate**	This is a true uncertainty and given the large-scale factors controlling it, the project team is unable to mitigate this factor.	-	-	-	-	-	-	-

Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
RU2	**Accelerating pace of development in interchange area**	1. Accelerate project development activities; specifically: a. Project design effort (see *Guide*, Table D-4a) to pre-empt developers' permit applications and approvals by the City; and b. Preparation of right-of-way appraisals and offers (see *Guide*, Table D-5a) in order to make offers to developers before they begin their planned developments. This could be difficult given the already-short timeframe for this project. 2. Coordinate more closely with the City, in an attempt to have the City avoid issuing any new development permits in right-of-way required by the project. This won't affect permits that have already been issued. This action would most likely reduce the likelihood of this risk occurring, but wouldn't reduce the costs if this risk occurs.	-	-	-	Reduce by 50% (say from M to L)	-	-	-

Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
CN2	**Additional Maintenance of Traffic required**	To reduce the risk of an ineffective MoT program or requiring significantly more MoT, QDOT could take the following actions, which aren't part of the current plan (*Guide*, Table D-4g): 1. Reduce traffic demand during closures (i.e., look for viable detours or provide alternative modes of transport), while still meeting QDOT's goal of maintaining the equivalent of two lanes of traffic along US 555 and SH 111. QDOT would have to work with the D/B contractor on this issue, perhaps starting with the RFP. 2. Seek early contractor involvement, and/or hold maintenance-of-traffic plan brainstorming or concept reviews with industry representatives. 3. QDOT could conduct more traffic modeling under various possible construction scenarios to better understand the potential problems, then translate these findings into requirements in RFP. 4. Require the D/B contractor to develop a contingency MoT plan as part of the proposal.	0.05 to Final Design	-	-	Reduce by 50% (say from H to M)	-	-	Reduce by 2/3 (67%)

Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
CN4	**Unable to construct interchange embankments as rapidly as assumed**	To reduce the risk of poorer-than-anticipated performance, QDOT could take the following actions (*Guide*, Table D-4c): 1. QDOT conducts additional investigation and analysis (beyond what's already planned) of the embankment foundation material to better ascertain which rapid-construction techniques are likely to succeed. Provide these findings to the D/B contractor in the anticipation that the contractor will use the information to select a more reliable construction method. 2. Require that the D/B contractor develop an alternative embankment construction technique (e.g., ground improvement) to be implemented without delay in the event that the planned technique does not work. This action could mitigate delay if the risk occurs, but could result in additional cost. The combined impact of these two actions is shown to the right. These actions could result in a reduced probability of occurrence or a reduced	0.1 to Final Design	- (can be done within existing schedule)	-	Reduce by 50% (say from M to L)	-	-	-

<table>
<tr><th rowspan="2">Risk</th><th rowspan="2">Risk or Opportunity Addressed

(see Risk Register for description)</th><th rowspan="2">Potential Risk Management Actions

(Proactive actions: Mitigate, Avoid, Allocate)</th><th colspan="3">Cost to Implement Actions (impacts to affected activity)</th><th colspan="4">Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)</th></tr>
<tr><th>Cost Change (current $M)</th><th>Schedule Change (months)</th><th>Disruption Change (million person-hours lost)</th><th>Probability</th><th>Cost Impact</th><th>Duration Impact</th><th>Disruption Impact</th></tr>
<tr><td></td><td></td><td>duration impact from occurrence, but probably not both. The group chose to characterize the benefits from these actions in terms of the reduced likelihood of the risk occurring.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CP2</td><td>Uncertain D/B contracting market conditions at time of bid</td><td>To reduce the risk of experiencing impacts from potentially poor market conditions, QDOT could take the following actions (<i>Guide</i>, Table D-6):
1. Use an alternative procurement method. A number of local contractors who do not traditionally bid on Design/Build contracts might bid on this contract if it were procured via other, more-traditional methods. However, this would be contrary to QDOT's rapid renewal strategy for this project. Hence, this action is unlikely.
2. Use alternative contract packaging. The single contract is already relatively small, so the group does not believe that creating two or more smaller packages will have any impact on bid prices.
3. Shift the project timeline to avoid any other major projects in the area that might consume</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

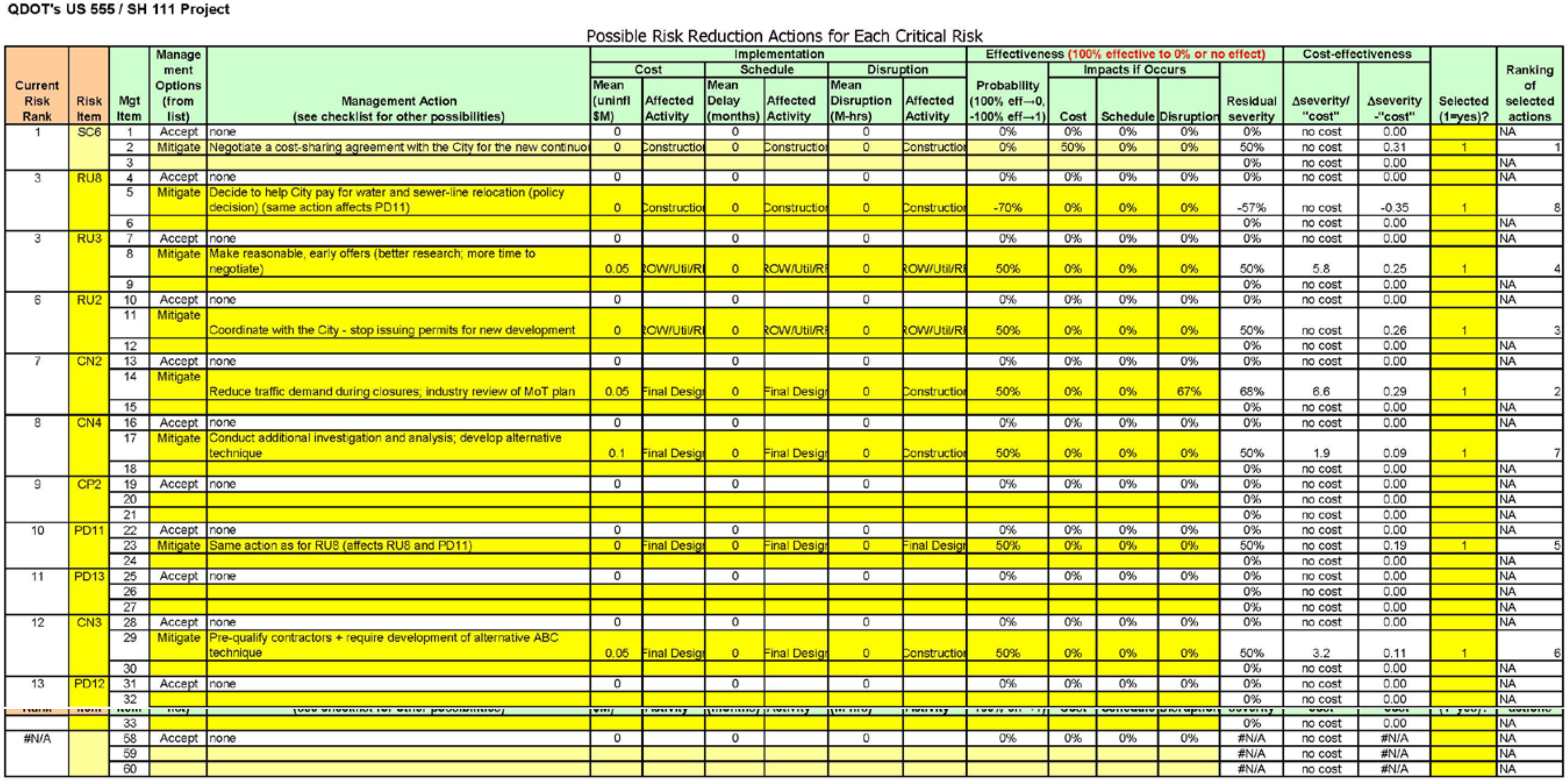
Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	Schedule Change (months)	Disruption Change (million person-hours lost)	Probability	Cost Impact	Duration Impact	Disruption Impact
		resources needed for this project. This is not feasible, given QDOT's rapid renewal strategy for this project. 4. QDOT could more proactively promote awareness of the project in the contracting community (e.g., through an outreach program to smaller contractors), in hopes to generate more interest. Overall, given how small (relatively) this project is, the group does not believe that it is feasible to significantly reduce this risk / uncertainty.							
PD11	**Cannot use City sewer system for project runoff (or City charges for use)**	Tied to the action described under RU8 (the benefits of that action are realized under this risk).	-	-	-	Reduce by 50% (say from M to L)	-	-	-
PD13	**Change in environmental document-ation**	QDOT is including what it believes to be conservative impacts in its Environmental Assessment. QDOT is also designing in an attempt to reduce project impacts and is communicating with the public about the project. Beyond these current actions, neither	-	-	-	-	-	-	-

Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	Schedule Change (months)	Disruption Change (million person-hours lost)	Probability	Cost Impact	Duration Impact	Disruption Impact
		the project team nor the risk assessment subject-matter experts could identify any feasible way to mitigate this risk.							
CN3	**Problems with planned accelerated bridge construction (ABC) technique**	To reduce the risk of poorer-than-anticipated performance, QDOT could take the following actions (*Guide*, Table D-4b): During design and/or procurement: 1. QDOT could require the D/B contractor to develop a parallel, alternative rapid bridge replacement technique as a mitigation measure, to be deployed if significant problems arise with the primary approach. 2. QDOT and/or the contractor could gather performance information for the proposed ABC technique to increase confidence that the technique will perform well for this application. 3. Pre-qualify and/or select contractors with a history of successful ABC under similar project circumstances. During construction, make sure contractor has the alternative	0.05 to Final Design	-	-	Reduce by 50% (say from H to M)	-	-	-

Risk	Risk or Opportunity Addressed (see Risk Register for description)	Potential Risk Management Actions (Proactive actions: Mitigate, Avoid, Allocate)	Cost to Implement Actions (impacts to affected activity)			Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)			
			Cost Change (current $M)	Schedule Change (months)	Disruption Change (million person-hours lost)	Probability	Cost Impact	Duration Impact	Disruption Impact
		technique ready to implement. Together, the group believes that these actions (which are not currently planned) should reduce the probability of the assessed impacts occurring, or reduce the magnitude of the impacts, but probably not both.							
PD12	**Structures impacted by Main Street realignment are eligible for Historic Register**	These structures will either be eligible for listing or they will not. The only way for QDOT to mitigate this risk is to avoid the structures altogether, which would require shifting the alignment. While this is a possibility, such a change would introduce additional problems that most likely would outweigh the benefits. Hence, the group believes that QDOT cannot reasonably reduce this risk.	-	-	-	-	-	-	-
CN1	**D/B construction phasing significantly different than assumed (opportunity)**	This "opportunity" is really more of an uncertainty related to how the Design/Builder will phase and construct the project. In theory, QDOT could attempt to influence the D/B construction schedule by using incentives for the contractor to accelerate construction (see *Guide*, Table D-2; Table D-4). However, there is currently significant resistance within QDOT to use of	-	-	-	-	-	-	-

Risk	**Risk or Opportunity Addressed** (see Risk Register for description)	**Potential Risk Management Actions** (Proactive actions: Mitigate, Avoid, Allocate)	**Cost to Implement Actions (impacts to affected activity)**			**Effectiveness of Actions (% reduction in risk factors relative to unmitigated factors in risk register)**			
			Cost Change (current $M)	**Schedule Change (months)**	**Disruption Change (million person-hours lost)**	**Probability**	**Cost Impact**	**Duration Impact**	**Disruption Impact**
		contractor incentives. Hence, the group was not able to identify any significant action (beyond QDOT's current strategy) to amplify this opportunity.							
PD8	**Change in Pavement Section and/or Type**	This cost "opportunity" would really reflect a change in QDOT's objectives for this project, and is not something the project team wants to pursue (i.e., a change in pavement type from concrete to asphalt would mean a change in the project objective of maximizing longevity of the new facility). Hence, no action is planned to increase this "opportunity."	-	-	-	-	-	-	-

Table E-2 Summary of Risk Reduction Identification (for risks and performance through construction only),, and Cost-Effectiveness Assessment and Evaluation (from template – see Attachment I)

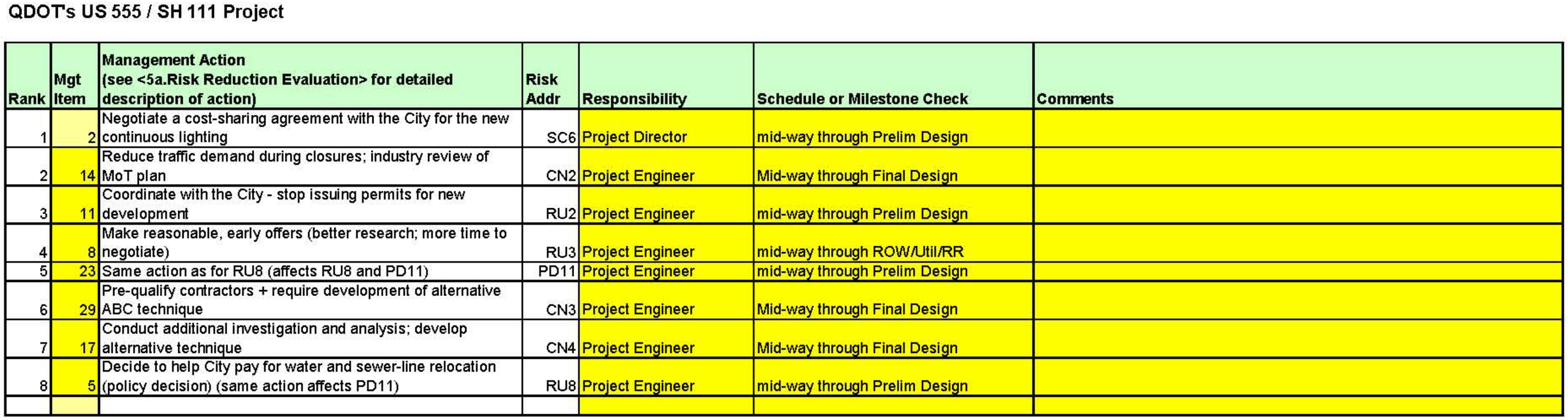


QDOT's US 555 / SH 111 Project

Possible Risk Reduction Actions for Each Critical Risk

					Implementation						Effectiveness (100% effective to 0% or no effect)					Cost-effectiveness			
					Cost		Schedule		Disruption			Impacts if Occurs							
Current Risk Rank	Risk Item	Mgt Item	Management Options (from list)	Management Action (see checklist for other possibilities)	Mean (uninfl $M)	Affected Activity	Mean Delay (months)	Affected Activity	Mean Disruption (M-hrs)	Affected Activity	Probability (100% eff→0, -100% eff→1)	Cost	Schedule	Disruption	Residual severity	Δseverity/ "cost"	Δseverity -"cost"	Selected (1=yes)?	Ranking of selected actions
1	SC6	1	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		2	Mitigate	Negotiate a cost-sharing agreement with the City for the new continuo	0	Constructio	0	Constructio	0	Constructio	0%	50%	0%	0%	50%	no cost	0.31	1	1
		3													0%	no cost	0.00		NA
3	RU8	4	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		5	Mitigate	Decide to help City pay for water and sewer-line relocation (policy decision) (same action affects PD11)	0	Constructio	0	Constructio	0	Constructio	-70%	0%	0%	0%	-57%	no cost	-0.35	1	8
		6													0%	no cost	0.00		NA
3	RU3	7	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		8	Mitigate	Make reasonable, early offers (better research; more time to negotiate)	0.05	ROW/Util/R	0	ROW/Util/R	0	ROW/Util/R	50%	0%	0%	0%	50%	5.8	0.25	1	4
		9													0%	no cost	0.00		NA
6	RU2	10	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		11	Mitigate	Coordinate with the City - stop issuing permits for new development	0	ROW/Util/R	0	ROW/Util/R	0	ROW/Util/R	50%	0%	0%	0%	50%	no cost	0.26	1	3
		12													0%	no cost	0.00		NA
7	CN2	13	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		14	Mitigate	Reduce traffic demand during closures; industry review of MoT plan	0.05	Final Desig	0	Final Desig	0	Constructio	50%	0%	0%	67%	68%	6.6	0.29	1	2
		15													0%	no cost	0.00		NA
8	CN4	16	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		17	Mitigate	Conduct additional investigation and analysis; develop alternative technique	0.1	Final Desig	0	Final Desig	0	Constructio	50%	0%	0%	0%	50%	1.9	0.09	1	7
		18													0%	no cost	0.00		NA
9	CP2	19	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		20													0%	no cost	0.00		NA
		21													0%	no cost	0.00		NA
10	PD11	22	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		23	Mitigate	Same action as for RU8 (affects RU8 and PD11)	0	Final Desig	0	Final Desig	0	Final Desig	50%	0%	0%	0%	50%	no cost	0.19	1	5
		24													0%	no cost	0.00		NA
11	PD13	25	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		26													0%	no cost	0.00		NA
		27													0%	no cost	0.00		NA
12	CN3	28	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		29	Mitigate	Pre-qualify contractors + require development of alternative ABC technique	0.05	Final Desig	0	Final Desig	0	Constructio	50%	0%	0%	0%	50%	3.2	0.11	1	6
		30													0%	no cost	0.00		NA
13	PD12	31	Accept	none	0		0		0		0%	0%	0%	0%	0%	no cost	0.00		NA
		32													0%	no cost	0.00		NA
		33													0%	no cost	0.00		NA
#N/A		58	Accept	none	0		0		0		0%	0%	0%	0%	#N/A	no cost	#N/A		NA
		59													#N/A	no cost	#N/A		NA
		60													#N/A	no cost	#N/A		NA

Table E-3. Risk Reduction Plan (from template – see Attachment I; for risks through construction only)



QDOT's US 555 / SH 111 Project

Rank	Mgt Item	Management Action (see <5a.Risk Reduction Evaluation> for detailed description of action)	Risk Addr	Responsibility	Schedule or Milestone Check	Comments
1	2	Negotiate a cost-sharing agreement with the City for the new continuous lighting	SC6	Project Director	mid-way through Prelim Design	
2	14	Reduce traffic demand during closures; industry review of MoT plan	CN2	Project Engineer	Mid-way through Final Design	
3	11	Coordinate with the City - stop issuing permits for new development	RU2	Project Engineer	mid-way through Prelim Design	
4	8	Make reasonable, early offers (better research; more time to negotiate)	RU3	Project Engineer	mid-way through ROW/Util/RR	
5	23	Same action as for RU8 (affects RU8 and PD11)	PD11	Project Engineer	mid-way through Prelim Design	
6	29	Pre-qualify contractors + require development of alternative ABC technique	CN3	Project Engineer	Mid-way through Final Design	
7	17	Conduct additional investigation and analysis; develop alternative technique	CN4	Project Engineer	Mid-way through Final Design	
8	5	Decide to help City pay for water and sewer-line relocation (policy decision) (same action affects PD11)	RU8	Project Engineer	mid-way through Prelim Design	

Table E-4. Mitigated Risk Factors (from template – see attachment I; for risks and performance through construction only)

QDOT's US 555 / SH 111 Project

Mitigated Risk Register

Item	Risk or Opportunity	Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Assessed Mitigated Impacts (if occur)						Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
			Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)			
			Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
PL	***Planning Risks***		0.01		0.00		0.00		0.02	7
PL1	Project funding delayed or reduced	0		0		0		0	0.00	51
PL2	Opposition to removing access to US 555 from 12th Street	L	VL	Construction	0	Construction	0	0	VL	30
PL3	Opposition to splitting alignment of SH 111 in the interchange area	0		0		0		0	0.00	51
PL4	Other stakeholder issues not captured separately	VL	VL	Prelim	VL	Prelim Design/Env	0	0	VL	48
PL15	#N/A			0		0		0	0.00	#N/A
SC	***Scoping Risks***		0.51		0.20		0.00		0.59	4
SC1	Change in East-West project limits	VL	VL	Construction	VL	Construction	0	0	VL	31
SC2	Change in North-South project limits	VL	VL	Construction	VL	Construction	0	0	VL	31
SC3	Additional local improvements required	M	L	Construction	L	Proc	0	0	VL	16
SC4	Increased aesthetics for US 555 / SH 111 interchange	VL	VL	Construction	VL	Construction	0	0	VL	31
SC5	Replace culvert over Wandering Creek	M	L	Construction	0	Construction	0	0	VL	17
SC6	Provide new lighting throughout project	H	M	Construction	0	Construction	0	0	L	6
SC7	ITS added to this project	VL	VL	Construction	VL	Construction	0	0	VL	31
SC15	#N/A			0		0		0	0.00	#N/A
PD	***Preliminary Design / Environmental Process Risks***		0.50		2.34		0.00		1.10	2
PD1	Shift alignment of US 555 at east end of project	VL	M	ROW/Util/RR	M	ROW/Util/RR	0	0	VL	25
PD2	Split alignment of SH 111 at US 555 interchange	VL	VL	ROW/Util/RR	VL	ROW/Util/RR	0	0	VL	42
PD3	Change in configuration of SH 111 / US 555 interchange	0	0	Construction	0	Prelim Design/Env	0	0	0.00	51
PD4	Ground improvement required in interchange area	L	M	Construction	L	Construction	0	0	VL	14
PD5	Shoulders required on US 555	VL	H	Construction	M	ROW/Util/RR	0	0	VL	21
PD6	Shoulders required on SH 111	VL	H	Construction	M	ROW/Util/RR	0	0	VL	21
PD7	Additional cost for signalized intersections	VL	VL	Construction	0	Construction	0	0	VL	50
PD8	Change in pavement section and/or type	M	-M	Construction	0	Construction	0	0	-L	184
PD9	Rehabilitate instead of reconstruct existing roadway	VL	VL	Construction	VL	Construction	0	0	VL	31
PD10	Change in stormwater design standards	VL	VL	Construction	VL	Construction	0	0	VL	31
PD11	Cannot use City sewer system for project runoff (or City charges for	L	M	ROW/Util/RR	L	ROW/Util/RR	0	0	VL	11
PD12	Structures impacted by Main Street realignment are historic	L	M	ROW/Util/RR	M	ROW/Util/RR	0	0	L	9
PD13	Change in environmental documentation	L	M	Prelim	H	Prelim Design/Env	0	0	L	5
PD14	Delays completing environmental documentation	M	0	Prelim	M	Prelim Design/Env	0	0	VL	12
PD15	Encounter unanticipated contamination in interchange area	M	VL	Construction	0	Construction	0	0	VL	26

Mitigated Risk Register										
Item	Risk or Opportunity	Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Assessed Mitigated Impacts (if occur)						Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
			Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)			
			Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
PD16	Additional wetland mitigation required for planned alignment	M	L	Construction	0	Construction	0	0	VL	17
PD25	#N/A			0		0		0	0.00	#N/A
EP	***Environmental Permits Risks***		0.00		0.30		0.00		0.07	6
EP1	Challenge to environmental determination or permits	VL	VL	Environmental	VL	Environmental	0	0	VL	46
EP2	Delay obtaining 404 permit	L	0	Environmental	M	Environmental	0	0	VL	23
EP15	#N/A			0		0		0	0.00	#N/A
RU	***ROW/Utility/RR/etc Risks***		2.04		0.57		0.00		2.27	1
RU1	Uncertainty in ROW inflation rate	H	M	ROW/Util/RR		0		0	M	3
RU2	Accelerating pace of development in interchange area	L	M	ROW/Util/RR	M	ROW/Util/RR	0	0	L	8
RU3	Unwilling sellers	M	M	ROW/Util/RR	0	ROW/Util/RR	0	0	L	7
RU4	Additional relocation or demolition required	0		0		0		0	0.00	51
RU5	Additional ROW required for planned project	VL	VL	ROW/Util/RR	VL	ROW/Util/RR	0	0	VL	42
RU6	Other delays to ROW planning	M	0	ROW/Util/RR	L	ROW/Util/RR	0	0	VL	24
RU7	Telecom utility wants a cost-sharing agreement	M	L	ROW/Util/RR	0	ROW/Util/RR	0	0	VL	19
RU8	QDOT helps City pay for water and sewer-line relocation	VH	M	ROW/Util/RR	0	ROW/Util/RR	0	0	M	1
RU9	Other utility relocation not completed on time	VL	VL	ROW/Util/RR	VL	ROW/Util/RR	0	0	VL	42
RU10	Damage existing utility or encounter unanticipated utility during	VL	VL	ROW/Util/RR	VL	ROW/Util/RR	0	0	VL	42
RU15	#N/A			0		0		0	0.00	#N/A
FD	***Final Design Risks***		0.00		0.00		0.00		0.00	8
FD1	#N/A			0		0		0	0.00	#N/A
FD15	#N/A			0		0		0	0.00	#N/A
CP	***Procurement Risks***		0.88		1.08		0.00		1.02	3
CP1	Uncertainty in construction-cost inflation rate	H	M	Construction		0		0	M	2
CP2	Uncertain D/B contracting market conditions at time of bid	0.25	1.185	Construction	1	Procurement	0	0	0.38	4
CP3	Material-supply issues	0		0		0		0	0.00	51
CP4	Change in project-delivery method	VL	VL	Procurement	VL	Procurement	0	0	VL	47
CP5	Accelerate pre-construction activities to reach NTP sooner	VL	VL	Prelim	VL	Prelim Design/Env	0	0	VL	48
CP6	Use incentives to accelerate D/B construction	VL	VL	Construction	VL	Construction	0	0	VL	31
CP7	Issues with D/B design or submittals	M	0	Final Design	M	Final Design	0	0	VL	51
CP8	Other problems with D/B contract procurement	L	0	Procurement	L	Procurement	0	0	VL	29
CP20	#N/A			0		0		0	0.00	#N/A
CN	***Construction Risks***		0.34		0.18		-0.02		0.22	5
CN1	D/B construction phasing significantly different than assumed	0.25		0	-2	Construction	-0.1	Construction	-0.44	185
CN2	Additional Maintenance of Traffic required	M	L	Construction	VL	Construction	0.0165	Construction	VL	15
CN3	Problems with planned accelerated bridge construction (ABC)	M	L	Construction	L	Construction	0	Construction	VL	13
CN4	Unable to construct interchange embankments as rapidly as	L	L	Construction	M	Construction	0	Construction	VL	10
CN5	Difficult foundation installation	L	L	Construction	L	Construction	VL	Construction	VL	20
CN6	Severe weather event significantly impacts construction	VL	VL	Construction	VL	Construction	VL	Construction	VL	31
CN7	Colder-than-usual winter	L	VL	Construction	VL	Construction	0	Construction	VL	28
CN8	Significant accident during construction	VL	VL	Construction	VL	Construction	VL	Construction	VL	31
CN9	Limited construction staging area in vicinity of interchange	M	VL	Construction	0	Construction	0	Construction	VL	26
CN10	Fish window in Wandering Creek	VL	VL	Construction	VL	Construction	VL	Construction	VL	31
CN11	Non-compliance with permits during construction	VL	VL	Construction	VL	Construction	VL	Construction	VL	31
CN12	Extended overheads as function of project delays	0		0		0		0	0.00	51
CN25	#N/A			0		0		0	0.00	#N/A
OM	***Operations Risks***		0.00		0.00		0.00		0.00	8
OM1	#N/A			0		0		0	0.00	#N/A

Mitigated Risk Register

Item	Risk or Opportunity	Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Assessed Mitigated Impacts (if occur)						Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
			Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)			
			Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
OM15	#N/A			0		0		0	0.00	#N/A
RP	***Replacement Risks***		0.00		0.00		0.00		0.00	8
RP1	#N/A			0		0		0	0.00	#N/A
RP15	#N/A			0		0		0	0.00	#N/A
FN	***Funding Risks***		0.00		0.00		0.00		0.00	8
FN1	#N/A			0		0		0	0.00	#N/A
FN10	#N/A			0		0		0	0.00	#N/A
	TOTAL (if comprehensive and non-overlapping set of risks)		4.28		4.67		-0.02		5.30	

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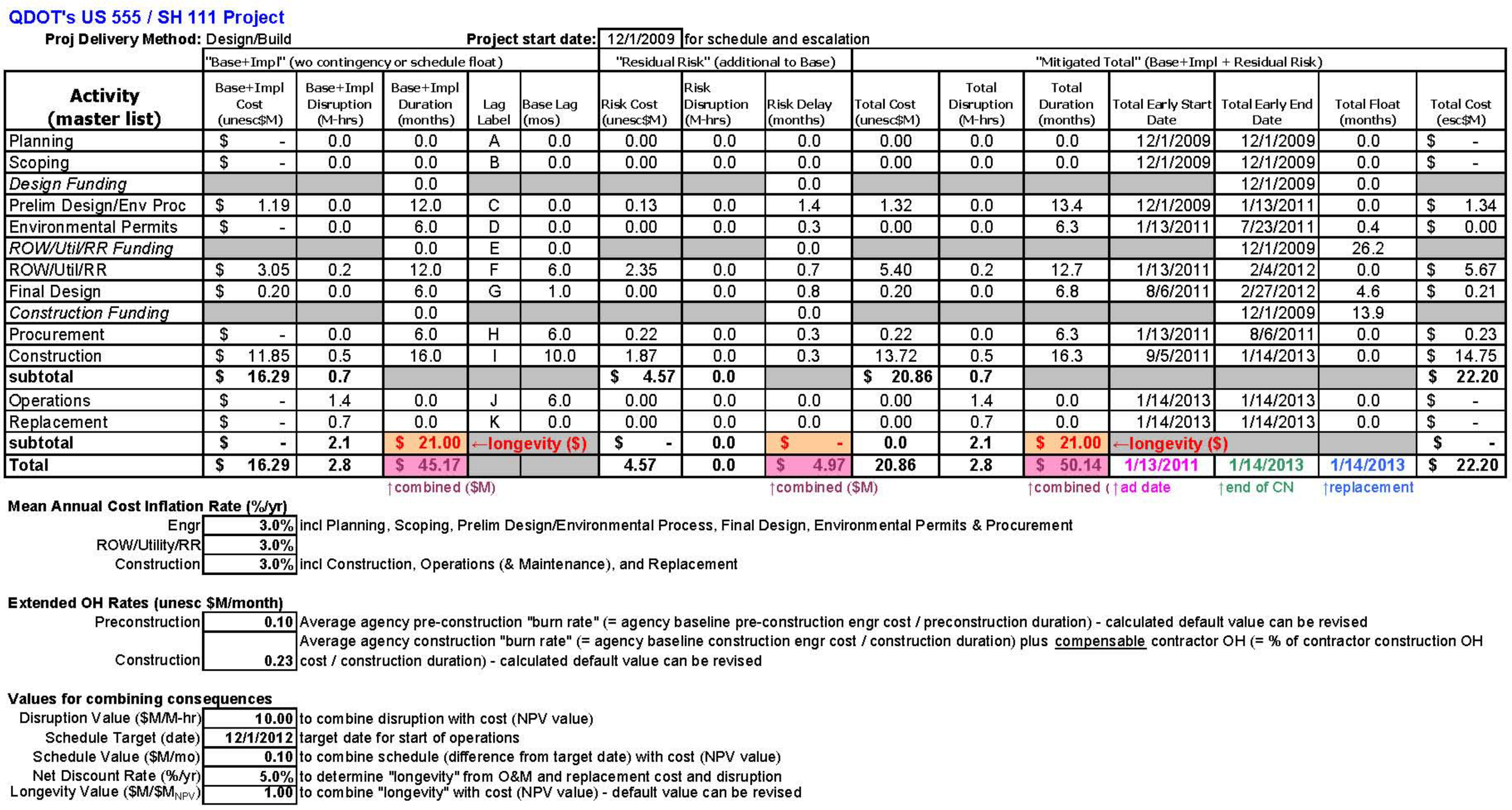
ATTACHMENT F. MITIGATED MEAN-VALUE PROJECT PERFORMANCE

The various revised base and mitigated risk inputs were used to calculate (using the MS Excel template – see Attachment I) approximate mean mitigated project performance (by activity and collectively), including cost (unescalated and escalated), schedule (milestone dates), disruption, and longevity (post construction cost, schedule and disruption), as well as combined performance (see Table F-1). The mean "severity" of each remaining risk was also determined (using the MS Excel template – see Attachment I)) in terms of its approximate contribution to the mean combined performance (see Table E-4), and the risks were then sorted by their mean severity (see Table F-2 and Figure F-1). As previously noted, only performance (and thus risks) through construction has been focused on for now.

Table F-1. Approximate Mean Mitigated Base+Risk Project Performance (from template – see Attachment I; through construction only)



QDOT's US 555 / SH 111 Project

Proj Delivery Method: Design/Build **Project start date:** 12/1/2009 for schedule and escalation

	"Base+Impl" (wo contingency or schedule float)					"Residual Risk" (additional to Base)			"Mitigated Total" (Base+Impl + Residual Risk)						
Activity (master list)	Base+Impl Cost (unesc$M)	Base+Impl Disruption (M-hrs)	Base+Impl Duration (months)	Lag Label	Base Lag (mos)	Risk Cost (unesc$M)	Risk Disruption (M-hrs)	Risk Delay (months)	Total Cost (unesc$M)	Total Disruption (M-hrs)	Total Duration (months)	Total Early Start Date	Total Early End Date	Total Float (months)	Total Cost (esc$M)
Planning	$ -	0.0	0.0	A	0.0	0.00	0.0	0.0	0.00	0.0	0.0	12/1/2009	12/1/2009	0.0	$ -
Scoping	$ -	0.0	0.0	B	0.0	0.00	0.0	0.0	0.00	0.0	0.0	12/1/2009	12/1/2009	0.0	$ -
Design Funding			0.0					0.0					12/1/2009	0.0	
Prelim Design/Env Proc	$ 1.19	0.0	12.0	C	0.0	0.13	0.0	1.4	1.32	0.0	13.4	12/1/2009	1/13/2011	0.0	$ 1.34
Environmental Permits	$ -	0.0	6.0	D	0.0	0.00	0.0	0.3	0.00	0.0	6.3	1/13/2011	7/23/2011	0.4	$ 0.00
ROW/Util/RR Funding			0.0	E	0.0			0.0					12/1/2009	26.2	
ROW/Util/RR	$ 3.05	0.2	12.0	F	6.0	2.35	0.0	0.7	5.40	0.2	12.7	1/13/2011	2/4/2012	0.0	$ 5.67
Final Design	$ 0.20	0.0	6.0	G	1.0	0.00	0.0	0.8	0.20	0.0	6.8	8/6/2011	2/27/2012	4.6	$ 0.21
Construction Funding			0.0					0.0					12/1/2009	13.9	
Procurement	$ -	0.0	6.0	H	6.0	0.22	0.0	0.3	0.22	0.0	6.3	1/13/2011	8/6/2011	0.0	$ 0.23
Construction	$ 11.85	0.5	16.0	I	10.0	1.87	0.0	0.3	13.72	0.5	16.3	9/5/2011	1/14/2013	0.0	$ 14.75
subtotal	**$ 16.29**	**0.7**				**$ 4.57**	**0.0**		**$ 20.86**	**0.7**					**$ 22.20**
Operations	$ -	1.4	0.0	J	6.0	0.00	0.0	0.0	0.00	1.4	0.0	1/14/2013	1/14/2013	0.0	$ -
Replacement	$ -	0.7	0.0	K	0.0	0.00	0.0	0.0	0.00	0.7	0.0	1/14/2013	1/14/2013	0.0	$ -
subtotal	**$ -**	**2.1**	**$ 21.00**	**←longevity ($)**		**$ -**	**0.0**	**$ -**	**0.0**	**2.1**	**$ 21.00**	**←longevity ($)**			**$ -**
Total	**$ 16.29**	**2.8**	**$ 45.17**			**4.57**	**0.0**	**$ 4.97**	**20.86**	**2.8**	**$ 50.14**	**1/13/2011**	**1/14/2013**	**1/14/2013**	**$ 22.20**
			↑combined ($M)					↑combined ($M)			↑combined (	↑ad date	↑end of CN	↑replacement	

Mean Annual Cost Inflation Rate (%/yr)

Engr	**3.0%**	incl Planning, Scoping, Prelim Design/Environmental Process, Final Design, Environmental Permits & Procurement
ROW/Utility/RR	**3.0%**	
Construction	**3.0%**	incl Construction, Operations (& Maintenance), and Replacement

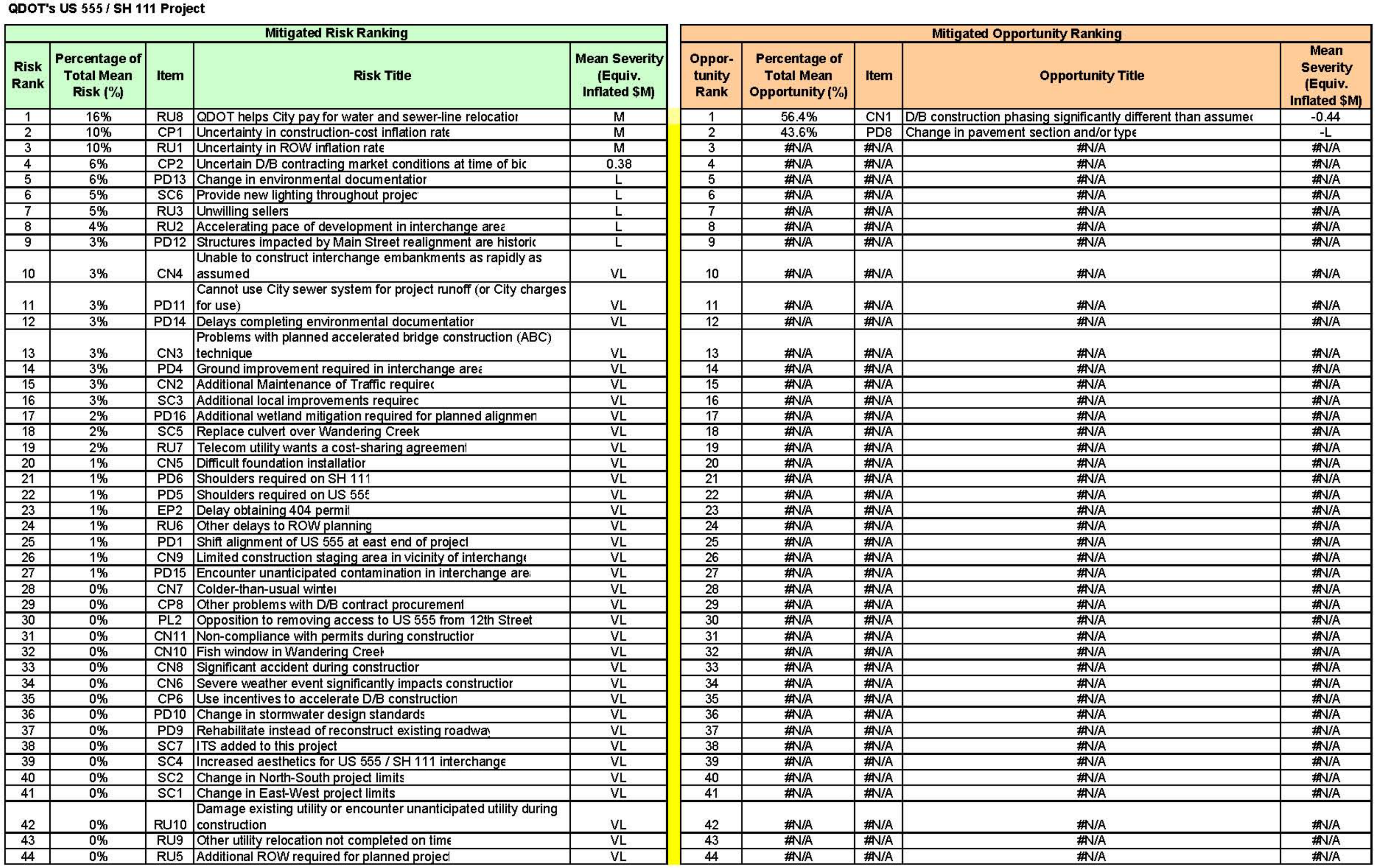
Extended OH Rates (unesc $M/month)

Preconstruction	**0.10**	Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / preconstruction duration) - calculated default value can be revised
Construction	**0.23**	Average agency construction "burn rate" (= agency baseline construction engr cost / construction duration) plus compensable contractor OH (= % of contractor construction OH cost / construction duration) - calculated default value can be revised

Values for combining consequences

Disruption Value ($M/M-hr)	**10.00**	to combine disruption with cost (NPV value)
Schedule Target (date)	**12/1/2012**	target date for start of operations
Schedule Value ($M/mo)	**0.10**	to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)	**5.0%**	to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	**1.00**	to combine "longevity" with cost (NPV value) - default value can be revised

Table F-2. Mitigated Risk Ranking (from template – see Attachment I; for risks and performance through construction only)

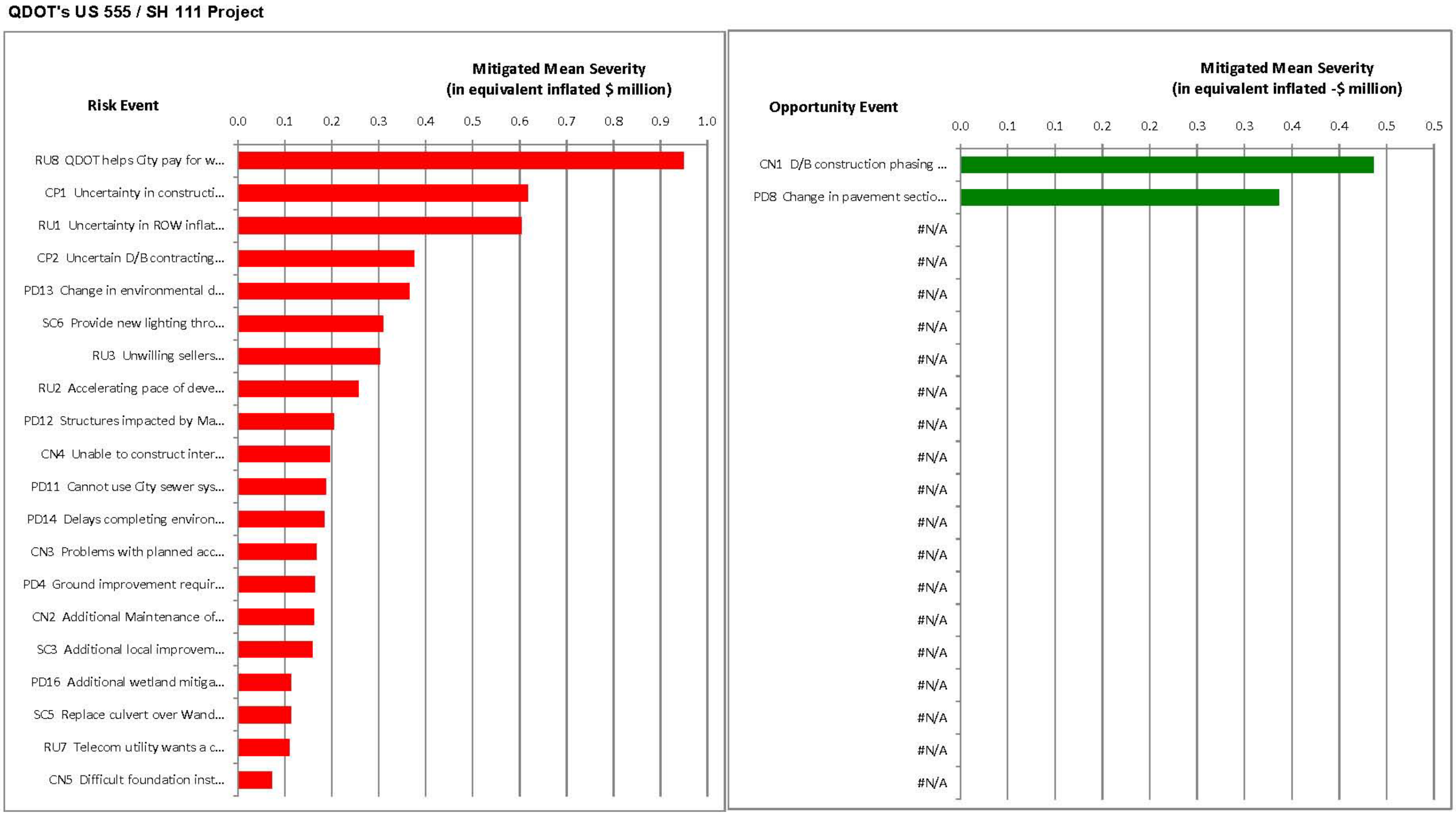


QDOT's US 555 / SH 111 Project

Mitigated Risk Ranking				
Risk Rank	**Percentage of Total Mean Risk (%)**	**Item**	**Risk Title**	**Mean Severity (Equiv. Inflated $M)**
1	16%	RU8	QDOT helps City pay for water and sewer-line relocatior	M
2	10%	CP1	Uncertainty in construction-cost inflation rate	M
3	10%	RU1	Uncertainty in ROW inflation rate	M
4	6%	CP2	Uncertain D/B contracting market conditions at time of bic	0.38
5	6%	PD13	Change in environmental documentatior	L
6	5%	SC6	Provide new lighting throughout projec	L
7	5%	RU3	Unwilling sellers	L
8	4%	RU2	Accelerating pace of development in interchange area	L
9	3%	PD12	Structures impacted by Main Street realignment are historic	L
10	3%	CN4	Unable to construct interchange embankments as rapidly as assumed	VL
11	3%	PD11	Cannot use City sewer system for project runoff (or City charges for use)	VL
12	3%	PD14	Delays completing environmental documentatior	VL
13	3%	CN3	Problems with planned accelerated bridge construction (ABC) technique	VL
14	3%	PD4	Ground improvement required in interchange area	VL
15	3%	CN2	Additional Maintenance of Traffic requirec	VL
16	3%	SC3	Additional local improvements requirec	VL
17	2%	PD16	Additional wetland mitigation required for planned alignmen	VL
18	2%	SC5	Replace culvert over Wandering Creek	VL
19	2%	RU7	Telecom utility wants a cost-sharing agreement	VL
20	1%	CN5	Difficult foundation installatior	VL
21	1%	PD6	Shoulders required on SH 111	VL
22	1%	PD5	Shoulders required on US 555	VL
23	1%	EP2	Delay obtaining 404 permit	VL
24	1%	RU6	Other delays to ROW planning	VL
25	1%	PD1	Shift alignment of US 555 at east end of project	VL
26	1%	CN9	Limited construction staging area in vicinity of interchange	VL
27	1%	PD15	Encounter unanticipated contamination in interchange are	VL
28	0%	CN7	Colder-than-usual winter	VL
29	0%	CP8	Other problems with D/B contract procurement	VL
30	0%	PL2	Opposition to removing access to US 555 from 12th Street	VL
31	0%	CN11	Non-compliance with permits during constructior	VL
32	0%	CN10	Fish window in Wandering Creek	VL
33	0%	CN8	Significant accident during constructior	VL
34	0%	CN6	Severe weather event significantly impacts constructior	VL
35	0%	CP6	Use incentives to accelerate D/B constructior	VL
36	0%	PD10	Change in stormwater design standards	VL
37	0%	PD9	Rehabilitate instead of reconstruct existing roadway	VL
38	0%	SC7	ITS added to this project	VL
39	0%	SC4	Increased aesthetics for US 555 / SH 111 interchange	VL
40	0%	SC2	Change in North-South project limits	VL
41	0%	SC1	Change in East-West project limits	VL
42	0%	RU10	Damage existing utility or encounter unanticipated utility during construction	VL
43	0%	RU9	Other utility relocation not completed on time	VL
44	0%	RU5	Additional ROW required for planned project	VL

Mitigated Opportunity Ranking				
Oppor-tunity Rank	**Percentage of Total Mean Opportunity (%)**	**Item**	**Opportunity Title**	**Mean Severity (Equiv. Inflated $M)**
1	56.4%	CN1	D/B construction phasing significantly different than assumec	-0.44
2	43.6%	PD8	Change in pavement section and/or type	-L
3	#N/A	#N/A	#N/A	#N/A
4	#N/A	#N/A	#N/A	#N/A
5	#N/A	#N/A	#N/A	#N/A
6	#N/A	#N/A	#N/A	#N/A
7	#N/A	#N/A	#N/A	#N/A
8	#N/A	#N/A	#N/A	#N/A
9	#N/A	#N/A	#N/A	#N/A
10	#N/A	#N/A	#N/A	#N/A
11	#N/A	#N/A	#N/A	#N/A
12	#N/A	#N/A	#N/A	#N/A
13	#N/A	#N/A	#N/A	#N/A
14	#N/A	#N/A	#N/A	#N/A
15	#N/A	#N/A	#N/A	#N/A
16	#N/A	#N/A	#N/A	#N/A
17	#N/A	#N/A	#N/A	#N/A
18	#N/A	#N/A	#N/A	#N/A
19	#N/A	#N/A	#N/A	#N/A
20	#N/A	#N/A	#N/A	#N/A
21	#N/A	#N/A	#N/A	#N/A
22	#N/A	#N/A	#N/A	#N/A
23	#N/A	#N/A	#N/A	#N/A
24	#N/A	#N/A	#N/A	#N/A
25	#N/A	#N/A	#N/A	#N/A
26	#N/A	#N/A	#N/A	#N/A
27	#N/A	#N/A	#N/A	#N/A
28	#N/A	#N/A	#N/A	#N/A
29	#N/A	#N/A	#N/A	#N/A
30	#N/A	#N/A	#N/A	#N/A
31	#N/A	#N/A	#N/A	#N/A
32	#N/A	#N/A	#N/A	#N/A
33	#N/A	#N/A	#N/A	#N/A
34	#N/A	#N/A	#N/A	#N/A
35	#N/A	#N/A	#N/A	#N/A
36	#N/A	#N/A	#N/A	#N/A
37	#N/A	#N/A	#N/A	#N/A
38	#N/A	#N/A	#N/A	#N/A
39	#N/A	#N/A	#N/A	#N/A
40	#N/A	#N/A	#N/A	#N/A
41	#N/A	#N/A	#N/A	#N/A
42	#N/A	#N/A	#N/A	#N/A
43	#N/A	#N/A	#N/A	#N/A
44	#N/A	#N/A	#N/A	#N/A

Figure F-1. Mitigated Risk Ranking (from template – see Attachment I; for risks and performance through construction only)



ATTACHMENT G. CONTINGENCY

For this project, the contingency requirements (both cost and schedule) for this project by phase are summarized in Table G-1, both by project phase and cumulative at the start (and end) of each project phase. As discussed in Chapter 7, in the absence of quantitative risk analysis (which was outside the scope of this *Risk Management Plan*) to objectively establish contingencies, the contingencies were established by judgment, considering the project risks.

It is interesting to note that if the total escalated cost was approximately normally (Gaussian) distributed (which would be reasonable based on the Central Limit Theorem), then: (a) the contingency target (80th) percentile of total escalated cost would be equal to the mean total escalated cost plus 0.84 times the standard deviation of total escalated cost; and (b) the contingency requirements would be the difference between the contingency target (80th) percentile and the base escalated cost. For example, if the standard deviation of total escalated cost was about 15% of the mean total escalated cost and the mean total escalated cost was 20% higher than the base escalated cost, then the contingency requirements would be about 13% of the mean total escalated cost and about 35% of the base escalated cost.

The protocol for using or releasing contingency consists of the following steps: <TBD>

Table G-1. Contingency Requirement (by project phase)

Project Phase	**During Phase**		**Cumulative at Start of Phase**	
	Cost (YOE$M)	**Schedule (mos)**	**Cost (YOE$M)**	**Schedule (mos)**
			30% = $5.1M	30% = 10.5 mos
Prelim Design	10% = $1.7M	10% = 3.5 mos		
			20% = $3.4M	20% = 7.0 mos
Procurement	10% = $1.7M	10% = 3.5 mos		
			10% = $1.7M	10% = 3.5 mos
Construction	8% = $1.4M	10% = 3.5 mos		
			2% = $0.3M	0% = 0 mos
Post-Construction	2% = $0.3M	0% = 0 mos		
			0% = $0	0% = 0 mos

Note: Base escalated cost through construction is $17.3M and base schedule is 35 months to completion.

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ATTACHMENT H. RECOVERY PLANS

For this project, the cost and schedule recovery requirements for each phase are presented in Table H-1, both by project phase and cumulative at the start of each project phase. As discussed in Chapter 8, in the absence of quantitative risk analysis (which was outside the scope of this *Risk Management Plan*) to objectively establish recovery requirements, the recovery requirements were established by judgment, considering the project risks.

It is interesting to note that if the total escalated cost was approximately normally (Gaussian) distributed (which would be reasonable based on the Central Limit Theorem), then: (a) the recovery target (95th) percentile of total escalated cost would be equal to the mean total escalated cost plus 1.64 times the standard deviation of total escalated cost; and (b) the recovery requirements would be the difference between the recovery target (95th) percentile and the contingency target (80th) percentile, i.e., 0.80 times the standard deviation of total escalated cost. For example, if the standard deviation of total escalated cost was about 15% of the mean total escalated cost and the mean total escalated cost was 20% higher than the base escalated cost, then the recovery requirements would be about 12% of the mean total escalated cost and about 15% of the base escalated cost.

The recovery actions (and their approximate net recovery value) that are available through each project phase are summarized in Table H-2. As shown, the available recovery savings is greater than the recovery required for each phase.

The protocol for implementing recovery plans consists of the following steps: <TBD>

Table H-1. Recovery Requirements (by project phase)

Project Phase	During Phase		Cumulative at Start of Phase	
	Cost (YOE$M)	Schedule (mos)	Cost (YOE$M)	Schedule (mos)
			15% = $2.6M	15% = 5.3 mos
Prelim Design	5% = $0.9M<$>	5% = 1.8 mos		
			10% = $1.7M	10% = 3.5 mos
Procurement	5% = $0.9M	5% = 1.8 mos		
			5% = $0.8M	5% = 1.7 mos
Construction	5% = $0.8M	5% = 1.7 mos		
			0% = $0	0% = 0 mos

Note: Base escalated cost through construction is $17.3M and base schedule is 35 months to completion.

Table H-2. Recovery Plans (by project phase)

Project Phase	Recovery Action	Net Saving	
		Cost (YOE$M)	Schedule (mos)
Prelim Design	<aaa>	<$>	<T>
	<bbb>	<$>	<T>
	<ccc>	<$>	<T>
	subtotal	<$>	<T>
Procurement	<ddd>	<$>	<T>
	<eee>	<$>	<T>
	<fff>	<$>	<T>
	subtotal	<$>	<T>
Construction	<ggg>	<$>	<T>
	<hhh>	<$>	<T>
	<iii>	<$>	<T>
	subtotal	<$>	<T>

ATTACHMENT I. TEMPLATE

An MS Excel workbook template (ref. Appendix E of the *Guide*) was used to document assessments and conduct simple mean-value analyses for this project, in lieu of quantitative risk analysis, as shown in previous attachments. Complete printouts from that template for this project are presented in this attachment.

<insert SHRP2 R09 Rapid Renewal Risk Management Planning Template (Beta 30June2010b) - Hypothetical QDOT Project.pdf>

Syllabus for Training Workshop for SHRP2 R09:
Guide for Managing Risks for Rapid Renewal Projects

Training Workshop Summary

The goal of this training workshop is to assist departments of transportation (DOTs) in understanding and applying risk management techniques throughout the project development process, especially for rapid renewal projects, thereby improving project performance. The approach is a synergy of theoretical principles, practical tools for implementation, and guidance for using the results in decisions concerning construction-management risk, as documented in the recent Guide for Managing Risks for Rapid Renewal Projects ("Guide"). The intended outcome of the workshop is 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, as well as development of an independent capability within the DOT 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. This is facilitated through use of forms and an MS Excel workbook template, which are provided to each participant and guides the user through the various steps of risk management, producing a Risk Register and parts of a Risk Management Plan (RMP). A notebook is provided to each participant at the beginning of the workshop, which contains: a copy of the Guide (including the hypothetical project and forms), copies of all the slides (with annotations in note format), a User Guide for the template, and a CD (which contains all the above, plus the animated slides, an introductory overview presentation, the template – both blank and the filled in example, additional references and this syllabus).

The workshop duration is two days, consisting of lectures, exercises (based on a hypothetical project throughout the course) and 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, and risk management planning and subsequent implementation (note: only an overview of quantitative risk analysis is provided).

Texts and Readings

Primary Text

Guide for Managing Risks for Rapid Renewal Projects, draft final report, by Golder Associates for NAS/TRB SHRP2 R09 (Dr. James Bryant, Program Officer), 22 March 2010 (note: this document is known informally as the "Guide") (on CD)

Secondary Texts

Guide to Risk Assessment and Allocation for Highway Construction Management, *Report # FHWA-PL-06-032, Federal Highway Administration, U.S. Department of Transportation, American Association of Stare Highway Transportation Officials, and the National Cooperative Highway Research Program*, Washington, DC, October 2006. (note: this document is known informally as the "Risk Guidelines") (on CD)

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

Selected papers (on CD)

Educational Objectives

The long-term workshop objective is to provide DOTs with an independent capability to conduct risk identification and assessment, and corresponding risk management, to improve project performance, especially for rapid renewal projects. Specifically by the end of this course, a participant should be able to:

- summarize the risk management process including project structuring, risk identification, risk assessment, risk analysis, and risk management planning and subsequent implementation (including risk monitoring and updates);
- explain how risk management can be applied throughout the project development process;
- identify and categorize risk and opportunity events and other key uncertainties in a formalized process to develop an appropriate Risk Register;
- apply select techniques to assess the likelihood of occurrence and impacts of occurrence (e.g., cost and schedule) for each risk in the Risk Register;
- apply select methodologies for appropriately combining assessed likelihoods and impacts into risk severity, which is then used to meaningfully prioritize risks;
- identify appropriate techniques to quantify uncertainty in project performance measures (e.g., cost and schedule) (note: the workshop does not teach how to implement these techniques due to time limitations and the unique student qualifications needed);
- identify, evaluate, and select among risk reduction techniques (including risk allocation and their contract provision considerations), and develop appropriate contingency allowances and plans, that results in an appropriate Risk Management Plan; and
- apply monitoring and updating techniques to systematically track risks and performance, and control contingencies, throughout the course of project development.

Preferably, participants should be key people in their DOT's risk management process, either as facilitators leading the process on projects, or as subject matter experts (SMEs) in various transportation disciplines (e.g., structures, construction, etc.) who will be relied on to provide their technical judgment on a continuing basis to the DOT's risk management program. Administrators and managers would benefit from a brief summary of the course (i.e., the first hour).

Course Schedule

Notes:

1. Times are approximate; adjustments might be made as the course progresses.
2. The first hour on Day 1 serves as a brief summary of the course.
3. Some participants (e.g., SMEs) might choose to skip Module 7, which is first activity on Day 2.
4. Some participants (e.g., SMEs) might choose to skip template training, which is after last break on Day 2.
5. Exercises are based on the hypothetical project presented in Appendix F of the *Guide* and generally carry over breaks, lunches and overnight.
6. Discussions generally carry over breaks.
7. Participants will be asked to fill out a course evaluation form (attached) at the end of Day 2.

Day 1 - Lectures and Exercises (8:30 a.m. – 4:30 p.m.)

8:30-9:00 AM	Module 1 – Introduction • Opening remarks from DOT top management staff • Introduction of participants (including sponsors, instructors, guests) • Overview of workshop syllabus (goals and agenda) and logistics
9:00-9:30 AM	Module 2 - Risk Management Process • Background of risk management (development of *Guide*) and workshop motivation (implementation of *Guide*) • Overview of risk management process, including benefits and challenges • Discussion
9:30-9:45 AM	*Break*
9:45-10:15 AM	Module 3 - Context for Rapid Renewal • Background of rapid renewal • Project performance objectives and project phases • Brief discussion of applicability for host Agency
10:15-10:45 AM	Module 3 - Presentation and Discussion of Hypothetical Project (which will be used throughout the course's practical exercises)
10:45-11:00 AM	*Break*
11:00-11:45 AM	Module 4 - Structuring the Project for Rapid Renewal • Goals for structuring • Structuring tools and techniques • Defining a "base" project (scope and strategy, including assumptions, and associated cost/schedule/disruption/longevity)
11:45-12:00 PM	Module 4 - Exercise and Discussion
12:00-1:00 PM	*Lunch*
1:00-1:15 PM	Module 4 - Exercise and Discussion (cont.)
1:15-1:45 PM	Module 5 - Risk Identification • Goals of risk identification • Risk identification tools and techniques (including list of generic risks) • Starting a Risk Register
1:45-2:00 PM	Module 5 Exercise and Discussion
2:00-2:15 PM	*Break*
2:15-2:45 PM	Module 5 Exercise and Discussion
2:45-3:15 PM	Module 6 Risk Assessment • Goals of risk assessment • Risk assessment tools and techniques • Completing and prioritizing the Risk Register
3:15-3:30 PM	*Break*
3:30-4:00 PM	Module 6 Risk Assessment (cont.)
4:00-4:30 PM	Module 6 - Exercise and Discussion

Day 2 - Lectures and Exercises (8:30 a.m. – 4:30 p.m.)

8:30-9:30 AM	Module 7 - Overview of Quantitative Risk Analysis • Goals of quantitative risk analysis • Overview of quantitative risk analysis tools and techniques • Example and Discussion
9:30-9:45 AM	*Break*
9:45-10:15 AM	Module 6 - Exercise and Discussion (cont.)
10:15-10:45 AM	Module 8 - Risk Management Planning • Goals of risk management • Risk reduction action identification and evaluation tools and techniques (including list of generic risk reduction methods) • Developing a Risk Management Program and Plan (including contingency) • Risk allocation (including contracting provisions)
10:45-11:00 AM	*Break*
11:00-11:30 AM	Module 8 - Risk Management Planning (continued)
11:30-12:00 PM	Module 8 – Exercise and Discussion
12:00-1:00 PM	*Lunch*
1:00-1:30 PM	Module 8 - Exercise and Discussion (continued)
1:30-2:00 PM	Module 9 - Implementing the Risk Management Plan • Goals of RMP implementation • Risk monitoring / update tools and techniques • Updating the Risk Register and the Risk Management Plan • Discussion
2:00-2:15 PM	*Break*
2:15-2:45 PM	Module 10 - Implementing the Guide • Goals of *Guide* implementation • Planning and logistics • Discussion
2:45-3:15 PM	Module 11 – Closing • Summary • Discussion
3:15-3:30 PM	*Break*
3:30-4:30 PM	Module 12 - Template Training

Instructors

Dr. William Roberds, Golder Associates' Principal and Lead Decision/Risk Analyst: Bill has over 30 years of relevant experience and has been with Golder Associates (a 7000+ international engineering consulting firm) since 1980, before which he taught at several universities and worked for several other geotechnical consultants. He is a recognized international expert in risk and decision analysis, especially subjective assessment elicitation and modeling. He has been responsible (both technically and as project manager or director) for a wide range of local, national, and international projects related to various aspects of siting, investigation, analysis, design, permitting, construction, operating, monitoring, remediating, decommissioning and post-decommissioning of civil, mining and environmental engineering projects, including highways and tunnels, for a wide range of private and public clients. Many of these projects included appropriate consideration of various types of consequences, including their associated uncertainties, and multiple stakeholders, including the public and regulators. Consensus on the technical evaluations and on the decision based on these evaluations was typically achieved on these projects through workshops he facilitated. He has written various guidebooks and trained people on how to conduct risk assessments and management. Currently, he is conducting probabilistic cost and schedule estimates on a number of mega-projects, including numerous projects for WSDOT, as well as for FTA, FHWA, Colorado DOT and CalTrans, for which he is also the project manager. On the topic of risk and decision analysis, Bill has more than 80 published papers, reports, and presentations; serves on various national (e.g., ASCE and TRB) and international (e.g. PMI, ISSMFE, and IUGS) committees; serves as a professional journal reviewer and advisor to various public agencies (e.g. USGS, USDOE, FTA); speaks by invitation (e.g., keynote) to various conferences, symposia and organizations; presents workshops and seminars (including teaching at Technical University of Torino Italy); and conducts funded research. Bill has an M.S. and D.Sc. in Civil Engineering from MIT and a BS (with distinction) in Civil Engineering from Stanford University.

Prof. Keith Molenaar is an Associate Professor with the Construction Engineering and Management (CEM) Program in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado at Boulder. He teaches graduate and undergraduate courses in Construction Cost Engineering, Construction Project Controls, Construction Planning and Scheduling, Construction Project Delivery, and Construction Equipment and Methods. He also teaches professional education classes for the American Society of Civil Engineering (ASCE) in the areas of Design-Build Project Delivery and Cost Engineering. His research focuses on project delivery strategies and techniques for infrastructure and constructed facilities. Prior to pursuing an academic career, Dr. Molenaar worked for Architectural Resource Consultants, Inc. where he specialized in pre-construction planning for owners and designers. His responsibilities included cost engineering, scheduling, and construction administration on a variety of project types. Some of Dr. Molenaar's recent recognitions include a Fulbright Scholarship (2007), the University of Colorado Provost Faculty Achievement Award, University of Colorado (2006), the Public Works Magazine, Top 50 "Trendsetter" (2004), the Design-Build Institute of America, Charter Designee, Design-Build Professional (2002), and the American Society of Civil Engineers, Thomas Finch Rowland Award (2001).

Dr. Travis C. McGrath, P.E., Golder Associates' Principal and Decision/Risk Analyst: Travis has been with Golder Associates for over 10 years. His primary expertise is in the application of probabilistic risk and decision analysis to complex engineered systems, including large transportation infrastructure projects. Recent examples include evaluating cost and schedule uncertainty for WSDOT's proposed "megaprojects" and numerous smaller projects as a member of various CEVP® teams. He has also led cost and schedule uncertainty and risk assessments for several large projects for the FTA, a number of other US state and Canadian provincial DOTs (e.g., Utah DOT, Colorado DOT, Pennsylvania Turnpike Commission, and Ontario Ministry of Transport), the Seattle DOT, and the Port of Seattle. Travis also co-developed and delivered training for WSDOT staff on CEVP and CRA, and has delivered training on risk assessment to other agencies and groups, including Ontario Ministry of Transport, North Carolina DOT, and Colorado DOT. In addition, his experience includes evaluating the risks associated with the closure of landfills, the development and closure of large mines, and the development of a water-supply wellfield; predicting the performance of a low-level nuclear-waste disposal facility; comparing alternative landfill final-cover systems; and predicting the performance of a complex mechanical system designed to transfer mine waste rock. He has also conducted research into the risks associated with investigating and remediating contaminated sites. Travis has an M.S. and Ph.D. in Civil Engineering from The University of Texas at Austin, and a B.S. in Civil Engineering (summa cum laude) from Seattle University. He is a former US Army Engineer officer and a registered Professional Engineer in the State of Washington.

Participant Evaluation of
NAS/TRB/SHRP2 Rapid Renewal Risk Management Training Workshop
for ___________ <DOT> on ________________ <dates>

With 5 being best, rate the following:	1	2	3	4	5
1. Did the presentation follow the course materials?	☐	☐	☐	☐	☐
2. Were the workshop goals and objectives clear?	☐	☐	☐	☐	☐
3. Were the goals and objectives met?	☐	☐	☐	☐	☐
4. Did the workshop advance your knowledge of risk management?	☐	☐	☐	☐	☐
5. Will the workshop help you assess and manage risk for your projects?	☐	☐	☐	☐	☐
6. Are you ready to facilitate risk management on relatively simple projects?	☐	☐	☐	☐	☐

7. For your DOT implementation, what type of implementation do you believe would have benefit? (Check all that apply and add comments (extend to back of page.)

☐ Use for moderately sized conventional projects (DBB).
Comments____
____

☐ Use for major conventional projects (DBB).
Comments____
____

☐ Use for non-conventional projects (DB, concessionaire, etc.).
Comments____
____

☐ Provide general training to department staff.
Comments____
____

☐ Develop a formal risk management program that is integrated in the project development process.
Comments____
____

☐ Other____
____

8. Please provide your comments/suggestions on the workshop (can extend to back of page, as needed).____
____
____
____

9. Would your DOT be interested in having additional training or project evaluations? (Yes or No)

Position (e.g., project manager, construction eng., consultant, etc.) _______________
Contact Information (Optional)
Name:_________________________________
Title: _________________________________
Employer: ______________________________
Address: _______________________________
City/State/Zip: ___________________________
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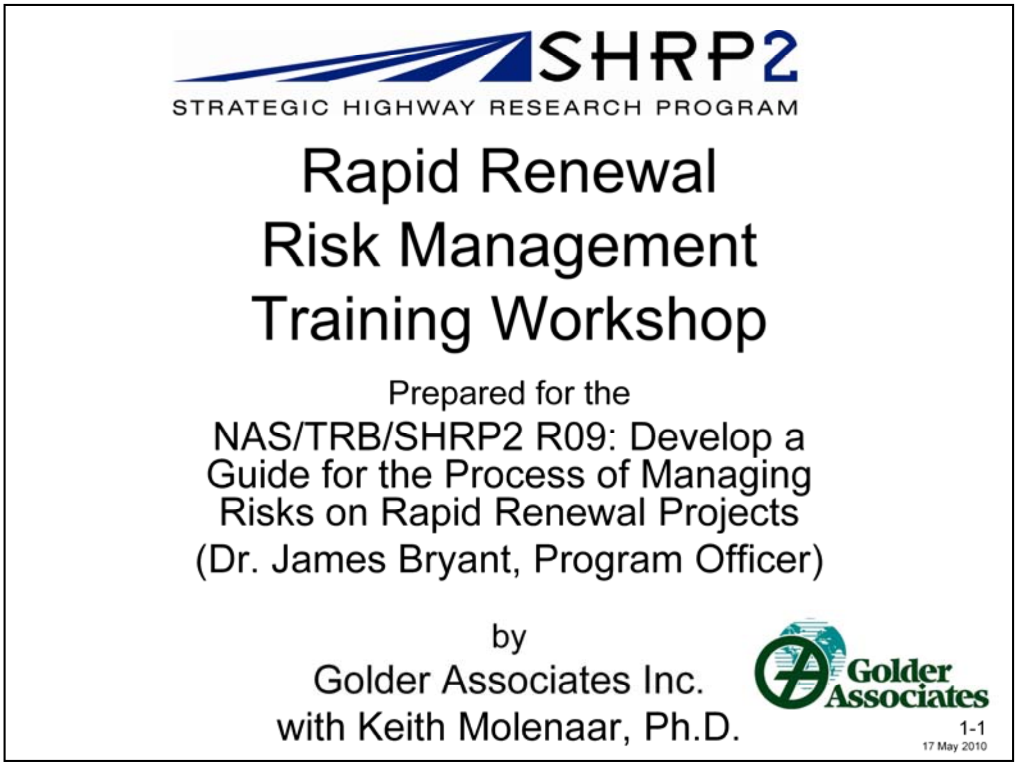
Participant Evaluation of
NAS/TRB/SHRP2 Rapid Renewal Risk Management Training Workshop
for ___________ <DOT> on ________________ <dates>

Additional comments:



STRATEGIC HIGHWAY RESEARCH PROGRAM

Rapid Renewal Risk Management Training Workshop

Prepared for the

NAS/TRB/SHRP2 R09: Develop a Guide for the Process of Managing Risks on Rapid Renewal Projects

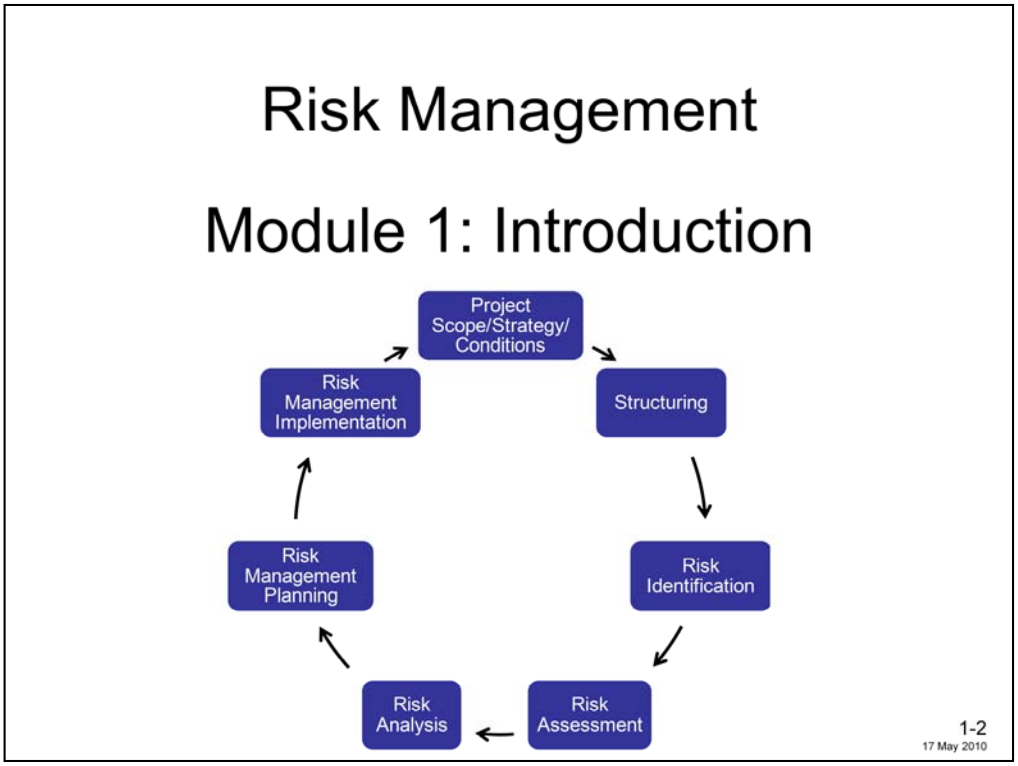
(Dr. James Bryant, Program Officer)

by

Golder Associates Inc.

with Keith Molenaar, Ph.D.

This course provides training to DOTs to implement the recently developed Guide for the Process of Managing Risks on Rapid Renewal Projects ("*Guide*"). This introduction module provides an overview of the Risk Management Training Workshop. The agenda for the workshop is at the end of this module. The course syllabus is attached separately.



Risk Management

Module 1: Introduction

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

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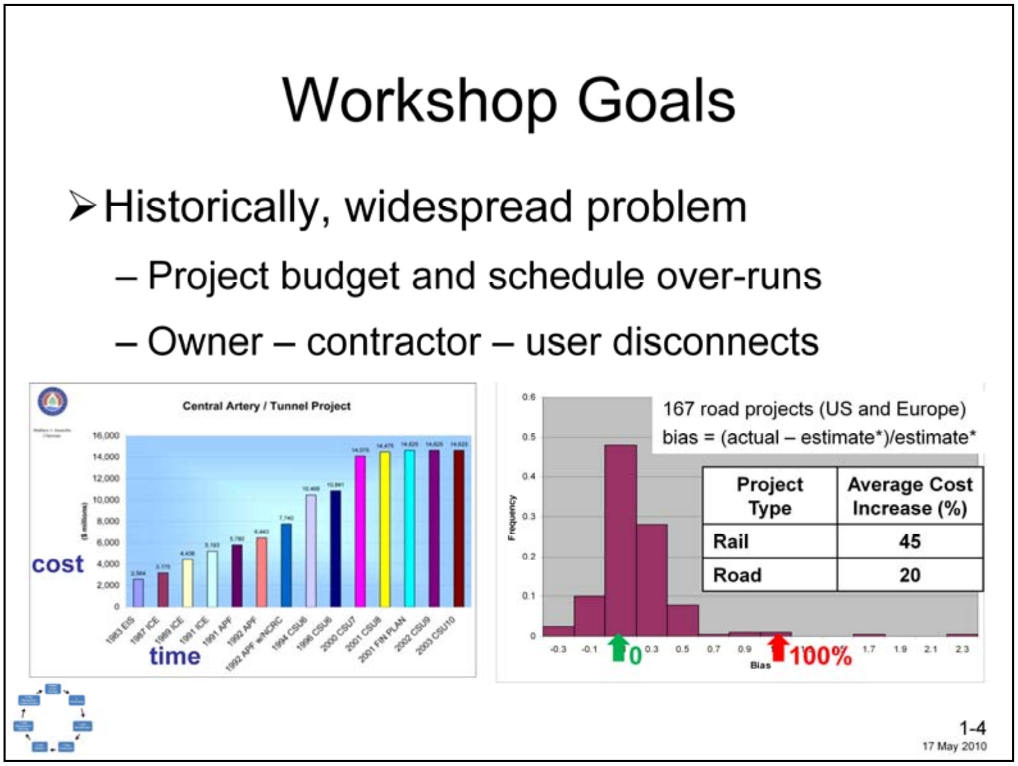
This figure represents a map of the risk management process. This map will be used throughout the course to guide us through the process. It should be noted that throughout the term “risks” includes opportunities (which are simply negative risks). Although developed specifically for rapid renewal projects, the process is generally applicable, i.e., to non-rapid renewal projects as well as even non-transportation projects.

Introduction

- Opening remarks
- Sponsors, Instructors and Participants
- Workshop goals
- Workshop agenda
- Workshop logistics

See training workshop syllabus and Chapter 1. Introduction in *Guide.*



Workshop Goals

- Historically, widespread problem
  - Project budget and schedule over-runs
  - Owner – contractor – user disconnects

167 road projects (US and Europe)
bias = (actual – estimate*)/estimate*

Project Type	Average Cost Increase (%)
Rail	45
Road	20

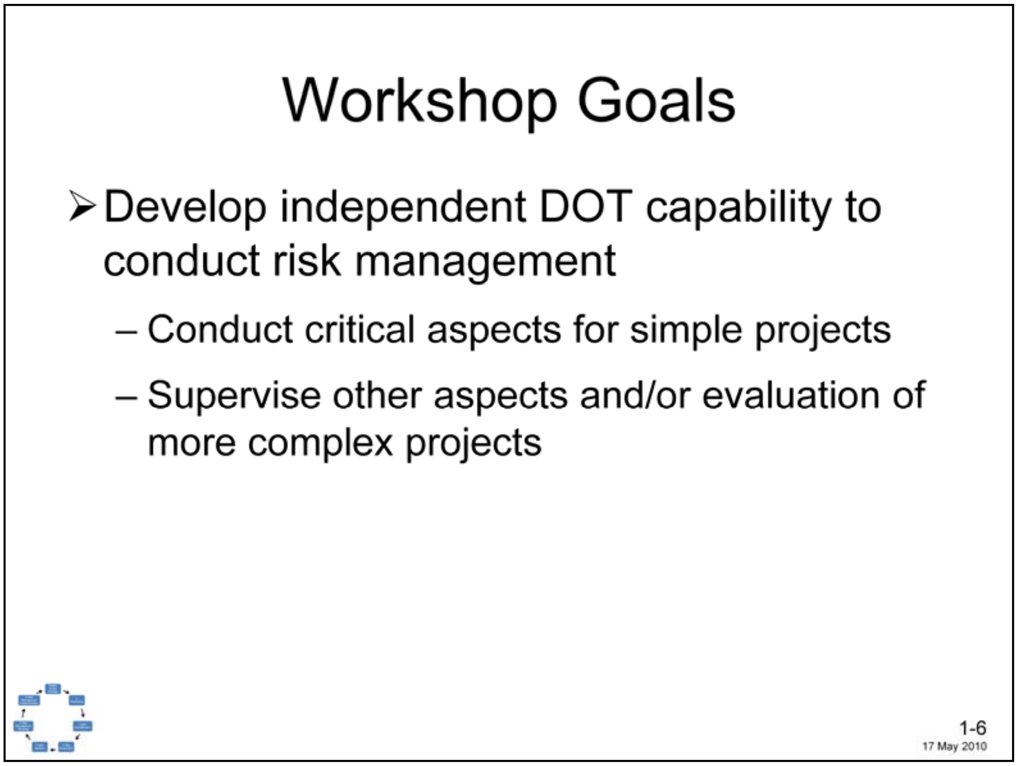
This histogram shows the “bias” in initial estimates for many roadway projects, where bias is the % cost increase (or “bias”) calculated as (final project cost) ÷ (estimate at time of decision to proceed) – 1.0 (ref. Flyvbjerg et al 2002 – see CD)

This table shows the same data as the histogram, but broken out into major project types. Road projects have faired better than rail or fixed link, but 20% average cost increase is still very high.

The conclusion is that most projects exceed (sometimes substantially) initial cost and schedule estimates, which often has significant repercussions (e.g., funding problems) – e.g., Big Dig, where the estimate grew about 700%. This has been consistent over the last 100 years. Although much of this might be due to optimism, it has been speculated that it might also be due (in part) to “strategic misrepresentation.”

Workshop Goals

- Rapid renewal focus
  - More complex
  - Additional criteria
- Risk management process to improve understanding and performance
  - Accurate
  - Defensible
  - Efficient
  - Compatible



Workshop Goals

- Develop independent DOT capability to conduct risk management
  - Conduct critical aspects for simple projects
  - Supervise other aspects and/or evaluation of more complex projects

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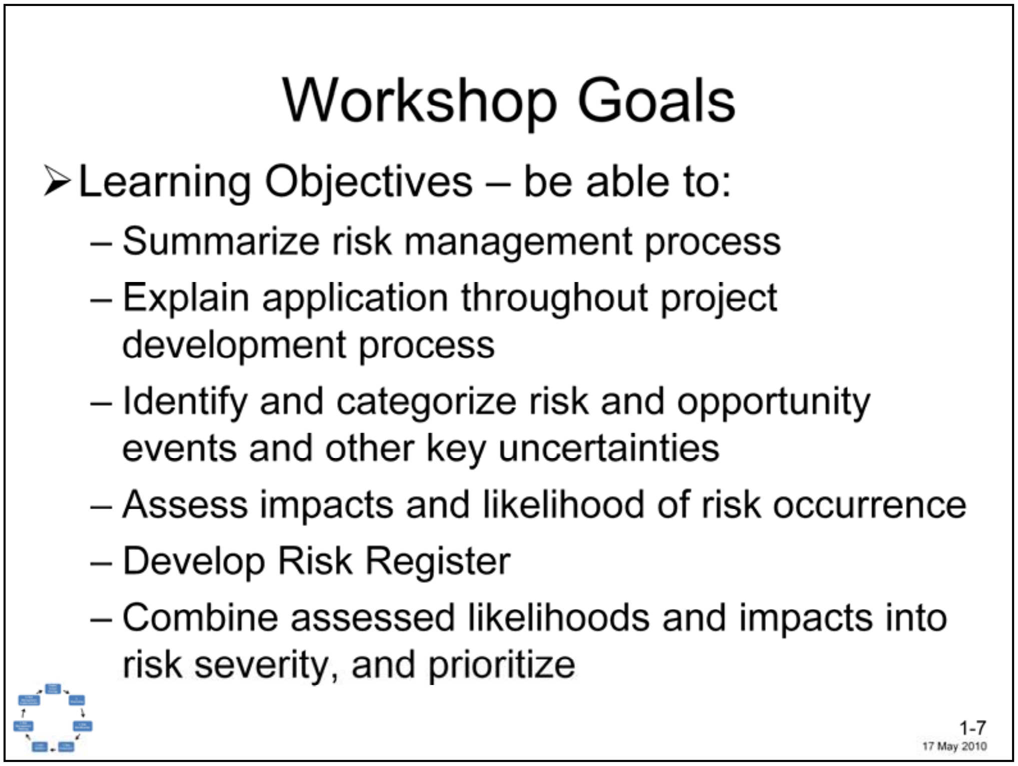
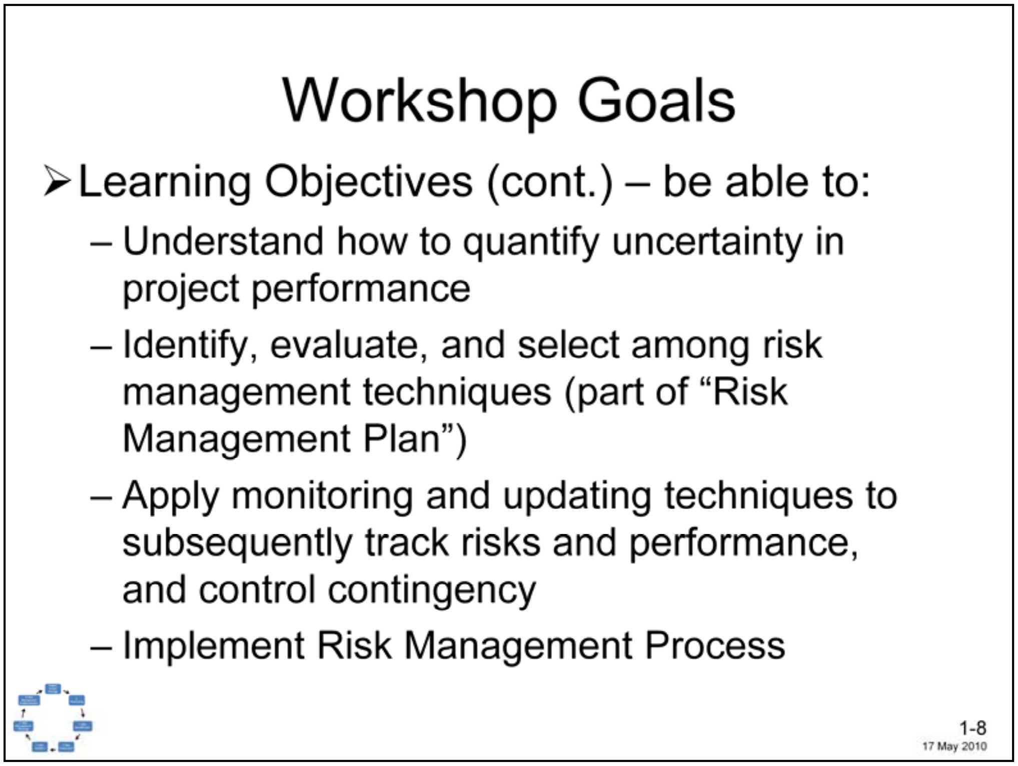
The goal is to develop independent (but limited) DOT capability to appropriately identify, assess, and manage/allocate project risks (i.e., to allow DOT to implement parts of NAS/TRB's "Guide to Managing Risks for Rapid Renewal Projects", or the "*Guide*", which forms the basis for this course) on relatively simple projects, and to supervise the evaluation of more complex projects and/or quantitative risk analysis. The *Guide* was in turn an expansion of FHWA's "Guide to Risk Assessment and Allocation for Highway Construction Management," or "*Risk Guidelines*".



Workshop Goals

- Learning Objectives – be able to:
  - Summarize risk management process
  - Explain application throughout project development process
  - Identify and categorize risk and opportunity events and other key uncertainties
  - Assess impacts and likelihood of risk occurrence
  - Develop Risk Register
  - Combine assessed likelihoods and impacts into risk severity, and prioritize

- Summarize the risk management process including structuring, risk identification, risk assessment, risk analysis, risk management planning and subsequent implementation
- Explain how risk management can be applied throughout the project development process
- Identify and categorize risk and opportunity events and other key uncertainties in a formalized process to develop a risk register
- Apply select techniques to assess the impacts of occurrence (e.g., cost and schedule) and likelihood of occurrence for each risk in the Risk Register
- Develop risk register, i.e., comprehensive and non-overlapping set of risks, as described by their impacts of occurrence (e.g., cost and schedule) and likelihood of occurrence
- Apply select methodologies for appropriately combining assessed likelihoods and impacts into risk severity



Workshop Goals

- Learning Objectives (cont.) – be able to:
  - Understand how to quantify uncertainty in project performance
  - Identify, evaluate, and select among risk management techniques (part of “Risk Management Plan”)
  - Apply monitoring and updating techniques to subsequently track risks and performance, and control contingency
  - Implement Risk Management Process

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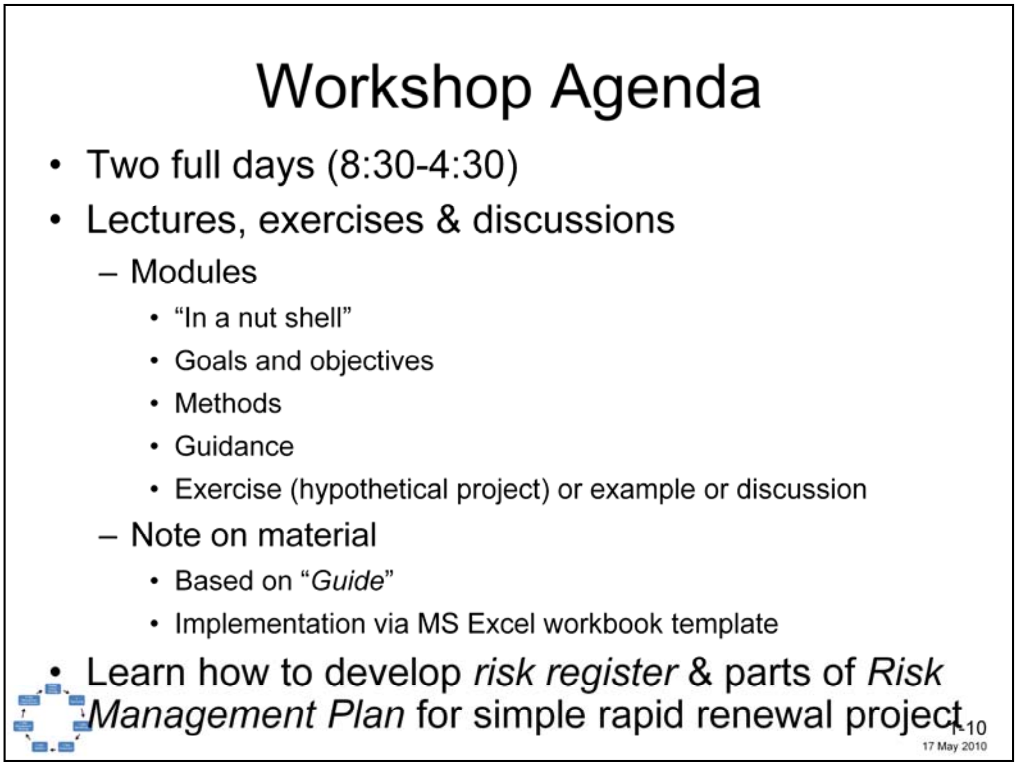
- Identify appropriate techniques to quantify uncertainty in project performance measures (e.g., cost and schedule) (note: the workshop does not teach how to implement these techniques due to time limitations and the unique student qualifications needed)
- Identify, evaluate, and select among standard risk reduction techniques, including appropriate risk allocation and their contract provision considerations, and develop contingency allowances and plans, to develop an appropriate *risk management plan*
- Apply monitoring and updating techniques to systematically track risks and performance, and control contingencies, throughout the course of project development
- Conduct the above risk management process, e.g., adequate organizational structure and resources, plan workshops, etc,

Introduction

- Opening remarks
- Sponsors, Instructors and Participants
- Workshop goals
- ➢ **Workshop agenda**
- Workshop logistics



Workshop Agenda

- Two full days (8:30-4:30)
- Lectures, exercises & discussions
  - Modules
    - “In a nut shell”
    - Goals and objectives
    - Methods
    - Guidance
    - Exercise (hypothetical project) or example or discussion
  - Note on material
    - Based on “*Guide*”
    - Implementation via MS Excel workbook template
- Learn how to develop *risk register* & parts of *Risk Management Plan* for simple rapid renewal project

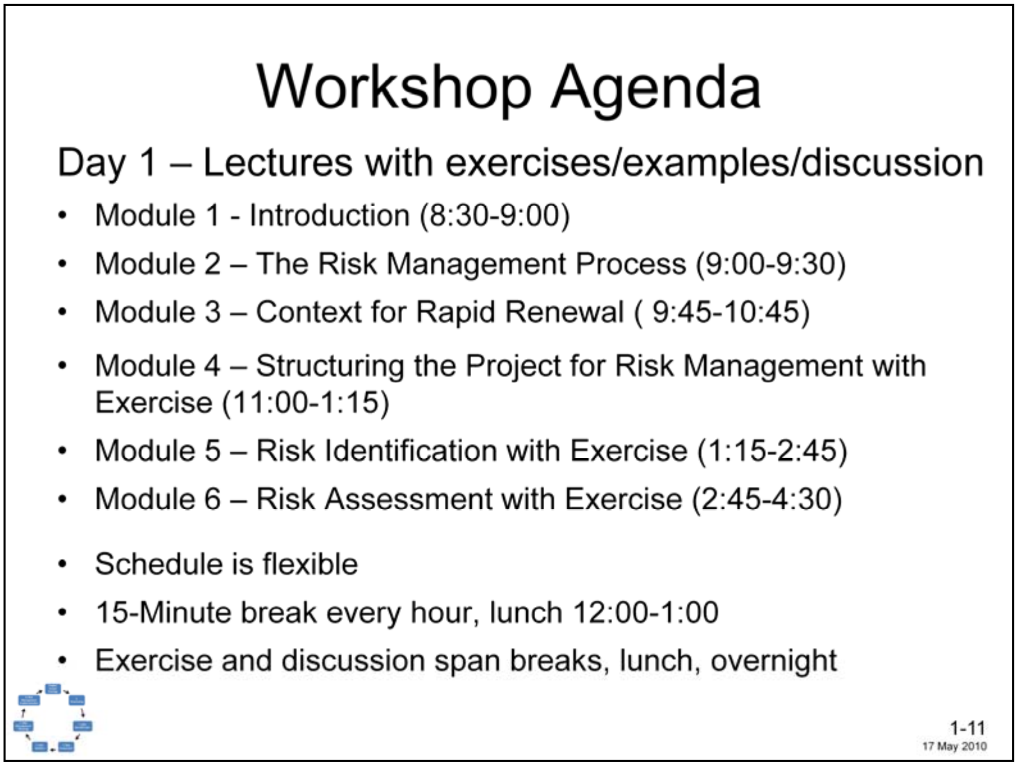
• Each module covers a specific topic (generally a chapter in the *Guide*) and is organized in a consistent way.

• Because the goal is to implement key parts of the *Guide*, the material is necessarily an extension of the *Guide* (i.e., new material not currently contained in the *Guide*).

•To facilitate implementation of the course material, hard copy forms and a corresponding MS Excel workbook template have been developed and given to each participant (see Appendix E in the *Guide*, and electronically on CD). The forms/template allows participants to complete the various steps in Risk Management for a particular project in a correct and efficient manner, with the template also doing the various calculations automatically.

• A hypothetical case study (see Appendix F in the *Guide*) is used throughout the workshop.

• Select key reference papers are also provided (on CD).

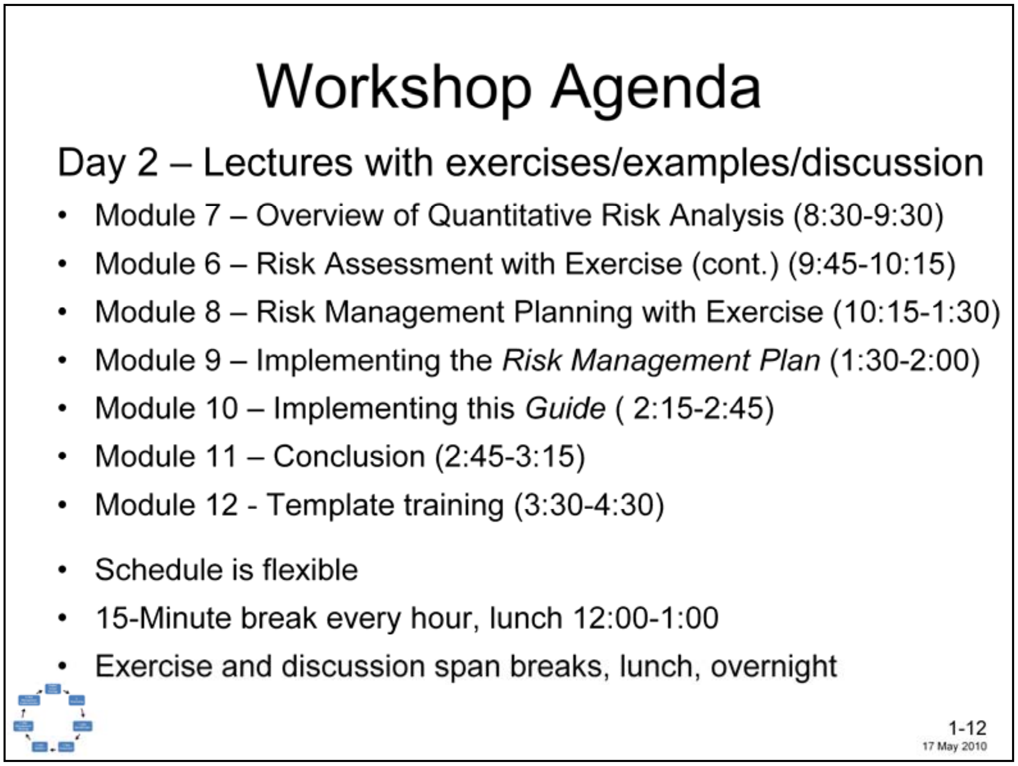


Workshop Agenda

Day 1 – Lectures with exercises/examples/discussion

- Module 1 - Introduction (8:30-9:00)
- Module 2 – The Risk Management Process (9:00-9:30)
- Module 3 – Context for Rapid Renewal (9:45-10:45)
- Module 4 – Structuring the Project for Risk Management with Exercise (11:00-1:15)
- Module 5 – Risk Identification with Exercise (1:15-2:45)
- Module 6 – Risk Assessment with Exercise (2:45-4:30)

- Schedule is flexible
- 15-Minute break every hour, lunch 12:00-1:00
- Exercise and discussion span breaks, lunch, overnight



Workshop Agenda

Day 2 – Lectures with exercises/examples/discussion

- Module 7 – Overview of Quantitative Risk Analysis (8:30-9:30)
- Module 6 – Risk Assessment with Exercise (cont.) (9:45-10:15)
- Module 8 – Risk Management Planning with Exercise (10:15-1:30)
- Module 9 – Implementing the *Risk Management Plan* (1:30-2:00)
- Module 10 – Implementing this *Guide* (2:15-2:45)
- Module 11 – Conclusion (2:45-3:15)
- Module 12 - Template training (3:30-4:30)

- Schedule is flexible
- 15-Minute break every hour, lunch 12:00-1:00
- Exercise and discussion span breaks, lunch, overnight

Introduction

- Opening remarks
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- Workshop goals
- Workshop agenda
- **Workshop logistics**

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Facility information (e.g., contacts, phones, restrooms, computers, power, internet, etc.) and safety/emergency egress.

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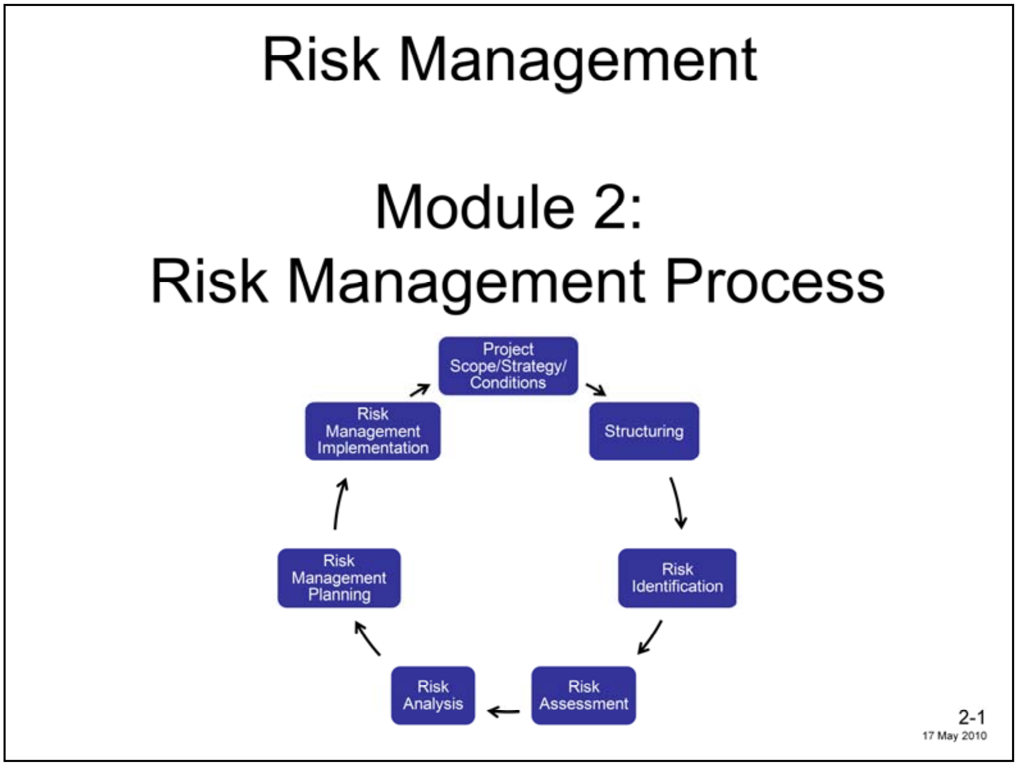

Risk Management

Module 2:
Risk Management Process

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

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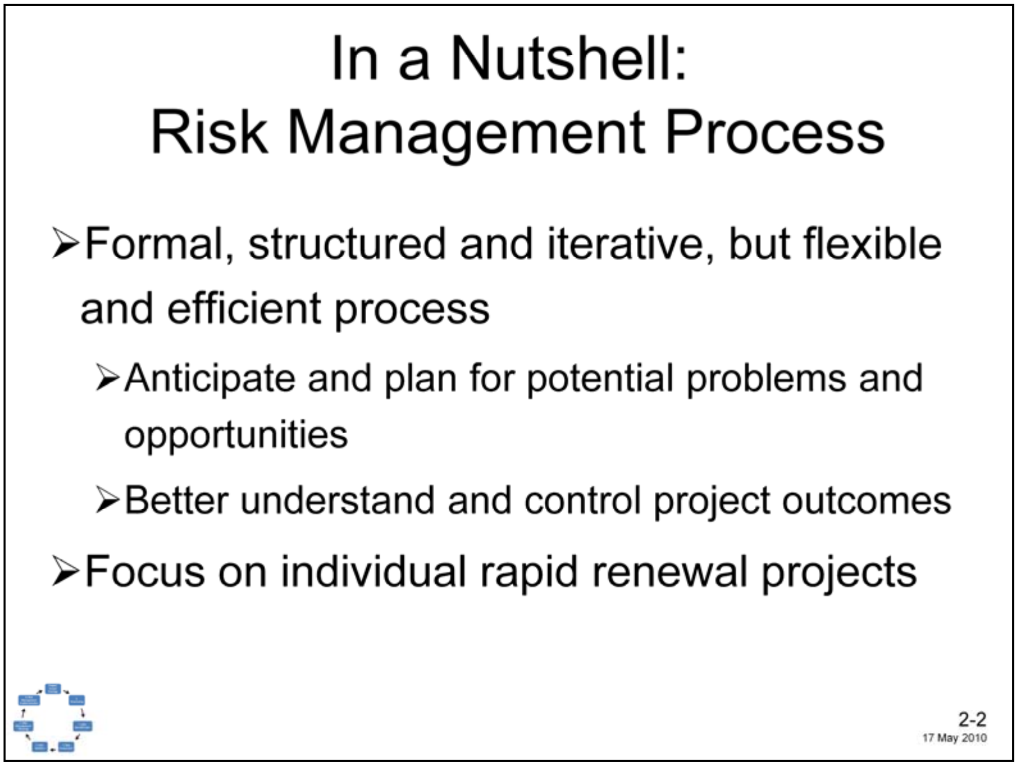
Map of formal, structured and iterative process for identifying, evaluating, and ultimately optimally managing risks (both proactive reduction of individual risks and reactive response to collective risks, in terms of contingency funds/float and recovery plans), which is used throughout this course.



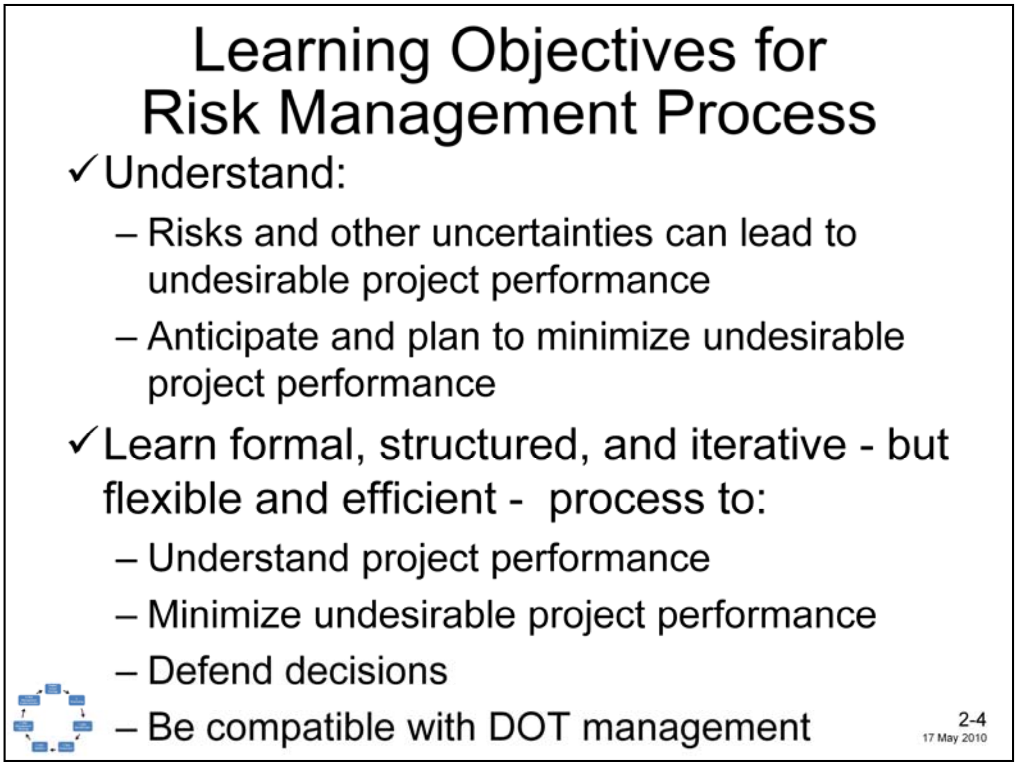
In a Nutshell: Risk Management Process

- Formal, structured and iterative, but flexible and efficient process
  - Anticipate and plan for potential problems and opportunities
  - Better understand and control project outcomes
- Focus on individual rapid renewal projects

Risk management is the formal, structured and iterative process of anticipating and planning for potential problems (“risks”), as well as opportunities (“negative risks”), *before* they occur, to better understand and control project outcomes (e.g., cost and schedule). It also needs to be adequately accurate and defensible, as well as flexible and efficient, and compatible with the DOT. The process is applicable to all kinds of projects (including programs of projects), but the focus here is on individual rapid renewal projects.

Risk Management Process

- Learning Objectives
- Background
- Methods
- Discussion of DOT Applicability
- Summary



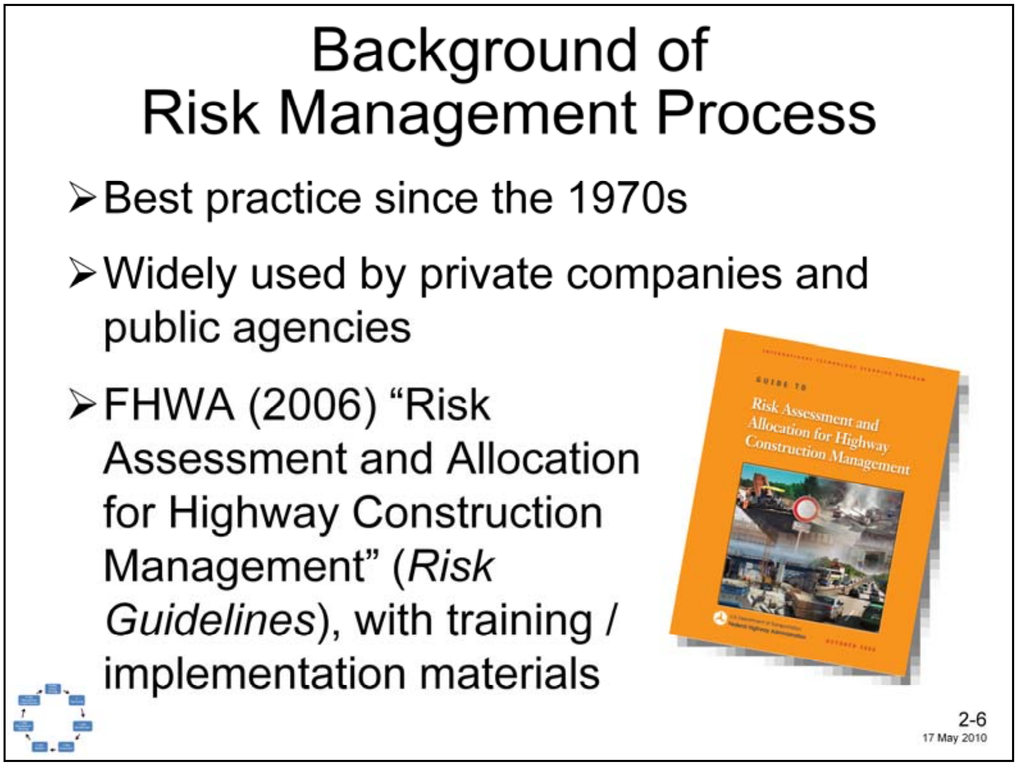
Learning Objectives for Risk Management Process

- ✓ Understand:
  - – Risks and other uncertainties can lead to undesirable project performance
  - – Anticipate and plan to minimize undesirable project performance
- ✓ Learn formal, structured, and iterative - but flexible and efficient - process to:
  - – Understand project performance
  - – Minimize undesirable project performance
  - – Defend decisions
  - – Be compatible with DOT management

- Understand the need for adequately anticipating and planning for potential problems (“risks”), as well as opportunities, that can significantly affect project outcomes, before they occur (“project risk management”), to:
  - Better understand possible project outcomes (e.g., establish realistic budgets and milestones)
  - Better control project outcomes (e.g., minimize cost and schedule)
  - Better allocate risks to the party that can best control them throughout the project development and construction process
- Establish a formal, structured and iterative, but flexible and efficient, process for project risk management, which is adequately accurate and defensible, as well as compatible with the DOT culture and organization.
- Focus on rapid renewal projects

Risk Management Process

- Learning Objectives
- **Background**
- Methods
- Discussion of DOT Applicability
- Summary



Background of Risk Management Process

- ➢Best practice since the 1970s
- ➢Widely used by private companies and public agencies
- ➢FHWA (2006) “Risk Assessment and Allocation for Highway Construction Management” (*Risk Guidelines*), with training / implementation materials

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For example:

Internationally:

•The Highway Agency in England (HARM) group conducts risk analysis on large projects and recommends project delivery methods (e.g., design-bid-build, design-build, public-private partnership, etc.).
• Ministry of Transport, Public Works, and Water Management in the Netherlands does financial risk analysis to evaluate Public-Private Partnership.

US Best Practices, by:

- Project Management Institute
- Association for the Advancement of Cost Engineering International
- US Department of Energy

Other US Examples:

- WSDOT Cost Estimating Validation Process (CVEP) and Cost Risk Analysis (CRA)
- Caltrans Risk Management Program
- Federal Highway Administration and Federal Transit Administration

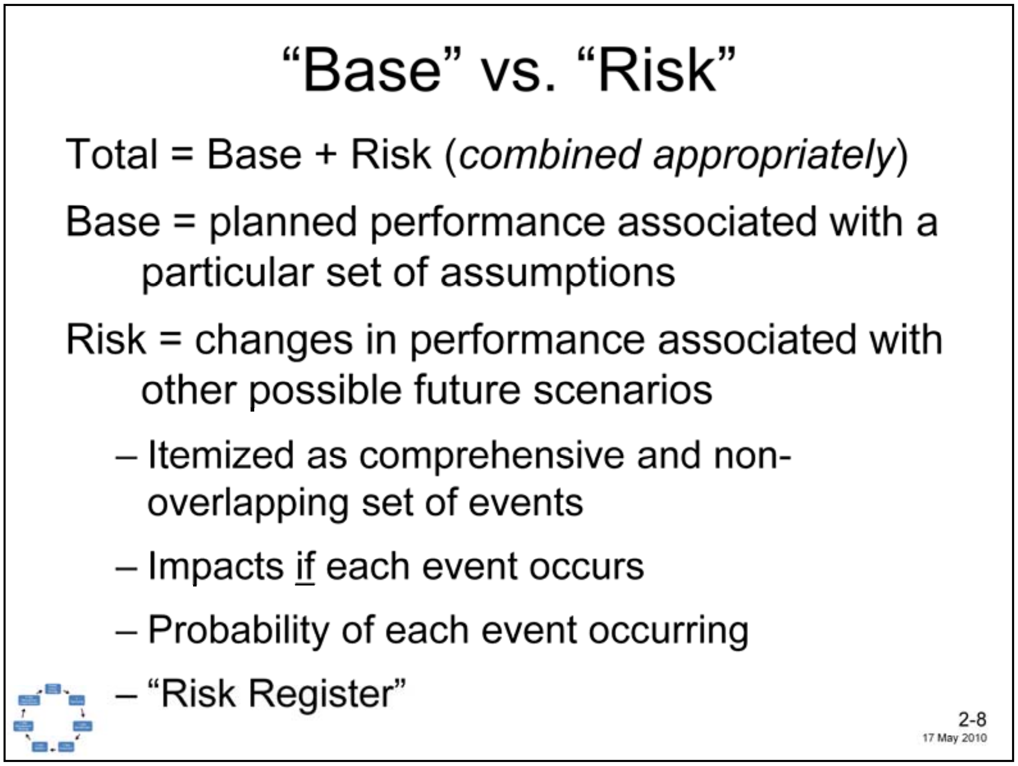
Private examples: Oil and gas; Manufacturing; Design-build development projects

Risk management should better align team goals with customer goals. A few examples of these concepts include:

- If there is a risk that the project cannot be completed by a required date through traditional design-bid-build methods, a design-build method may be selected to share the risk and achieve the customer goals.
- If there is a risk that traffic will be adversely affected by the project, a lane rental contract may be selected to align team members with customer goals.
- If there is a risk that a project could have environmental impacts during construction, incentives may be included in the contract to align team goals with the larger customer goals.

Risk Management Process

- Learning Objectives
- Background
- **Methods**
- Discussion of DOT Applicability
- Summary



“Base” vs. “Risk”

Total = Base + Risk (*combined appropriately*)

Base = planned performance associated with a particular set of assumptions

Risk = changes in performance associated with other possible future scenarios

- Itemized as comprehensive and non-overlapping set of events
- Impacts if each event occurs
- Probability of each event occurring
- “Risk Register”

For example: Suppose that the “base” assumption for costing and scheduling a task is that suitable materials are on hand. However, there is a chance (e.g., 1 in 4) that suitable materials will not be there when needed, in which case it will cost extra and take extra time to obtain those materials – this is a “risk”.

Conversely, if the base assumption is that suitable materials are not on hand and must be obtained, then there is a chance (e.g., 3 in 4) that suitable materials are already on hand, in which case the time and cost to obtain those materials will be saved – this is an “opportunity”.

Project Changes Over Time

- Changes in base and/or risk due to:
  - Project development
  - Changing conditions
  - Unplanned events
  - New information
- Risks eventually either occur (become base) or not (go away)
- Proactively manage specific risks (or base via VE) resulting in "residual" risk
- Establish and control contingency for collective residual risks

Risk Management Process

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

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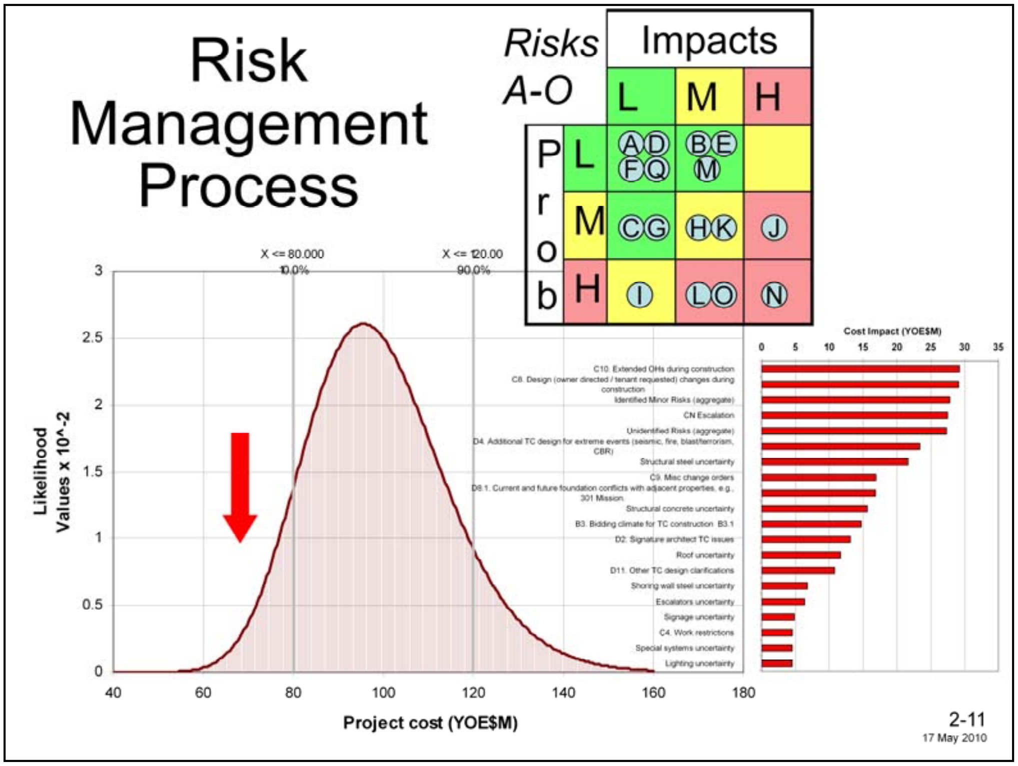
- A formal, systematic and iterative approach is required to provide accurate and defensible results. A flexible process (especially regarding level of detail) is needed for efficiency.
- Steps in process (see *Guide*):
  1. Structuring – define “base” scope, strategy, conditions and assumptions, and associated performance
  2. Risk Identification – identify comprehensive and non-overlapping set of potential problems and opportunities (events) relative to the base (“Risk Register”)
  3. Risk Assessment – assess (either qualitatively or quantitatively) the impacts and probability of each risk
  4. Risk Analysis – if assess risks (and other uncertainties) quantitatively, can quantify uncertainty in performance
  5. Risk Management Planning – identify, evaluate and recommend ways to cost-effectively reduce individual risks, as well as establish contingency allowances and plans (“Risk Management Plan” or “RMP”)
  6. Risk Management Implementation – carry out RMP, including tracking/monitoring/updating risks and contingencies
- Various methods are available for each step, which will be discussed later. Each has advantages and disadvantages and must be compatible. Choose the appropriate method(s) for specific application, considering needs for accuracy and defensibility, as well as associated effort.
- Medical analogy:
  - diagnosis (risk assessment)
  - treatment (risk management)



Risk Management Process

Risks A-O		Impacts L	Impacts M	Impacts H
Prob	L	A D F Q	B E M	
	M	C G	H K	J
	H	I	L O	N

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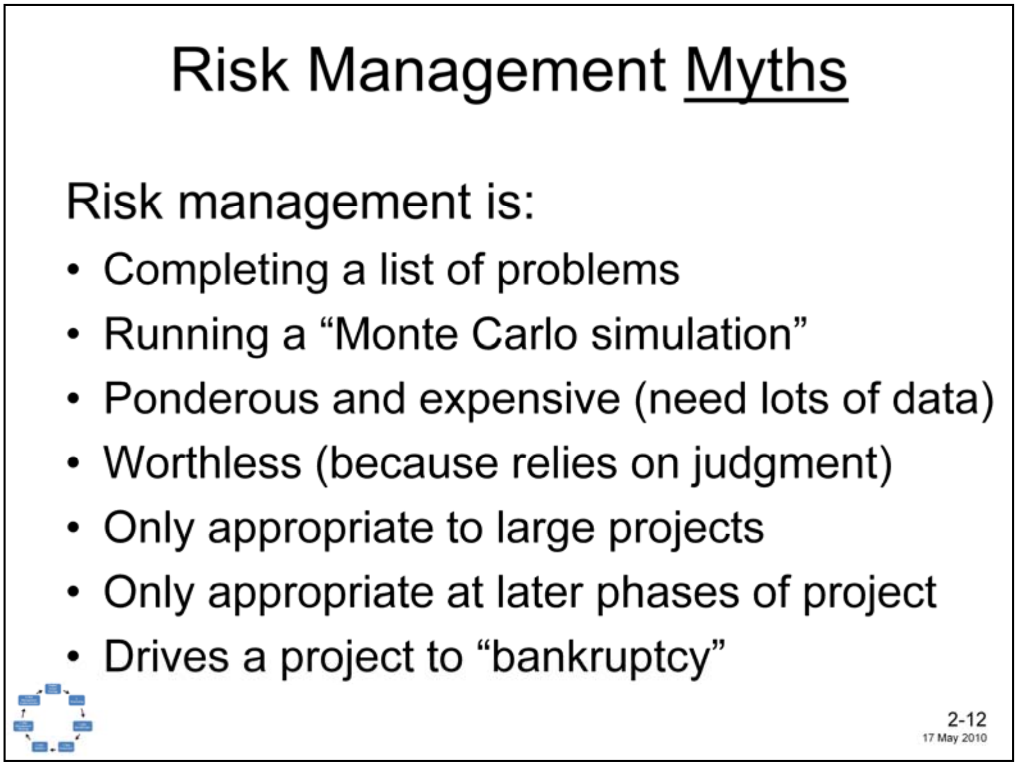
- Quantitative:
  - Quantify significance of each risk (e.g., for subsequent risk management cost-benefit analysis)
  - Quantify uncertainty in project performance (e.g., total escalated cost)
- Qualitative:
  - Rate each risk (e.g., to guide subsequent risk management)
  - Influence project performance estimate (e.g., contingency)



Risk Management Myths

Risk management is:

- Completing a list of problems
- Running a “Monte Carlo simulation”
- Ponderous and expensive (need lots of data)
- Worthless (because relies on judgment)
- Only appropriate to large projects
- Only appropriate at later phases of project
- Drives a project to “bankruptcy”

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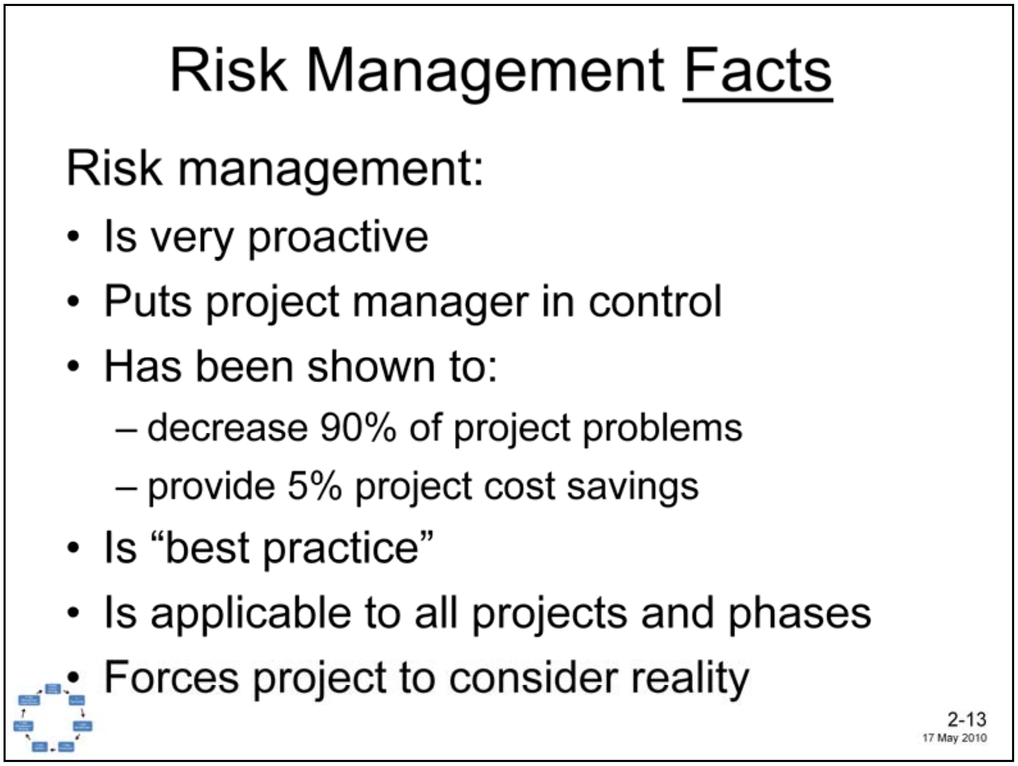
Risk Management Myths:

- Risk management is simply completing a list of what can go wrong
- Risk management is simply running a Monte Carlo simulation – a “black box” based on statistics that are difficult to obtain
- Risk management is ponderous, expensive and only appropriate to large projects and later project phases
- Risk management can drive a project to bankruptcy or unreasonable funding requests



Risk Management Facts

Risk management:

- Is very proactive
- Puts project manager in control
- Has been shown to:
  - decrease 90% of project problems
  - provide 5% project cost savings
- Is "best practice"
- Is applicable to all projects and phases
- Forces project to consider reality

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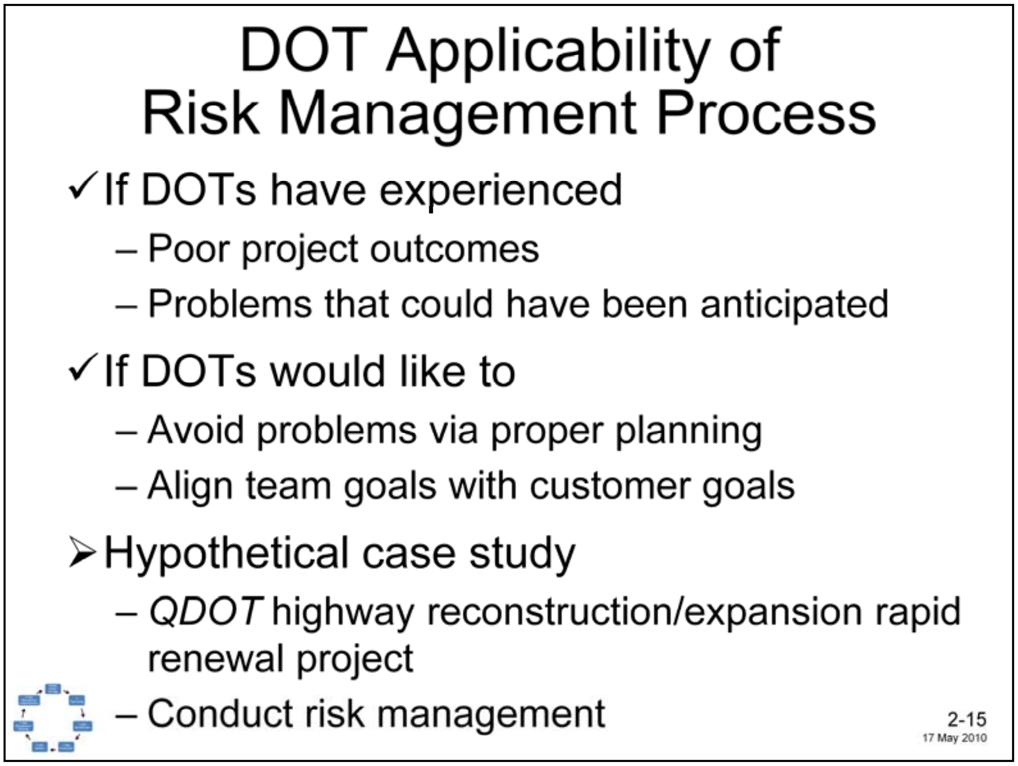
Risk Management Facts:

- Risk management is a very proactive task (as opposed to reactive, which is often too late) – it consists of anticipating potential problems as early as possible and appropriately planning for them beforehand
- Risk management allows the project manager to be in control of the project as much as possible instead of the project being in control of the project manager
- Studies show that the use of Risk Management can:
  - decrease 90% of project problems - *Project Management Institute*
  - result in 5% project cost savings - *Construction Management Institute*
- Widely recognized (and used) as best practice, which can be used for all projects and project phases – can be efficient because flexible (e.g., re level of detail)
- Attempts to match reality (possible outcomes and their relative likelihood), not worst or optimistic cases

Risk Management Process

- Learning Objectives
- Background
- Methods
- **Discussion of DOT Applicability**
- Summary



DOT Applicability of Risk Management Process

- ✓ If DOTs have experienced
  - – Poor project outcomes
  - – Problems that could have been anticipated
- ✓ If DOTs would like to
  - – Avoid problems via proper planning
  - – Align team goals with customer goals
- ➢ Hypothetical case study
  - – *QDOT* highway reconstruction/expansion rapid renewal project
  - – Conduct risk management

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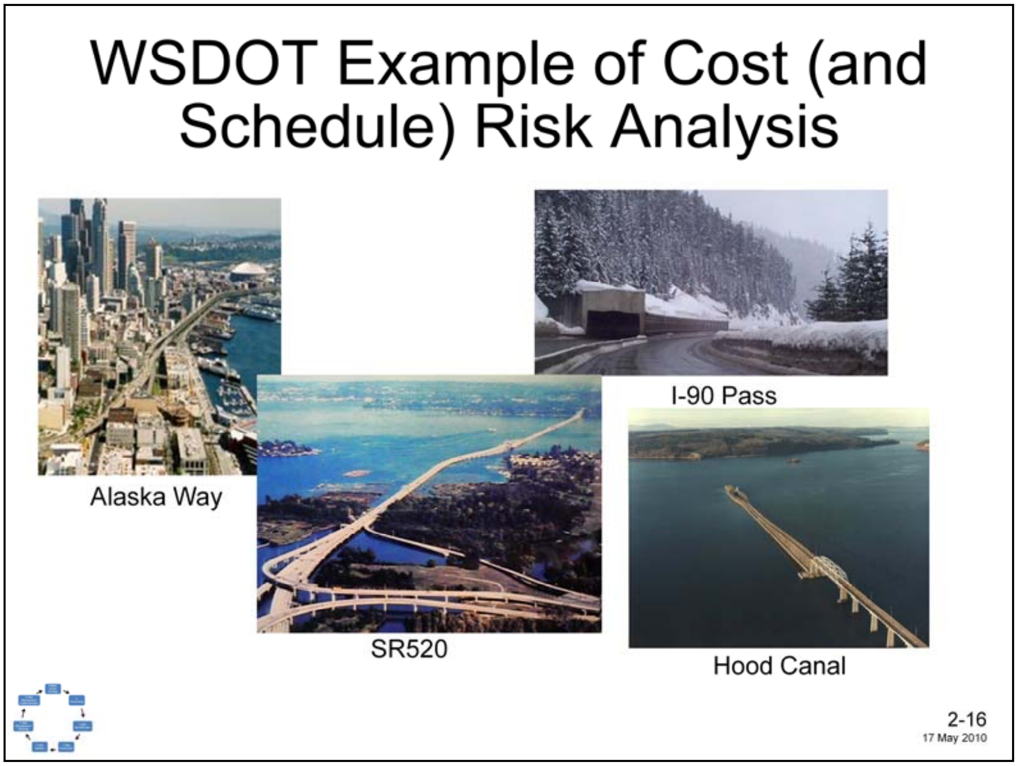
- Which DOT projects have experienced problems resulting in poor project outcomes (e.g., schedule and cost overruns)?
- What kind of problems were experienced (e.g., differing site conditions, haz mat, utility relocations, problems with new construction techniques, project delivery issues, politics, etc.)?
- Could the possibility of those problems have been recognized beforehand (e.g., "what if")? If so, when?
- Would project plans have changed if those potential problems had been recognized beforehand?
  - If so, how and how would that have changed the project outcome?
  - If not, why not?
- Can risks be better allocated to align project team goals (DOT and contractors) with customer goals?
  - Can we improve current DOT understanding of appropriate risk allocation?
  - Can we better select when to apply alternative contracting methods?

A hypothetical case study, which will be used throughout the workshop, is presented in Appendix F of the *Guide*:

QDOT is planning a significant highway reconstruction/expansion project. The objectives are to minimize cost, minimize schedule, and minimize disruption during construction, and maximize longevity of the constructed facility after construction. Recognizing the uncertainty and risk inherent in this project, QDOT decided to conduct risk assessment and risk management planning, followed by implementation of the resulting *Risk Management Plan*, to optimize satisfaction of these objectives (as described in general terms in Chapter 2 of the *Guide*). To accomplish this (as subsequently described in Chapter 10 of the *Guide*), QDOT:

- convened a group of project-team staff and independent subject-matter experts from the key project disciplines, facilitated by a qualified risk elicitor and analyst, to conduct risk assessment and risk management planning (consistent with the principles, processes and guidance described throughout the *Guide*); and
- assigned a Risk Manager (with adequate authority and resources) to implement the resulting *Risk Management Plan*.



WSDOT Example of Cost (and Schedule) Risk Analysis

Prior to 2002, WSDOT experienced significant cost growth on some projects (e.g., from $150M to $1B on one particular project over ten years of planning), which led to line item project funding from the State legislature and defeat (by public vote) of a major funding package. In response, in 2002 WSDOT (supported by Golder Associates and Prof. Molenaar) developed a Cost Risk Analysis program. Since 2002, more than 100 projects, with capital cost of more than $30B, have been evaluated, and several hundred people have been trained. This has resulted in fewer cost / schedule overruns, and better public support (including more funding). For more information on the WSDOT Cost Risk Analysis and their Cost Estimating Validation Tool, refer to:

<www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment>

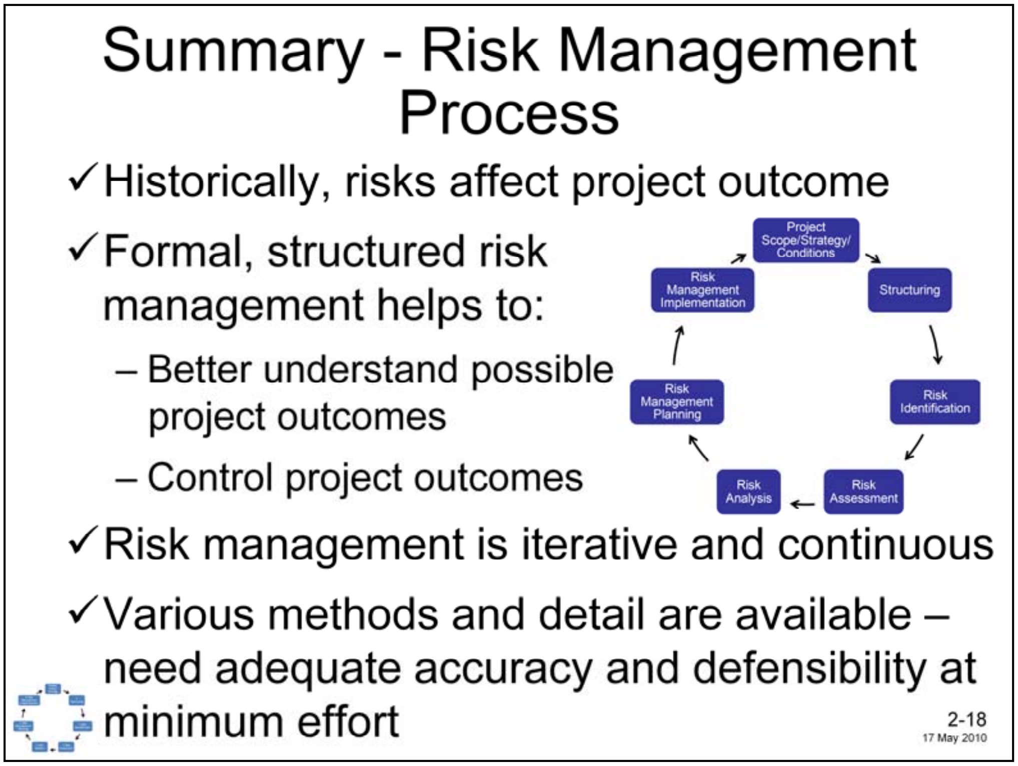
Four of WSDOT's ten mega-projects are shown: SR-99 Alaska Way Viaduct, I-90 east of Snoqualmie Pass, Hood Canal floating bridge, SR520 floating bridge.

FHWA and FTA, as well as many US state and Canadian provincial highway departments and other public agencies (e.g., turnpike authorities, transit agencies, etc.), have used similar approaches, often based on the WSDOT program.

Risk Management Process

- Learning Objectives
- Background
- Methods
- Discussion of DOT Applicability

➢ **Summary**



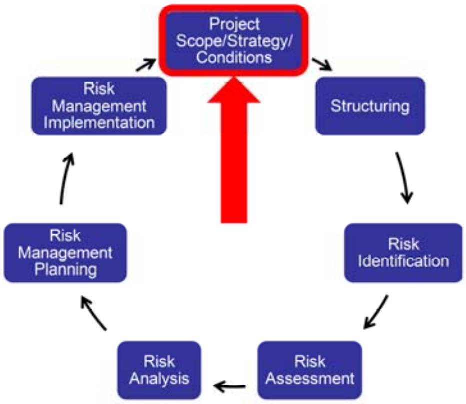
Summary - Risk Management Process

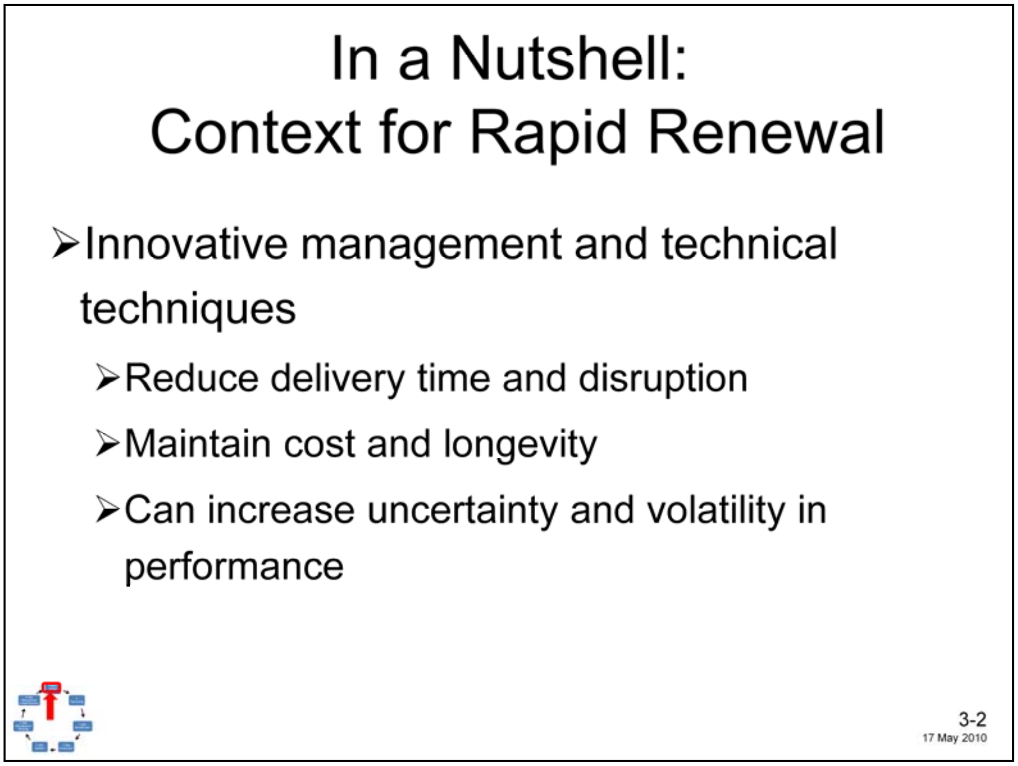
- ✓ Historically, risks affect project outcome
- ✓ Formal, structured risk management helps to:
  - Better understand possible project outcomes
  - Control project outcomes
- ✓ Risk management is iterative and continuous
- ✓ Various methods and detail are available – need adequate accuracy and defensibility at minimum effort

- As shown historically, many projects have significant risks that can affect project outcomes (e.g., schedule and cost overruns). Typically, most project managers already do “risk management” but not in a systematic manner.
- Also as shown, formal/structured risk management helps to:
  - Better understand possible project outcomes (e.g., budget and milestones)
  - Control project outcomes (e.g., minimize schedule and cost)
- For maximum benefit, risk management should be done throughout project development
- Various methods are available for conducting risk management. Each has advantages and disadvantages (e.g., limitations and pitfalls). Different methods might be more appropriate at various stages of project development.
- Various levels of detail can be used, which will affect accuracy and defensibility, as well as effort.

Risk Management

Module 3:
Context for Rapid Renewal





In a Nutshell:
Context for Rapid Renewal

- Innovative management and technical techniques
  - Reduce delivery time and disruption
  - Maintain cost and longevity
  - Can increase uncertainty and volatility in performance

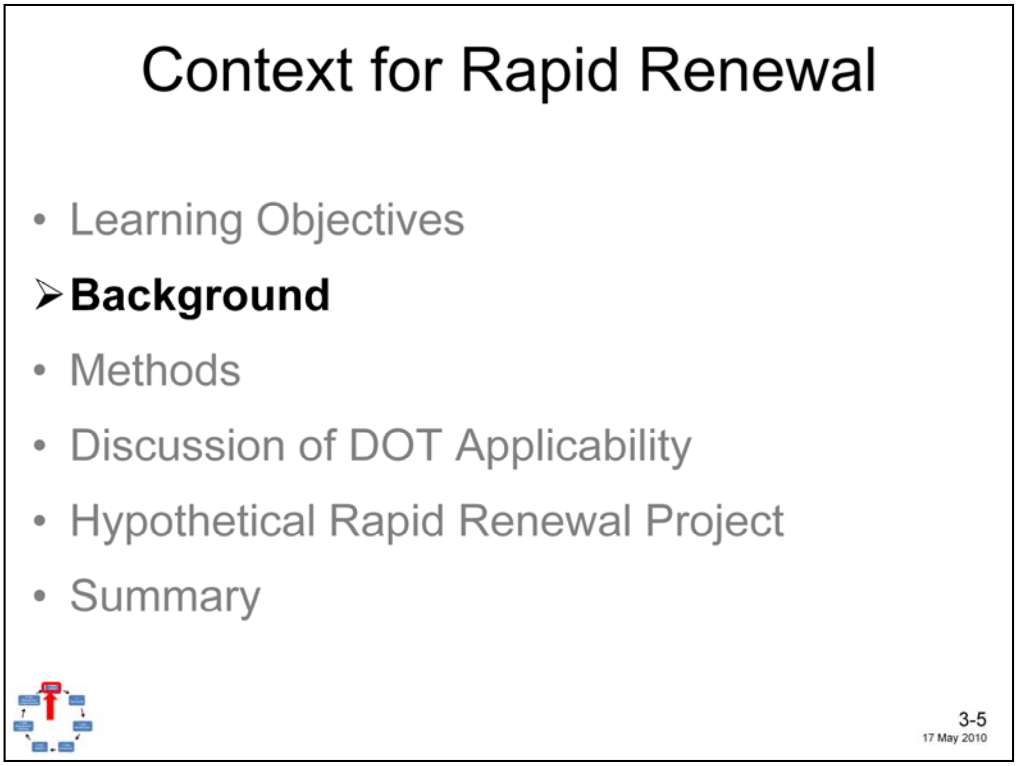
With the increasing challenges posed by aging infrastructure and reduced funding, rapid renewal strategies and tactics will be increasingly required to deliver long-lasting projects quickly, cost-effectively, and with minimal disruption. However, such rapid renewal strategies and techniques are, in many cases, somewhat innovative and thus might perform in unexpected ways. This uncertainty, especially in high-visibility projects that serve as critical transportation links, can impact the public’s opinion of our highway agencies and ultimately the performance of our transportation network. Formal and consistent risk management will be required to help ensure that state highway agencies meet their objectives for rapid renewal projects.

Context for Rapid Renewal

- Learning Objectives
- Background
- Methods
- Discussion of DOT Applicability
- Hypothetical Rapid Renewal Project
- Summary

Learning Objectives for Rapid Renewal Context

- ✓ Understand rapid renewal
  - – Strategies and tactics/methods
  - – Project performance objectives
  - – Project phases
- ✓ Understand context for risk management process in the rapid renewal context



Context for Rapid Renewal

- Learning Objectives
- **Background**
- Methods
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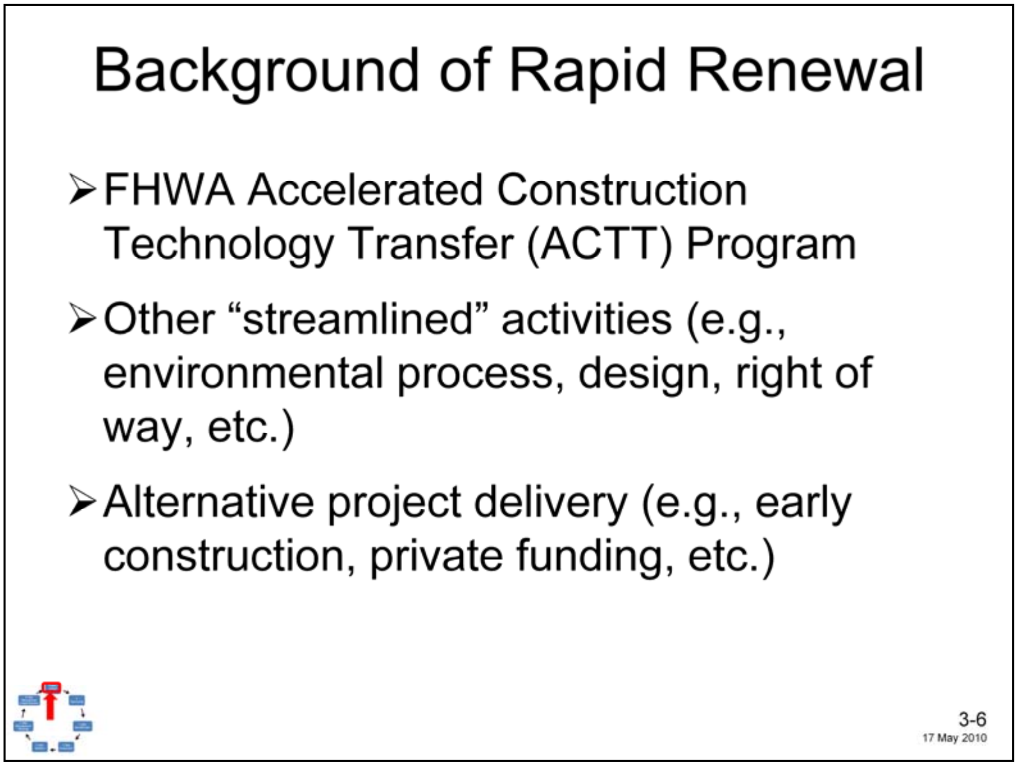
- Summary



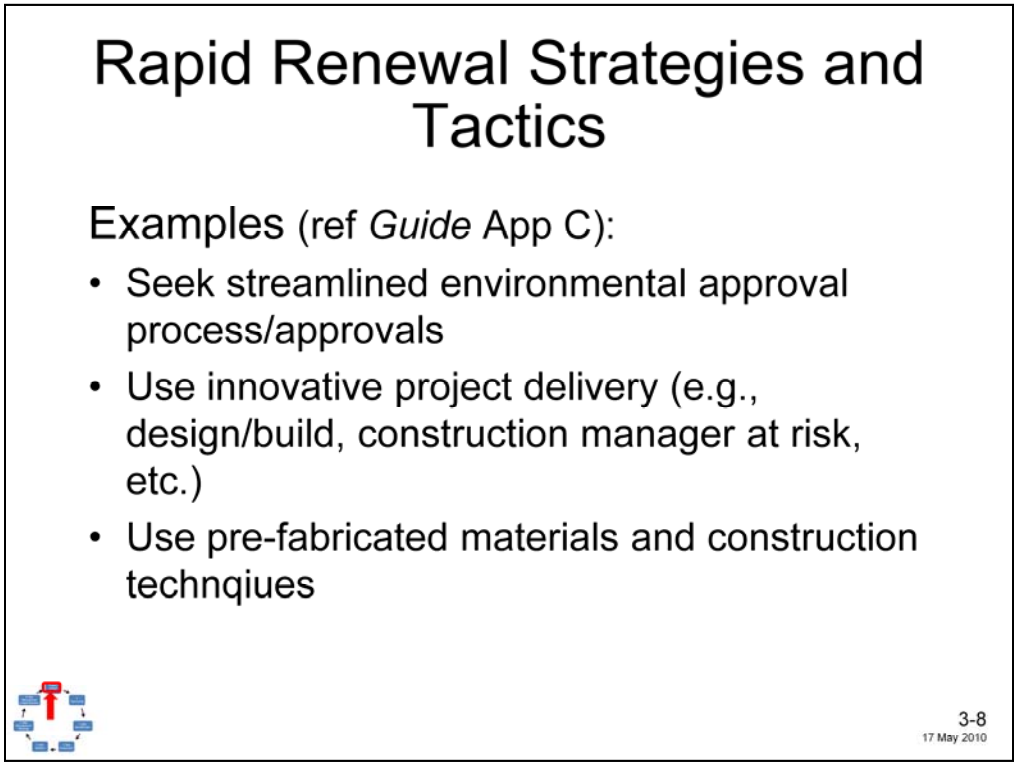
Background of Rapid Renewal

- FHWA Accelerated Construction Technology Transfer (ACTT) Program
- Other “streamlined” activities (e.g., environmental process, design, right of way, etc.)
- Alternative project delivery (e.g., early construction, private funding, etc.)

The Federal Highway Administration (FHWA), American Association of State Highway Transportation Officials (AASHTO), and the Transportation Research Board (TRB) have been actively developing the concepts underlying rapid renewal. The FHWA and AASHTO have been at the forefront of the effort through their work on the Accelerated Construction Technology Transfer (ACTT) Program. Although “construction” is in the ACTT title, the program addresses all phases of project delivery.

Context for Rapid Renewal

- Learning Objectives
- Background
- ➢ **Methods**
- Discussion of DOT Applicability
- Hypothetical Rapid Renewal Project
- Summary



Rapid Renewal Strategies and Tactics

Examples (ref *Guide* App C):

- Seek streamlined environmental approval process/approvals
- Use innovative project delivery (e.g., design/build, construction manager at risk, etc.)
- Use pre-fabricated materials and construction technqiues

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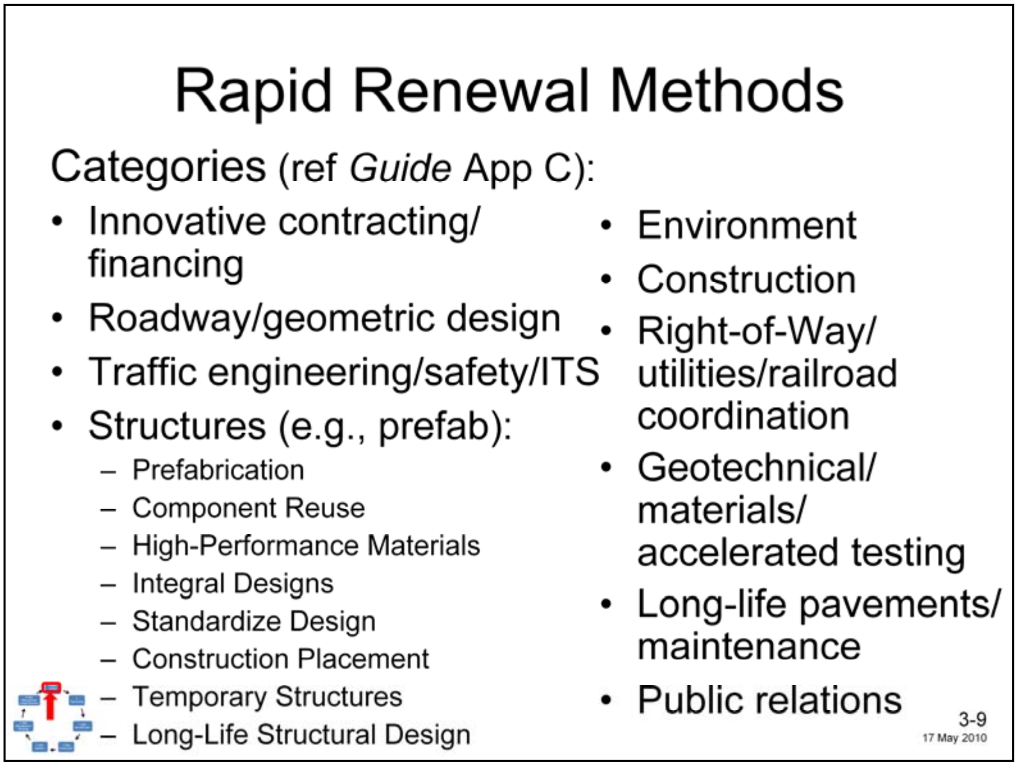
Table 3-1. Typical Project Phases and Example Rapid Renewal Strategies (in *Guide*).

Project Phases	**Typical Activities**	**Example Rapid Renewal Strategies**
Planning	Determine purpose and need; consider environmental factors; facilitate public involvement/ participation; consider interagency conditions; etc.	Conduct accelerated programmatic/ portfolio planning; conduct accelerated internal coordination; conduct accelerated external planning; etc.
Scoping	Determine design criteria and parameters; make preliminary plans such as alternative selections; assign geometry; project delivery strategy; programming; obtain funding authorization; etc.	Conduct accelerated and comprehensive scoping; employ master planning/integrated project development process; use innovative project delivery (e.g., design-build, construction manager at risk, etc.); etc.
Environmental	Conduct environmental analysis including discipline studies; NEPA/SEPA; alternatives analysis; documentation; public hearings; etc.	Accelerate the environmental documentation process; seek streamlined environmental approval process/approvals; streamline mitigation planning and implementation; etc.
Design	Develop plans (preliminary and final), specifications; estimates; traffic control plans; etc.	Accelerate design process; seek streamlined design approvals; hold early constructability reviews; use innovative and/or long-life designs; etc.
Right-of-Way, Utilities, and Railroad	Determine right of way impact; develop right of way approach; acquire right of way; determine utilities impacts; coordinate with utilities; develop railroad impact; coordinate with railroad; etc.	Accelerate right-of-way planning; accelerate right-of-way acquisition; conduct early utility planning and coordination of agreements; accelerate utility relocation; conduct early railroad planning and coordination of agreements; etc.
Procurement	Prepare contract documents, advertise for bid/proposals; hold a pre-bid conference; receive and analyze bids/proposals; etc.	Use alternative contract packaging; employ advanced procurement; etc.
Construction	Initiate contract; mobilize; conduct inspection and materials testing; administer contract; control traffic; etc.	Use prefabricated materials and construction techniques; use modular construction techniques; full road closures or other innovated management of traffic techniques; etc.
Operations	Operate facility; monitor performance; provide services for customers; etc.	Consider privatized operations and maintenance; etc.
Replacement (or Decommissioning)	Planning for replacement; design and construction or replacement; decommissioning if appropriate; etc.	Accelerate planning for replacement or decommissioning; etc.



Rapid Renewal Methods

Categories (ref *Guide* App C):

- Innovative contracting/ financing
- Roadway/geometric design
- Traffic engineering/safety/ITS
- Structures (e.g., prefab):
  - Prefabrication
  - Component Reuse
  - High-Performance Materials
  - Integral Designs
  - Standardize Design
  - Construction Placement
  - Temporary Structures
  - Long-Life Structural Design
- Environment
- Construction
- Right-of-Way/ utilities/railroad coordination
- Geotechnical/ materials/ accelerated testing
- Long-life pavements/ maintenance
- Public relations

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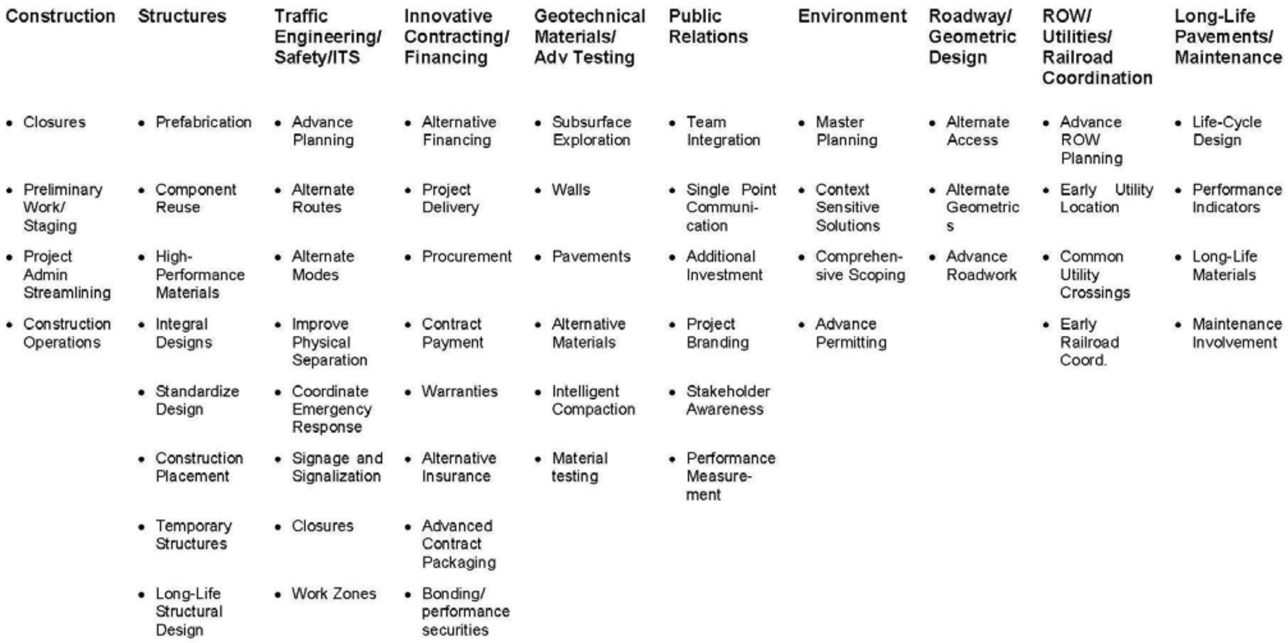
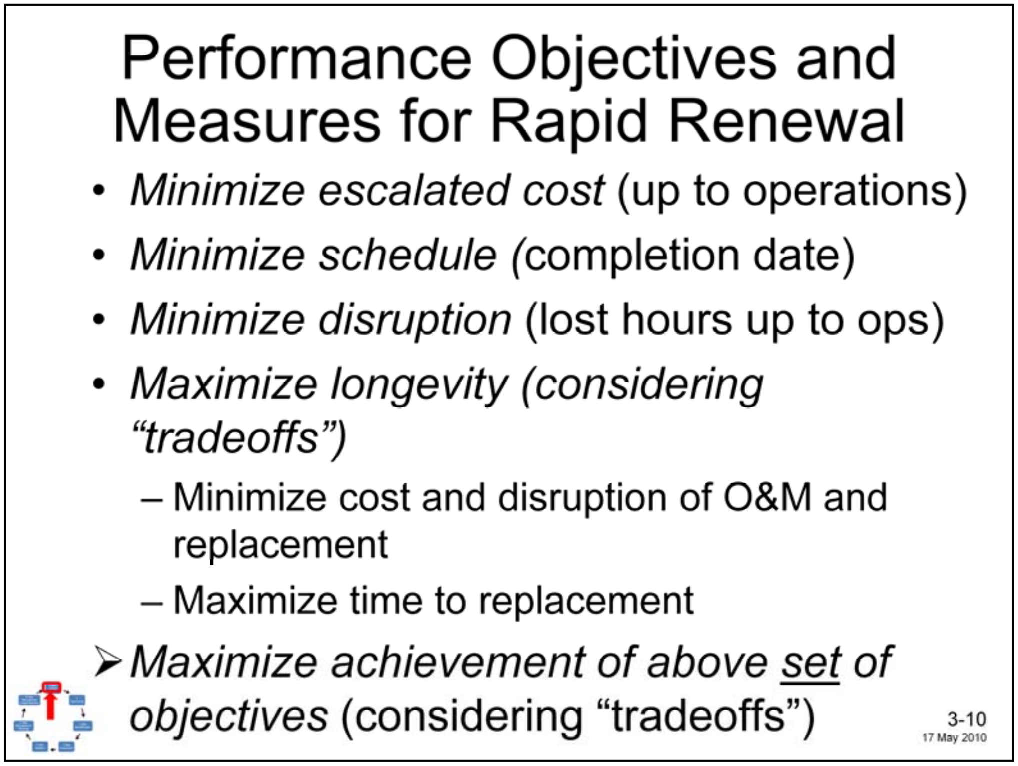
Each of the functional areas in this list can impact rapid renewal projects. Figure C-2. Rapid Renewal Inventory Hierarchy (in the *Guide*) describes how these functional areas contribute to rapid renewal projects. These functional areas are based on the ACTT areas of expertise and analysis.



Construction	Structures	Traffic Engineering/ Safety/ITS	Innovative Contracting/ Financing	Geotechnical Materials/ Adv Testing	Public Relations	Environment	Roadway/ Geometric Design	ROW/ Utilities/ Railroad Coordination	Long-Life Pavements/ Maintenance
• Closures	• Prefabrication	• Advance Planning	• Alternative Financing	• Subsurface Exploration	• Team Integration	• Master Planning	• Alternate Access	• Advance ROW Planning	• Life-Cycle Design
• Preliminary Work/ Staging	• Component Reuse	• Alternate Routes	• Project Delivery	• Walls	• Single Point Communication	• Context Sensitive Solutions	• Alternate Geometrics	• Early Utility Location	• Performance Indicators
• Project Admin Streamlining	• High-Performance Materials	• Alternate Modes	• Procurement	• Pavements	• Additional Investment	• Comprehensive Scoping	• Advance Roadwork	• Common Utility Crossings	• Long-Life Materials
• Construction Operations	• Integral Designs	• Improve Physical Separation	• Contract Payment	• Alternative Materials	• Project Branding	• Advance Permitting		• Early Railroad Coord.	• Maintenance Involvement
	• Standardize Design	• Coordinate Emergency Response	• Warranties	• Intelligent Compaction	• Stakeholder Awareness				
	• Construction Placement	• Signage and Signalization	• Alternative Insurance	• Material testing	• Performance Measurement				
	• Temporary Structures	• Closures	• Advanced Contract Packaging						
	• Long-Life Structural Design	• Work Zones	• Bonding/ performance securities						



Performance Objectives and Measures for Rapid Renewal

- *Minimize escalated cost* (up to operations)
- *Minimize schedule (*completion date)
- *Minimize disruption* (lost hours up to ops)
- *Maximize longevity (considering "tradeoffs")*
  - – Minimize cost and disruption of O&M and replacement
  - – Maximize time to replacement

➢ *Maximize achievement of above set of objectives* (considering "tradeoffs")

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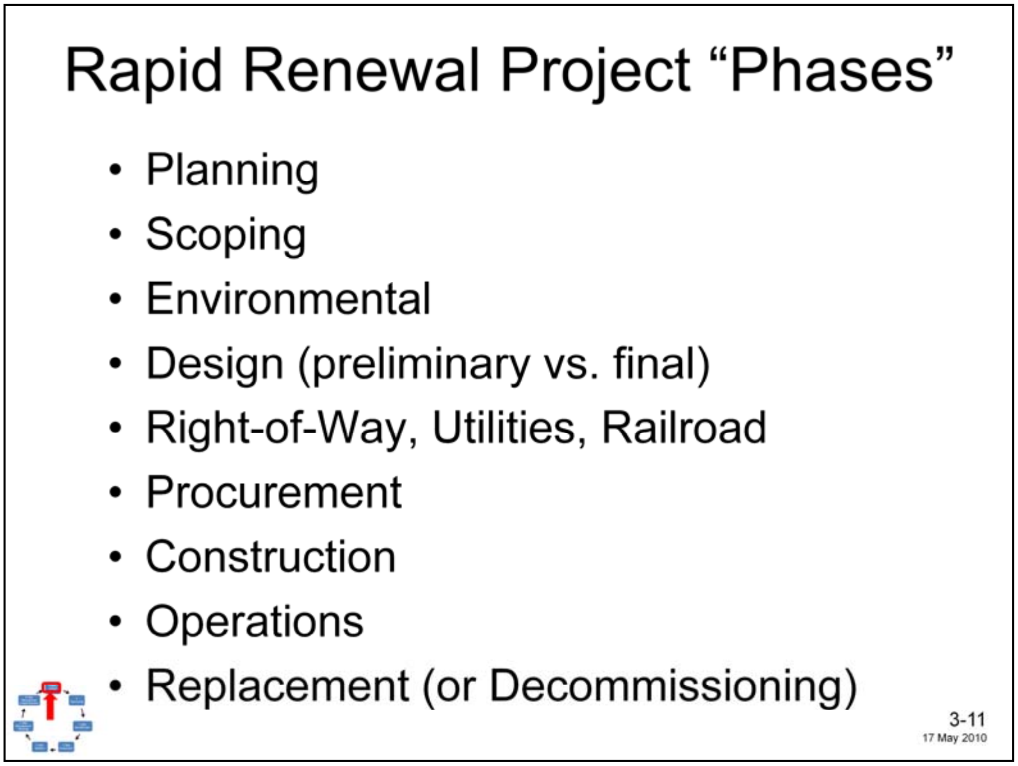
Additional performance objectives/measures for rapid renewal projects could include the following, depending upon project circumstances:

- Maximize chance to secure adequate project funding (funding delays covered in schedule performance measure);
- Minimize environmental impacts throughout project life;
- Minimize safety impacts during construction and throughout project life;
- Maximize stakeholder satisfaction regarding other project performance measures; and
- Maximize revenue during operations, if applicable.



Rapid Renewal Project "Phases"

- Planning
- Scoping
- Environmental
- Design (preliminary vs. final)
- Right-of-Way, Utilities, Railroad
- Procurement
- Construction
- Operations
- Replacement (or Decommissioning)

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Table 3-1. Typical Project Phases and Example Rapid Renewal Strategies (in *Guide*)

Project Phases	Typical Activities	Example Rapid Renewal Strategies
Planning	Determine purpose and need; consider environmental factors; facilitate public involvement/ participation; consider interagency conditions; etc.	Conduct accelerated programmatic/ portfolio planning; conduct accelerated internal coordination; conduct accelerated external planning; etc.
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Design	Develop plans (preliminary and final), specifications; estimates; traffic control plans; etc.	Accelerate design process; seek streamlined design approvals; hold early constructability reviews; use innovative and/or long-life designs; etc.
ROW, Utilities & RR	Determine right of way impact; develop right of way approach; acquire right of way; determine utilities impacts; coordinate with utilities; develop RR impact; coordinate with RR; etc.	Accelerate right-of-way planning; accelerate right-of-way acquisition; conduct early utility planning and coordination of agreements; accelerate utility relocation; conduct early RR planning and coordination of agreements; etc.
Procurement	Prepare contract documents, advertise for bid/proposals; hold a pre-bid conference; receive and analyze bids/proposals; etc.	Use alternative contract packaging; employ advanced procurement; etc.
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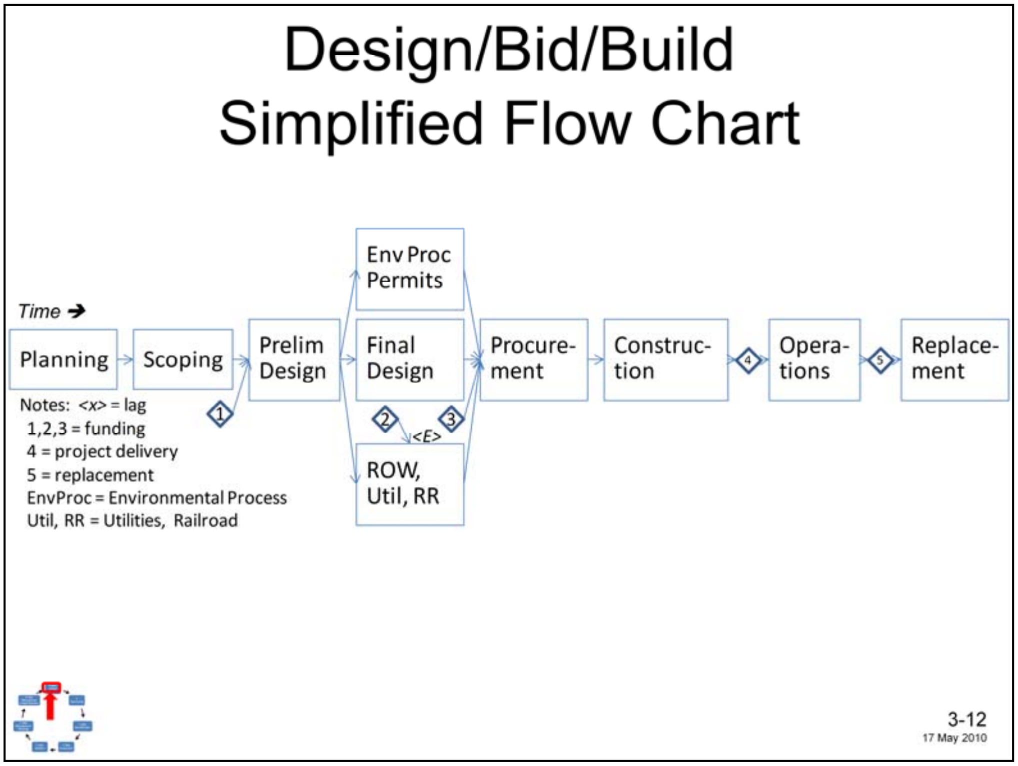

Design/Bid/Build Simplified Flow Chart

Time ➔

Planning

Scoping

Prelim Design

Env Proc Permits

Final Design

ROW, Util, RR

Procure-ment

Construc-tion

Opera-tions

Replace-ment

Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

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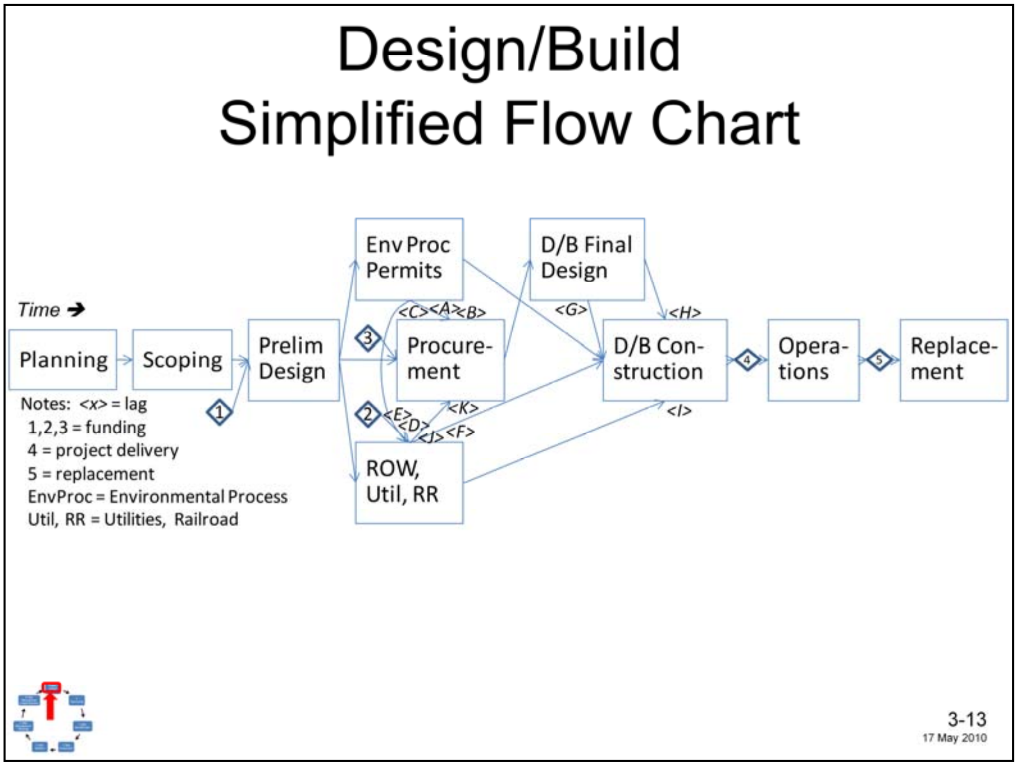
Note: Each box represents a phase, with the left side of the box representing the start and the right side representing the finish, and the top and bottom representing some point in between. Each arrow into a box represents a precedent requirement for that phase.

Simple level of detail – can be much more complicated.

Linear process.



Design/Build
Simplified Flow Chart

Time ➔

Planning

Scoping

Prelim Design

Env Proc Permits

Procure-ment

ROW, Util, RR

D/B Final Design

D/B Con-struction

Opera-tions

Replace-ment

<A> <B> <C> <D> <E> <F> <G> <H> <I> <J> <K>

① ② ③ ④ ⑤

Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

Note: Each box represents a phase, with the left side of the box representing the start and the right side representing the finish, and the top and bottom representing some point in between. Each arrow into a box represents a precedent requirement for that phase.

Simple level of detail – can be much more complicated.

Not as linear as design/bid/build - accelerates project delivery.

Context for Rapid Renewal

- Learning Objectives
- Background
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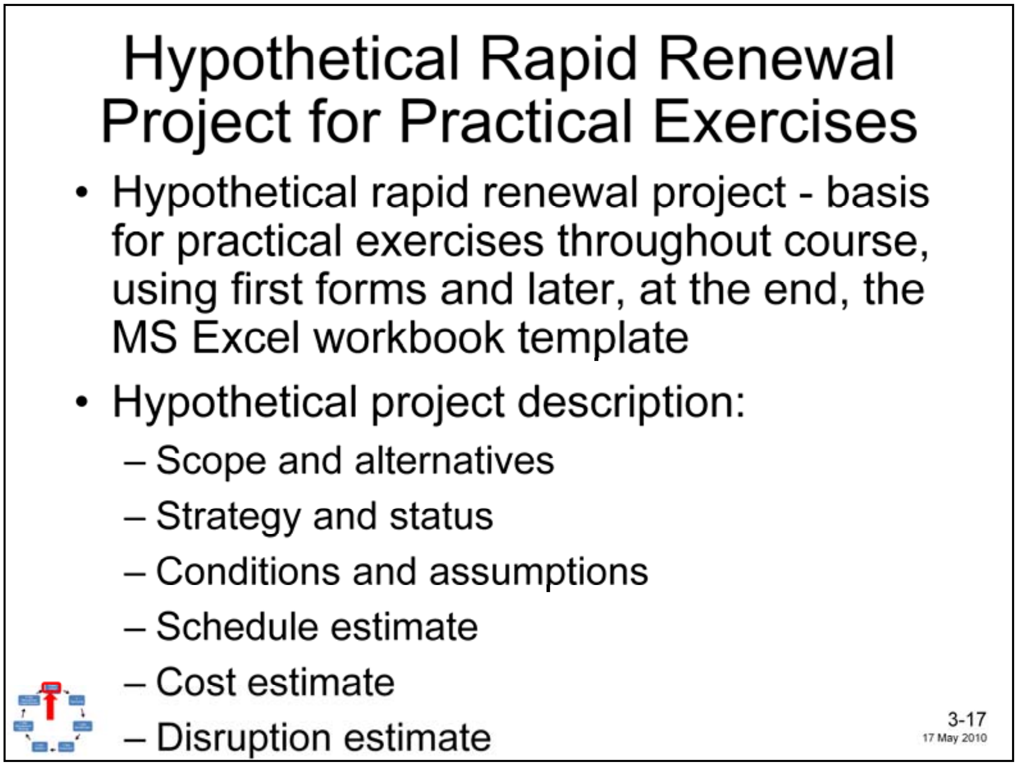
- **Discussion of DOT Applicability**
- Hypothetical Rapid Renewal Project
- Summary

DOT Applicability of Rapid Renewal

- ✓ Previous rapid renewal projects?
  - Methods?
  - Problems?
- ✓ Future rapid renewal projects?
  - Methods?
  - Concerns?

Context for Rapid Renewal

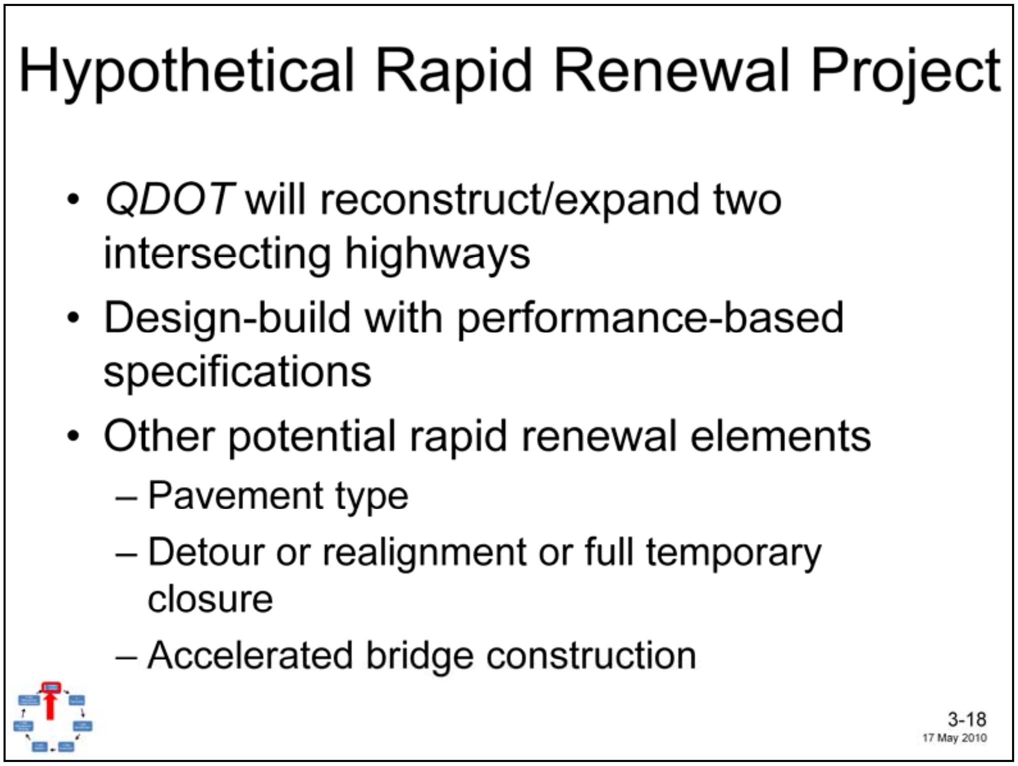
- Learning Objectives
- Background
- Methods
- **Discussion of DOT Applicability**
- ➢ **Hypothetical Rapid Renewal Project**
- Summary



Hypothetical Rapid Renewal Project for Practical Exercises

- Hypothetical rapid renewal project - basis for practical exercises throughout course, using first forms and later, at the end, the MS Excel workbook template
- Hypothetical project description:
  - Scope and alternatives
  - Strategy and status
  - Conditions and assumptions
  - Schedule estimate
  - Cost estimate
  - Disruption estimate

Hypothetical rapid renewal project, which will be used as an example throughout the workshop, is presented in Appendix F of the *Guide*.



Hypothetical Rapid Renewal Project

- *QDOT* will reconstruct/expand two intersecting highways
- Design-build with performance-based specifications
- Other potential rapid renewal elements
  - – Pavement type
  - – Detour or realignment or full temporary closure
  - – Accelerated bridge construction

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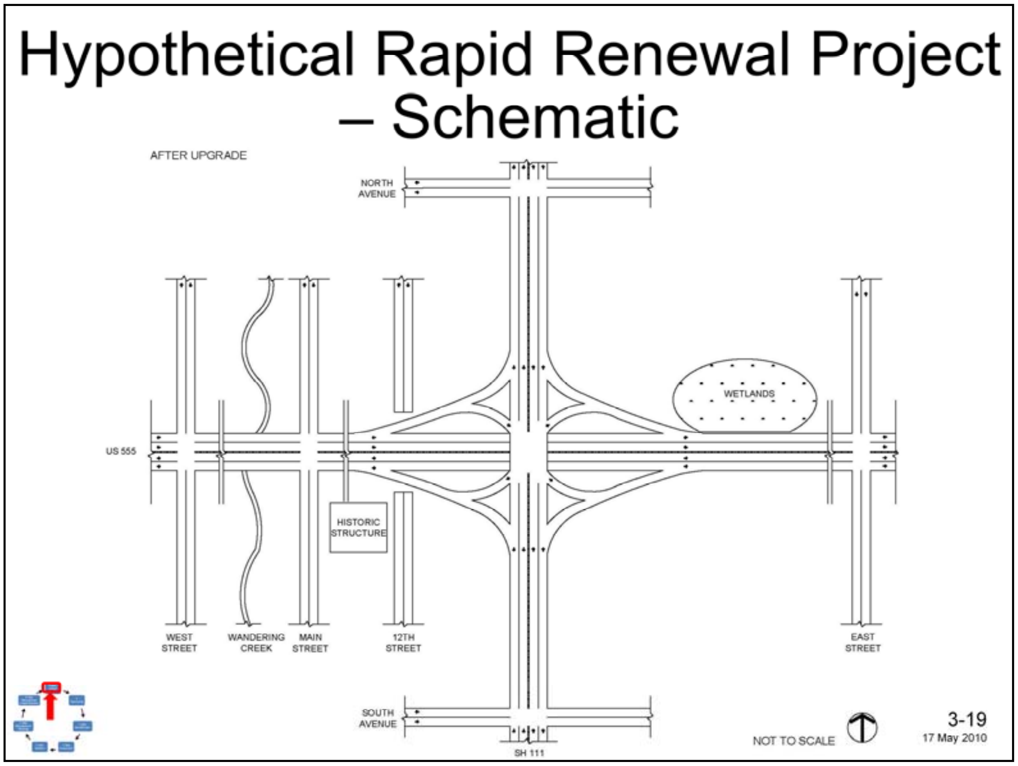
Hypothetical rapid renewal project, which will be used as an example throughout the workshop, is presented in Appendix F of the *Guide*:

QDOT is planning to reconstruct and expand segments of two existing (intersecting) highways, US 555 and SH 111, through a rapidly-developing suburban area. The existing highways are nearly 40 years old, have increasingly inadequate capacity, and are expensive to maintain. These facilities are the only viable east-west (US 555) and north-south (SH 111) routes for commercial traffic for several miles in either direction. Therefore, it is imperative that the necessary improvements be made quickly and with minimal disruption. QDOT would also like to minimize construction costs and future repair cycles and maintenance requirements, as well as eventual replacement issues. To help achieve these objectives, QDOT plans to encourage contractor innovation through the use of performance-based specifications and incentives, and to procure with an innovative project delivery method (i.e., design-build). It is expected that accelerated bridge construction techniques, minimally disruptive MOT, and innovative pavement design, among other rapid renewal elements (as described in App C of the *Guide*), will be considered for this project.



Hypothetical Rapid Renewal Project – Schematic

From hypothetical rapid renewal project description in Appendix F of the *Guide*, where other information regarding more detailed scope, strategy/status and conditions/assumptions is also provided using this form.

Key elements:

- Overpass structure (SPUI) and ramps with fill/retaining walls.
- Widening and approaches on fill with retaining walls.

Summary Project Description

Brief Project Description:
<insert>

Project Scope, Strategy/Status, and Key Conditions and Assumptions (identify):

- Detailed scope (including alternatives): <insert>
- Funding: <insert>
- Design:
  - Design level: <insert>
  - Structural: <insert>
  - Geotechnical: <insert>
  - Drainage: <insert>
  - Pavement: <insert>
  - Systems (including lighting and ITS)
  - Design deviations: <insert>
- Environmental:
  - Environmental documentation: <insert>
  - Wetlands: <insert>
  - Streams: <insert>
  - ESA: <insert>
  - Floodplain: <insert>
  - Stormwater: <insert>
  - Contaminated/hazardous waste: <insert>
  - Section 106: <insert>
  - 4(f): <insert>
  - Permitting (incl 404): <insert>
- Right of way and other agreements
  - Right-of-Way: <insert>
  - Utilities: <insert>
  - Railroad: <insert>
  - Other stakeholders: <insert>
- Procurement:
  - Delivery method: <insert>
  - Contract packaging: <insert>
  - Market (general and specialty): <insert>
- Construction:
  - Construction access/restrictions (including seasonal, events, shifts/hours): <insert>
  - Maintenance of traffic/business: <insert>
  - Construction phasing: <insert>
- Post-construction ("longevity"):
  - O&M: <insert>
  - Replacement: <insert>

Project Schedule (delivery, O&M, replacement – abstracted on next sheet):
<summarize major activities/milestones, including discussion of basis and bias/conservatism>

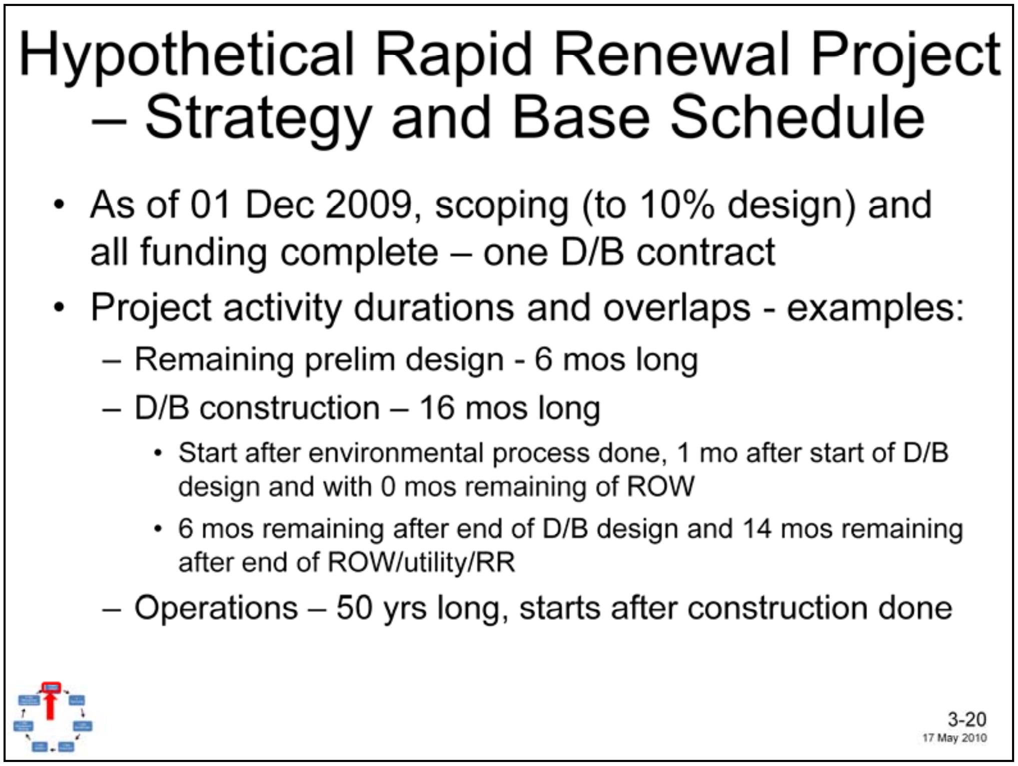
Project Cost Estimate (delivery, O&M, replacement – abstracted on next sheet):
<summarize major elements and costs, including discussion of basis and bias/conservatism, escalation, NPV for long term, disruption cost, and schedule and longevity value>

Project Disruption Estimate (delivery, O&M, replacement – abstracted on next sheet):
<summarize major elements and disruption, including discussion of basis and bias/conservatism>

Project Tradeoffs (disruption, schedule, longevity):
<summarize policy values for combining performance measures>

Project Performance Analysis:
<summarize project schedule, cost (including inflation), disruption, longevity, and combined performance>

Project Schematics (Scope and Flowchart, customized or simplified – see next sheet):
<insert>



Hypothetical Rapid Renewal Project – Strategy and Base Schedule

- As of 01 Dec 2009, scoping (to 10% design) and all funding complete – one D/B contract
- Project activity durations and overlaps - examples:
  - Remaining prelim design - 6 mos long
  - D/B construction – 16 mos long
    - Start after environmental process done, 1 mo after start of D/B design and with 0 mos remaining of ROW
    - 6 mos remaining after end of D/B design and 14 mos remaining after end of ROW/utility/RR
  - Operations – 50 yrs long, starts after construction done

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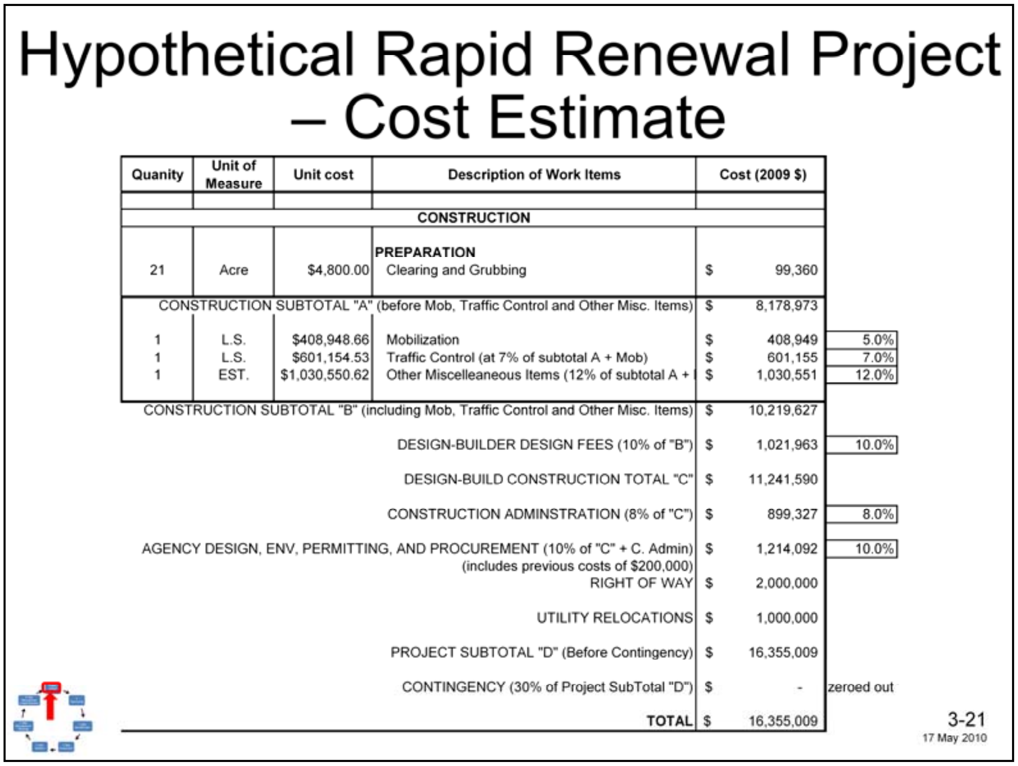
From hypothetical rapid renewal project description in Appendix F of Guide.

Key schedule elements:

- Remaining prelim design - 6 mos long
- Environmental process - 12 mos long, starts after prelim design done
- ROW/utilities/RR – 12 mos long, starts after prelim design done, tied to environmental process
- Procurement - 8 mos long, starts after prelim design done, tied to environmental process and to ROW/utilities/RR
- D/B design – 6 mos long, starts after procurement done
- D/B construction – 16 mos long
  - Start after environmental process done, 1 mo after start of D/B design and with X mos remaining of ROW
  - 6 mos remaining after end of D/B design and 14 mos remaining after end of ROW/utility/RR
- Operations – 50 yrs long, starts after construction done
- Replacement – 2 yrs long, start after operations done



Hypothetical Rapid Renewal Project – Cost Estimate

Quanity	Unit of Measure	Unit cost	Description of Work Items	Cost (2009 $)	
CONSTRUCTION					
			PREPARATION		
21	Acre	$4,800.00	Clearing and Grubbing	$ 99,360	
CONSTRUCTION SUBTOTAL "A" (before Mob, Traffic Control and Other Misc. Items)				$ 8,178,973	
1	L.S.	$408,948.66	Mobilization	$ 408,949	5.0%
1	L.S.	$601,154.53	Traffic Control (at 7% of subtotal A + Mob)	$ 601,155	7.0%
1	EST.	$1,030,550.62	Other Miscelleaneous Items (12% of subtotal A +	$ 1,030,551	12.0%
CONSTRUCTION SUBTOTAL "B" (including Mob, Traffic Control and Other Misc. Items)				$ 10,219,627	
DESIGN-BUILDER DESIGN FEES (10% of "B")				$ 1,021,963	10.0%
DESIGN-BUILD CONSTRUCTION TOTAL "C"				$ 11,241,590	
CONSTRUCTION ADMINSTRATION (8% of "C")				$ 899,327	8.0%
AGENCY DESIGN, ENV, PERMITTING, AND PROCUREMENT (10% of "C" + C. Admin) (includes previous costs of $200,000)				$ 1,214,092	10.0%
RIGHT OF WAY				$ 2,000,000	
UTILITY RELOCATIONS				$ 1,000,000	
PROJECT SUBTOTAL "D" (Before Contingency)				$ 16,355,009	
CONTINGENCY (30% of Project SubTotal "D")				$ -	zeroed out
TOTAL				$ 16,355,009	

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From hypothetical rapid renewal project description in Appendix F of Guide.

Quanity	Unit of Measure	Unit cost	Description of Work Items	Cost (2009 $)	
CONSTRUCTION					
			PREPARATION		
21	Acre	$4,800.00	Clearing and Grubbing	$ 99,360	
26,397	S.Y.	$8.40	Removing Cement Conc. Pavement	$ 221,735	
26,397	S.Y.	$4.80	Removing Asphalt Conc. Pavement	$ 126,706	
			GRADING		
33,393	C.Y.	$9.60	Roadway Excavation Incl. Haul	$ 320,573	
27,960	C.Y.	$4.20	Common Borrow incl. Haul	$ 117,432	
3,107	C.Y.	$14.40	Gravel Borrow Incl. Haul	$ 44,741	
31,067	C.Y.	$1.20	Embankment Compaction	$ 37,280	
			DRAINAGE		
42	Each	$2,160.00	Grate Inlet Type 1 or 2	$ 90,720	
6	Each	$3,600.00	Drop Inlet Type 1	$ 21,600	
21,120	L.F.	$78.00	Plain St. Culv. Pipe 0.109 In. Thick 36 In. Diam.	$ 1,647,360	
50	L.F.	$1,800.00	St. Stru. Pipe Arch 8 Guage 20 Ft. 0 In. Span	$ 89,100	
			STRUCTURE		
3,972	S.F.	$145.00	Bridge No. (easy bridge)	$ 575,940	
8,673	S.F.	$22.00	Concrete Retaining Wall	$ 190,806	
			SURFACING		
27,047	Ton	$12.00	Crushed Surfacing Bace Course	$ 324,564	
			CEMENT CONC. PAVEMENT		
16,696	C.Y.	$110.00	Cement Conc. Pavement	$ 1,836,560	
882	S.Y.	$146.00	Bridge Approach Slab	$ 128,772	
			ASPHALT CONCRETE PAVEMENT		
1,100	Ton	$36.00	Miscellaneous Asphalt Conc. Pavement	$ 39,600	
			EROSION CONTROL AND PLANTING		
2	Acre	$2,400.00	Seeding, Fertilizing and Mulching	$ 4,800	
1	EST.	$85,000.00	Temporary Water Pollution/Erosion Control	$ 85,000	
1,564	C.Y.	$13.20	Topsoil Type B	$ 20,645	
1	EST.	$150,000.00	Miscellaneous Landscaping		
			TRAFFIC		
15,840	L.F.	$120.00	Special Conc. Barrier Type 5	$ 1,900,800	
8	Each	$14,400.00	Permanent Impact Attenuator	$ 115,200	
214,000	L.F.	$0.12	Paint Line	$ 25,680	
1	L.S.	$24,000.00	Permanent Sigining	$ 24,000	
			OTHER ITEMS		
4,000	L.F.	$18.00	Temporary Barrier Glare Screen	$ 72,000	
1	EST.	$12,000.00	Roadside Cleanup	$ 12,000	
1	EST.	$6,000.00	Trimming and Cleanup	$ 6,000	
CONSTRUCTION SUBTOTAL "A" (before Mob, Traffic Control and Other Misc. Items)				$ 8,178,973	
1	L.S.	$408,948.66	Mobilization	$ 408,949	5.0%
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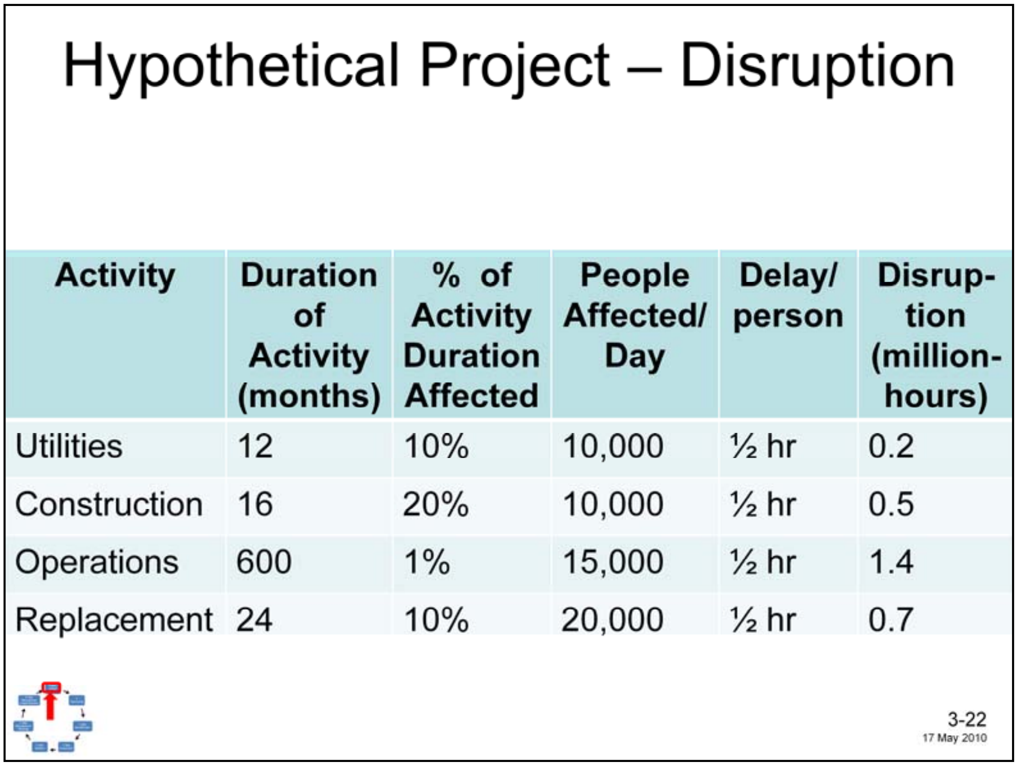

Hypothetical Project – Disruption

Activity	Duration of Activity (months)	% of Activity Duration Affected	People Affected/ Day	Delay/ person	Disrup-tion (million-hours)
Utilities	12	10%	10,000	½ hr	0.2
Construction	16	20%	10,000	½ hr	0.5
Operations	600	1%	15,000	½ hr	1.4
Replacement	24	10%	20,000	½ hr	0.7

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From hypothetical rapid renewal project description in Appendix F of Guide.

Context for Rapid Renewal

- Learning Objectives
- Background
- Methods
- Discussion of DOT Applicability
- Hypothetical Rapid Renewal Project

➢ **Summary**

Summary - Rapid Renewal Context

- ✓ Rapid renewal projects increasingly required
- ✓ Expanded performance objectives:
  - Minimize schedule and minimize disruption
  - Minimize cost and maximize longevity
- ✓ Rapid renewal projects are innovative but risky
- ✓ Need formal risk management

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

Risk Management

Module 4:
Structuring the Project for Risk Management

Project Scope/Strategy/ Conditions

Structuring

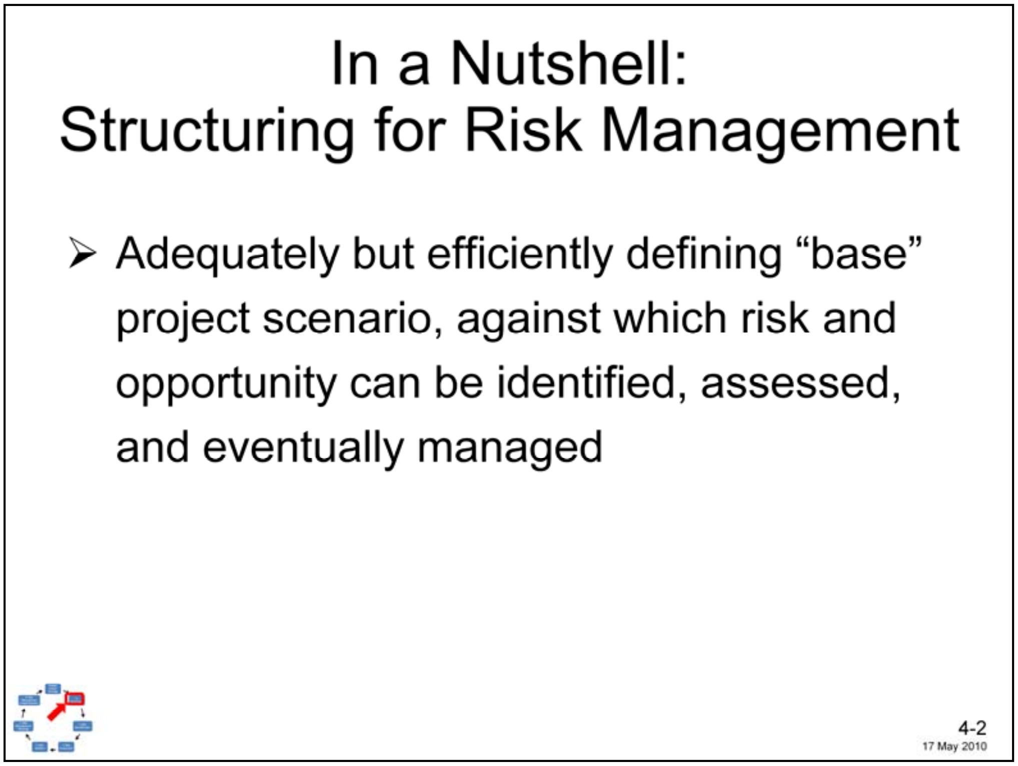
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



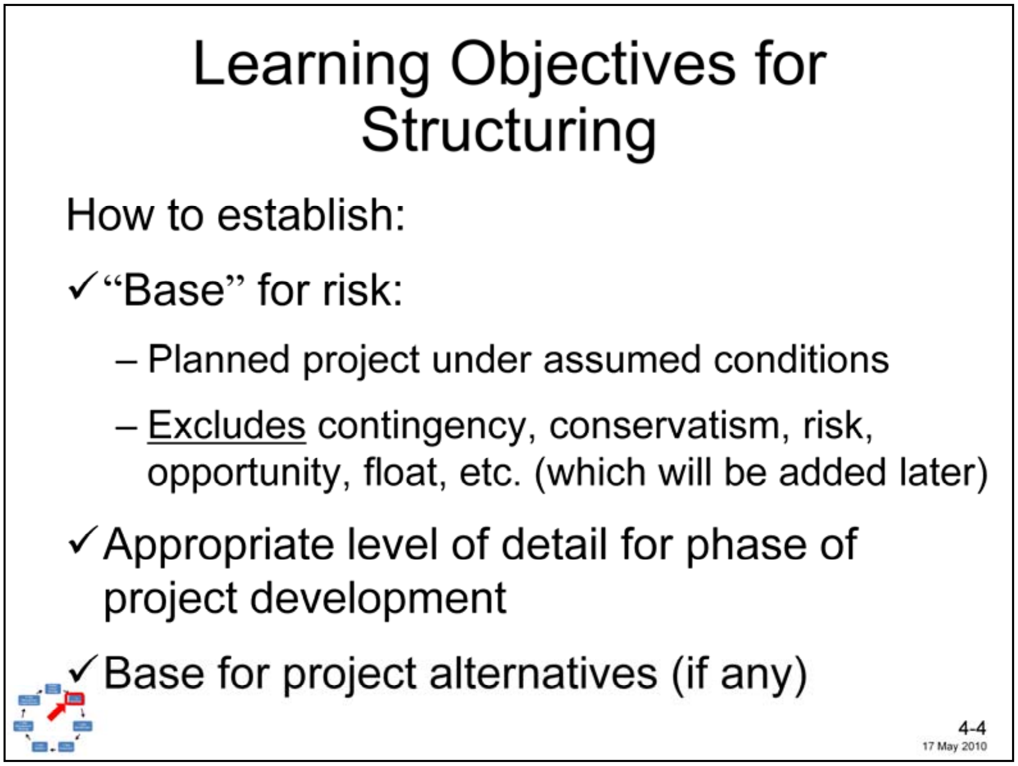
In a Nutshell: Structuring for Risk Management

- Adequately but efficiently defining “base” project scenario, against which risk and opportunity can be identified, assessed, and eventually managed

As previously discussed (Module 2): Total = Base + Risk

Structuring for Risk Management

- Learning Objectives
- Defining “base” project
- Practical Exercise
- Summary



Learning Objectives for Structuring

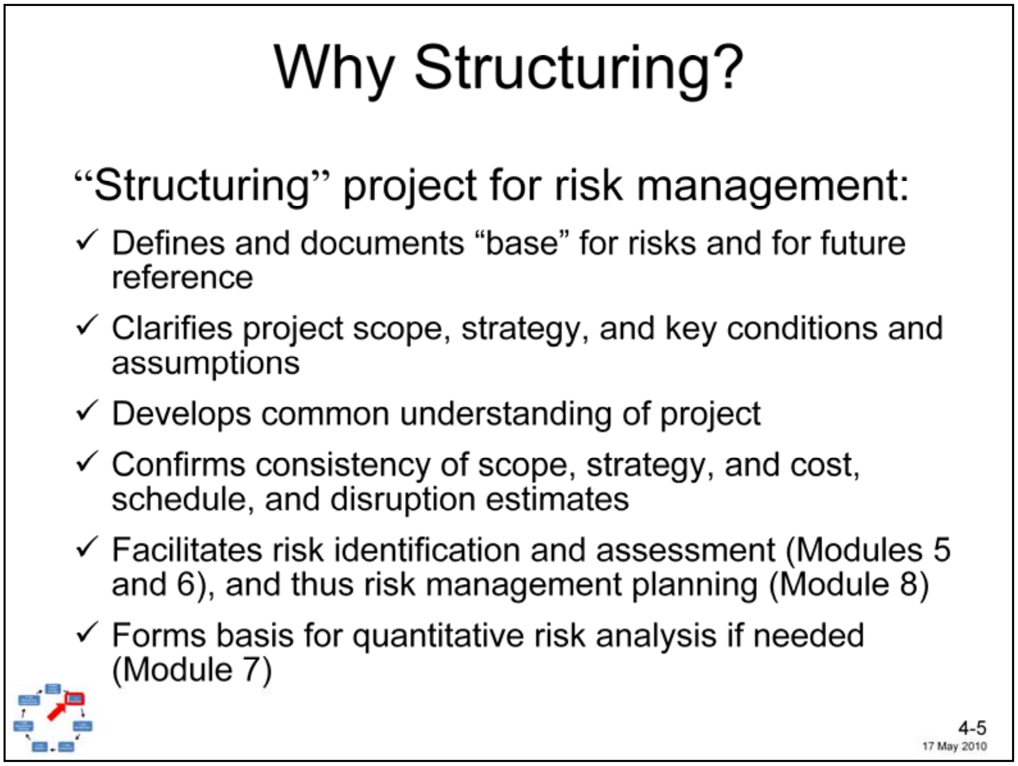
How to establish:

- ✓ "Base" for risk:
  - – Planned project under assumed conditions
  - – Excludes contingency, conservatism, risk, opportunity, float, etc. (which will be added later)
- ✓ Appropriate level of detail for phase of project development
- ✓ Base for project alternatives (if any)

Need to define base because risks and opportunity must be considered relative to base.

Level of detail of project description (including project cost and schedule estimate, as well as design documents) varies with phase of project development, ranging from very simple descriptions (e.g., several item cost and schedule estimates, and simple design sketches) at conceptual planning to very complex (e.g., several thousand item cost and schedule estimates, and extensive design documents) at bid time.

If considering major project alternatives (e.g., different alignment or different project delivery), need base for each alternative, although there will generally be many similarities among them. Choose one case to describe fully, and simply identify differences from that case for each alternative.



Why Structuring?

"Structuring" project for risk management:

- ✓ Defines and documents "base" for risks and for future reference
- ✓ Clarifies project scope, strategy, and key conditions and assumptions
- ✓ Develops common understanding of project
- ✓ Confirms consistency of scope, strategy, and cost, schedule, and disruption estimates
- ✓ Facilitates risk identification and assessment (Modules 5 and 6), and thus risk management planning (Module 8)
- ✓ Forms basis for quantitative risk analysis if needed (Module 7)

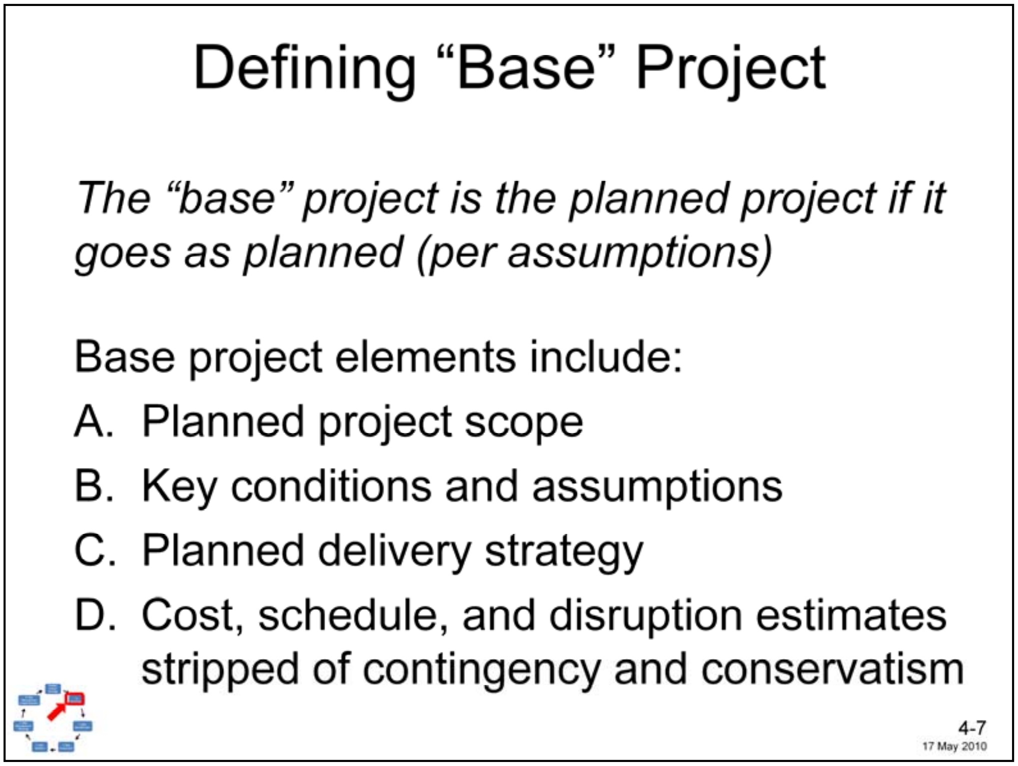
For example:

- risks will be defined as additive to "base" – if base is defined on high end of range, then risks might be low and opportunities might be high
- explicit or implicit assumptions (e.g., "I assume", "should happen", etc.), even if reasonable, might not turn out to be true, i.e., risk

The "alignment" that occurs among the project team, as well as the validation (if independent reviewers are involved), during structuring is very valuable in its own right.

Structuring for Risk Management

- Learning Objectives
- **➢ Defining "base" project**
- Practical Exercise
- Summary



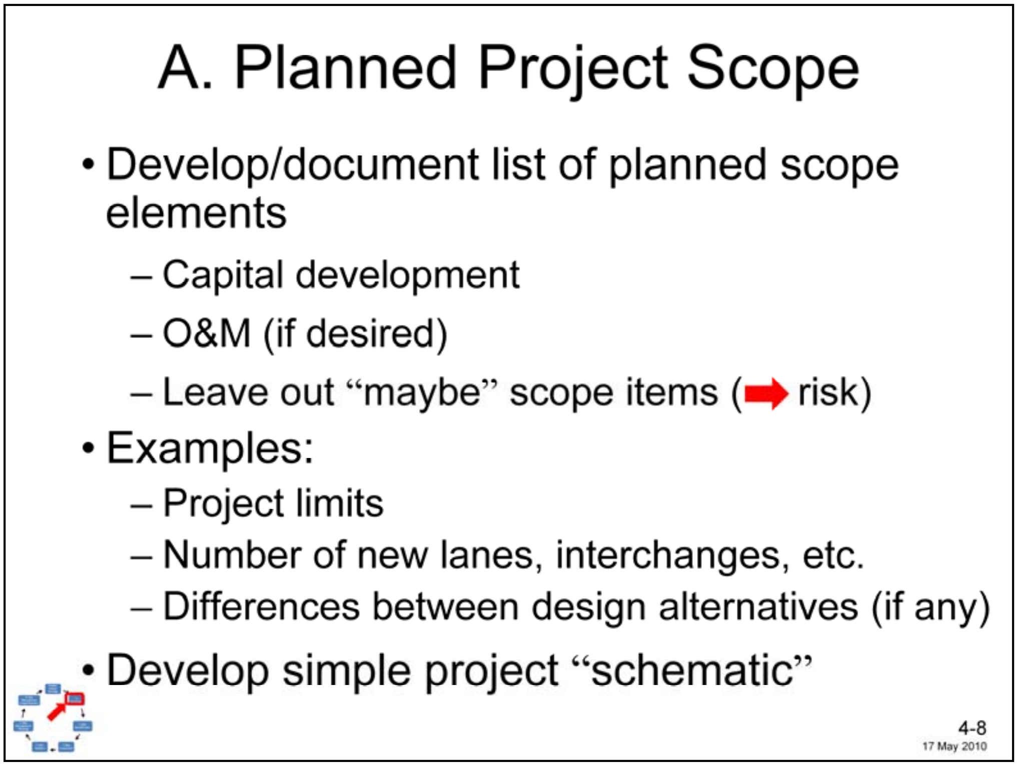
Defining “Base” Project

The “base” project is the planned project if it goes as planned (per assumptions)

Base project elements include:

A. Planned project scope
B. Key conditions and assumptions
C. Planned delivery strategy
D. Cost, schedule, and disruption estimates stripped of contingency and conservatism

Each of these four items are expanded upon in the following slides.



A. Planned Project Scope

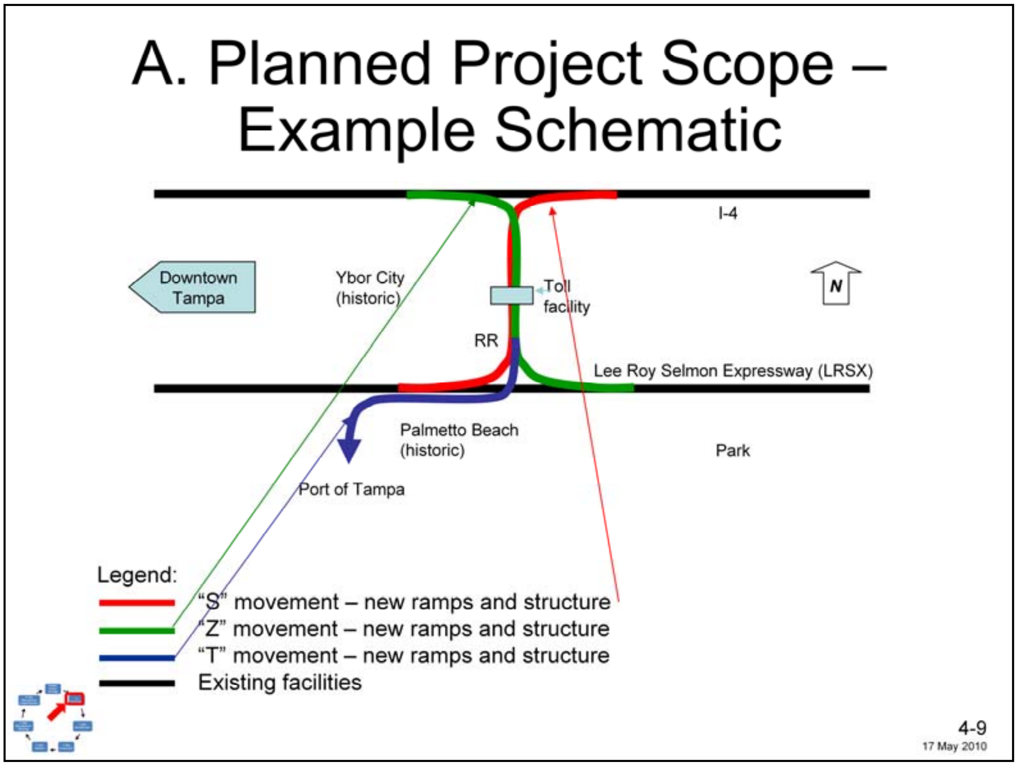
- Develop/document list of planned scope elements
  - Capital development
  - O&M (if desired)
  - Leave out “maybe” scope items (➡ risk)
- Examples:
  - Project limits
  - Number of new lanes, interchanges, etc.
  - Differences between design alternatives (if any)
- Develop simple project “schematic”

Examples of planned scope elements:

- Project limits
- Differences between design alternatives (if evaluating multiple alternatives)
- Number of new lanes, interchanges, etc.
- Vertical and horizontal alignment
- Number and types of new structures (and foundations)
- Number and types of cut and fill retaining walls
- Pavement type
- Replacement versus rehabilitation
- etc.

Often, lingering scope decisions get finalized while defining a “base” for risk assessment – a nice side-benefit

See Summary Project Description Base Form (in Appendix E of the Guide and on CD).



A. Planned Project Scope – Example Schematic

Legend:

- 🟥 “S” movement – new ramps and structure
- 🟩 “Z” movement – new ramps and structure
- 🟦 “T” movement – new ramps and structure
- ⬛ Existing facilities

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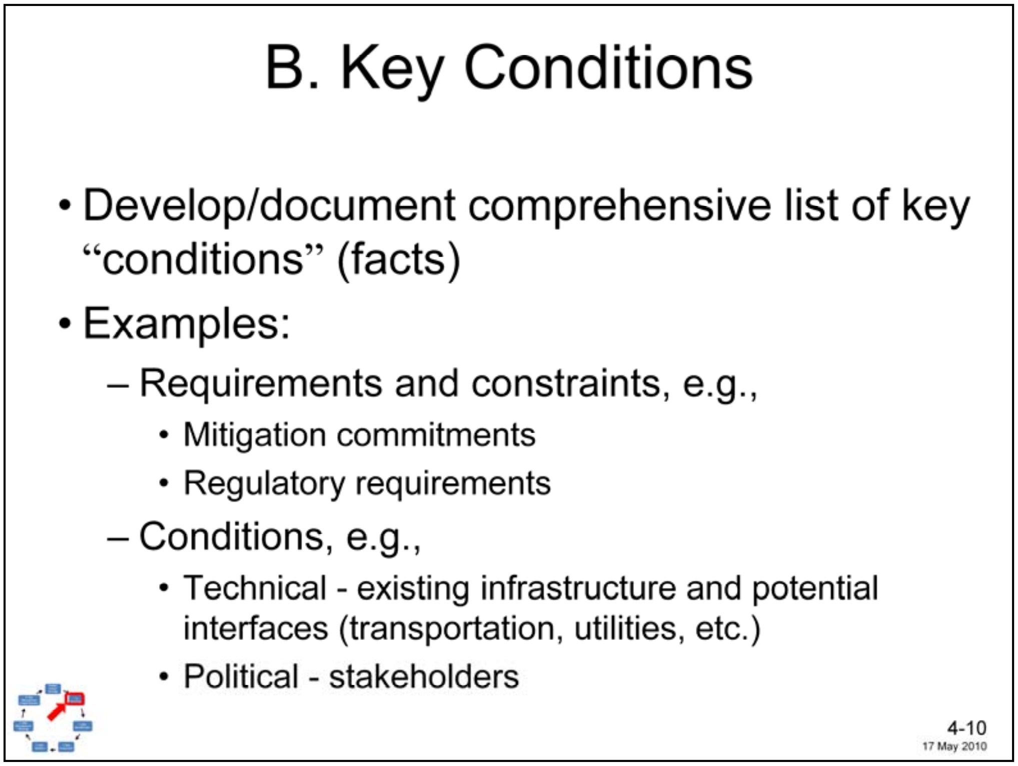
Example: Key scope elements include new S, Z, and T movements, and toll facility.



B. Key Conditions

- Develop/document comprehensive list of key "conditions" (facts)
- Examples:
  - – Requirements and constraints, e.g.,
    - Mitigation commitments
    - Regulatory requirements
  - – Conditions, e.g.,
    - Technical - existing infrastructure and potential interfaces (transportation, utilities, etc.)
    - Political - stakeholders

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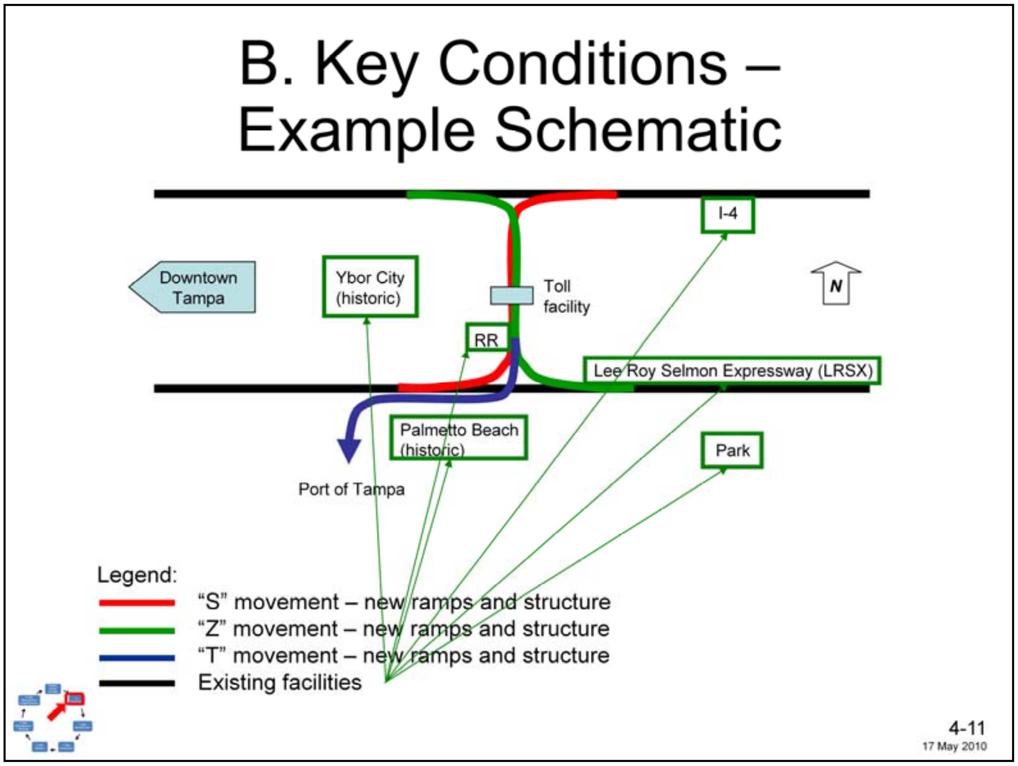
Examples:

- Requirements and constraints
  - political commitments
  - design standards and specifications
  - environmental standards / process (documentation, approvals, etc.)
  - mitigation requirements
  - procurement
- Technical conditions
  - existing infrastructure and potential interfaces (transportation, utilities, etc.)
  - environmental conditions (wetlands, streams, parks, historic areas, etc.)
  - real estate (land use, development pressure, etc.)
  - ground conditions
  - market conditions
- Political conditions
  - stakeholders
  - owner policies
  - funding

See Summary Project Description Base Form (in Appendix E of the Guide and on CD).



B. Key Conditions – Example Schematic

Legend:

- 🟥 “S” movement – new ramps and structure
- 🟩 “Z” movement – new ramps and structure
- 🟦 “T” movement – new ramps and structure
- ⬛ Existing facilities

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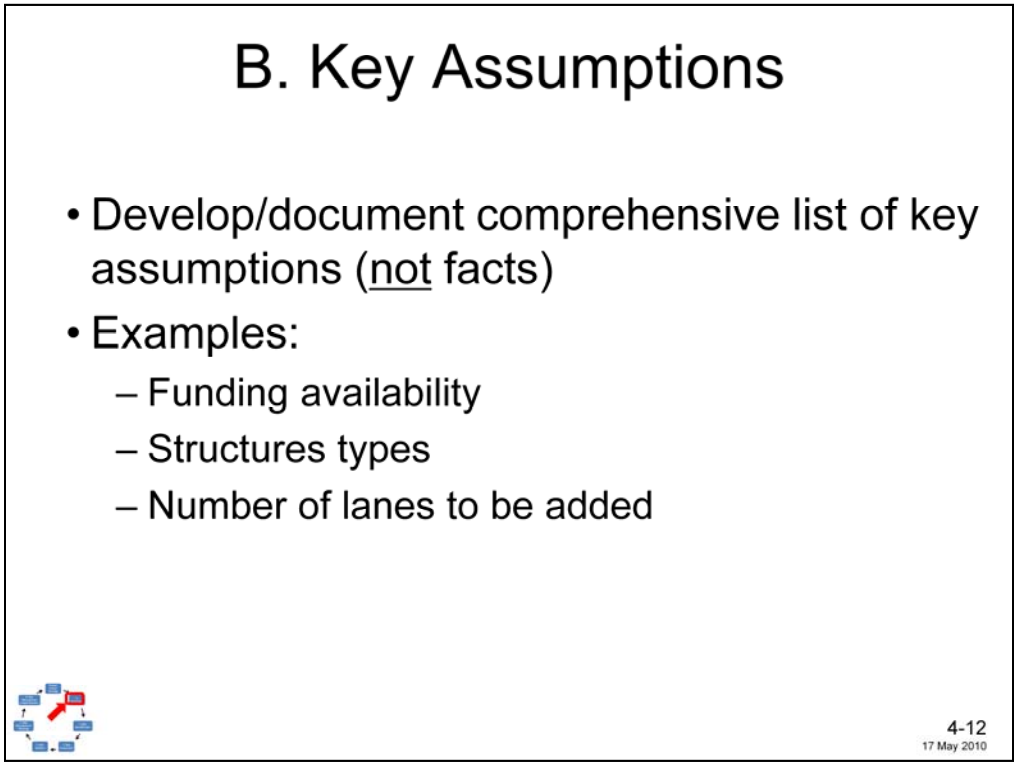
Example: Some key conditions that could significantly affect project are shown in green boxes. There are many other conditions not shown (e.g., other stakeholders, ground conditions, other existing roads/traffic, etc.).



B. Key Assumptions

- Develop/document comprehensive list of key assumptions (not facts)
- Examples:
  - – Funding availability
  - – Structures types
  - – Number of lanes to be added

Document the project status (at the time of the risk assessment) and key assumptions used to develop the scope, cost estimate, and schedule estimate. These assumptions, while necessary, are often somewhat arbitrary. Identifying uncertainty in these assumptions usually forms the basis for much of the project risk and opportunity. Clarifying key assumptions helps everyone understand the project. Using a template to document key assumptions helps make sure you cover all the issues.

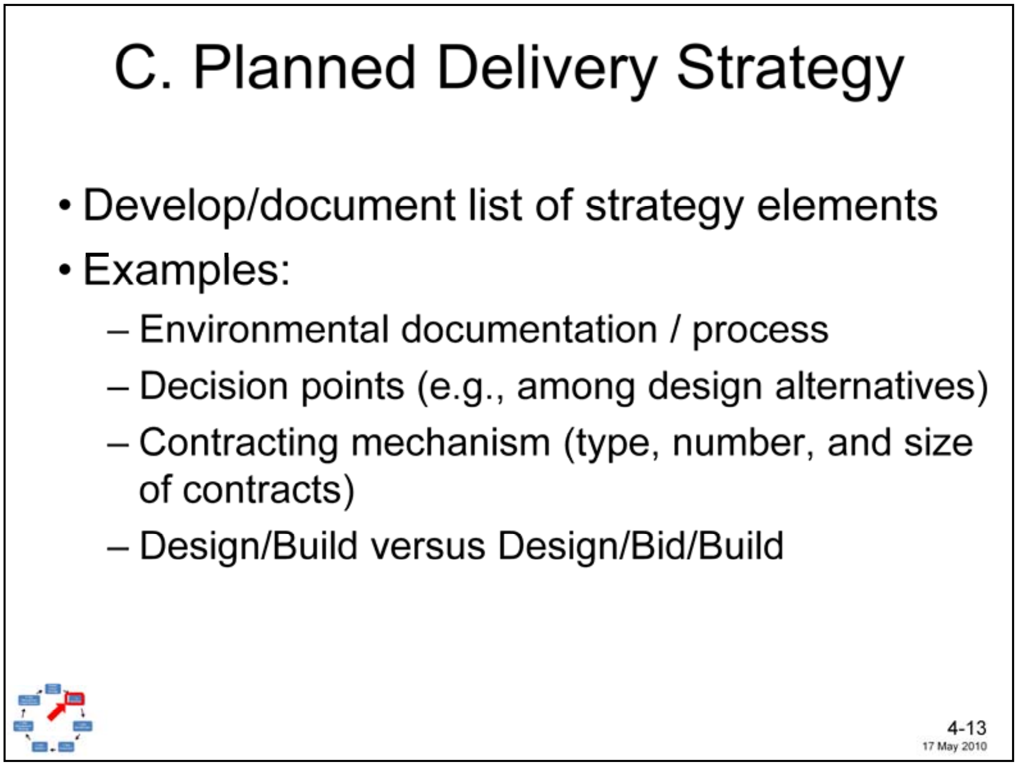
Example topics:

- Funding availability (e.g., full state funding available by <date>)
- Political process results (e.g., support and no opposition)
- Environmental process results (e.g., EA/FONSI, vs. EIS/ROD, required)
- Real estate acquisition process results (e.g., donation of key parcels)
- Horizontal and vertical alignment, and design capacity
- Structures and foundation types (e.g., steel girder superstructure on drilled shaft foundations)
- Design standard exceptions (e.g., shoulder width exceptions granted without delay)
- Market conditions (e.g., several bids)
- Project delivery approach (e.g., single design/bid/build contract)

See Summary Project Description Base Form (in Appendix E of the Guide and on CD).

Actual example (only a few topics are shown):

- Pavement: Primarily concrete, except for the LRSX widening, which is asphalt.
- Structures: Primarily (85%) structures project – 32 bridges. Structural options are being considered – see design level discussed elsewhere. Elevated on solid, cast-in-place columns/piers (150) – see geotech (discussed elsewhere) for foundations. No noise walls required due to height of structures.
- Earthwork: Minimal, except for “plug” for toll plaza, because the bridges and ramps are mostly on structure. Plug will be 40-ft high MSE wall, built next to active railroad and road – possible tunnel/elevator/stairs inside for access to gantry on top. MSE walls at ends of structures.



C. Planned Delivery Strategy

- Develop/document list of strategy elements
- Examples:
  - Environmental documentation / process
  - Decision points (e.g., among design alternatives)
  - Contracting mechanism (type, number, and size of contracts)
  - Design/Build versus Design/Bid/Build

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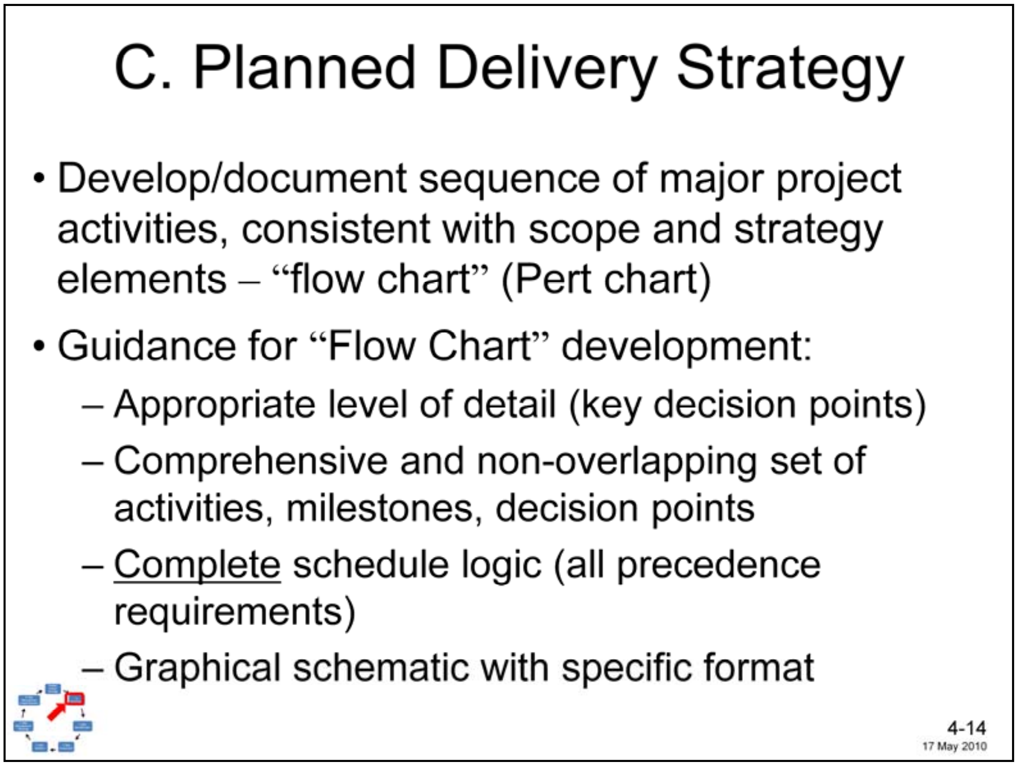
Describe how the project will be developed and delivered. Examples:

- Environmental documentation / process
- Decision points (e.g., among design alternatives)
- Key stakeholder input / approvals
- Key funding dates
- Right-of-way acquisition
- Contracting mechanism (type, number, and size of contracts)
- Construction sequencing

See Summary Project Description Base Form (in Appendix E of the Guide and on CD).



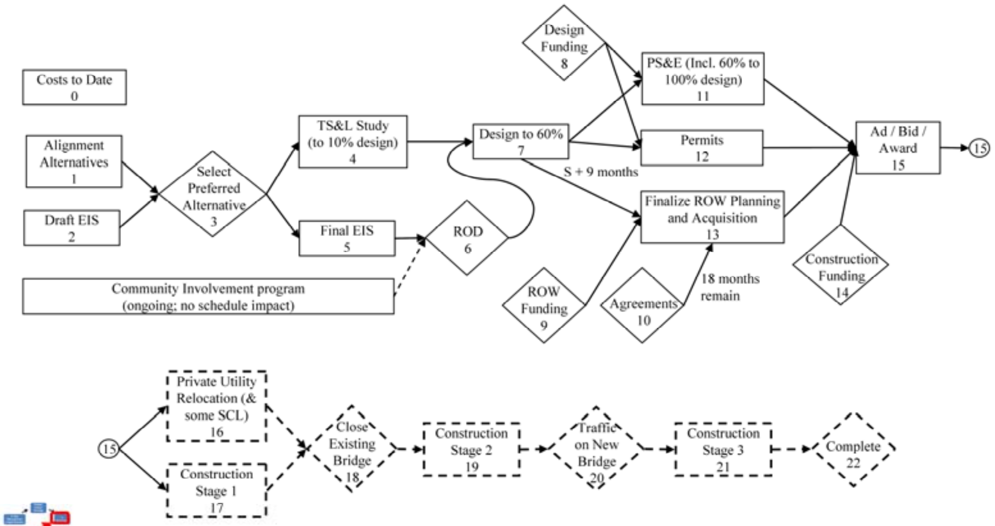
C. Planned Delivery Strategy

- Develop/document sequence of major project activities, consistent with scope and strategy elements – "flow chart" (Pert chart)
- Guidance for "Flow Chart" development:
  - Appropriate level of detail (key decision points)
  - Comprehensive and non-overlapping set of activities, milestones, decision points
  - Complete schedule logic (all precedence requirements)
  - Graphical schematic with specific format

- Major project activities include:
  - Planning
  - Scoping
  - Preliminary design
  - Final design and PS&E (if Design/Bid/Build); RFQ/RFP if Design-Build
  - Environmental documentation (and related discipline studies, etc.) and determination (e.g., Record of Decision)
  - Environmental permitting
  - Right-of-Way planning and acquisition
  - Utility coordination and relocation (early and during construction)
  - Railroad coordination
  - Other approval milestones (internal and by stakeholders)
  - Procurement (letting, etc.)
  - Construction (sequenced)
  - O&M
  - Replacement (or decommissioning)
- Want adequate level of detail – not too simple or too complex. Include key decision points.
- Want comprehensive and non-overlapping set of strategy elements and activities (all activities, milestones, scope items, costs, etc. have a "home")
- Determine *all* precedence requirements for each activity. Check by isolating each activity and asking what must be done before that activity can start and/or finish. Show finish-to-start, finish-to-finish, start plus lag, finish minus lag. Must recognize that alternative critical paths might emerge when apply risks.
- Develop graphically in schematic format (similar to Pert chart) – see next slide for example.

Often, development of a flowchart helps to clarify project strategy, exposing disconnects or errors in existing project schedule or helping to develop strategy that doesn't yet exist.

C. Planned Delivery Strategy - Example



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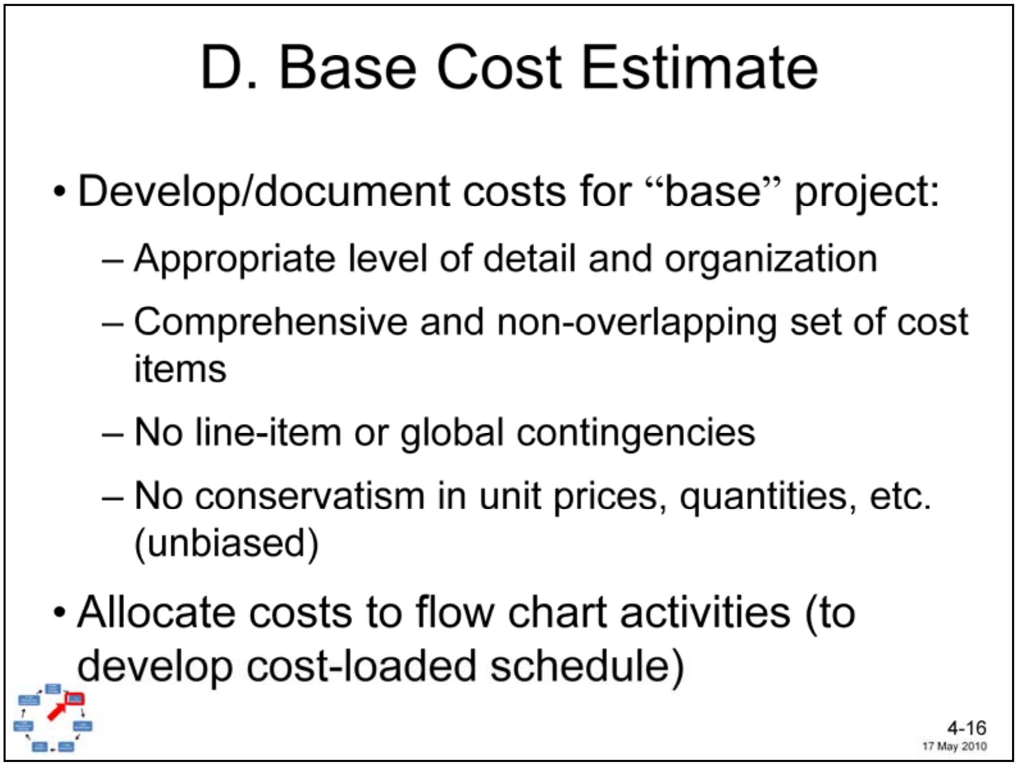
A flowchart is essentially a Pert chart, and depicts the sequence of project activities, with time generally progressing left to right (although not to scale, which will vary in any case when risks are applied). Each activity is a box - start of activity is left side of activity box and end of activity is right side of activity box, with in between times represented by top or bottom of box. Milestones are diamonds with date and no duration. Arrows represent precedence requirements: finish or start (+ or - lag) of one activity to start or finish (+ or - lag) of another activity. An activity cannot proceed until all of its precedence requirements are satisfied. The flowchart does not change as schedule risks occur (although decision or branch points can be included).

Example (not same example as for scope and conditions):
Solid lines represent pre-construction activities; dashed lines represent construction activities. Notice the activities and their precedence requirements. At the time of this risk assessment, this project was at 10% design; not much was known about how construction would be sequenced. Hence, the flow chart shows more detail for pre-construction activities than for construction. This level of detail, while not substantial, was deemed appropriate for this project at this point in time.



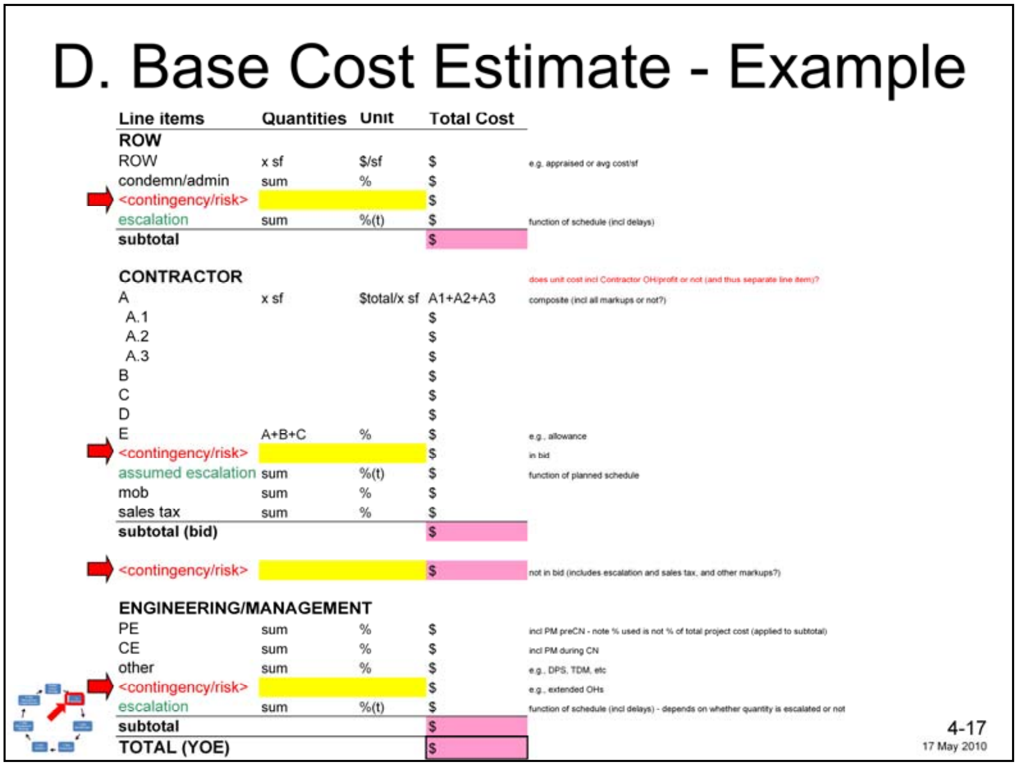
D. Base Cost Estimate

- Develop/document costs for “base” project:
  - Appropriate level of detail and organization
  - Comprehensive and non-overlapping set of cost items
  - No line-item or global contingencies
  - No conservatism in unit prices, quantities, etc. (unbiased)
- Allocate costs to flow chart activities (to develop cost-loaded schedule)

Establish the base cost – without risk or opportunity – required to build the base project as defined previously (scope, conditions, assumptions, and strategy). This might involve validating an existing cost estimate, i.e., checking for completeness, accuracy (no calculation errors or double counting), and reasonableness (re quantities and unit costs), focusing on larger cost items (aggregating smaller cost items). Specifically:

- Ensure all project costs are accounted for, with no double-counting, and that the cost factors are reasonable and combined appropriately
- Exclude line-item and global contingencies – these will be developed by the risk assessment
- Remove conservatism in unit prices, quantities, etc. to the extent possible, because that conservatism is meant to account for risk

Because the risk will be added to the base, the base cost (or at least the base cost assumptions) is needed before risk can be discussed.



D. Base Cost Estimate - Example

Line items	Quantities	Unit	Total Cost	
ROW				
ROW	x sf	$/sf	$	e.g. appraised or avg cost/sf
condemn/admin	sum	%	$	
<contingency/risk>			$	
escalation	sum	%(t)	$	function of schedule (incl delays)
subtotal			$	
CONTRACTOR				does unit cost incl Contractor OH/profit or not (and thus separate line item)?
A	x sf	$total/x sf	A1+A2+A3	composite (incl all markups or not?)
A.1			$	
A.2			$	
A.3			$	
B			$	
C			$	
D			$	
E	A+B+C	%	$	e.g., allowance
<contingency/risk>			$	in bid
assumed escalation	sum	%(t)	$	function of planned schedule
mob	sum	%	$	
sales tax	sum	%	$	
subtotal (bid)			$	
<contingency/risk>			$	not in bid (includes escalation and sales tax, and other markups?)
ENGINEERING/MANAGEMENT				
PE	sum	%	$	incl PM preCN - note % used is not % of total project cost (applied to subtotal)
CE	sum	%	$	incl PM during CN
other	sum	%	$	e.g., DPS, TDM, etc
<contingency/risk>			$	e.g., extended OHs
escalation	sum	%(t)	$	function of schedule (incl delays) - depends on whether quantity is escalated or not
subtotal			$	
TOTAL (YOE)			$	

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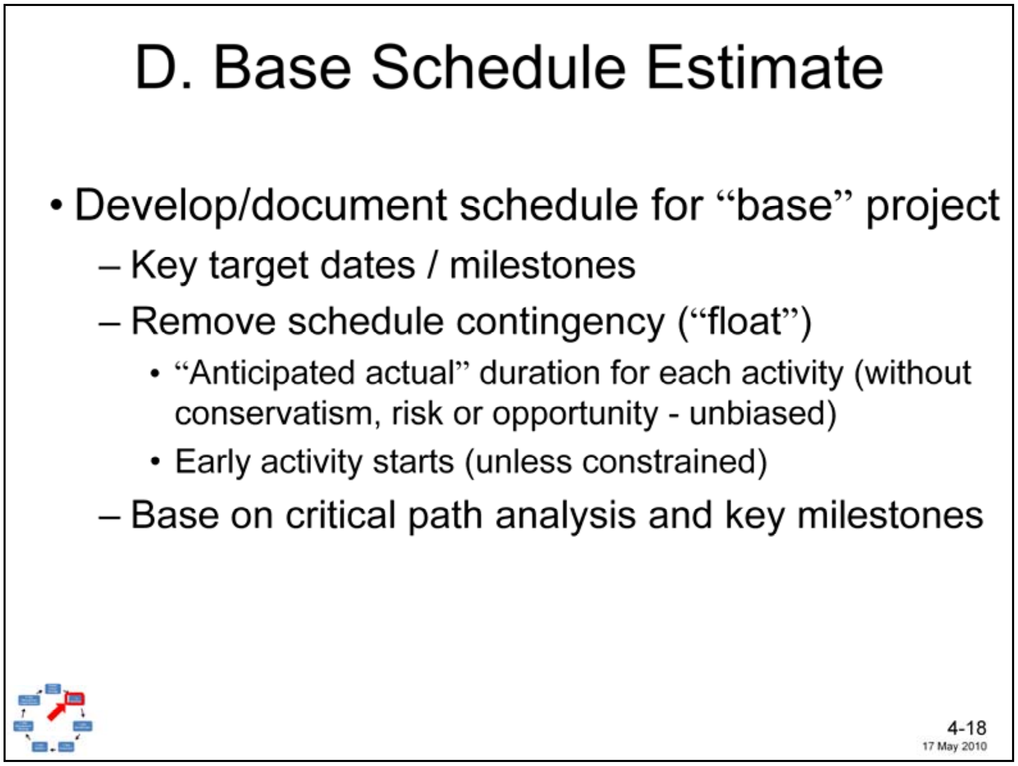
Example of a simple cost estimate format. Explicit contingencies are noted (highlighted in yellow). Implicit contingencies (conservatism) might lie within the estimated quantities and/or unit costs (or markups).



D. Base Schedule Estimate

- Develop/document schedule for “base” project
  - Key target dates / milestones
  - Remove schedule contingency (“float”)
    - “Anticipated actual” duration for each activity (without conservatism, risk or opportunity - unbiased)
    - Early activity starts (unless constrained)
  - Base on critical path analysis and key milestones

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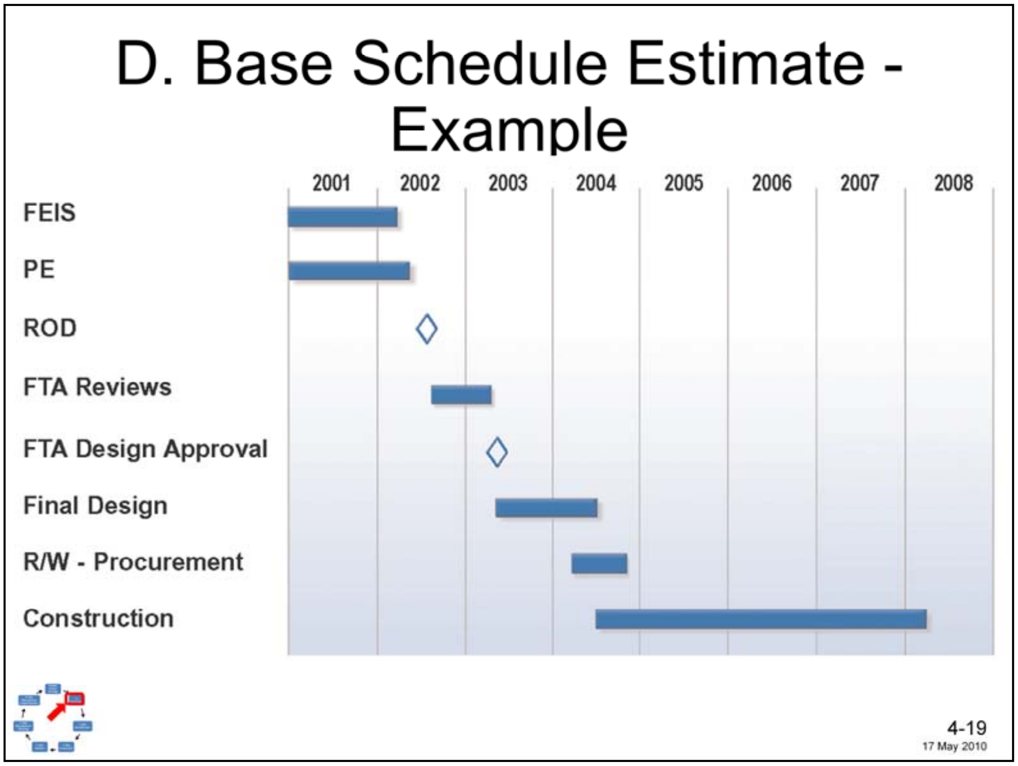
Establish the schedule – without risk or opportunity – required to complete the base project. Identify key target dates / milestones to track, e.g., start of construction, project completion, etc.

Because the risk will be added to the base and schedule is non-linear, the base schedule is needed before risk can be discussed.



D. Base Schedule Estimate - Example

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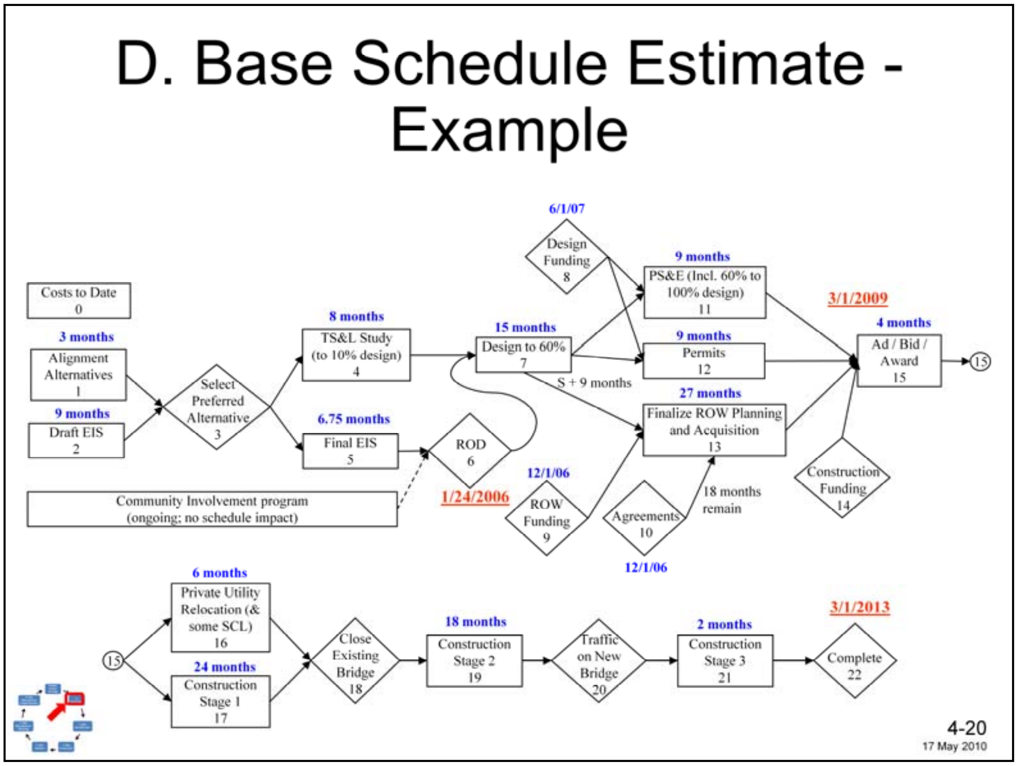
Example of a simple schedule. Precedence requirements can be shown but are typically difficult to follow in such Gantt or bar charts. This schedule is for a particular set of activity durations, and might change if schedule risks occur.



D. Base Schedule Estimate - Example

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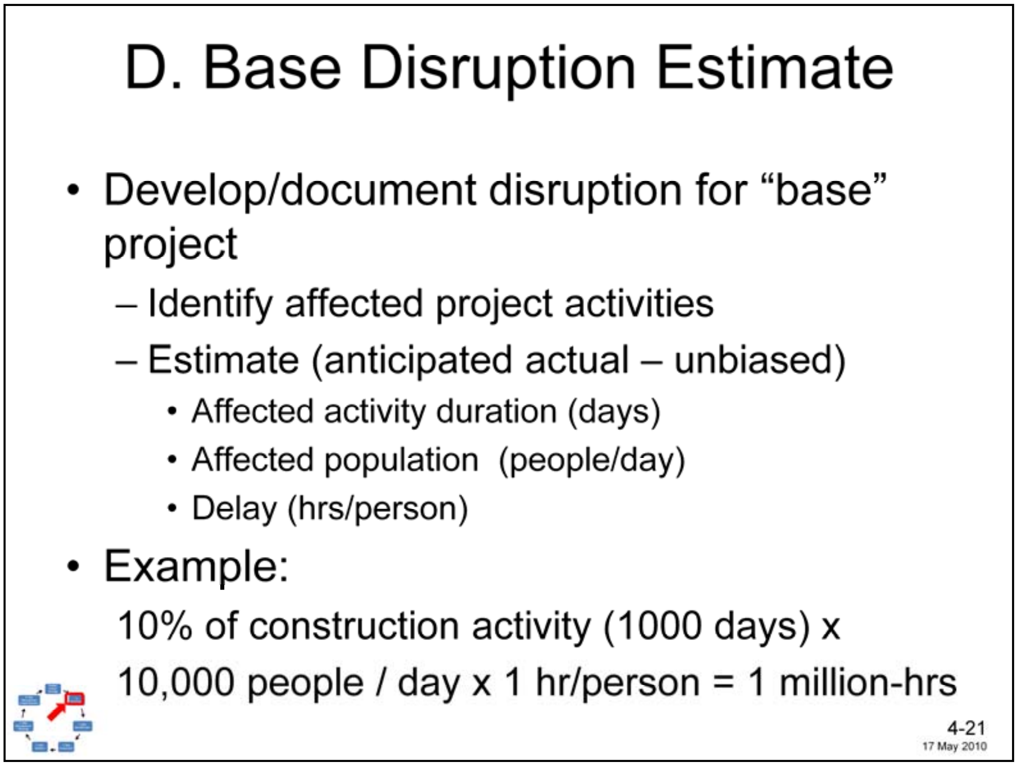
Activity durations and lags have been added to previous example flow chart. Based on the logic and durations, the schedule (early start and finish of each activity, and the critical path and activity floats, from late start and finishes of each activity) can be determined.

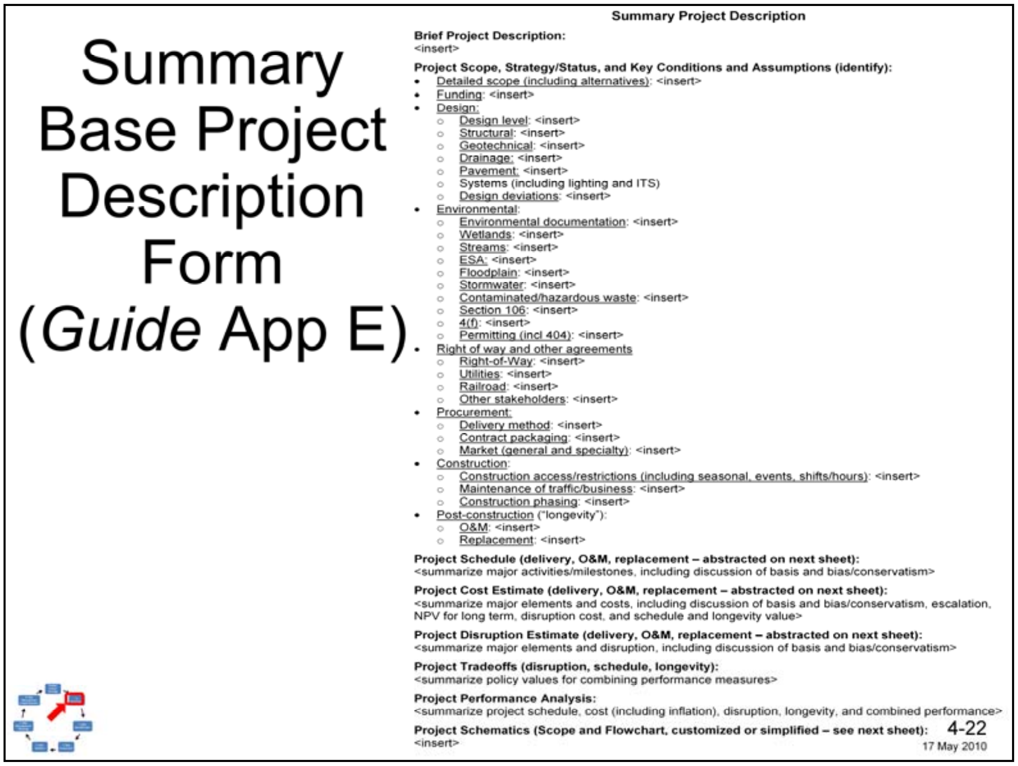
- *Values in "blue" are base durations or base target dates for external influences (inputs).*
- *"Orange, underlined" dates are key base schedule dates that* ***result*** *from the blue values applied to the flow chart (outputs).*



D. Base Disruption Estimate

- Develop/document disruption for “base” project
  - – Identify affected project activities
  - – Estimate (anticipated actual – unbiased)
    - Affected activity duration (days)
    - Affected population (people/day)
    - Delay (hrs/person)
- Example:

10% of construction activity (1000 days) x
10,000 people / day x 1 hr/person = 1 million-hrs



Summary Base Project Description Form (*Guide* App E).

Summary Project Description

Brief Project Description:
<insert>

Project Scope, Strategy/Status, and Key Conditions and Assumptions (identify):

- Detailed scope (including alternatives): <insert>
- Funding: <insert>
- Design:
  - Design level: <insert>
  - Structural: <insert>
  - Geotechnical: <insert>
  - Drainage: <insert>
  - Pavement: <insert>
  - Systems (including lighting and ITS)
  - Design deviations: <insert>
- Environmental:
  - Environmental documentation: <insert>
  - Wetlands: <insert>
  - Streams: <insert>
  - ESA: <insert>
  - Floodplain: <insert>
  - Stormwater: <insert>
  - Contaminated/hazardous waste: <insert>
  - Section 106: <insert>
  - 4(f): <insert>
  - Permitting (incl 404): <insert>
- Right of way and other agreements
  - Right-of-Way: <insert>
  - Utilities: <insert>
  - Railroad: <insert>
  - Other stakeholders: <insert>
- Procurement:
  - Delivery method: <insert>
  - Contract packaging: <insert>
  - Market (general and specialty): <insert>
- Construction:
  - Construction access/restrictions (including seasonal, events, shifts/hours): <insert>
  - Maintenance of traffic/business: <insert>
  - Construction phasing: <insert>
- Post-construction ("longevity"):
  - O&M: <insert>
  - Replacement: <insert>

Project Schedule (delivery, O&M, replacement – abstracted on next sheet):
<summarize major activities/milestones, including discussion of basis and bias/conservatism>

Project Cost Estimate (delivery, O&M, replacement – abstracted on next sheet):
<summarize major elements and costs, including discussion of basis and bias/conservatism, escalation, NPV for long term, disruption cost, and schedule and longevity value>

Project Disruption Estimate (delivery, O&M, replacement – abstracted on next sheet):
<summarize major elements and disruption, including discussion of basis and bias/conservatism>

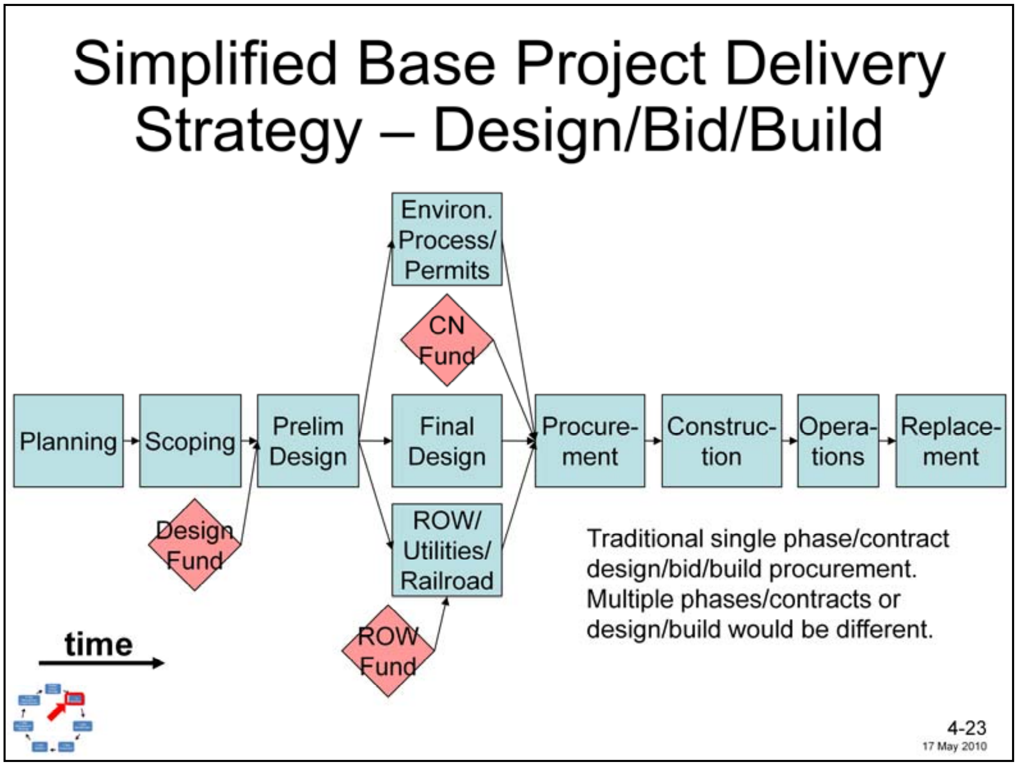
Project Tradeoffs (disruption, schedule, longevity):
<summarize policy values for combining performance measures>

Project Performance Analysis:
<summarize project schedule, cost (including inflation), disruption, longevity, and combined performance>

Project Schematics (Scope and Flowchart, customized or simplified – see next sheet):
<insert>

Ensure collect all relevant project information.

See Summary Project Description Base Form (in Appendix E of the Guide and on CD).



Simplified Base Project Delivery Strategy – Design/Bid/Build

Planning
Scoping
Design Fund
Prelim Design
Environ. Process/ Permits
CN Fund
Final Design
ROW/ Utilities/ Railroad
ROW Fund
Procure- ment
Construc- tion
Opera- tions
Replace- ment

Traditional single phase/contract design/bid/build procurement. Multiple phases/contracts or design/build would be different.

time

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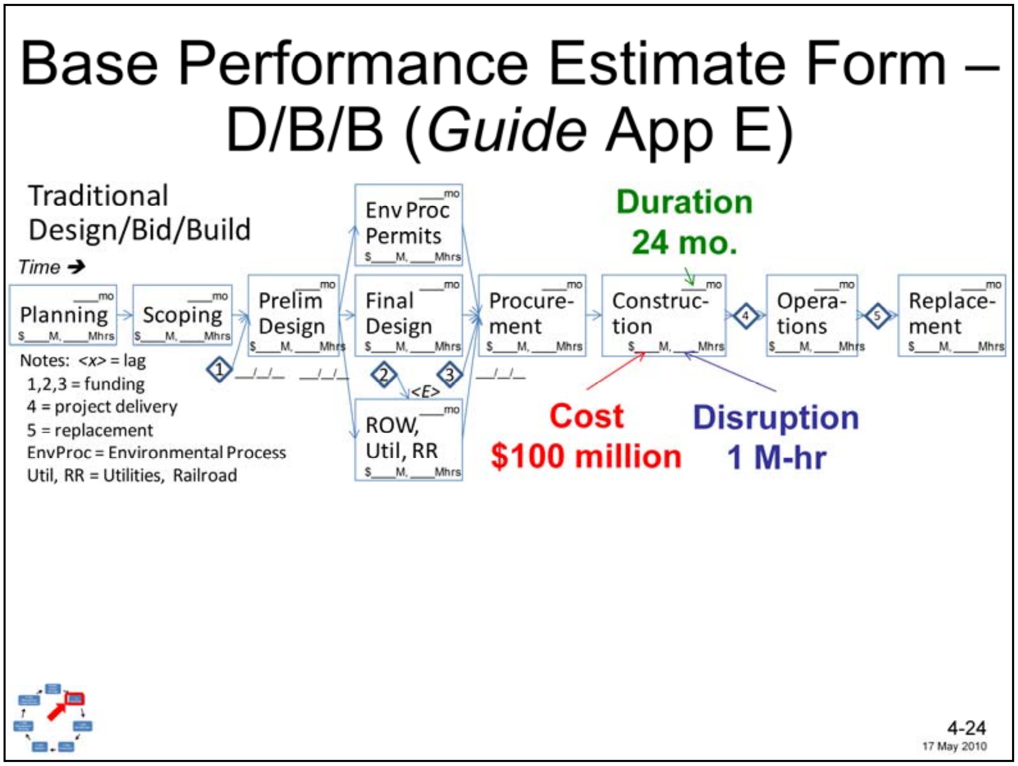
Very basic, generic flow chart is shown for a traditional single phase/contract D/B/B procurement, in which environmental process/permitting and ROW/utility relocation activities, as well as design, must be complete before going to ad. However, it can also be used to approximately describe more complicated projects. This (and a similar one for D/B) flow chart will be the basis for identifying and assessing risks in this course. This simple flowchart would generally not be adequate for quantitative risk analysis.

The activities include:

- **Planning** – very conceptual design (based on purpose and need, considering various requirements)
- **Scoping** – planning level design (to about 10%), based on which a project is established; typically does not require significant funds
- **Prelim Design** – from 10% design to 30% design; requires adequate funding to start
- **Environmental process/permits** – environmental documents and approvals, as well as subsequent permits; requires a particular level of design (≥10%) to start, so that there might be a lag to the start of environmental process/permits after the start of design
- **ROW/utilities/RR** – ROW acquisition (including condemnations, relocations, etc.), utility relocations, and any railroad agreements needed for the project; requires a particular level of design (≥10%) to start of planning, so that there might be a lag to the start of ROW/utilities/RR after the start of design; also requires adequate funding before can proceed beyond planning, so that there might be a lag to the finish of ROW/utilities/RR after funding is available
- **Final Design** – from about 30% design to approved final design and bid documents
- **Procurement** – ad, bid, award, negotiate and finally NTP; requires completion of design (including bid documents) and adequate funding, as well as completion of environmental process/permits and ROW/utilities/RR activities before can start (go to ad)
- **Construction** – from NTP (end of procurement) to close out, includes all contractor activities as well as owner/CM activities
- **Operations** – post-construction, includes maintenance
- **Replacement** – reconstruction (or decommissioning) at end of design life

Note: In many cases, the various funding milestones (design, ROW, construction) will coincide.



Base Performance Estimate Form – D/B/B (*Guide* App E)

Traditional Design/Bid/Build

Time ➔

Duration 24 mo.

Cost $100 million

Disruption 1 M-hr

Notes: <*x*> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

This information will eventually be input into an MS Excel workbook template developed for this course (provided on CD and presented in Template module), which models the “standard” D/B/B flow chart previously discussed (and copied above).

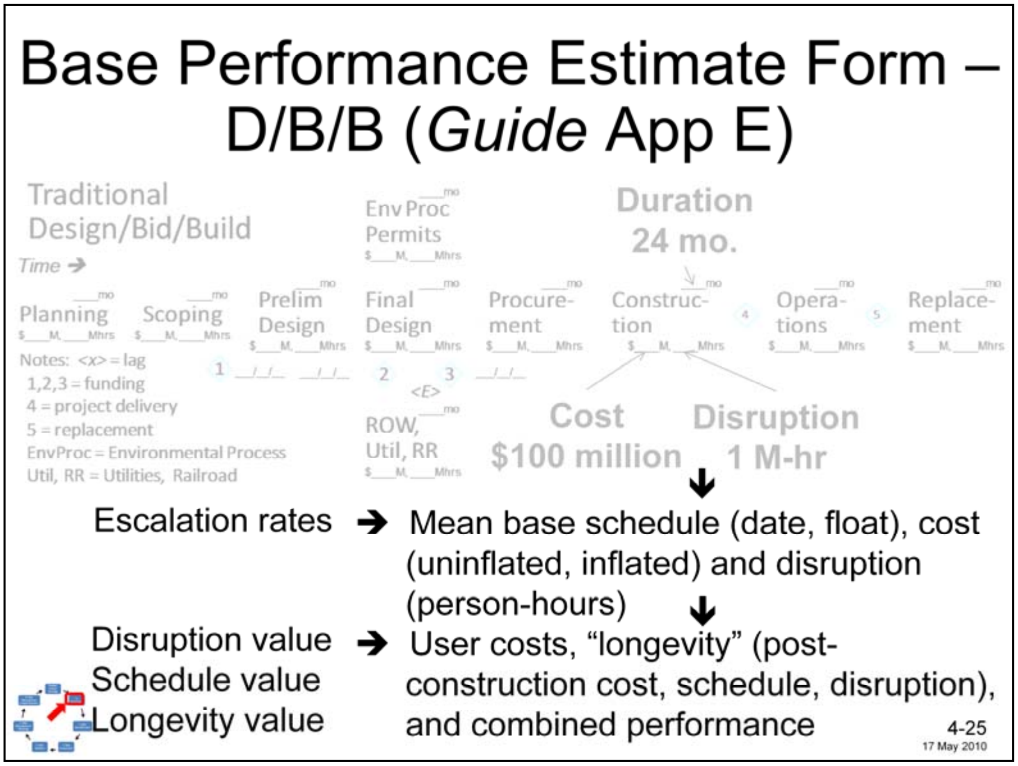
- Inputs include:
    - Project start date (from which schedule and escalation are derived)
    - “Base” unescalated cost, duration and disruption (exclusive of risk, contingency, float) for each major project activity, and lags (if any) for several activities – might need allocation matrix to go from cost items to activities
    - Funding availability milestone dates
    - Average annual escalation rates (over appropriate time periods) for various types of activities.

Note: Other values are eventually needed to combine measures.

- The total base project costs (unescalated and escalated) and disruption, base activity schedule dates, base activity float and base activity escalated costs are computed automatically in the worksheet, based on the standard D/B/B flow chart, early activity starts, and escalation to each activity midpoint at its specified escalation rate. The schedule is determined through standard critical path methods.

Note: These are only base costs, schedule and disruption, without consideration of risk. Total performance will be determined once risks are added in.

- If “expected values” (probability-weighted average values) are used for inputs, then the outputs are also approximately expected values. However, there will generally be significant uncertainty in the outputs due to significant uncertainties in the inputs, which will not be assessed or considered when using the template – uncertainties in the inputs and in the outputs are discussed further in Module 7 (Quantitative Risk Analysis).



Base Performance Estimate Form – D/B/B (*Guide* App E)

Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

Escalation rates ➔ Mean base schedule (date, float), cost (uninflated, inflated) and disruption (person-hours)

Disruption value
Schedule value
Longevity value ➔ User costs, "longevity" (post-construction cost, schedule, disruption), and combined performance

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A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

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- Inputs include:
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Note: These are only base costs, schedule and disruption, without consideration of risk. Total performance will be determined once risks are added in.

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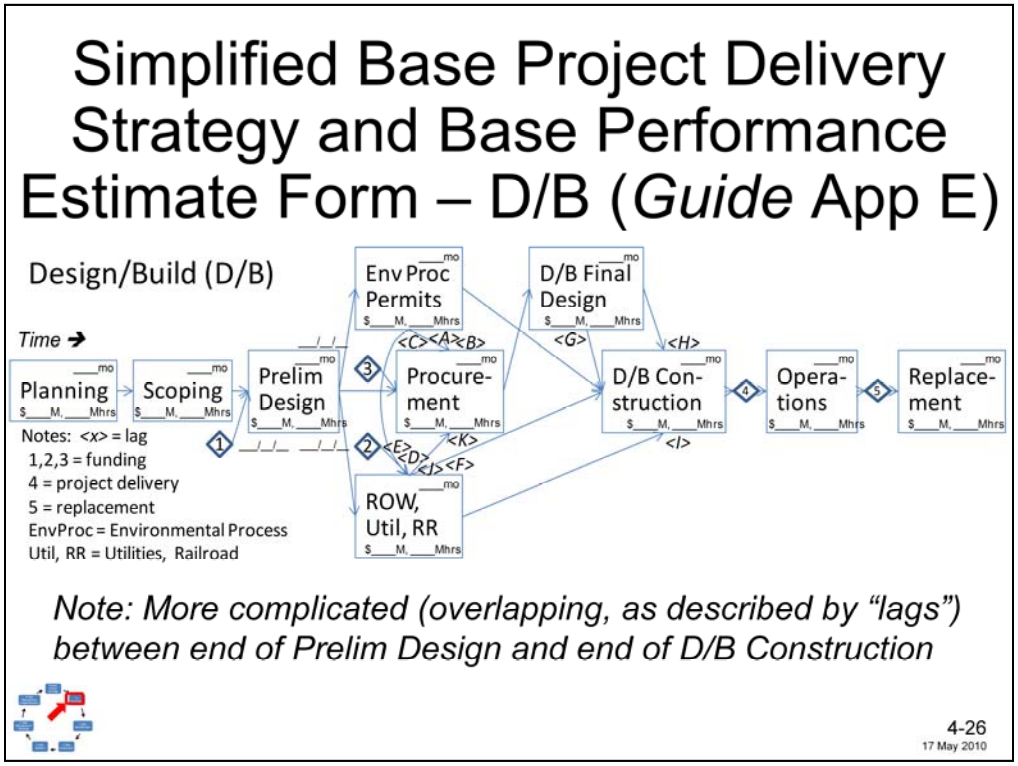


Simplified Base Project Delivery Strategy and Base Performance Estimate Form – D/B (*Guide* App E)

Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

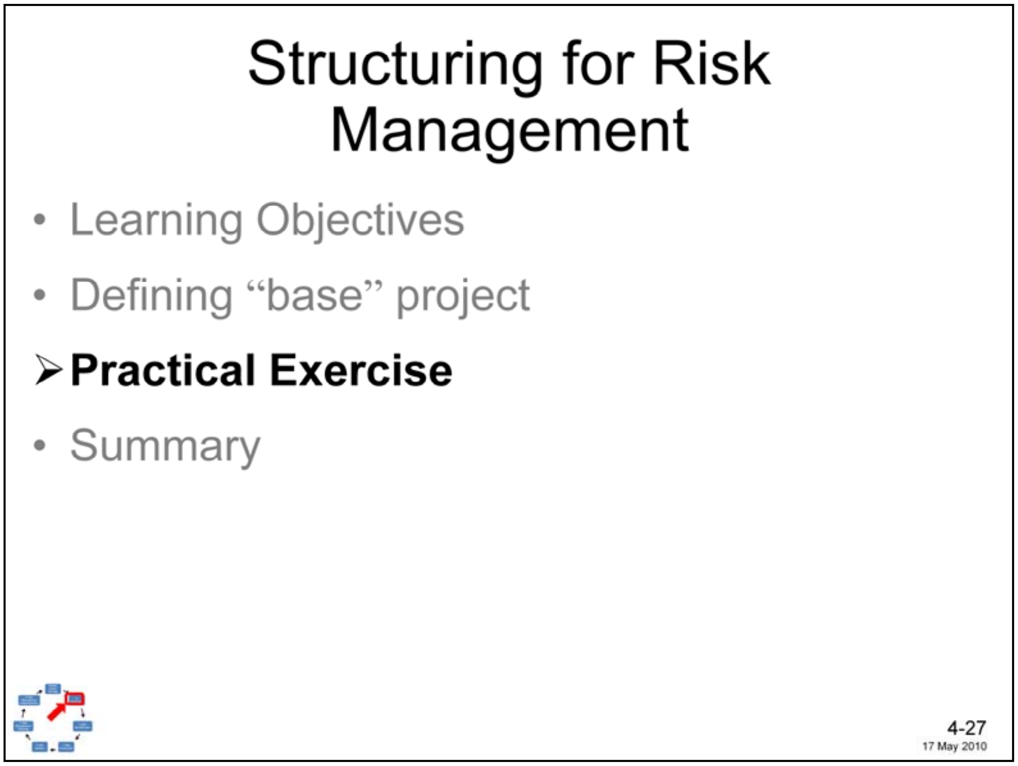
Note: More complicated (overlapping, as described by "lags") between end of Prelim Design and end of D/B Construction

Very basic, generic flow chart is shown for a non-traditional single phase/contract D/B procurement, in which environmental process/permitting and ROW/utility relocation activities, as well as design, do not have to be complete before going to ad. Although it can also be used to approximately describe more complicated projects, it would generally not be adequate for quantitative risk analysis.

The phases and analysis are essentially the same as for D/B/B.

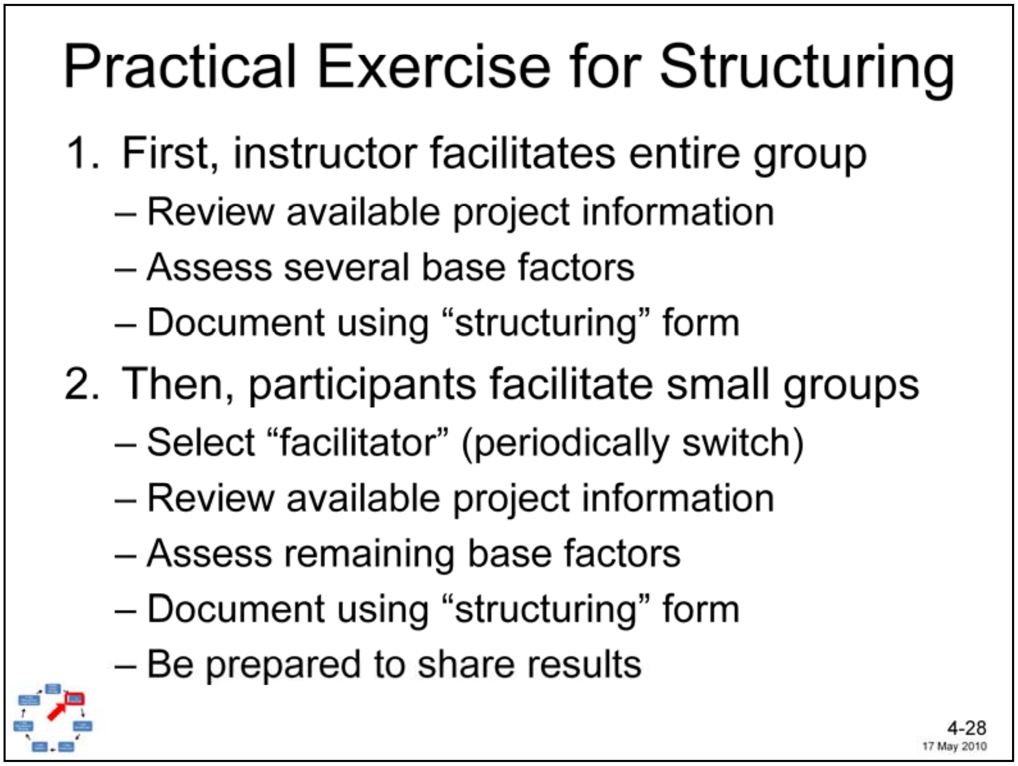
A hard copy of this form is also presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

The MS Excel workbook template developed for this course (provided on CD and presented in Template Module 12) also accommodates this strategy.



Structuring for Risk Management

- Learning Objectives
- Defining “base” project
- ➢ **Practical Exercise**
- Summary



Practical Exercise for Structuring

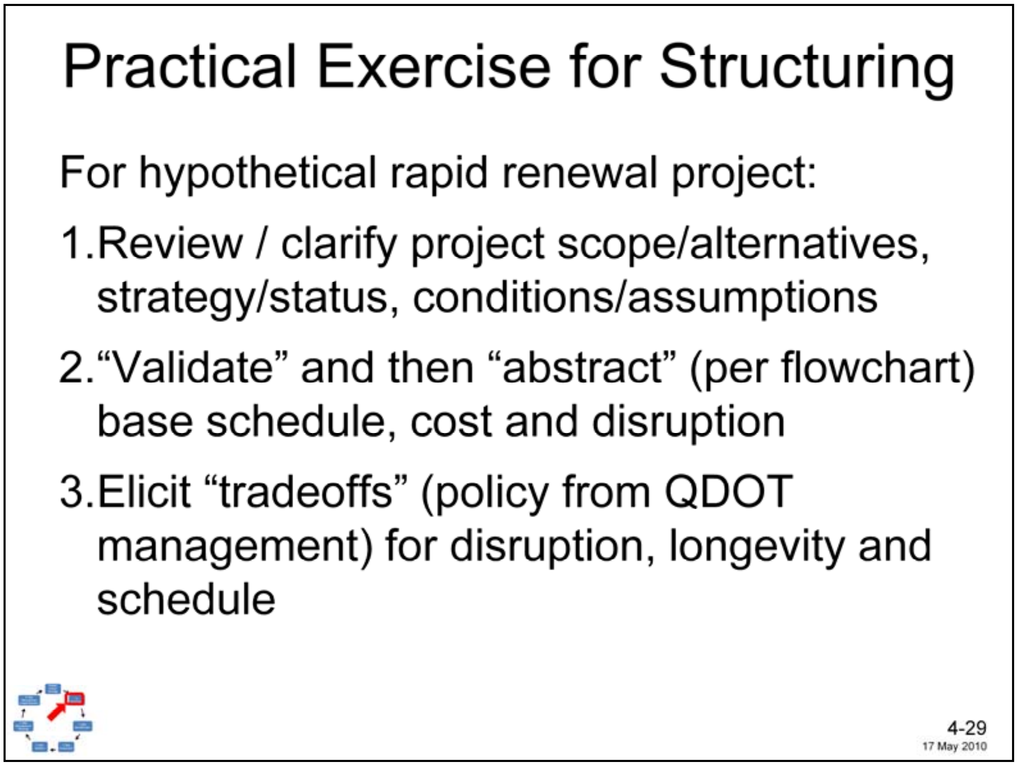
1. First, instructor facilitates entire group
   - Review available project information
   - Assess several base factors
   - Document using "structuring" form
2. Then, participants facilitate small groups
   - Select "facilitator" (periodically switch)
   - Review available project information
   - Assess remaining base factors
   - Document using "structuring" form
   - Be prepared to share results

Following the principles outlined in Chapter 4 of the *Guide*, QDOT presented the project's scope/strategy/status and key conditions/assumptions (see App A of Risk Management Plan) and cost, schedule and disruption estimates to the combined group of key project-team staff and independent subject-matter experts.

Facilitated by a "base lead", the group reviewed, de-biased, and validated the cost, schedule and disruption estimates for the assumptions stated below. The results were "base" cost, schedule and disruption estimates, exclusive of risk and opportunity. For quantitative risk analysis (Chapter 7 of the *Guide*), this review and validation was in more detail than for risk identification and qualitative risk analysis (Chapter 6 of the *Guide*), and included assessments of ranges of costs and durations (and correlations among them) (see Appendix B of Risk Management Plan).

Facilitated by a "risk lead", the group adopted a D/B standard simplified graphical "flow chart" describing the sequence of major project activities. This simplified flow chart serves as the basis for risk identification and assessment, and subsequent proactive individual risk reduction identification and evaluation. For quantitative risk analysis (Chapter 7 of the *Guide*), this flow chart was developed in more detail to serve as the basis for a better integrated cost and schedule model for the project. (see Appendix F of the *Guide*).

For both risk identification/assessment and quantitative risk analysis, mean base project performance (i.e., schedule, uninflated and inflated cost, and disruption) was approximately calculated using a risk model. For risk identification/assessment, QDOT established "tradeoff values" (which are policy rather than technical issues), which allowed the various project performance measures to be combined, e.g.: a) combining post-construction schedule, cost and disruption into "longevity"; and b) combining schedule, cost and disruption through construction with longevity into "severity".



Practical Exercise for Structuring

For hypothetical rapid renewal project:

1. Review / clarify project scope/alternatives, strategy/status, conditions/assumptions
2. "Validate" and then "abstract" (per flowchart) base schedule, cost and disruption
3. Elicit "tradeoffs" (policy from QDOT management) for disruption, longevity and schedule

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See Appendix A of Risk Management Plan in Appendix F of the *Guide*.

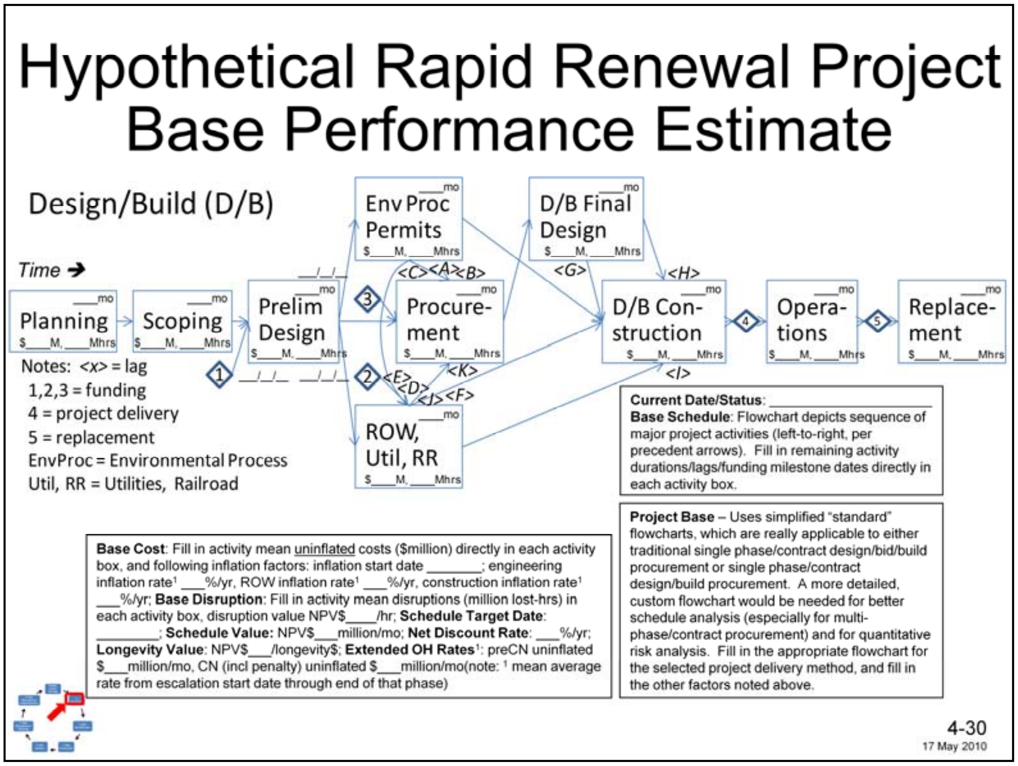
Validate and abstract:

- **Base Schedule** - Note dates on standard flow chart, and determine base durations for each activity. Confirm that (considering the scope) these durations are reasonable (not aggressive or conservative) or revise them to be realistic. Remember that an activity's base duration should be the time it would take to complete the activity under the base assumptions, excluding any float and any risks/opportunities – the base duration should not simply be the time available to complete the activity.
- **Base Cost** - Confirm that (considering the scope) unit costs and quantities are reasonable (not aggressive or conservative) or revise them, and that no cost items have been missed. Once "validated", strip out explicit contingency and allocate costs to major activities in standard flowchart; e.g., construction cost and CM cost go to the Construction activity. Also confirm escalation rates and extended OH rates.
- **Base Disruption** - Confirm that (considering the scope) values are reasonable (not aggressive or conservative) or revise them to be realistic, and that no disruptive activities have been missed.

Elicit "tradeoffs", which are policy rather than technical issues, from management:

- disruption (user costs)
- longevity (net discount rate, value of longevity)
- schedule (value of completion date)

.



Hypothetical Rapid Renewal Project Base Performance Estimate

Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

Current Date/Status: ____________________
Base Schedule: Flowchart depicts sequence of major project activities (left-to-right, per precedent arrows). Fill in remaining activity durations/lags/funding milestone dates directly in each activity box.

Project Base – Uses simplified "standard" flowcharts, which are really applicable to either traditional single phase/contract design/bid/build procurement or single phase/contract design/build procurement. A more detailed, custom flowchart would be needed for better schedule analysis (especially for multi-phase/contract procurement) and for quantitative risk analysis. Fill in the appropriate flowchart for the selected project delivery method, and fill in the other factors noted above.

Base Cost: Fill in activity mean <u>uninflated</u> costs ($million) directly in each activity box, and following inflation factors: inflation start date ________; engineering inflation rate¹ ___%/yr, ROW inflation rate¹ ___%/yr, construction inflation rate¹ ___%/yr; **Base Disruption**: Fill in activity mean disruptions (million lost-hrs) in each activity box, disruption value NPV$____/hr; **Schedule Target Date**: _________; **Schedule Value:** NPV$___million/mo; **Net Discount Rate**: ___%/yr; **Longevity Value**: NPV$___/longevity$; **Extended OH Rates**¹: preCN uninflated $___million/mo, CN (incl penalty) uninflated $___million/mo(note: ¹ mean average rate from escalation start date through end of that phase)

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See *Summary Project Description Base Form* (in Appendix E of the *Guide* and on CD) – a copy to use for this practical exercise is contained at the end of this module.

This information will eventually be input into an MS Excel workbook template developed for this course, which models the "standard" D/B flow chart previously discussed (and copied above).

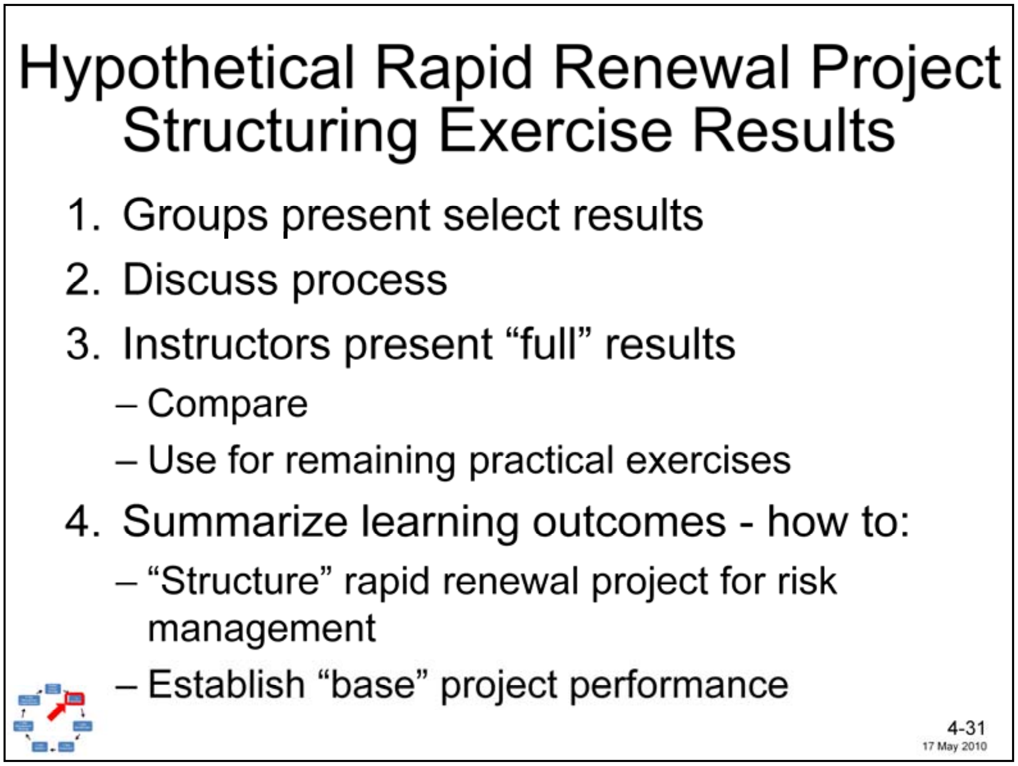
- Inputs include:
  - Project start date (from which schedule and escalation are derived)
  - "Base" unescalated cost, duration and disruption (exclusive of risk, contingency, float) for each major project activity, and lags (if any) for several activities – might need allocation matrix to go from cost items to activities
  - Funding availability milestone dates
  - Average annual escalation rates (over appropriate time periods) for various types of activities.

Note: Other values ("tradeoffs") are eventually needed to combine measures.

- The total base project costs (unescalated and escalated) and disruption, base activity schedule dates, base activity float and base activity escalated costs are computed automatically in the worksheet, based on the standard flow chart, early activity starts, and escalation to each activity midpoint at its specified escalation rate. The schedule is determined through standard critical path methods.

Note: These are only base costs/schedule/disruption, without consideration of risk. Total performance will be determined once risks are added in.

- If "expected values" (probability-weighted average values) are used for inputs, then the outputs are also approximately expected values. However, there will generally be significant uncertainty in the outputs due to significant uncertainties in the inputs, which will <u>not</u> be assessed or considered when using the template.



Hypothetical Rapid Renewal Project Structuring Exercise Results

1. Groups present select results
2. Discuss process
3. Instructors present “full” results
   - Compare
   - Use for remaining practical exercises
4. Summarize learning outcomes - how to:
   - “Structure” rapid renewal project for risk management
   - Establish “base” project performance

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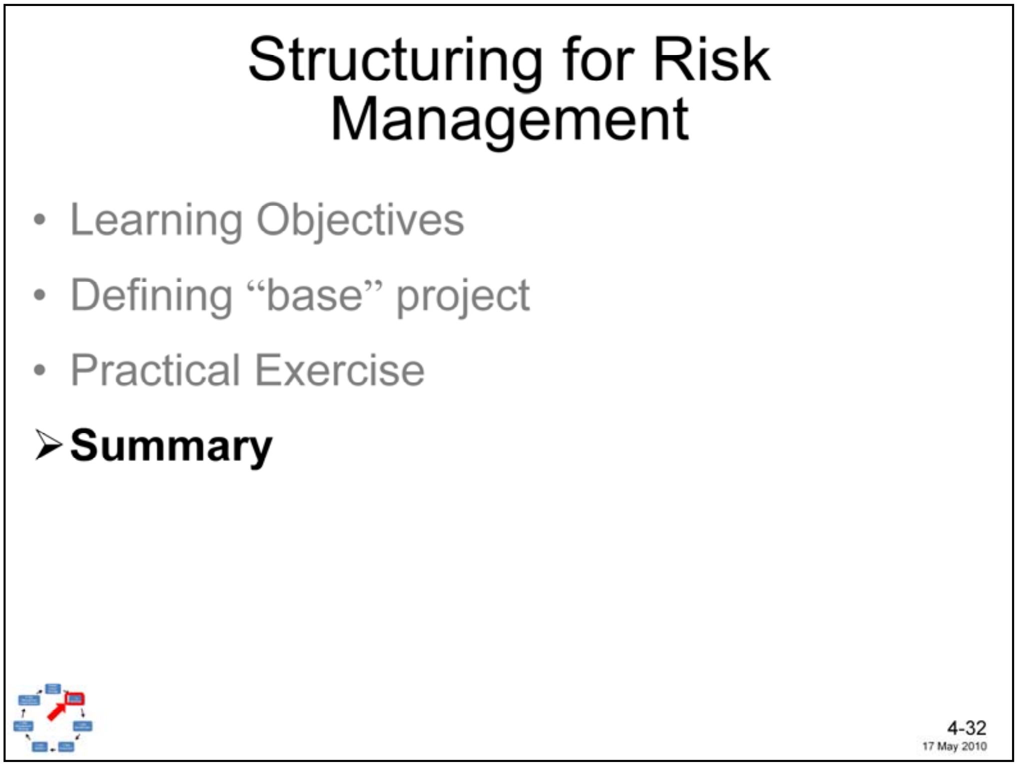
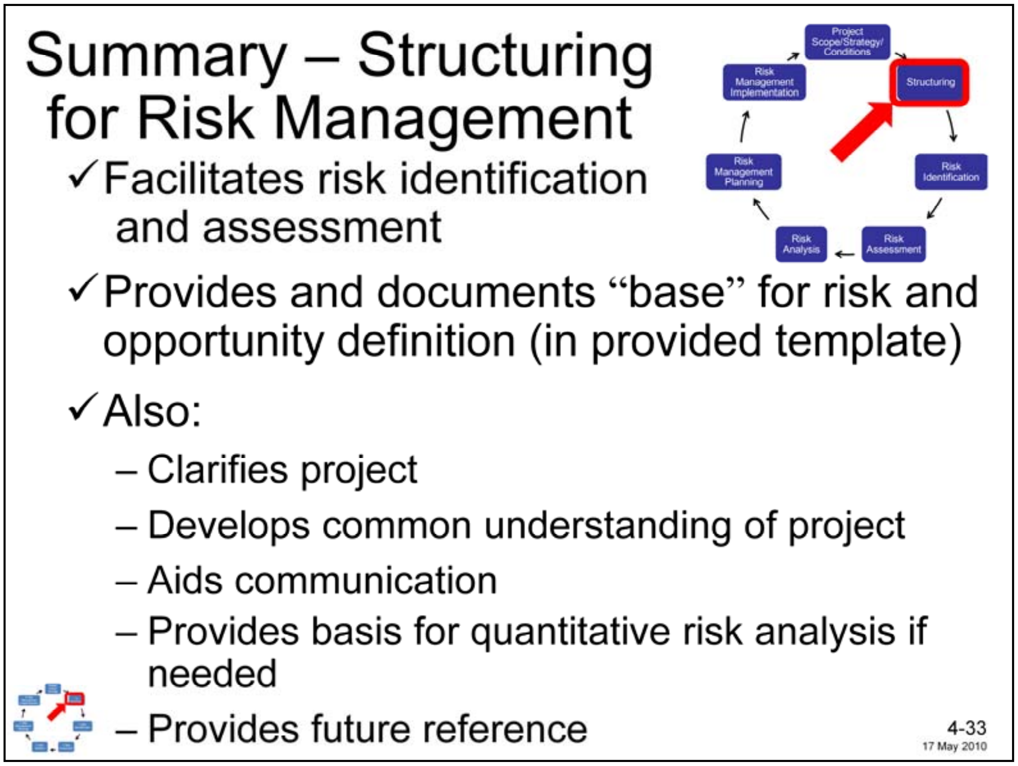
Instructors’ results will be handed out after participants’ results have been presented and discussed. These results, which will be used for remaining practical exercises, should be inserted in Appendix F of the *Guide* for future reference.



Structuring for Risk Management

- Learning Objectives
- Defining “base” project
- Practical Exercise
- **Summary**



Summary – Structuring for Risk Management

- ✓ Facilitates risk identification and assessment
- ✓ Provides and documents "base" for risk and opportunity definition (in provided template)
- ✓ Also:
  - Clarifies project
  - Develops common understanding of project
  - Aids communication
  - Provides basis for quantitative risk analysis if needed
  - Provides future reference

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"Structuring" a rapid renewal project for risk management is a necessary and valuable first step in the risk management process. It provides the "base" for identifying risks and opportunities, assessing them (and for quantitative risk analysis, if desired), and eventually managing them; it also documents the current state for future reference. If done appropriately, structuring facilitates subsequent risk identification and assessment, as well as clarifies the important elements of the project, providing a common understanding and a communication tool.

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Summary Project Description

Brief Project Description:
<insert>

Project Scope, Strategy/Status, and Key Conditions and Assumptions (identify):

- Detailed scope (including alternatives): <insert>
- Funding: <insert>
- Design:
    - Design level: <insert>
    - Structural: <insert>
    - Geotechnical: <insert>
    - Drainage: <insert>
    - Pavement: <insert>
    - Systems (including lighting and ITS)
    - Design deviations: <insert>
- Environmental:
    - Environmental documentation: <insert>
    - Wetlands: <insert>
    - Streams: <insert>
    - ESA: <insert>
    - Floodplain: <insert>
    - Stormwater: <insert>
    - Contaminated/hazardous waste: <insert>
    - Section 106: <insert>
    - 4(f): <insert>
    - Permitting (incl 404): <insert>
- Right of way and other agreements
    - Right-of-Way: <insert>
    - Utilities: <insert>
    - Railroad: <insert>
    - Other stakeholders: <insert>
- Procurement:
    - Delivery method: <insert>
    - Contract packaging: <insert>
    - Market (general and specialty): <insert>
- Construction:
    - Construction access/restrictions (including seasonal, events, shifts/hours): <insert>
    - Maintenance of traffic/business: <insert>
    - Construction phasing: <insert>
- Post-construction (“longevity”):
    - O&M: <insert>
    - Replacement: <insert>

Project Schedule (delivery, O&M, replacement – abstracted on next sheet):
<summarize major activities/milestones, including discussion of basis and bias/conservatism>

Project Cost Estimate (delivery, O&M, replacement – abstracted on next sheet):
<summarize major elements and costs, including discussion of basis and bias/conservatism, escalation, NPV for long term, disruption cost, and schedule and longevity value>

Project Disruption Estimate (delivery, O&M, replacement – abstracted on next sheet):
<summarize major elements and disruption, including discussion of basis and bias/conservatism>

Project Tradeoffs (disruption, schedule, longevity):
<summarize policy values for combining performance measures>

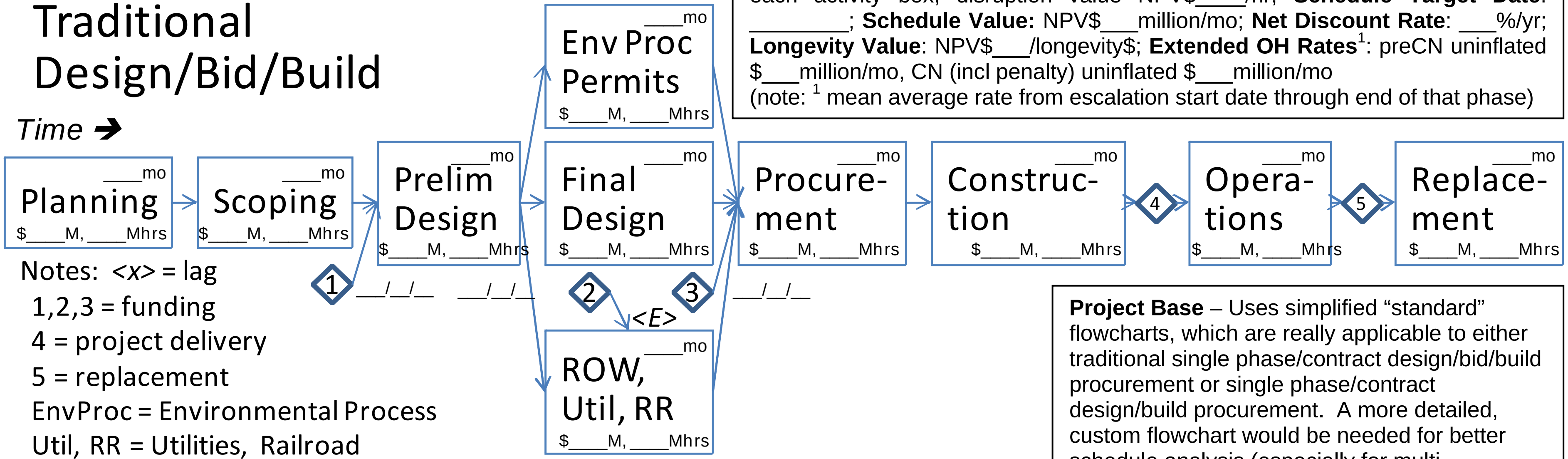
Project Performance Analysis:
<summarize project schedule, cost (including inflation), disruption, longevity, and combined performance>

Project Schematics (Scope and Flowchart, customized or simplified – see next sheet):
<insert>

Current Date/Status: ______________________________
Base Schedule: Flowchart depicts sequence of major project activities (left-to-right, per precedent arrows). Fill in remaining activity durations/lags/funding milestone dates directly in each activity box.

Base Cost: Fill in activity mean uninflated costs ($million) directly in each activity box, and following inflation factors: inflation start date _______; engineering inflation rate[1] ___%/yr, ROW inflation rate[1] ___%/yr, construction inflation rate[1] ___%/yr; **Base Disruption**: Fill in activity mean disruptions (million lost-hrs) in each activity box, disruption value NPV$____/hr; **Schedule Target Date**: ________; **Schedule Value:** NPV$___million/mo; **Net Discount Rate**: ___%/yr; **Longevity Value**: NPV$___/longevity$; **Extended OH Rates**[1]: preCN uninflated $___million/mo, CN (incl penalty) uninflated $___million/mo
(note: [1] mean average rate from escalation start date through end of that phase)

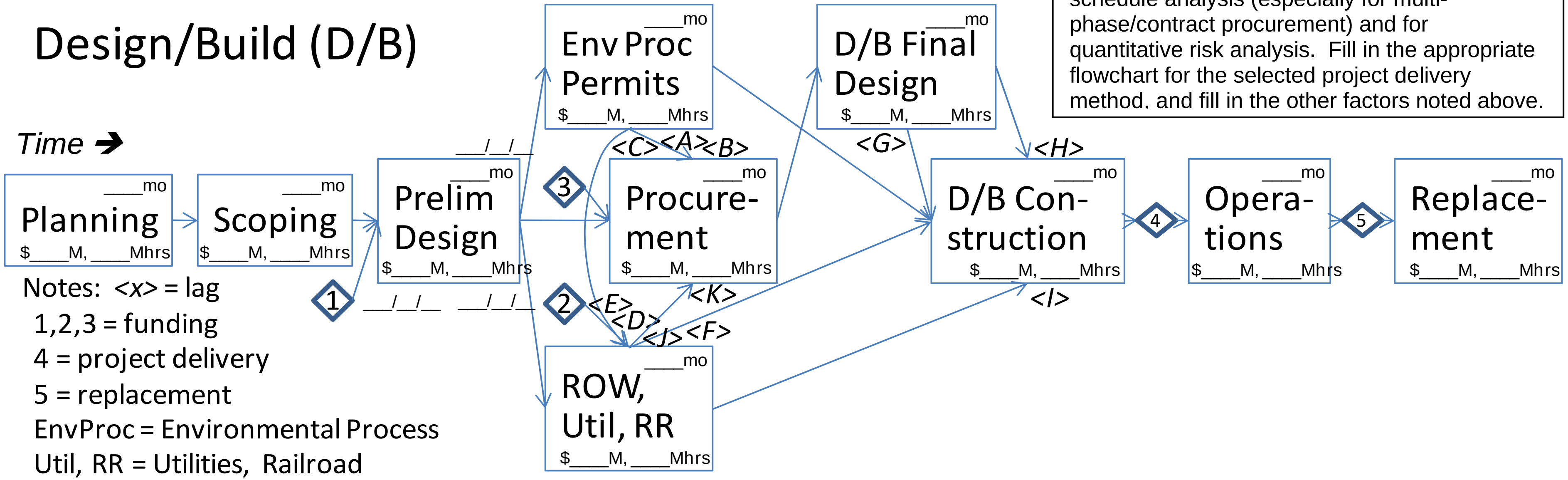
Traditional Design/Bid/Build



Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

Project Base – Uses simplified "standard" flowcharts, which are really applicable to either traditional single phase/contract design/bid/build procurement or single phase/contract design/build procurement. A more detailed, custom flowchart would be needed for better schedule analysis (especially for multi-phase/contract procurement) and for quantitative risk analysis. Fill in the appropriate flowchart for the selected project delivery method. and fill in the other factors noted above.

Design/Build (D/B)



Notes: <x> = lag
1,2,3 = funding
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5 = replacement
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Risk Management

Module 5:
Risk Identification

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

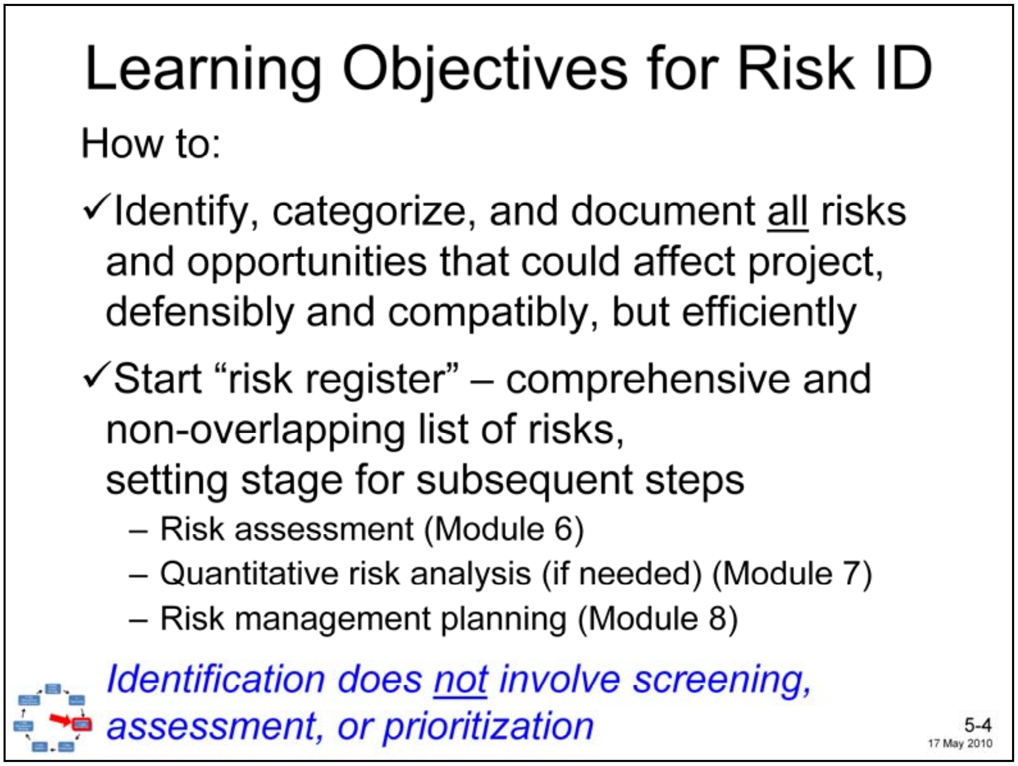
Risk Management Implementation

In a Nutshell:
Risk Identification

- *Identifying*, *categorizing* and *documenting* (in *risk register*) comprehensive, non-overlapping set of “risks” (potential problems) and “opportunities” (potential improvements)
- Events that *might* occur, which are outside of base assumptions and could change “base” project performance

Risk Identification

- Learning Objectives
- Risk Identification
  - Process
  - Guidance
- Practical Exercise
- Summary



Learning Objectives for Risk ID

How to:

✓Identify, categorize, and document <u>all</u> risks and opportunities that could affect project, defensibly and compatibly, but efficiently

✓Start “risk register” – comprehensive and non-overlapping list of risks, setting stage for subsequent steps

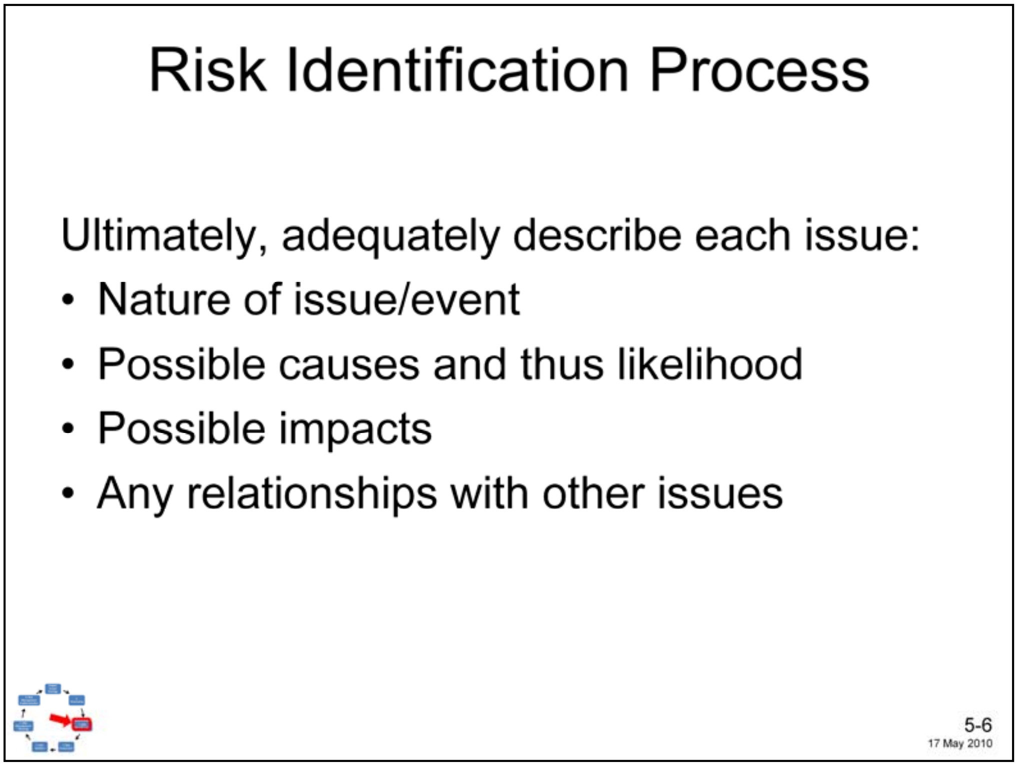
- Risk assessment (Module 6)
- Quantitative risk analysis (if needed) (Module 7)
- Risk management planning (Module 8)

Identification does <u>not</u> involve screening, assessment, or prioritization

- At end of the project, everything significant that actually happened during project (changes from base) should have been identified during risk identification as possibilities (although not necessarily predicted).
- After structuring, this is the critical next step in Risk Management process
- Risks should be non-overlapping (as well as comprehensive) to avoid double-counting; this does not mean that risks should be mutually exclusive because many risks could occur together.
- No screening is done at this time, since the significance of the various risks will be determined later, at which point those that are not significant will be identified as such and there will be a record of this determination.

Risk Identification

- Learning Objectives
- **Risk Identification**
  - **Process**
  - **Guidance**
- Practical Exercise
- Summary



Risk Identification Process

Ultimately, adequately describe each issue:

- Nature of issue/event
- Possible causes and thus likelihood
- Possible impacts
- Any relationships with other issues

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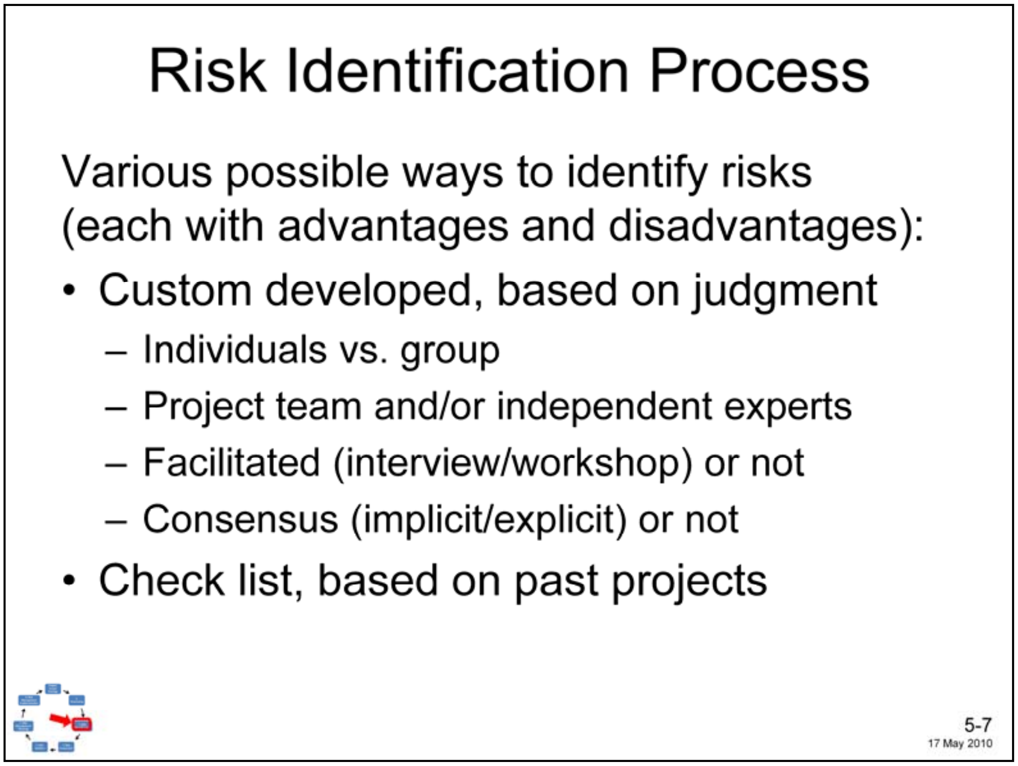
- Document:
  - Label
  - Title / short description
  - “Scenario” description, including impacts of occurrence
  - Possible causes and their likelihood, and thus likelihood of scenario occurrence
  - Relationships with other issues (e.g., precluded if another event occurs)
- Example:

Can’t get materials, labor, or specialized equipment when needed for construction - Excludes cost premium associated with market competition, which is captured in a separate risk. This issue deals with the potential that when needed, adequate resources simply won’t be available. Includes: materials (shortage of supply); labor (e.g., all being used elsewhere); oil and fuel; and unique equipment. Any of these factors could result in increased construction cost and/or construction schedule delay.



Risk Identification Process

Various possible ways to identify risks (each with advantages and disadvantages):

- Custom developed, based on judgment
  - Individuals vs. group
  - Project team and/or independent experts
  - Facilitated (interview/workshop) or not
  - Consensus (implicit/explicit) or not
- Check list, based on past projects

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• Individual expert interviews do not provide interaction among experts (which is valuable for understanding and providing consensus, where preliminary work might have to be subsequently redone to accommodate additional late viewpoints), and is therefore not preferred unless the experts are unavailable for a group workshop.

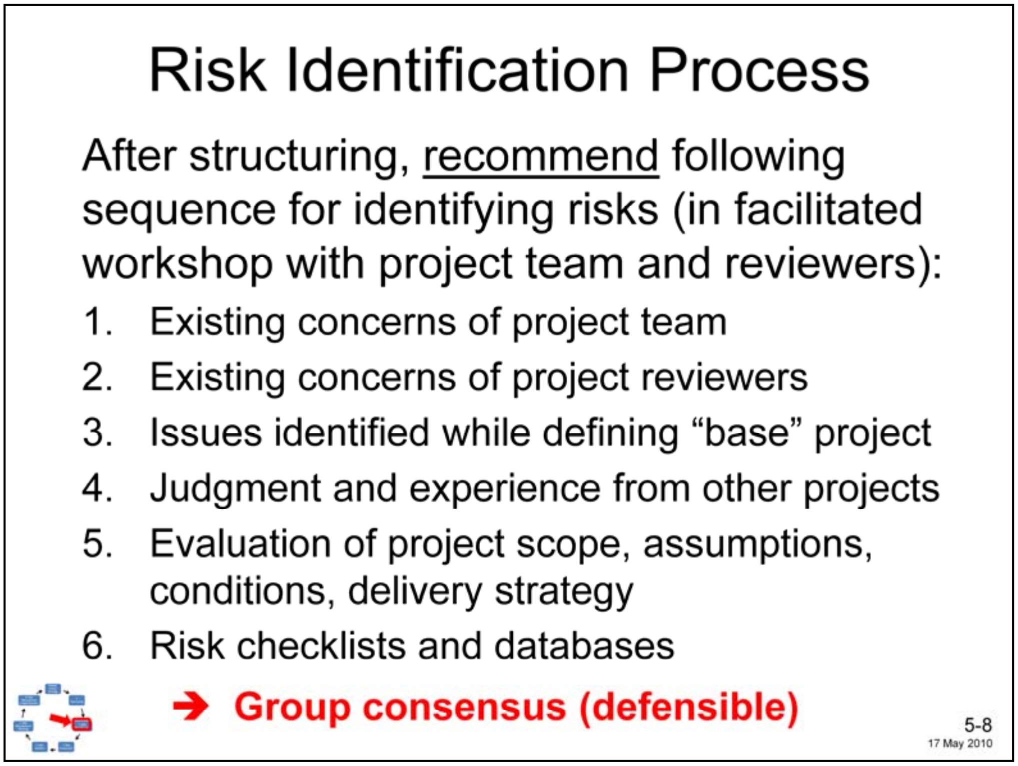
• Although project team knows the project, they are often overly optimistic or defensive. Independent exerts can counter this bias.

• Qualified facilitator can conduct individual interviews or workshops to efficiently achieve risk identification objectives. Otherwise, the objectives will likely not be achieved.

• Consensus is important for defensibility of the results. Consensus can be as strong as a written statement from all participants that they agree with the results (explicit) to a statement by the facilitator that he considered all opinions in his results (implicit).

• Note: Other more formal techniques are generally used for special applications, e.g., where defensibility is critical and resources are available. Examples include, Nominal Group, Crawford-Slip, Delphi, and others.

• Checklists are useful to trigger ideas, but should not be used as the sole source of risks.



Risk Identification Process

After structuring, <u>recommend</u> following sequence for identifying risks (in facilitated workshop with project team and reviewers):

1. Existing concerns of project team
2. Existing concerns of project reviewers
3. Issues identified while defining "base" project
4. Judgment and experience from other projects
5. Evaluation of project scope, assumptions, conditions, delivery strategy
6. Risk checklists and databases

➔ **Group consensus (defensible)**

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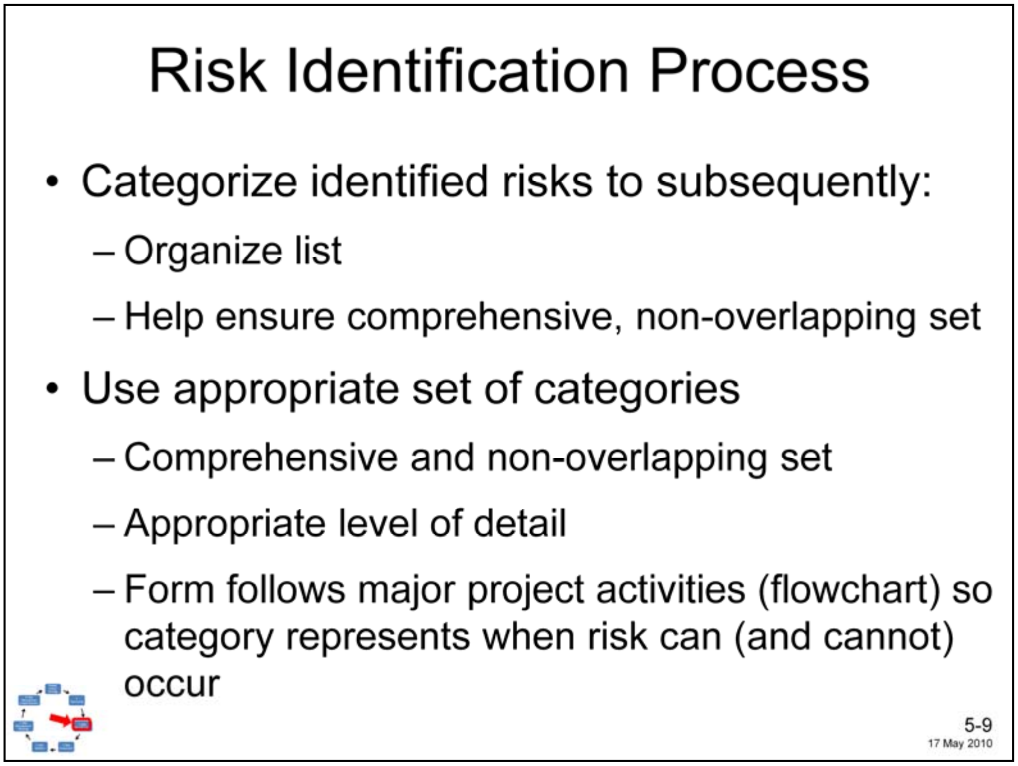
- Issues of concern should be developed *in above order, to reduce bias.*
- Existing concerns of project team are "what keeps me awake at night is…"
- Existing concerns of independent subject-matter experts reviewing the project are "what concerns me about this project is…".
- Suitable risk checklists and databases are presented in Appendix D of the *Guide*:
  - Generic list of risks for non-rapid renewal projects by project [phase (summary)
  - Generic list of risks for rapid renewal projects by project [phase (summary and detail)

However, note that risk checklists are generic "shopping lists" to be used <u>at the end</u> of the identification process to help ensure no major issues were missed. They are not proper risk registers! Also, they are neither non-overlapping nor necessarily comprehensive (otherwise there would never be new risks), and are not necessarily at the appropriate level of detail nor project-specific.



Risk Identification Process

- Categorize identified risks to subsequently:
  - Organize list
  - Help ensure comprehensive, non-overlapping set
- Use appropriate set of categories
  - Comprehensive and non-overlapping set
  - Appropriate level of detail
  - Form follows major project activities (flowchart) so category represents when risk can (and cannot) occur

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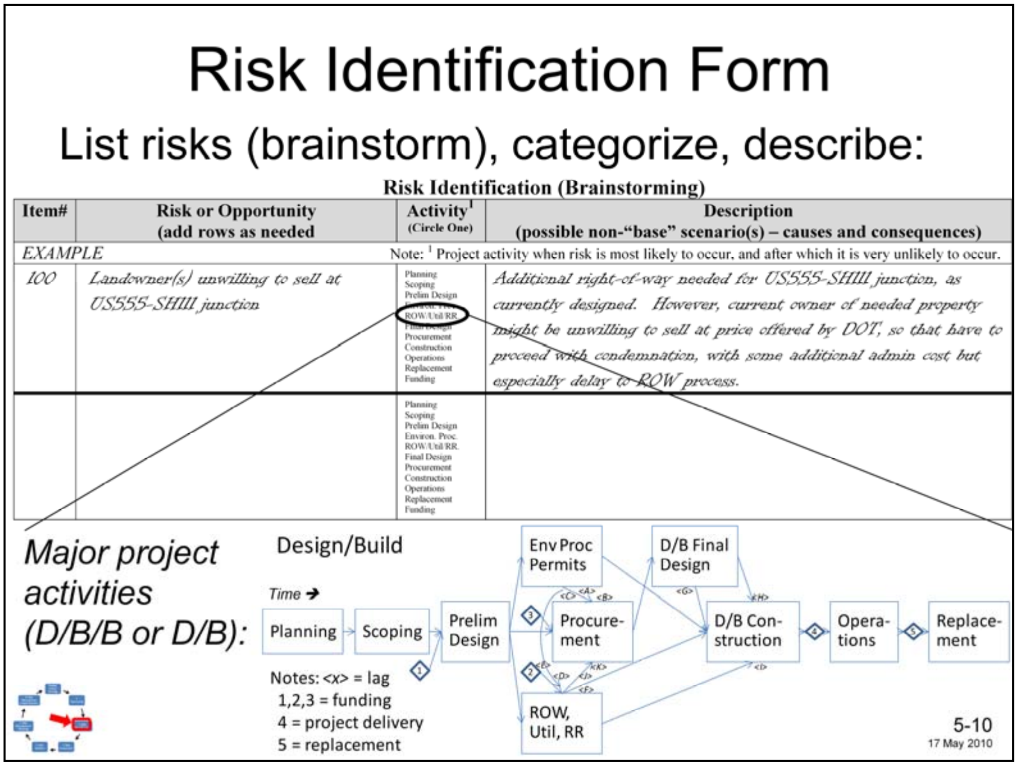
Categories help organize large lists and help identify gaps and overlaps. Generally, the categories don’t need to be rigid - some risks could fit in multiple categories.

• The forms and template for this course use the project phases during which the risk is most likely to occur and after which the risk is unlikely too occur:

- Planning (PL)
- Scoping (SC)
- Prelim Design (PD)
- Environmental Process (EP)
- ROW/Utilities/RR (RU)
- Final Design (FD)
- Procurement (CP)
- Construction (CN)
- Operations (OM)
- Replacement (RP)
- Funding (FN)

• However, other possible set of risk categories , e.g., the following simple set:

- Project engineering (pre-construction)
- ROW
- Construction (including construction engineering)



Risk Identification Form

List risks (brainstorm), categorize, describe:

Risk Identification (Brainstorming)

Item#	Risk or Opportunity (add rows as needed	Activity[1] (Circle One)	Description (possible non-"base" scenario(s) – causes and consequences)
EXAMPLE		Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur.	
100	*Landowner(s) unwilling to sell at US555-SHIII junction*	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding	*Additional right-of-way needed for US555-SHIII junction, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.*
		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding	

Major project activities (D/B/B or D/B):

Notes: <x> = lag
1,2,3 = funding
4 = project delivery
5 = replacement

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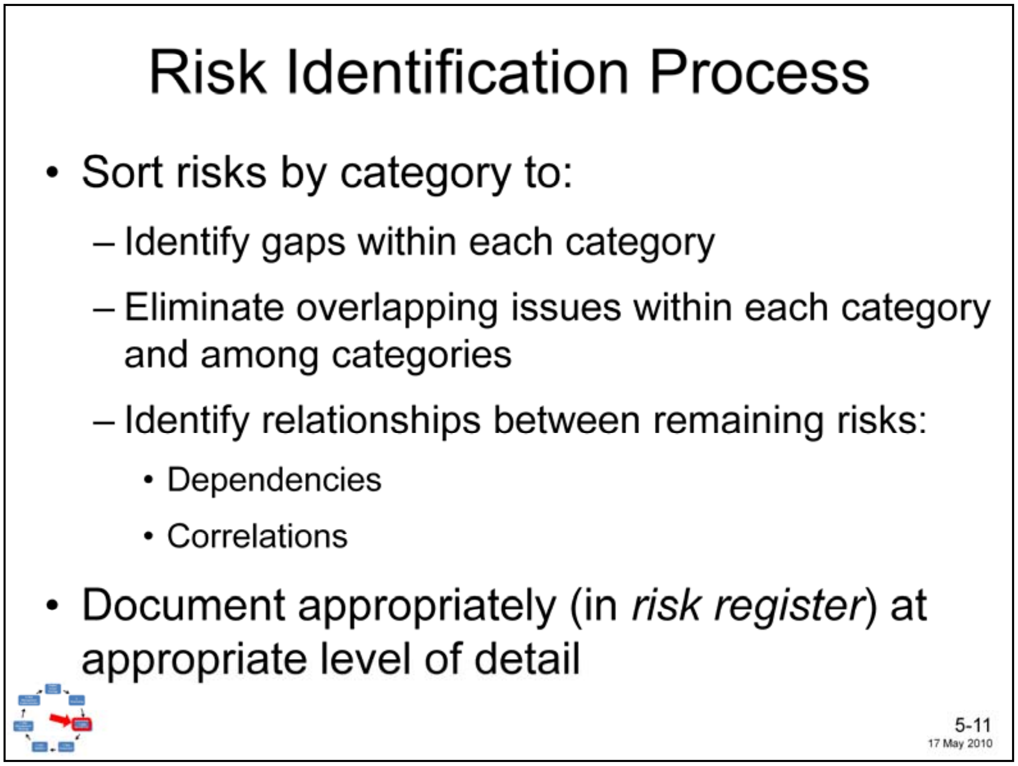
17 May 2010

A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

This information will eventually be input into an MS Excel workbook template developed for this course (provided on CD and presented in Template module) – in fact, the template is designed to be filled in directly (on the fly) during the workshop, bypassing the paper form.

Inputs include:

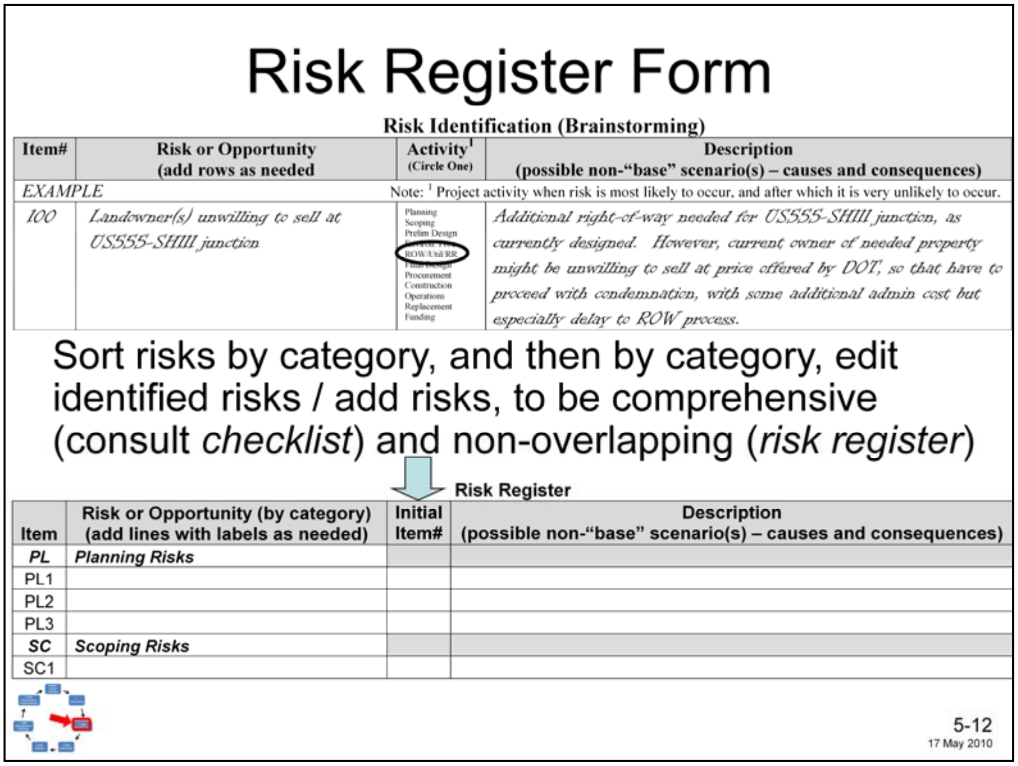
- Risk (or opportunity) short, descriptive title
- Risk category (per major project activity) – select from list
- More detailed description



Risk Identification Process

- Sort risks by category to:
  - Identify gaps within each category
  - Eliminate overlapping issues within each category and among categories
  - Identify relationships between remaining risks:
    - Dependencies
    - Correlations
- Document appropriately (in *risk register*) at appropriate level of detail

- Relationships:
  - Dependencies are where occurrence (or non-occurrence) of one risk depends on occurrence (or non-occurrence) of another (e.g., chain of events).
  - Correlations are where two risks might be likely to occur together (e.g., through a common cause).
- Note that it is desired to define the risks as independent of each other as possible. To do this often requires combining various dependent or correlated risks into one larger risk, with various scenarios (e.g., through use of an event or probability tree – see Module 7). However, this detail will be masked in the simplified approach adopted in this course.
- Typically several tens of risks are an appropriate number. Having too many risks (i.e., too much detail) is inefficient and increases the chance of overlaps among them and/or the chance of missed dependencies/correlations, whereas too few risks increases the chance of missing risks (not being comprehensive).



Risk Register Form

Risk Identification (Brainstorming)

Item#	**Risk or Opportunity** **(add rows as needed**	**Activity[1]** **(Circle One)**	**Description** **(possible non-"base" scenario(s) – causes and consequences)**
EXAMPLE		Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur.	
100	*Landowner(s) unwilling to sell at US555-SHIII junction*	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding	*Additional right-of-way needed for US555-SHIII junction, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.*

Sort risks by category, and then by category, edit identified risks / add risks, to be comprehensive (consult *checklist*) and non-overlapping (*risk register*)

Risk Register

Item	**Risk or Opportunity (by category)** **(add lines with labels as needed)**	**Initial Item#**	**Description** **(possible non-"base" scenario(s) – causes and consequences)**
PL	***Planning Risks***		
PL1			
PL2			
PL3			
SC	***Scoping Risks***		
SC1			

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A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

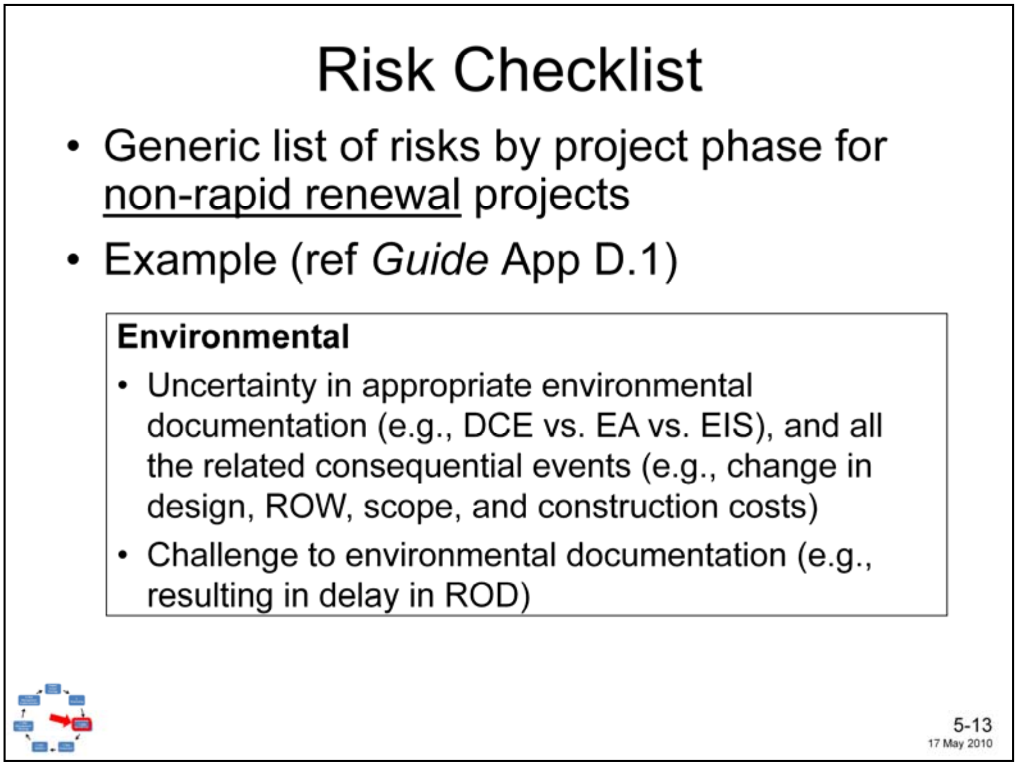
This information will eventually be input into MS Excel workbook template developed for this course (provided on CD and presented in Software module) – in fact, the template is designed to automatically categorize the previously identified risks and then be filled in directly (on the fly) during the workshop, bypassing the paper form.

Inputs include:

- Risk number
- Risk (or opportunity) short descriptive title
- More detailed description

Note that this sheet supersedes the risk identification form, which is only used for brainstorming and then feeds this form.

The risk check list (see Appendix D of the Guide) should be checked to ensure the risks in each risk category are comprehensive and non-overlapping.



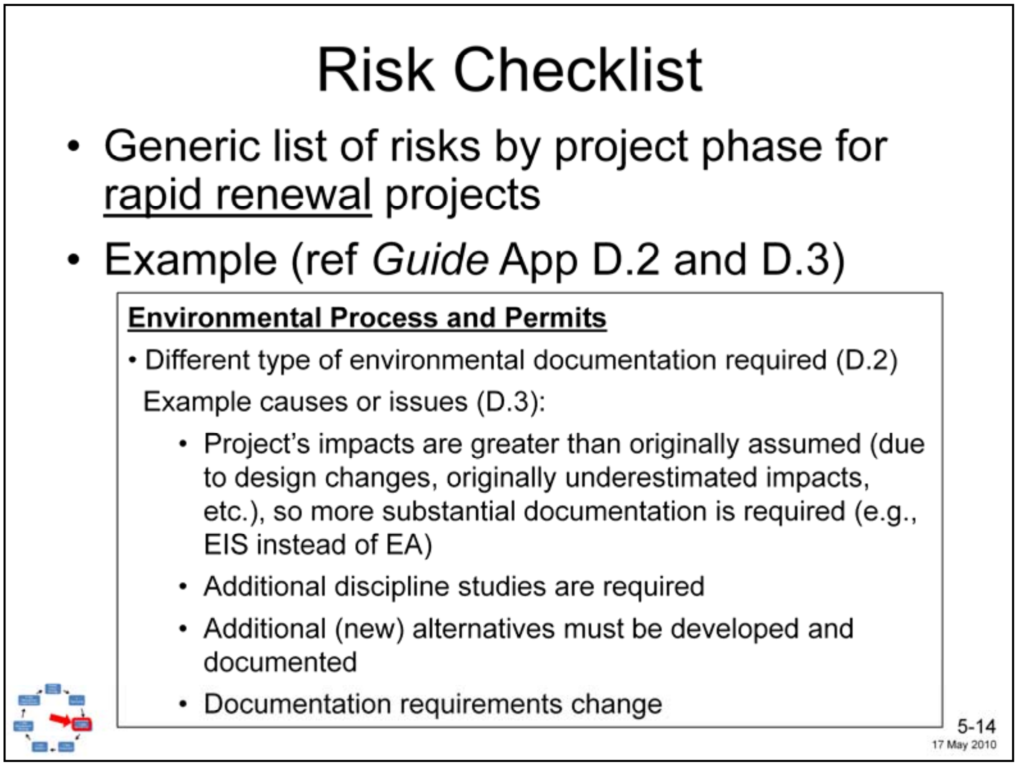
Risk Checklist

- Generic list of risks by project phase for <u>non-rapid renewal</u> projects
- Example (ref *Guide* App D.1)

Environmental

- Uncertainty in appropriate environmental documentation (e.g., DCE vs. EA vs. EIS), and all the related consequential events (e.g., change in design, ROW, scope, and construction costs)
- Challenge to environmental documentation (e.g., resulting in delay in ROD)

Checklist provided in Appendix D.1 Risk Checklist for Traditional Transportation Projects of the Guide



Risk Checklist

- Generic list of risks by project phase for <u>rapid renewal</u> projects
- Example (ref *Guide* App D.2 and D.3)

<u>Environmental Process and Permits</u>

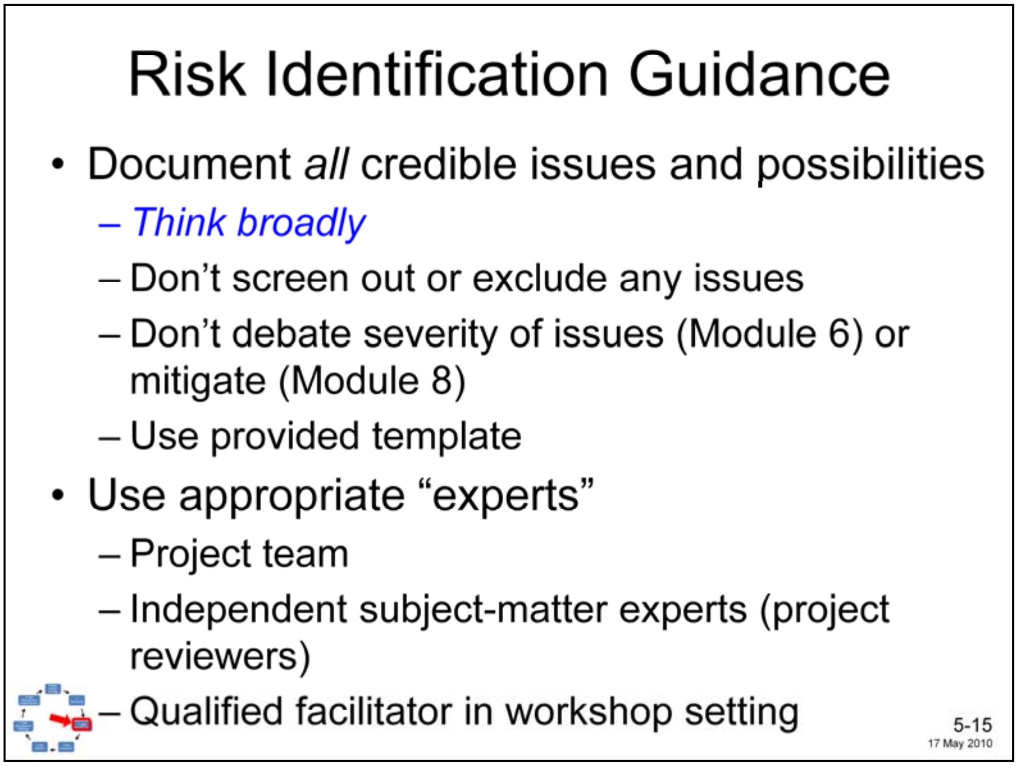
- Different type of environmental documentation required (D.2)

Example causes or issues (D.3):

- Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.), so more substantial documentation is required (e.g., EIS instead of EA)
- Additional discipline studies are required
- Additional (new) alternatives must be developed and documented
- Documentation requirements change

Checklist provided in Appendix D.2 Summary Risk Checklist for Rapid Renewal Projects and D.3 Rapid Renewal Risk Categories and Potential Risk Management Actions by Project Phase of the Guide

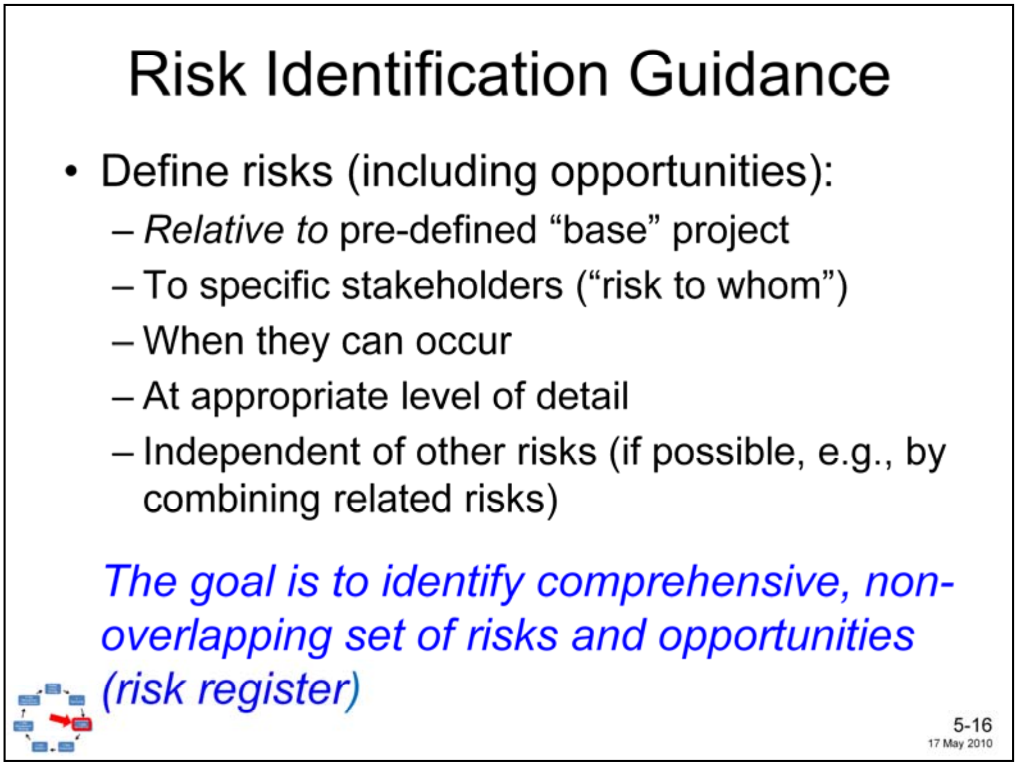
Rapid-Renewal Strategy	Related Risk or Opportunity Categories
Accelerate the environmental documentation process Examples: • Leverage master planning (see Project Scoping) • Conduct early coordination (see Planning) • Identify documentation requirements early • Identify and avoid major impacts early (historical, cultural, archaeological)	Note: the individual risk categories (and their related examples, below) might apply to any or all of the renewal category examples (shown to the left).
	Different type of documentation required Example causes or issues: • Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.), so more substantial documentation is required (e.g., EIS instead of EA) • Additional discipline studies are required • Additional (new) alternatives must be developed and documented • Documentation requirements change



Risk Identification Guidance

- Document *all* credible issues and possibilities
  - *Think broadly*
  - Don’t screen out or exclude any issues
  - Don’t debate severity of issues (Module 6) or mitigate (Module 8)
  - Use provided template
- Use appropriate “experts”
  - Project team
  - Independent subject-matter experts (project reviewers)
  - Qualified facilitator in workshop setting

- To develop comprehensive set of risks, document *all* credible issues and possibilities
  - Don’t prematurely screen out “minor” issues – this will happen automatically later.
  - Don’t debate the severity of issues (likelihood or magnitude of impacts) – that comes later
  - Don’t try to fix issues – that will also come later
  - *Think broadly. Consider other projects you’ve worked on; look at how much they changed from original concept to completion.*
  - *If at all possible, do not exclude any major issues!*
    - *Excluding major uncertainties is the quickest way to misleading or erroneous results.*
    - *If you must exclude something (for whatever reason), document the exclusion explicitly. Remember – results will be conditional on these exclusions, and may be misleading if this is not clearly understood by the user of those results.*
- Project-independent experts (reviewers) are important to provide additional perspective; the project team is often too close to the project (and possibly has a conflict of interest) to recognize or acknowledge some risks.
- ***The intent of this course is to train you to eventually be a qualified facilitator for such workshops.***

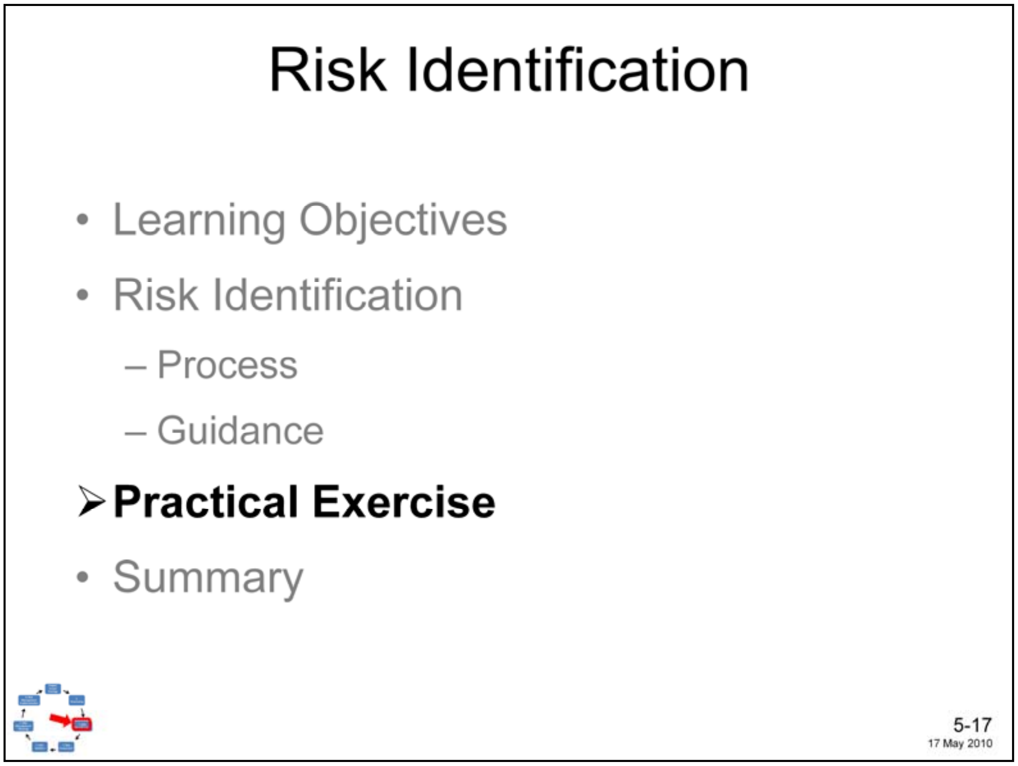


Risk Identification Guidance

- Define risks (including opportunities):
  - *Relative to* pre-defined “base” project
  - To specific stakeholders (“risk to whom”)
  - When they can occur
  - At appropriate level of detail
  - Independent of other risks (if possible, e.g., by combining related risks)

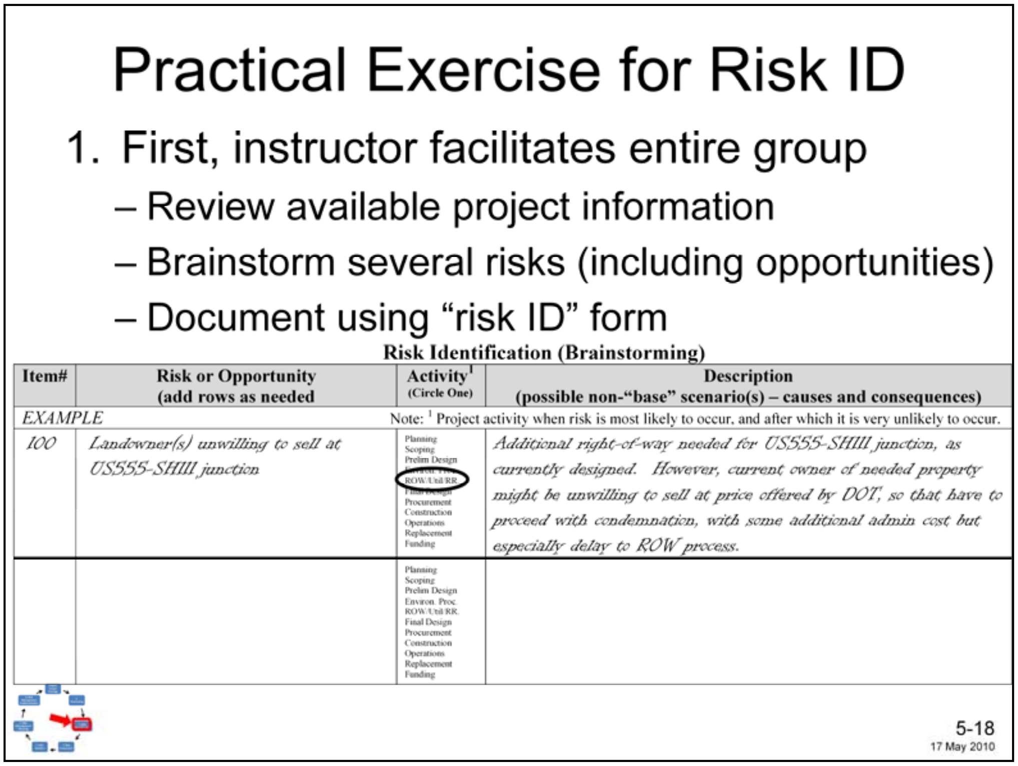
The goal is to identify comprehensive, non-overlapping set of risks and opportunities (risk register)

- Define issues at an appropriate level of detail
  - Issues defined too vaguely or too “lumped” are hard to assess (a lot of implicit factoring)
  - Defining too many separate, detailed issues could lead to:
    - Overlaps among issues
    - Missing important relationships among issues (i.e., dependencies and correlations)
    - Missing larger issues (i.e., “missing the forest for the trees” problem)
- To the extent possible, define issues to be independent of each other (e.g., by combining related issues in terms of scenarios – see below)
- Eliminate overlap among risks through their description (e.g., “this risk excludes xxx which is covered under separate risk”)
- Decomposition techniques (e.g., event trees, see Module 4) are great tools for:
  - Establishing reasonable levels of detail
  - Capturing important relationships among issues and combining related risks



Risk Identification

- Learning Objectives
- Risk Identification
  - Process
  - Guidance
- **Practical Exercise**
- Summary



Practical Exercise for Risk ID

1. First, instructor facilitates entire group
   - Review available project information
   - Brainstorm several risks (including opportunities)
   - Document using “risk ID” form

Risk Identification (Brainstorming)

Item#	**Risk or Opportunity (add rows as needed**	**Activity[1] (Circle One)**	**Description (possible non-“base” scenario(s) – causes and consequences)**
EXAMPLE		Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur.	
100	*Landowner(s) unwilling to sell at US555-SHIII junction*	Planning Scoping Prelim Design Environ. Proc [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding	*Additional right-of-way needed for US555-SHIII junction, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.*
		Planning Scoping Prelim Design Environ. Proc ROW/Util/RR Final Design Procurement Construction Operations Replacement Funding	

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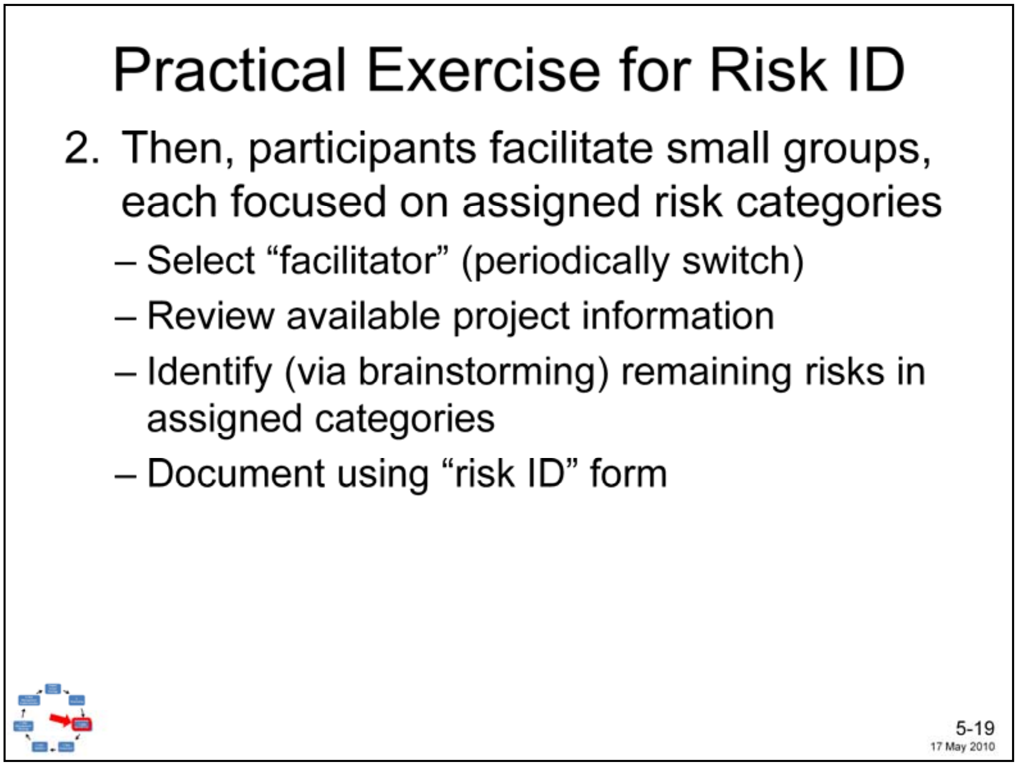
See separate project description in Appendix F of the Guide and completed Summary Project Base Description Form from Module 4.

Brainstorm risks and document using *Risk Identification Form* (in Appendix E of the *Guide* and on CD) - a copy to use for this practical exercise is contained at the end of this module.

Following the principles and process outlined in Chapter 5 of the *Guide*, the facilitated combined group of key project-team staff and independent subject-matter experts identified, categorized, and documented in the project risk register nearly 70 risks and opportunities (relative to the base) with cost, schedule, and/or disruption impacts. The risks and opportunities (hereafter collectively termed risks) spanned all remaining phases of the project, and were categorized by the project phase in which they were most likely to occur (and after which they could be “retired”). Note that at this point in the risk assessment, the group did not discuss the likelihood or severity for any of the risks.

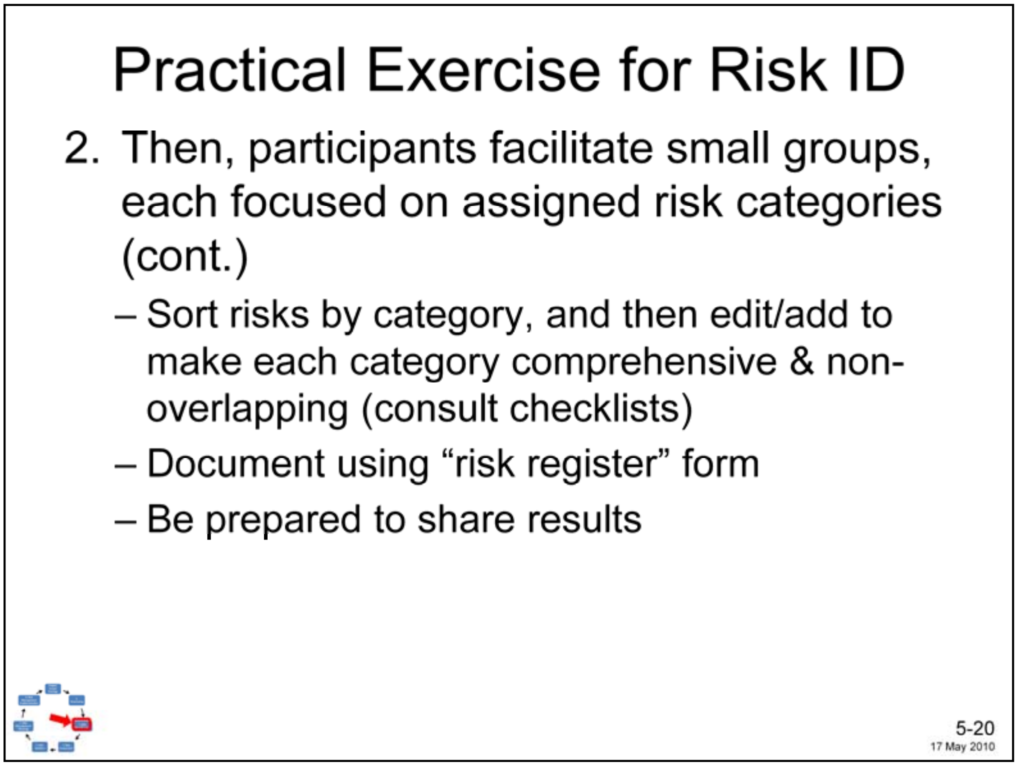
Initially, risks were simply brainstormed by the group and then categorized. Once the initial list of risks were categorized, the group added risks to complete each category, finally referring to the checklists (Appendix D of the *Guide*), and then edited the risks to eliminate any overlap. Each risk and opportunity that was ultimately recorded in the risk register was defined such that it was approximately independent of, and did not overlap with, the other risks in the register, and collectively were comprehensive.



Practical Exercise for Risk ID

2. Then, participants facilitate small groups, each focused on assigned risk categories
   - – Select “facilitator” (periodically switch)
   - – Review available project information
   - – Identify (via brainstorming) remaining risks in assigned categories
   - – Document using “risk ID” form

See separate project description in Appendix F of the Guide and completed Summary Project Base Description Form from Module 4



Practical Exercise for Risk ID

2. Then, participants facilitate small groups, each focused on assigned risk categories (cont.)
    - Sort risks by category, and then edit/add to make each category comprehensive & non-overlapping (consult checklists)
    - Document using “risk register” form
    - Be prepared to share results

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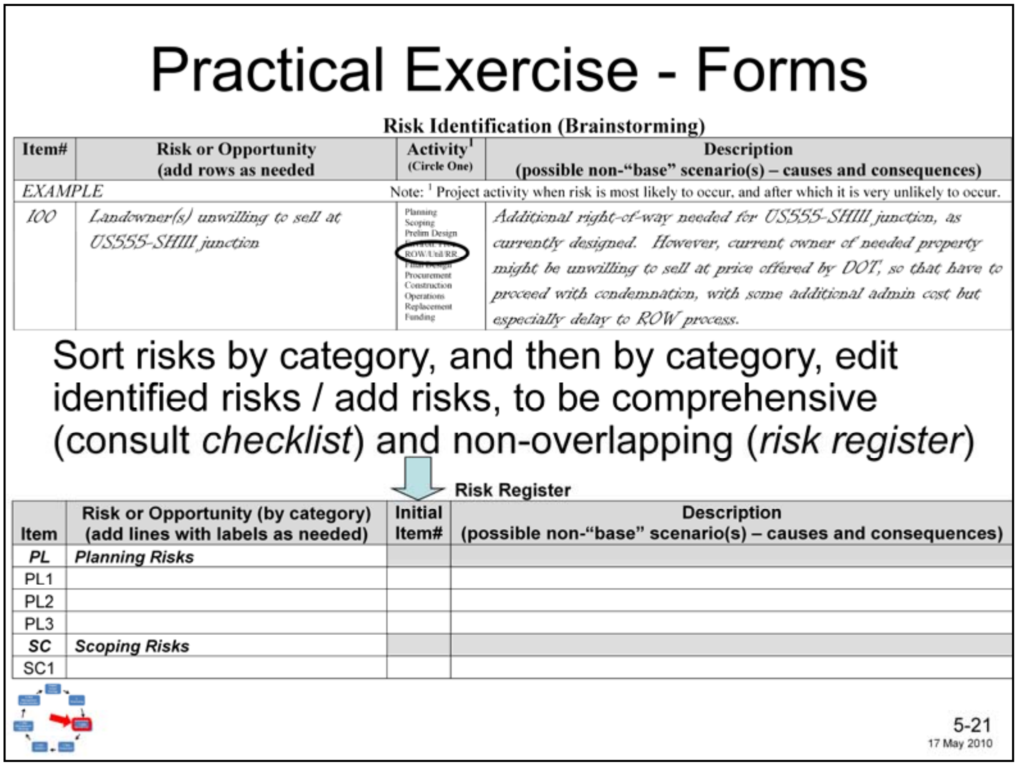
See separate project description in Appendix F of the Guide and completed Summary Project Base Description Form from Module 4



Practical Exercise - Forms

Risk Identification (Brainstorming)

Item#	Risk or Opportunity (add rows as needed	Activity[1] (Circle One)	Description (possible non-"base" scenario(s) – causes and consequences)
EXAMPLE		Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur.	
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Sort risks by category, and then by category, edit identified risks / add risks, to be comprehensive (consult *checklist*) and non-overlapping (*risk register*)

Risk Register

Item	Risk or Opportunity (by category) (add lines with labels as needed)	Initial Item#	Description (possible non-"base" scenario(s) – causes and consequences)
PL	***Planning Risks***		
PL1			
PL2			
PL3			
SC	***Scoping Risks***		
SC1			

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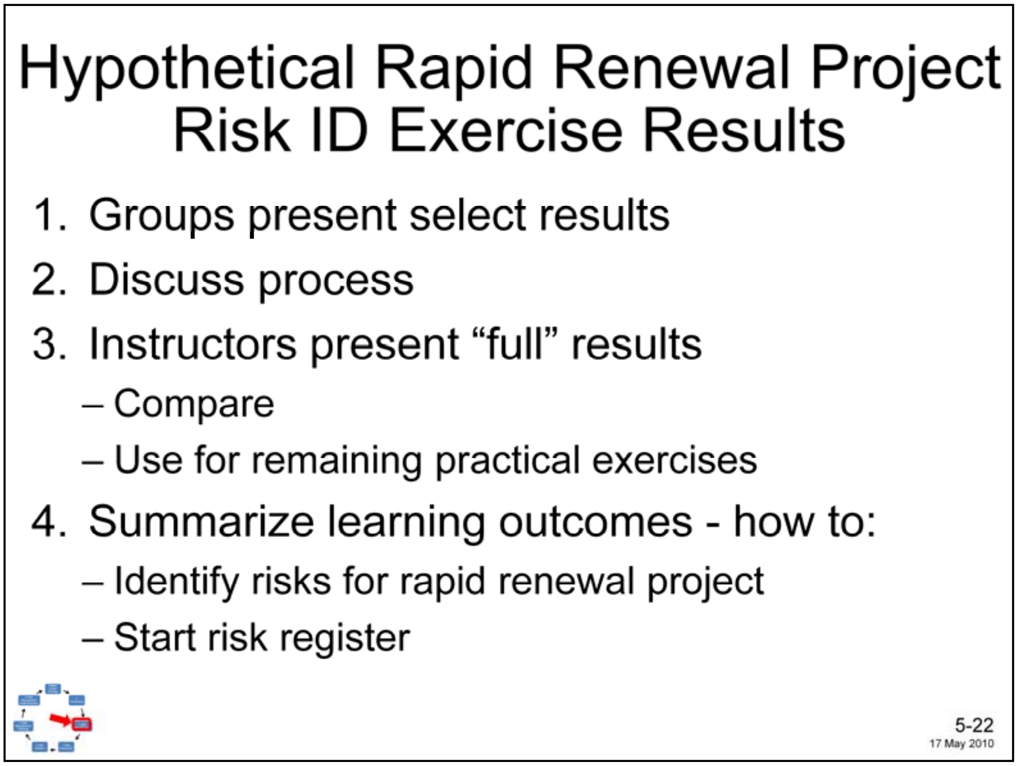
Categorize and edit using *Risk Register Form* (in Appendix E of the *Guide* and on CD) - a copy to use for this practical exercise is contained at the end of this module.

Once completed, review check list in Appendix D of the *Guide* to see if anything has been missed and, if so, add it to ensure comprehensiveness (but keep it non-overlapping).



Hypothetical Rapid Renewal Project Risk ID Exercise Results

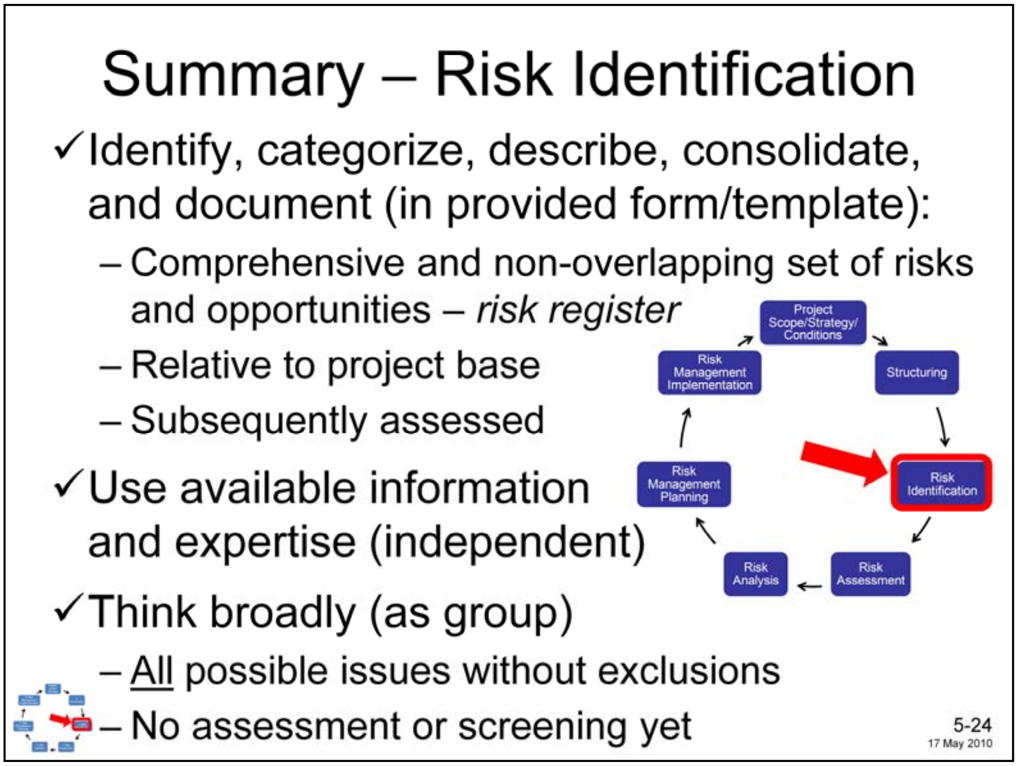
1. Groups present select results
2. Discuss process
3. Instructors present “full” results
   - Compare
   - Use for remaining practical exercises
4. Summarize learning outcomes - how to:
   - Identify risks for rapid renewal project
   - Start risk register

Instructors’ results will be handed out after participants’ results have been presented and discussed. These results, which will be used for remaining practical exercises, should be inserted in Appendix F of the *Guide* for future reference.

Risk Identification

- Learning Objectives
- Risk Identification
  - Process
  - Guidance
- Practical Exercise

➢ **Summary**



Summary – Risk Identification

- ✓ Identify, categorize, describe, consolidate, and document (in provided form/template):
  - – Comprehensive and non-overlapping set of risks and opportunities – *risk register*
  - – Relative to project base
  - – Subsequently assessed
- ✓ Use available information and expertise (independent)
- ✓ Think broadly (as group)
  - – All possible issues without exclusions
  - – No assessment or screening yet

• *At end of the project, everything significant that actually happened during project (changes from base) should have been identified during risk identification as possibilities (although not necessarily predicted).*

• *Consult checklists as final step*

• A “critical mass” group, including project-independent reviewers, for each risk discipline is important.

• Facilitation (by qualified facilitators) can help substantially.

Risk Identification (Brainstorming)

Item#	**Risk or Opportunity (add rows as needed**	**Activity[1] (Circle One)**	**Description (possible non-"base" scenario(s) – causes and consequences)**
EXAMPLE			Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur.
100	Landowner(s) unwilling to sell at US555-SH111 junction	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding	Additional right-of-way needed for US555-SH111 junction, as currently designed. However, current owner of needed property might be unwilling to sell at price offered by DOT, so that have to proceed with condemnation, with some additional admin cost but especially delay to ROW process.
		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding	
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		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding	

Risk Identification (Brainstorming)

Item#	**Risk or Opportunity (add rows as needed**	**Activity[1] (Circle One)**	**Description (possible non-"base" scenario(s) – causes and consequences)**
EXAMPLE	Note: [1] Project activity when risk is most likely to occur, and after which it is very unlikely to occur.		
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		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding	
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		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding	

Risk Register

Item	Risk or Opportunity (by category) (add lines with labels as needed)	Initial Item#	Description (possible non-“base” scenario(s) – causes and consequences)
PL	***Planning Risks***		
PL1			
PL2			
PL3			
SC	***Scoping Risks***		
SC1			
SC2			
SC3			
SC4			
PD	***Preliminary Design Risks***		
PD1			
PD2			
PD3			
PD4			
EP	***Environmental Process Risks***		
EP1			
EP2			
EP3			
EP4			
EP5			
RU	***ROW/Utility/RR/etc Risks***		
RU1			
RU2			
RU3			
RU4			
FD	***Final Design Risks***		
FD1			
FD2			
FD3			
FD4			

Risk Register

Item	Risk or Opportunity (by category) (add lines with labels as needed)	Initial Item#	Description (possible non-“base” scenario(s) – causes and consequences)
CP	***Procurement Risks***		
CP1			
CP2			
CP3			
CP4			
CP5			
CN	***Construction Risks***		
CN1			
CN2			
CN3			
CN4			
CN5			
CN6			
CN7			
CN8			
CN9			
CN10			
OM	***Operations Risks***		
OM1			
OM2			
OM3			
RP	***Replacement Risks***		
RP1			
RP2			
RP3			
FN	***Funding Risks***		
FN1			
FN2			
FN3			

Note: Transfer risks from Risk ID Form (brainstorming) to appropriate category. Edit to be comprehensive/non-overlapping. See checklists.

Risk Management

Module 6:
Risk Assessment

Project Scope/Strategy/ Conditions

Structuring

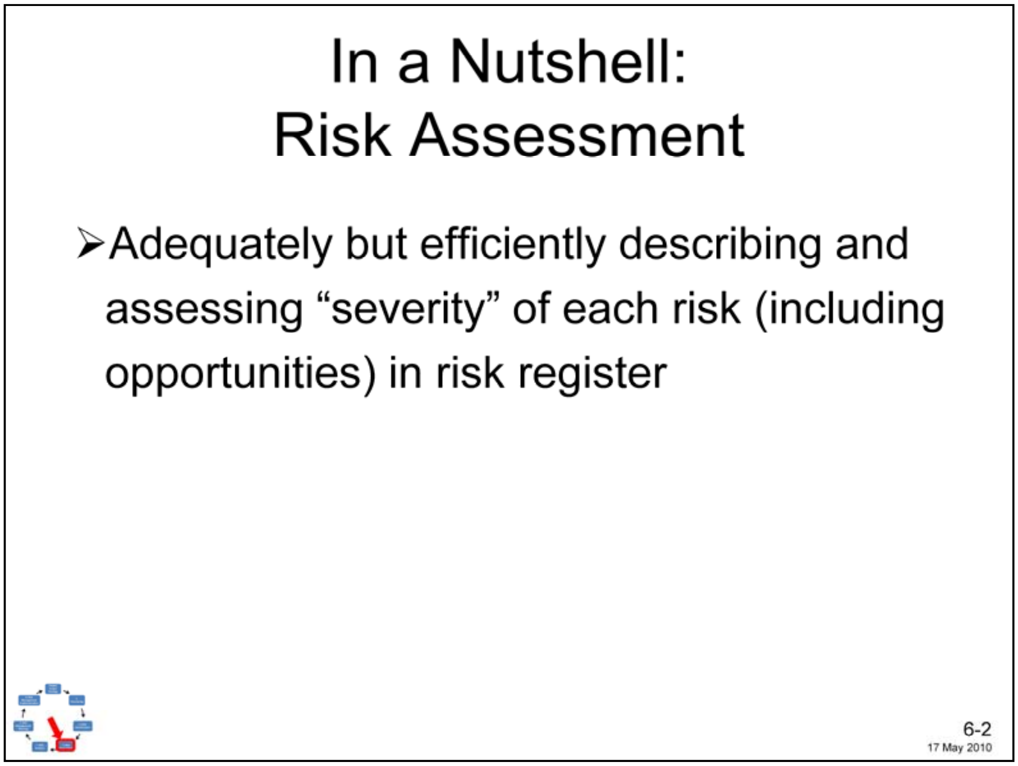
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



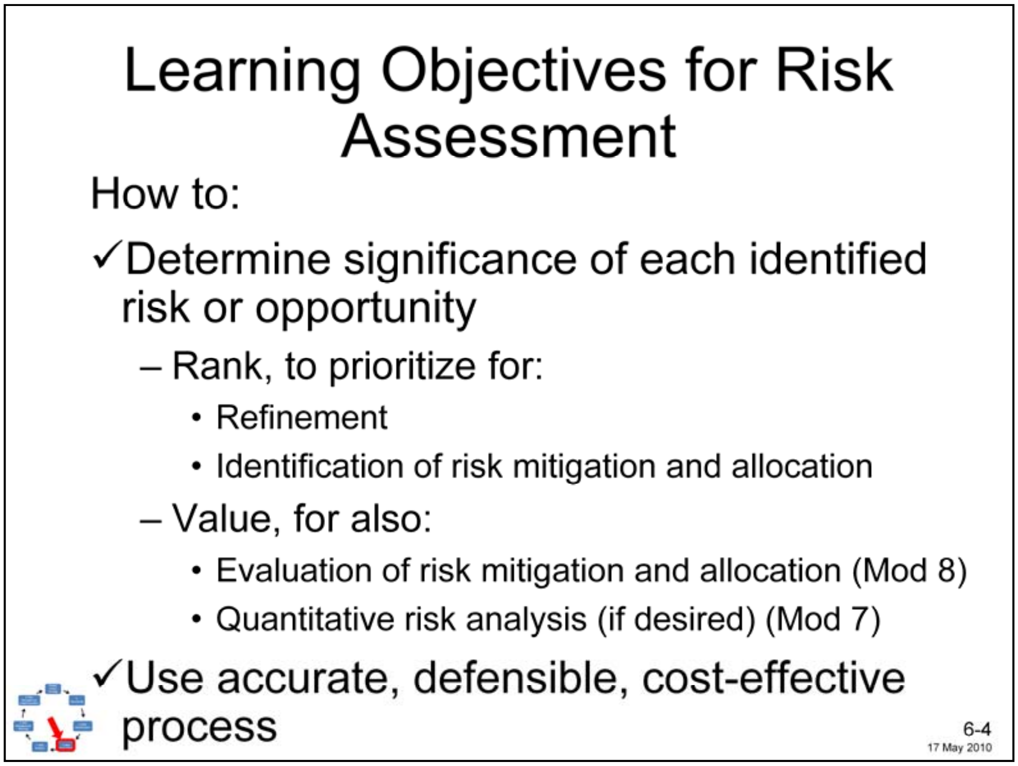
In a Nutshell: Risk Assessment

- Adequately but efficiently describing and assessing “severity” of each risk (including opportunities) in risk register

As previously discussed (Module 2), “severity” of a risk considers both its likelihood of occurrence and its consequences if it does occur. Even through risk factors (impacts and probability of occurrence) might be subjectively assessed, it is generally more accurate to assess the factors (as accurately as possible) and then appropriately combine them to determine risk severity, as opposed to assessing risk severity directly. This is because people’s perceptions of risk severity are often inaccurate, i.e., for various reasons, they incorrectly perceive some risks to be much larger or much smaller than they really are – such incorrect perceptions can generally be mitigated by assessing the more detailed factors and then logically combining them.

Risk Assessment

- Learning Objectives
- Available Methods
  - – Process
  - – Guidance
- Assessing Risk Factors
- Practical Exercise
- Summary



Learning Objectives for Risk Assessment

How to:

✓Determine significance of each identified risk or opportunity

- Rank, to prioritize for:
  - Refinement
  - Identification of risk mitigation and allocation
- Value, for also:
  - Evaluation of risk mitigation and allocation (Mod 8)
  - Quantitative risk analysis (if desired) (Mod 7)

✓Use accurate, defensible, cost-effective process

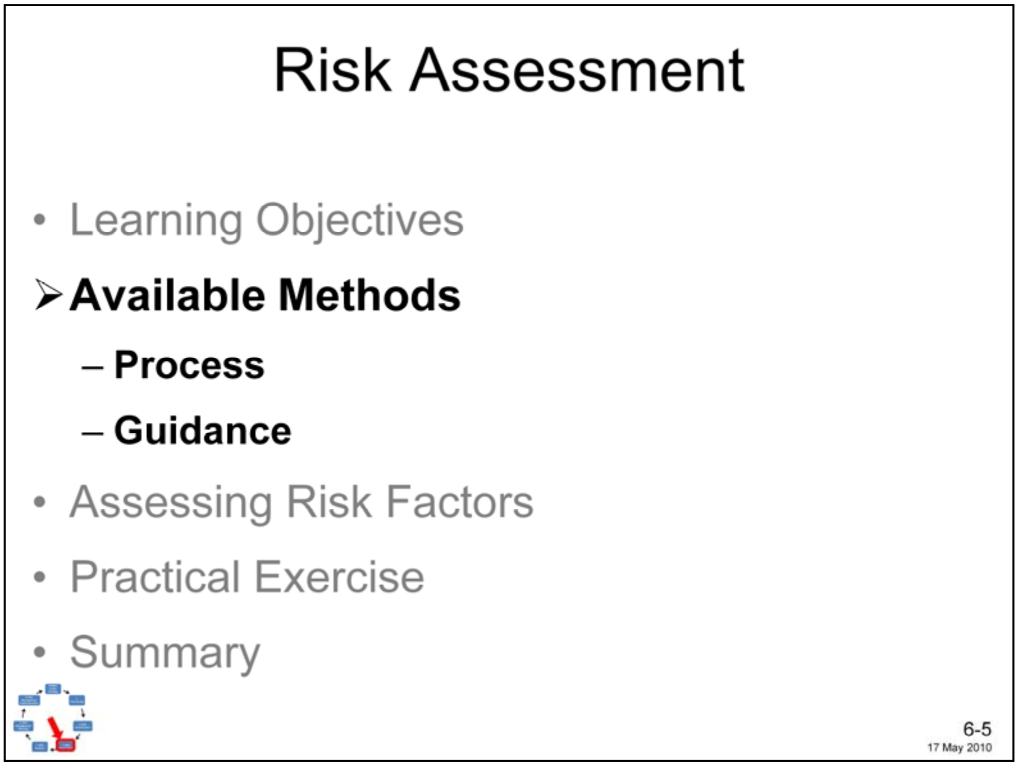
6-4

17 May 2010

The risks need to be prioritized in order to focus limited resources on their assessment and on their management. To adequately prioritize risks, as well as to predict project performance, their severity must assessed.

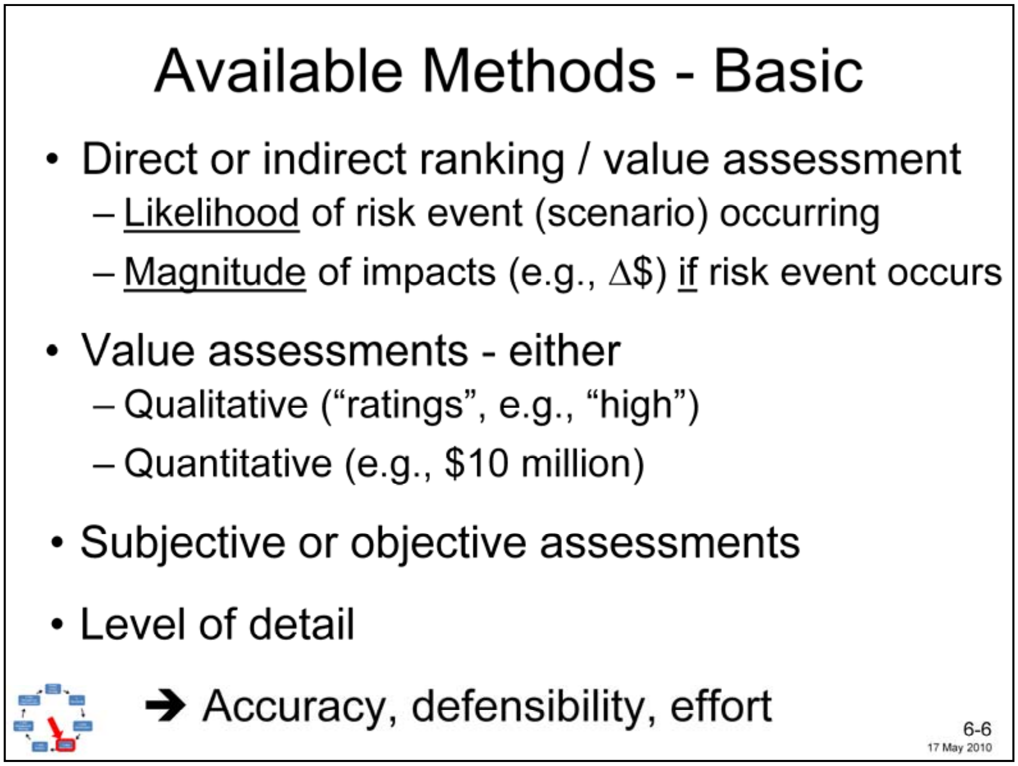
Typically, both risk ranking and risk value assessment are done by assessing risk “factors” (e.g., likelihood of occurrence and cost and schedule impacts of occurrence), and then appropriately combining those factors. If the value is determined, then the rank can be determined based on that value. The risks can be evaluated either qualitatively (e.g., “small” risk) or quantitatively (e.g., $1M value). If done qualitatively, “ratings” are used, which are typically easier to assess but much more approximate than quantitative assessments. Care must be taken in combining qualitative assessments.

Clearly, in risk assessment, this step (input assessments) can be the most expensive part (i.e., expert labor intensive). Care must be taken to make it as efficient as possible, as well as to provide adequately accurate and defensible results.



Risk Assessment

- Learning Objectives
- **Available Methods**
  - **Process**
  - **Guidance**
- Assessing Risk Factors
- Practical Exercise
- Summary



Available Methods - Basic

- Direct or indirect ranking / value assessment
  - Likelihood of risk event (scenario) occurring
  - Magnitude of impacts (e.g., Δ$) if risk event occurs
- Value assessments - either
  - Qualitative ("ratings", e.g., "high")
  - Quantitative (e.g., $10 million)
- Subjective or objective assessments
- Level of detail

➔ Accuracy, defensibility, effort

6-6
17 May 2010

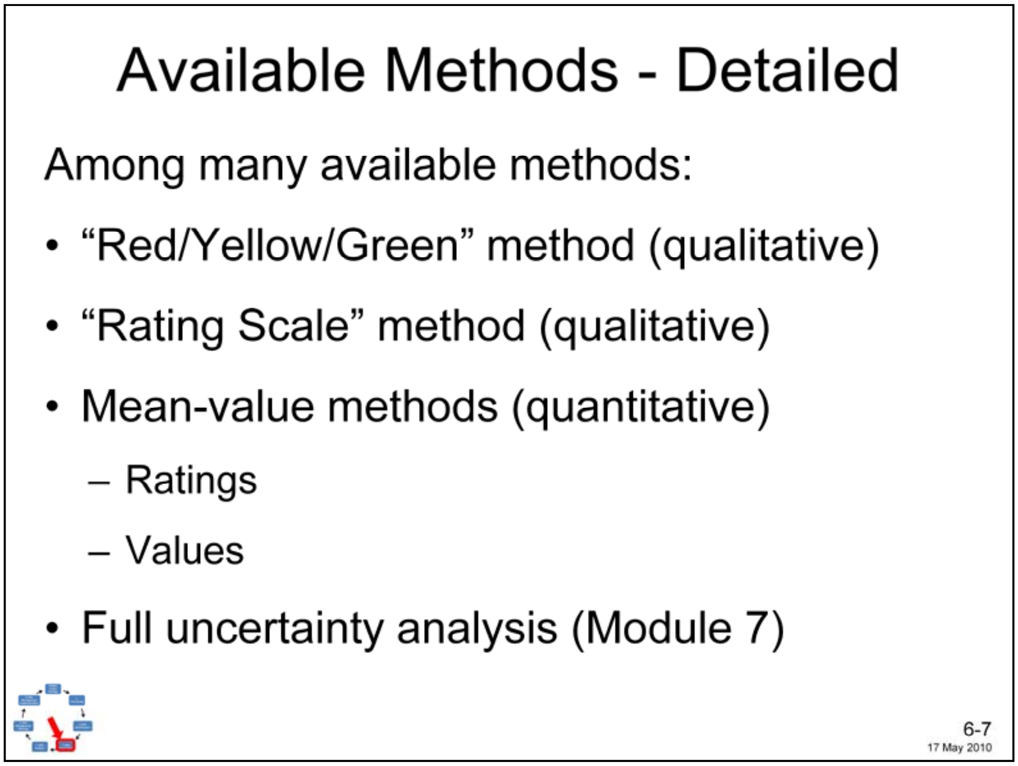
Conceptually, assessors can rank risks or assess their values directly, i.e., Risk A is more significant than Risk B, or Risk A has a value of $1M (a range of $0 to $5M). However, it is difficult to implicitly (rather than explicitly) assess and combine the various risk factors correctly. Hence, typically this is done by explicitly assessing the risk factors (likelihood of occurrence and impacts of occurrence, e.g., direct cost, non-critical path schedule, disruption by activity ➔ derived impacts), which are easier to assess correctly, and then appropriately combining those factor assessments in an explicit way, which can be checked. Such combined assessments can then be used to rank the risks.

Value assessments can be qualitative (e.g., "small" chance of occurrence) or quantitative (e.g., 10% chance of occurrence). Qualitative assessments (in terms of "ratings", which must be defined, e.g., as ranges of quantitative values, to avoid ambiguities) are typically easier to assess but much more approximate. Care must be taken in combining qualitative assessments correctly, and even so they are typically not as useful (e.g., in evaluating cost-effectiveness of risk reduction actions.

Objective assessments (e.g., based on measurements, or statistics of measurements) of values are generally very defensible and thus desirable. However, such measurements typically do not exist for the values of interest (although they might be similar). Instead, "subjective" assessment, based on judgment considering available information, is typically required. Care must be taken to make these as accurate and defensible as possible without spending too much effort.

Similarly, the level of detail can vary from very broad to very detailed. Generally, more detail (to a point) provides more accuracy and defensibility but at greater effort; at some point, however, more detail actually results in less accuracy and defensibility (i.e., it's "too complicated").

The goal is to achieve adequate accuracy and defensibility of results, with reasonable effort.



Available Methods - Detailed

Among many available methods:

- "Red/Yellow/Green" method (qualitative)
- "Rating Scale" method (qualitative)
- Mean-value methods (quantitative)
  - Ratings
  - Values
- Full uncertainty analysis (Module 7)

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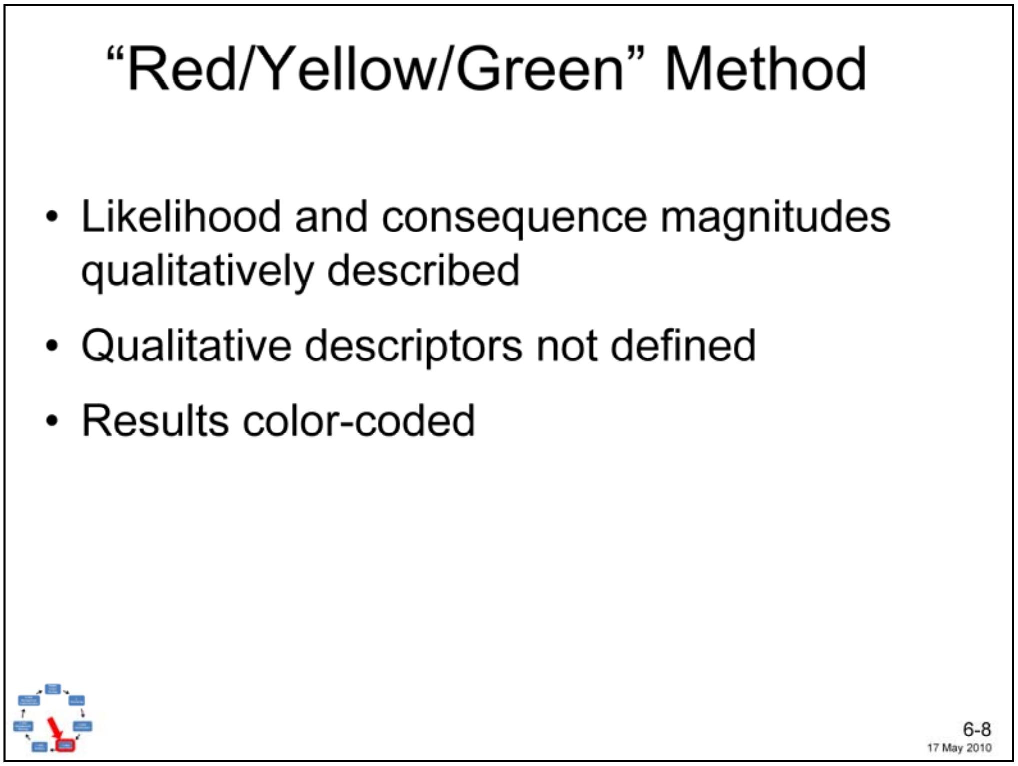
Many methods are available. We'll briefly discuss some of the more common methods, even if not recommended, so that you'll be better informed.

For these four particular methods, each approach builds on the preceding approach. The primary differences are as follows:

- "Red/Yellow/Green" method – very common, but often problematic
  - Usually no defined rating scales
  - Ambiguous (or no) combination of risk factors
- "Rating Scale" method - common, but often problematic
  - Numerical rating scales, but scales might be arbitrary
  - Combination of risk factors might not be accurate (because done incorrectly, which is, unfortunately, common)
- Mean-value method - recommended
  - Either:
    - Rating scales are defined on a mean-value basis, or
    - Mean consequences are assessed directly (no rating scales are used)
  - Combination of risk factors is unambiguous and mathematically correct
- Full uncertainty analysis (discussed in Module 7, not necessary for ranking and risk management, only for quantitative risk assessment)
  - Characterizes uncertainties in, and correlations among, risk factors



“Red/Yellow/Green” Method

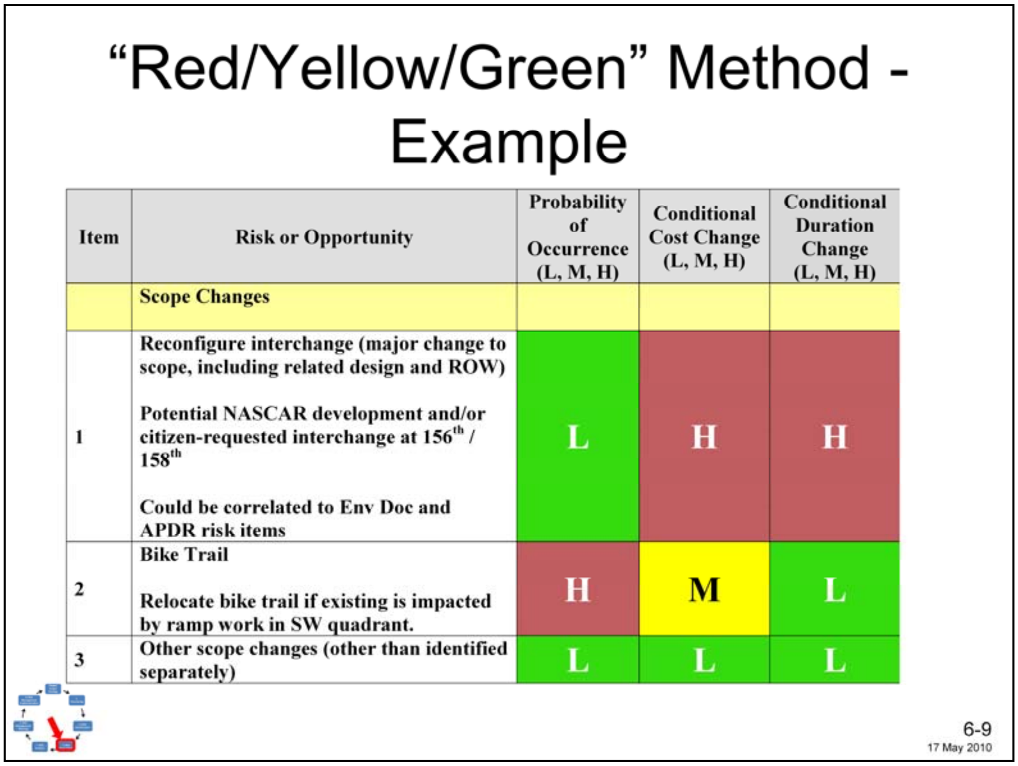
- Likelihood and consequence magnitudes qualitatively described
- Qualitative descriptors not defined
- Results color-coded

• Both the likelihood and consequence magnitudes are categorized using qualitative descriptors (e.g., Low, Medium, or High)

• These qualitative descriptors are usually not strictly defined (e.g., Low = <2), although they could be

• The results are often color-coded, shown graphically in terms of red (high), yellow (medium), and green (low) shaded matrices

An example is shown in Chapter 6 of Guide.



"Red/Yellow/Green" Method - Example

Item	Risk or Opportunity	Probability of Occurrence (L, M, H)	Conditional Cost Change (L, M, H)	Conditional Duration Change (L, M, H)
	Scope Changes			
1	Reconfigure interchange (major change to scope, including related design and ROW) Potential NASCAR development and/or citizen-requested interchange at 156th / 158th Could be correlated to Env Doc and APDR risk items	L	H	H
2	Bike Trail Relocate bike trail if existing is impacted by ramp work in SW quadrant.	H	M	L
3	Other scope changes (other than identified separately)	L	L	L

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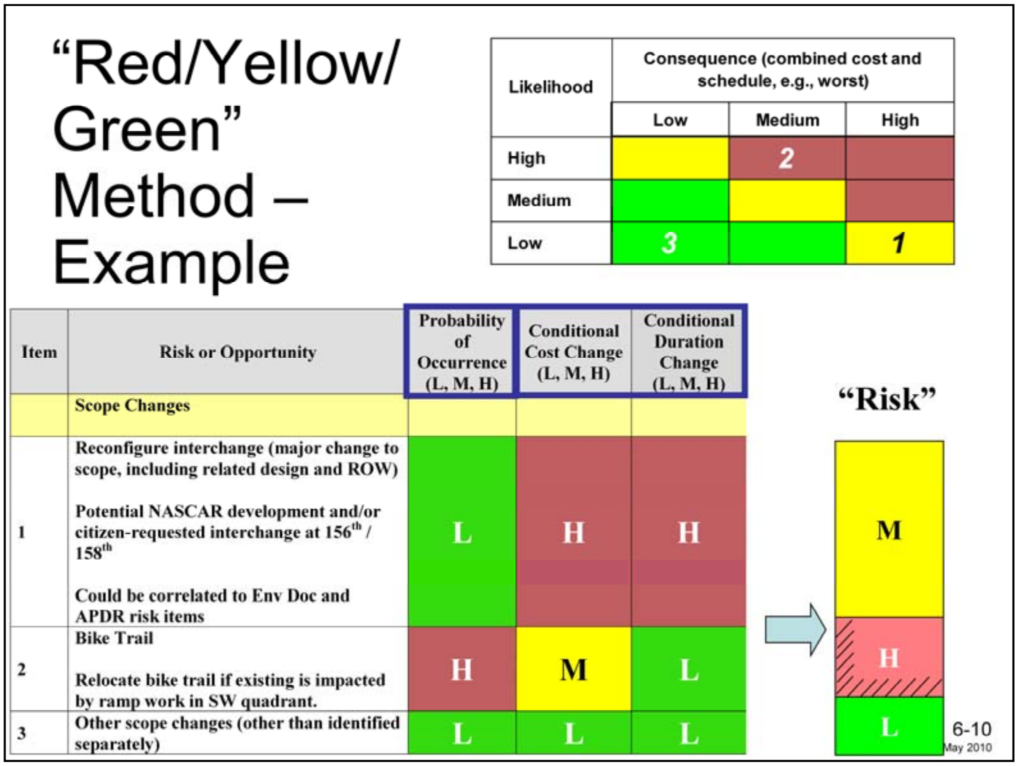
This is an excerpt from a highway project. Only cost and schedule impacts are shown – disruption and longevity (which is derived from post-construction cost, schedule and disruption) impacts should also be considered.



"Red/Yellow/ Green" Method – Example

Likelihood	Consequence (combined cost and schedule, e.g., worst)		
	Low	Medium	High
High	🟨	🟥 2	🟥
Medium	🟩	🟨	🟥
Low	🟩 3	🟩	🟨 1

Item	Risk or Opportunity	Probability of Occurrence (L, M, H)	Conditional Cost Change (L, M, H)	Conditional Duration Change (L, M, H)
	Scope Changes			
1	Reconfigure interchange (major change to scope, including related design and ROW) Potential NASCAR development and/or citizen-requested interchange at 156th / 158th Could be correlated to Env Doc and APDR risk items	L	H	H
2	Bike Trail Relocate bike trail if existing is impacted by ramp work in SW quadrant.	H	M	L
3	Other scope changes (other than identified separately)	L	L	L

"Risk"

M

H

L

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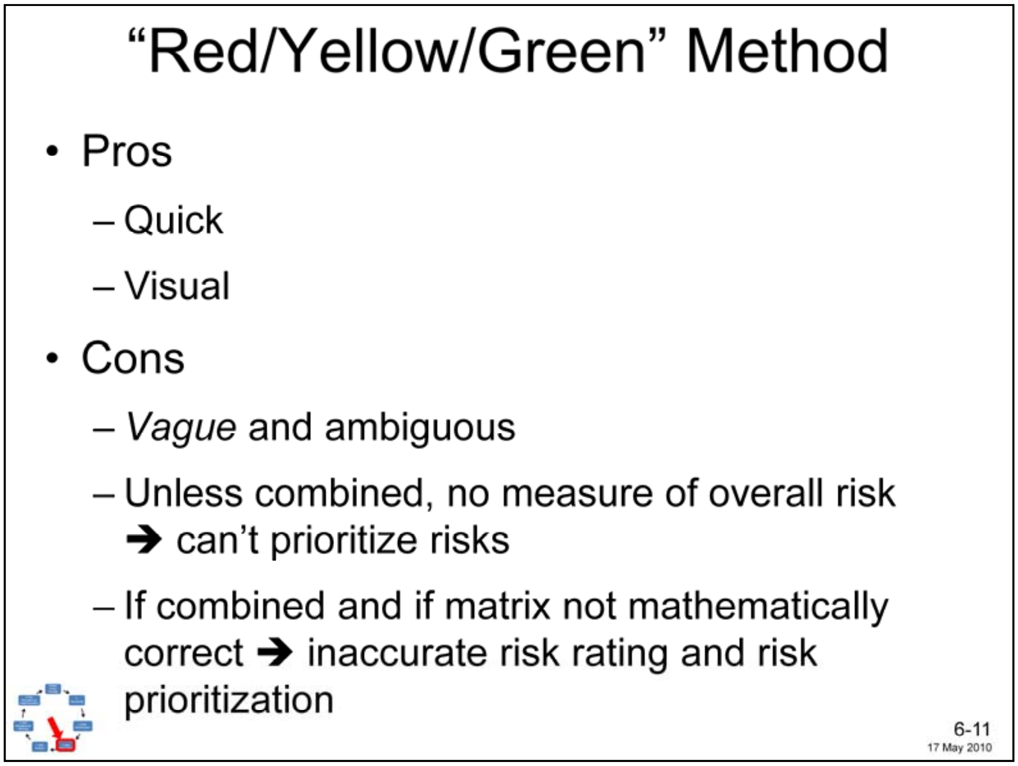
<u>Might</u> combine Likelihood rating with Consequence ratings to get "Risk" rating. As will be shown for other methods, this could be done through matrices showing which combinations of likelihood and consequences result in various categories of risk, although there would generally not be any mathematical basis for the matrix, only a subjective assessment. Notice that the Risk rating for Risk 2 would decrease to medium if the matrix changed slightly so that high likelihood and medium consequence produced medium (instead of high) risk.

Only cost and schedule impacts are shown – disruption and longevity (which is derived from post-construction cost, schedule and disruption) impacts should also be considered and folded into the "combined" consequence.



“Red/Yellow/Green” Method

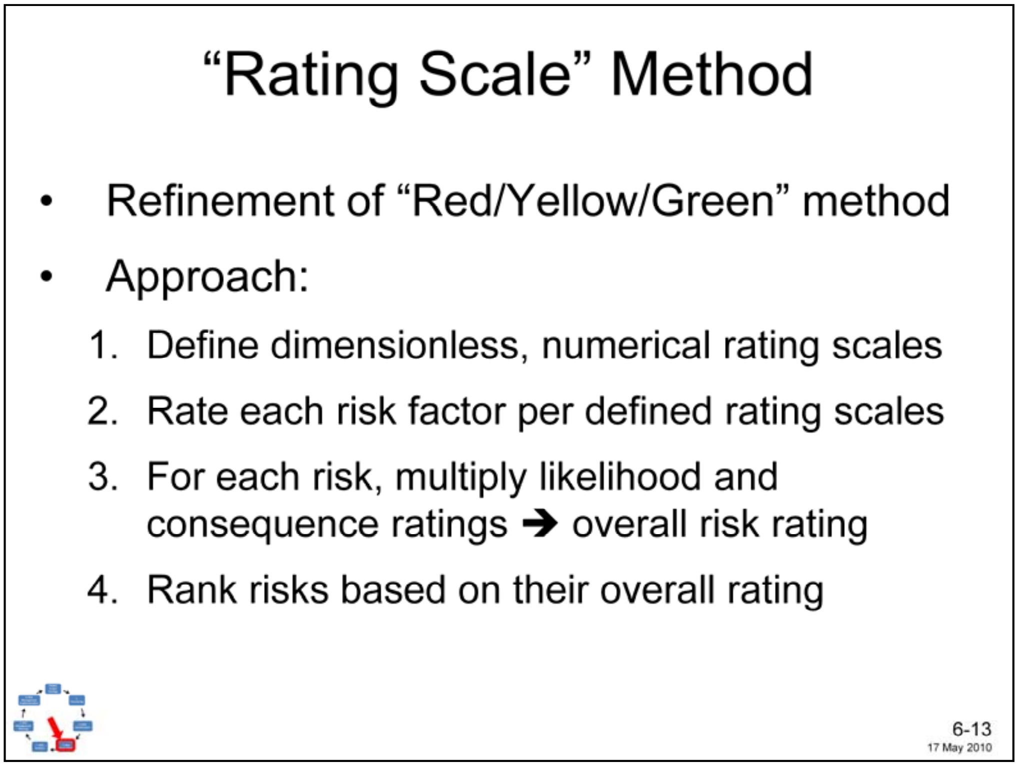
- Pros
  - Quick
  - Visual
- Cons
  - *Vague* and ambiguous
  - Unless combined, no measure of overall risk ➔ can’t prioritize risks
  - If combined and if matrix not mathematically correct ➔ inaccurate risk rating and risk prioritization

- Rating classifications (L, M, H) are usually not defined (what do they really mean?). Different people might interpret them differently.
- When using qualitative ratings for likelihood and consequence:
  - If not combined, can’t get measure of overall risk and therefore can’t prioritize risks
  - If combined, the combinations are ambiguous (and perhaps mathematically incorrect). For example, what risk is associated with “H” likelihood and “L” consequence? H x L = M? And is this the same as M x M = M? or L x H = M?

Available Methods - Detailed

Among many available methods:

- “Red/Yellow/Green” method (qualitative)
- ➢ **“Rating Scale” method (qualitative)**
- Mean-value method (quantitative)
- Full uncertainty analysis (Module 7)



“Rating Scale” Method

- Refinement of “Red/Yellow/Green” method
- Approach:
  1. Define dimensionless, numerical rating scales
  2. Rate each risk factor per defined rating scales
  3. For each risk, multiply likelihood and consequence ratings ➔ overall risk rating
  4. Rank risks based on their overall rating

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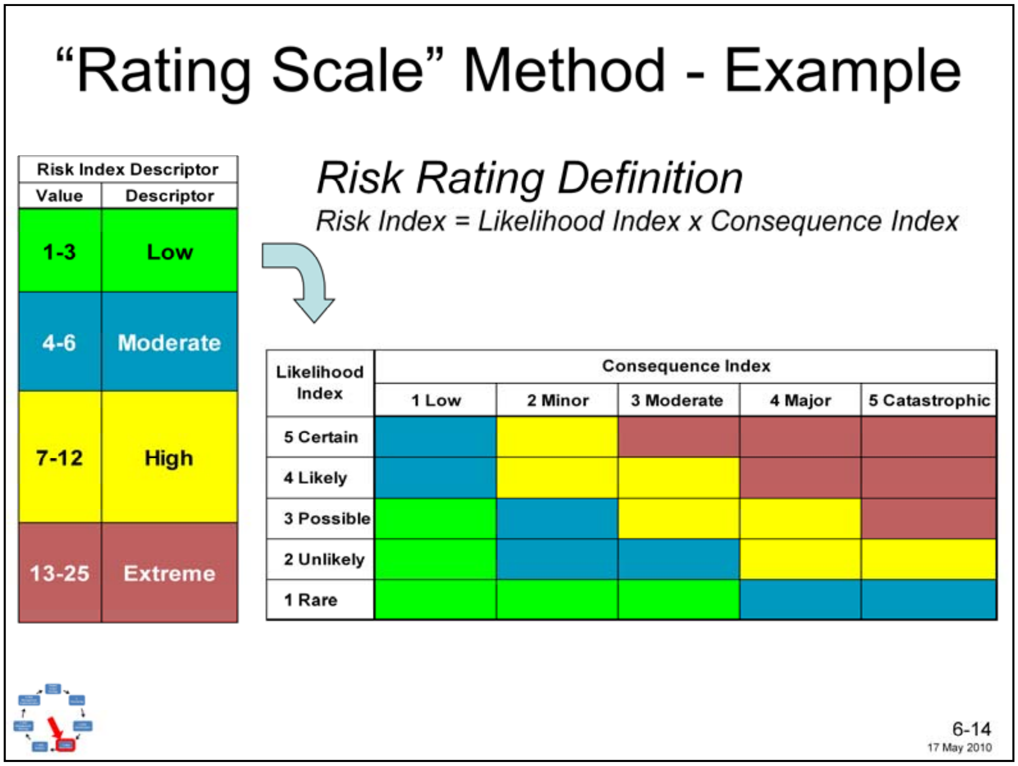
Approach

1. Define dimensionless, numerical rating scales for both likelihood and combined consequences. For example, 1=“rare” to 5=“certain” for likelihood and 1=“low” to 5=“catastrophic” for consequences. Typically still qualitative.
2. Rate likelihood and consequences for each risk (and opportunity) per the defined rating scales
3. Multiply the ratings for likelihood and consequences (e.g., 1 x 3 = 3) to get overall rating for each risk
4. Rank the risks based on their overall rating



"Rating Scale" Method - Example

Risk Index Descriptor	
Value	Descriptor
1-3	Low
4-6	Moderate
7-12	High
13-25	Extreme

Risk Rating Definition

Risk Index = Likelihood Index x Consequence Index

Likelihood Index	Consequence Index				
	1 Low	2 Minor	3 Moderate	4 Major	5 Catastrophic
5 Certain	🟦	🟨	🟥	🟥	🟥
4 Likely	🟦	🟨	🟨	🟥	🟥
3 Possible	🟩	🟦	🟨	🟨	🟥
2 Unlikely	🟩	🟦	🟦	🟨	🟨
1 Rare	🟩	🟩	🟩	🟦	🟦

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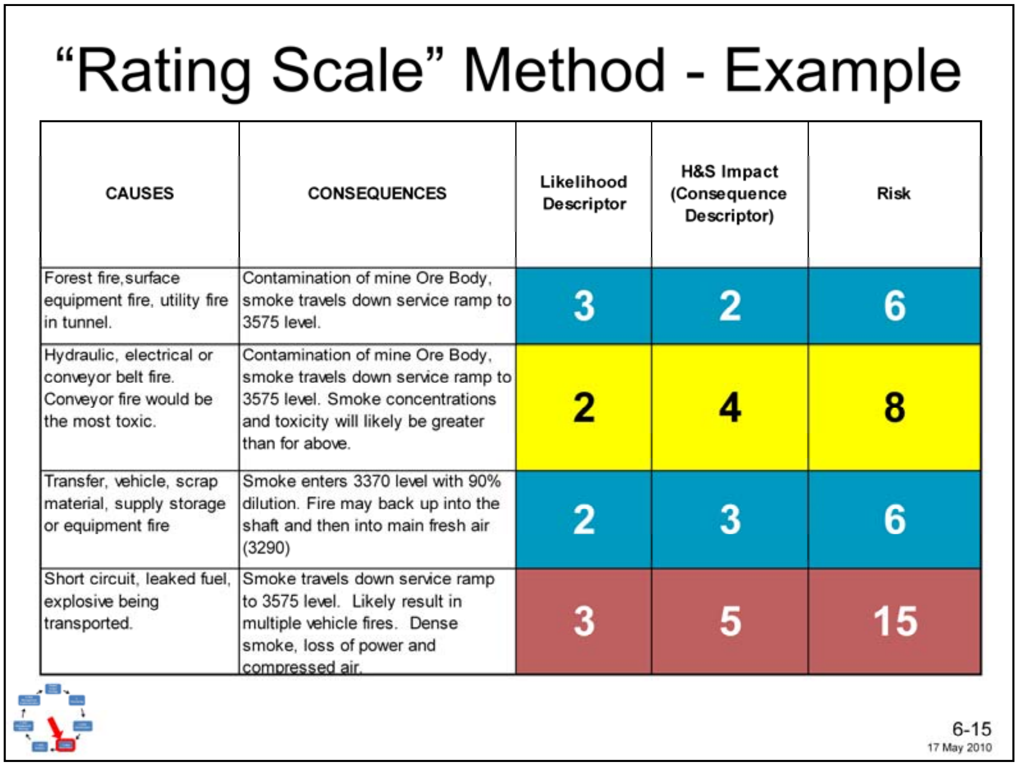
Excerpt from mine-fire risk assessment.

Risk Index Value = Likelihood Index (1-5) x Consequence Index (1-5). Implicitly assumes that (L=1) x (C=5) = (L=5) x (C=1) = (R=5).

Although this is mathematically correct, there is no guarantee that the scales have been appropriately defined (i.e., need linear scale if multiplying factors or log scale if adding factors)



"Rating Scale" Method - Example

CAUSES	CONSEQUENCES	Likelihood Descriptor	H&S Impact (Consequence Descriptor)	Risk
Forest fire,surface equipment fire, utility fire in tunnel.	Contamination of mine Ore Body, smoke travels down service ramp to 3575 level.	3	2	6
Hydraulic, electrical or conveyor belt fire. Conveyor fire would be the most toxic.	Contamination of mine Ore Body, smoke travels down service ramp to 3575 level. Smoke concentrations and toxicity will likely be greater than for above.	2	4	8
Transfer, vehicle, scrap material, supply storage or equipment fire	Smoke enters 3370 level with 90% dilution. Fire may back up into the shaft and then into main fresh air (3290)	2	3	6
Short circuit, leaked fuel, explosive being transported.	Smoke travels down service ramp to 3575 level. Likely result in multiple vehicle fires. Dense smoke, loss of power and compressed air.	3	5	15

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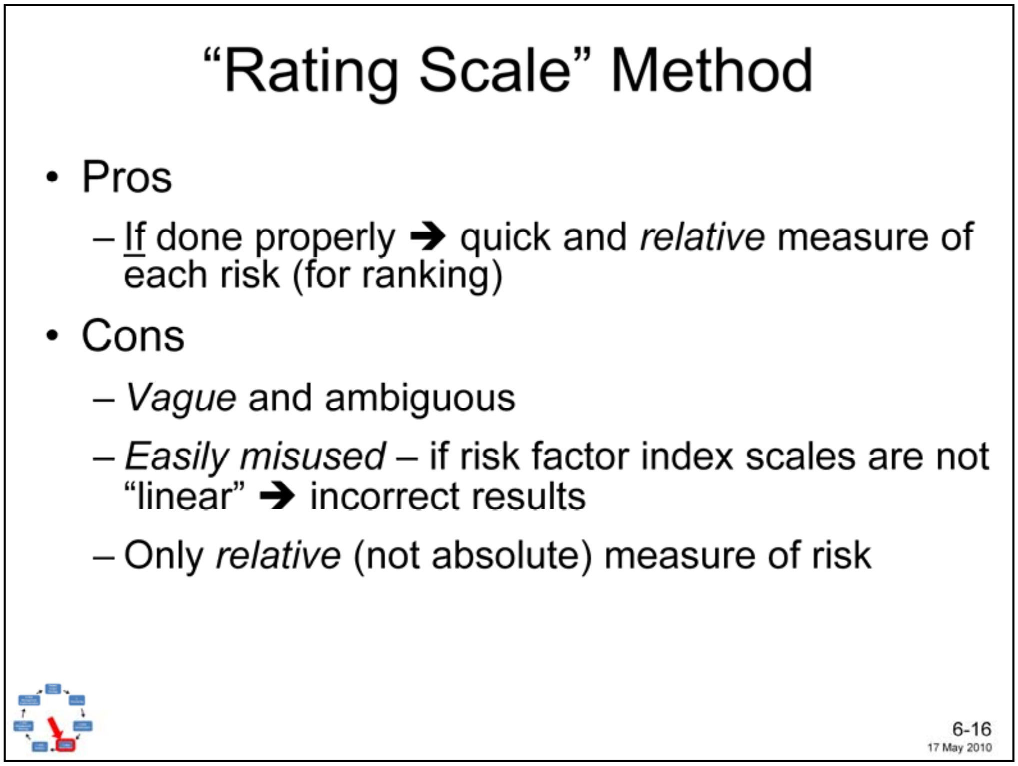
Example continued - excerpt from mine-fire risk assessment. In this example, health and safety (H&S) is the only impact of interest, rather than cost, schedule, disruption and longevity. However, the concept is the same. Often, for multiple consequences, consequence indices for each type are used and then combined (e.g., added and normalized back to a 1-5 scale).

Risk Index Value = Likelihood Index (1-5) x Consequence Index (1-5). Implicitly assumes that (L=1) x (C=5) = (L=5) x (C=1) = (R=5).



“Rating Scale” Method

- Pros
  - <u>If</u> done properly ➔ quick and *relative* measure of each risk (for ranking)
- Cons
  - *Vague* and ambiguous
  - *Easily misused* – if risk factor index scales are not “linear” ➔ incorrect results
  - Only *relative* (not absolute) measure of risk

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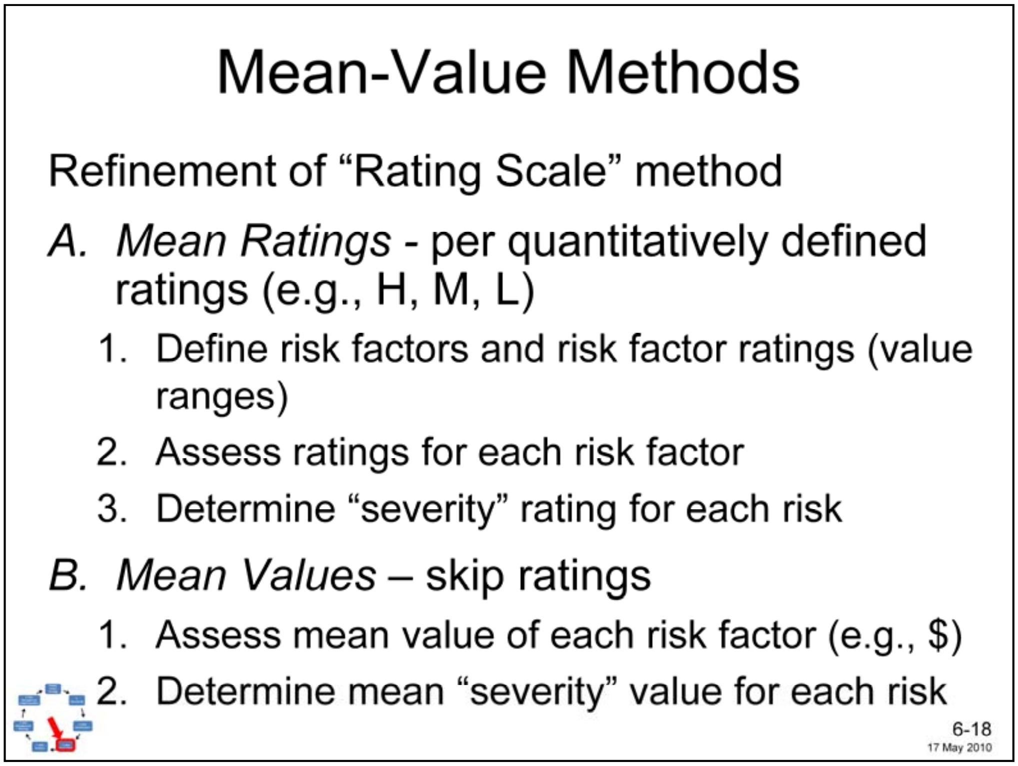
- Pros
  - <u>If</u> done properly, quick way to provide a *relative* measure of risk (e.g., on a scale of 1 to 25), adequate for ranking of risks
- Cons
  - *Like “Red/Yellow/Green” method, unless the indices are quantitatively defined, different people might interpret the various index categories (e.g., Likelihood = “1 Rare”) differently*
  - *Easily misused*
    - Values for likelihood and consequence are commonly multiplied together to get overall measure of risk, and values for different consequences are commonly added together to get the combined consequence index.
    - But this is valid *only if* the scales have been defined to be “linear,” which is often not the case (have seen this many times). Linear scale means that a score of 2 is twice the magnitude of a score of 1, a score of 4 is twice the magnitude of a score of 2, etc.
  - Even if done properly, only provides a *relative* measure of risk (i.e., risk of 20 is greater than a risk of 15), not an absolute measure (i.e., in terms of $ or months)

Available Methods - Detailed

Among many available methods:

- “Red/Yellow/Green” method (qualitative)
- “Rating Scale” method (qualitative)
- **Mean-value method (quantitative)**
  - **Ratings (defined value ranges) → L, M, H**
  - **Values → $, months**
- Full uncertainty analysis (Module 7)



Mean-Value Methods

Refinement of “Rating Scale” method

A. *Mean Ratings* - per quantitatively defined ratings (e.g., H, M, L)
   1. Define risk factors and risk factor ratings (value ranges)
   2. Assess ratings for each risk factor
   3. Determine “severity” rating for each risk

B. *Mean Values* – skip ratings
   1. Assess mean value of each risk factor (e.g., $)
   2. Determine mean “severity” value for each risk

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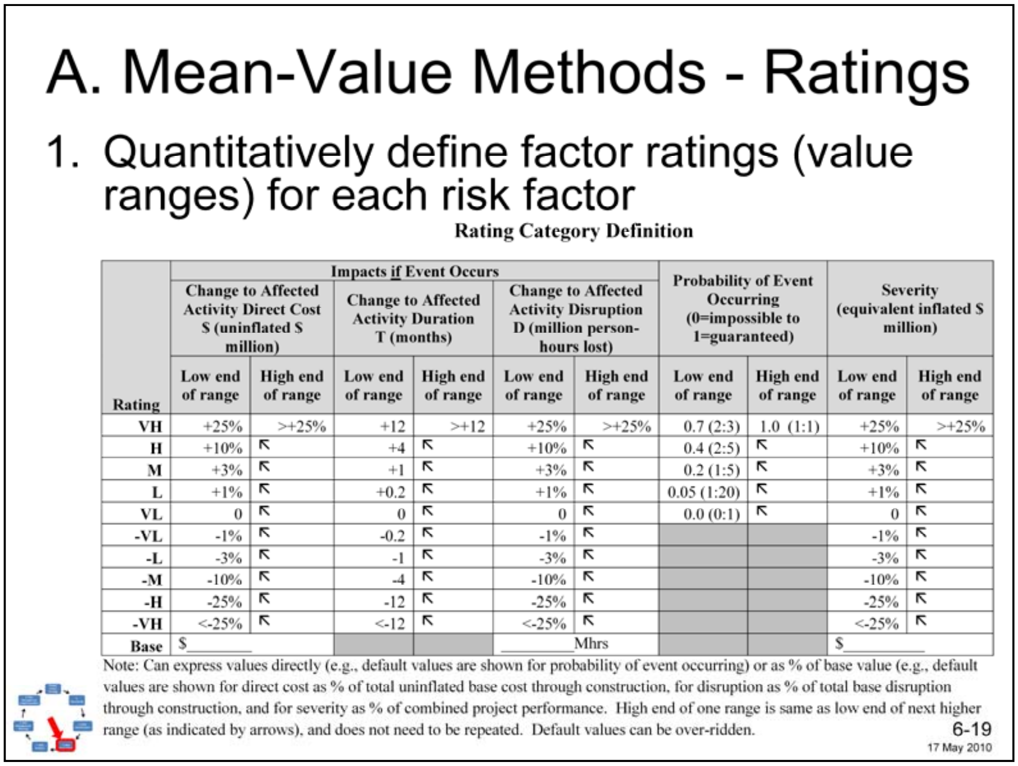
- Both approaches build on the “Rating Scale” method
  - The Mean *Ratings* approach characterizes risks in terms of *mean ratings* (which are categories or ranges of values that are easier to assess than absolute values)
    - Uses category mean ratings (e.g., L, M, H) defined as ranges of mean values to characterize individual risk factors (i.e., likelihood and impacts)
    - Using established “tradeoffs” among different types of consequences, <u>mathematically</u> produces a mean “severity” rating (e.g., L, M, H) for each risk
  - The Mean *Values* approach simply skips the ratings and characterizes risks in terms of *mean values* (which, as probability-weighted average values, are more refined but also more difficult to assess than categories/ratings)
    - Characterizes individual risk factors directly in terms of mean values in specific units/dimensions (e.g., $)
    - Using established “tradeoffs”, <u>mathematically</u> produces a mean “severity” in equivalent units (e.g., $) for each risk
- For efficiency, we generally recommend the *Mean Ratings* method for your application, especially for initial evaluations which can subsequently be refined using *Mean Values method*, but the course template can do both (even a mixture)



A. Mean-Value Methods - Ratings

1. Quantitatively define factor ratings (value ranges) for each risk factor

Rating Category Definition

Rating	Impacts if Event Occurs						Probability of Event Occurring (0=impossible to 1=guaranteed)		Severity (equivalent inflated $ million)	
	Change to Affected Activity Direct Cost S (uninflated $ million)		Change to Affected Activity Duration T (months)		Change to Affected Activity Disruption D (million person-hours lost)					
	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range
VH	+25%	>+25%	+12	>+12	+25%	>+25%	0.7 (2:3)	1.0 (1:1)	+25%	>+25%
H	+10%	↖	+4	↖	+10%	↖	0.4 (2:5)	↖	+10%	↖
M	+3%	↖	+1	↖	+3%	↖	0.2 (1:5)	↖	+3%	↖
L	+1%	↖	+0.2	↖	+1%	↖	0.05 (1:20)	↖	+1%	↖
VL	0	↖	0	↖	0	↖	0.0 (0:1)	↖	0	↖
-VL	-1%	↖	-0.2	↖	-1%	↖			-1%	↖
-L	-3%	↖	-1	↖	-3%	↖			-3%	↖
-M	-10%	↖	-4	↖	-10%	↖			-10%	↖
-H	-25%	↖	-12	↖	-25%	↖			-25%	↖
-VH	<-25%	↖	<-12	↖	<-25%	↖			<-25%	↖
Base	$________				________Mhrs				$________	

Note: Can express values directly (e.g., default values are shown for probability of event occurring) or as % of base value (e.g., default values are shown for direct cost as % of total uninflated base cost through construction, for disruption as % of total base disruption through construction, and for severity as % of combined project performance. High end of one range is same as low end of next higher range (as indicated by arrows), and does not need to be repeated. Default values can be over-ridden.

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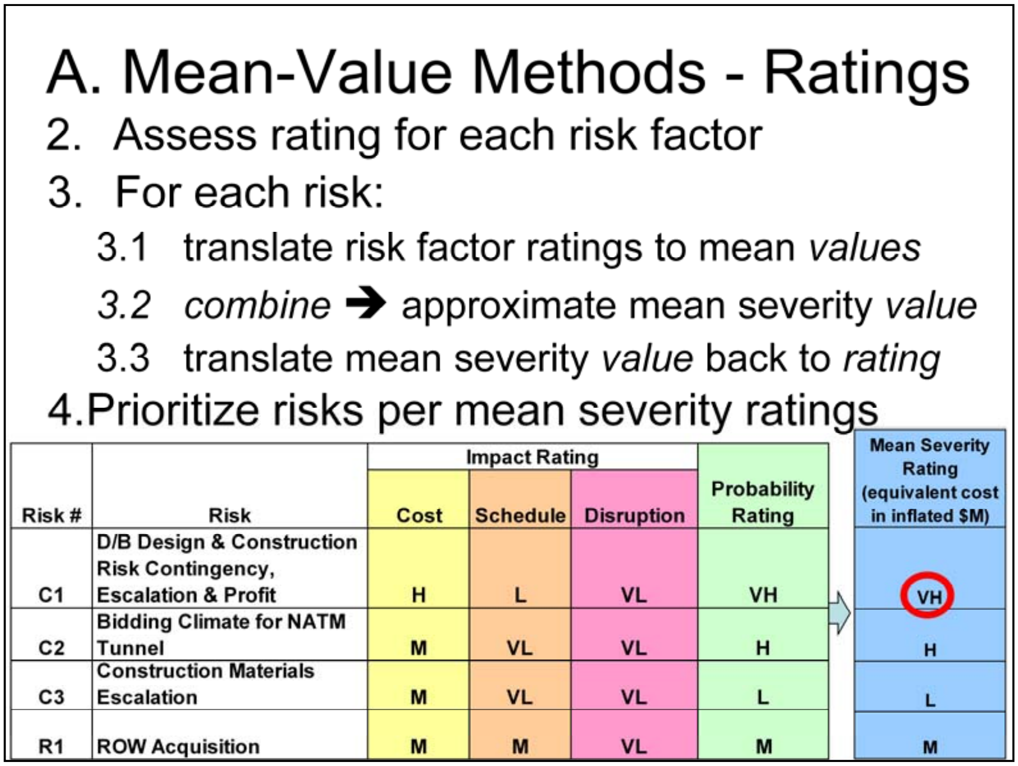
- A rating is a qualitative (rather than quantitative) descriptor. This particular approach uses *category ratings* (e.g., L, M, H) for each risk factor
- The category rating for each risk factor is defined by (based on) specific ranges of values for that category and factor, which in turn define a *category mean value*:
  - Probability of occurrence (e.g., in % or 0 to 1 or odds)
  - Mean value for each consequence type (e.g., $, months). Costs are expressed either in $ or as a percentage of the project unescalated base cost (from Module 2), whereas schedule impacts are expressed in terms of months delay and disruption impacts are expressed in terms of user lost-hours (or similar to cost could be expressed as a percentage of the project base disruption from Module 2). The cost, schedule and disruption impacts are assigned to specific project activities, from which critical path schedule delay and longevity impacts can be derived - schedule delay for a risk is not necessarily to the project's critical path.

  Note: Default values for each rating are used in the course template, although the ranges and mean values can be revised. The unescalated cost, schedule and disruption impacts by activity are translated to an equivalent escalated project cost (considering critical path impacts and associated extended OHs, as well as escalation), and equivalent "value" of schedule delays, disruption and longevity impacts, which (as subsequently discussed) is done automatically in the course template.
  - The upper end of a range is the same as the lower end of the next higher range (as indicated by the arrows), and thus does not need to be repeated.
- For example:
  - In the default values, "-L" cost rating is defined by the range in cost of savings of -3% to -1% of the base unescalated project cost, with a mean value of -2%. If the base unescalated project cost was $30M, then the range of additional unescalated costs for "–L" would be -$0.9M to -$0.3M, with a mean value (which would be used for mean-value risk-ranking purposes) of -$0.6M (which would be escalated and combined with schedule and disruption impacts).
  - In the table above, "H" probability rating is defined by the range in probabilities of 0.4 to 0.7, with a mean value of 0.55.

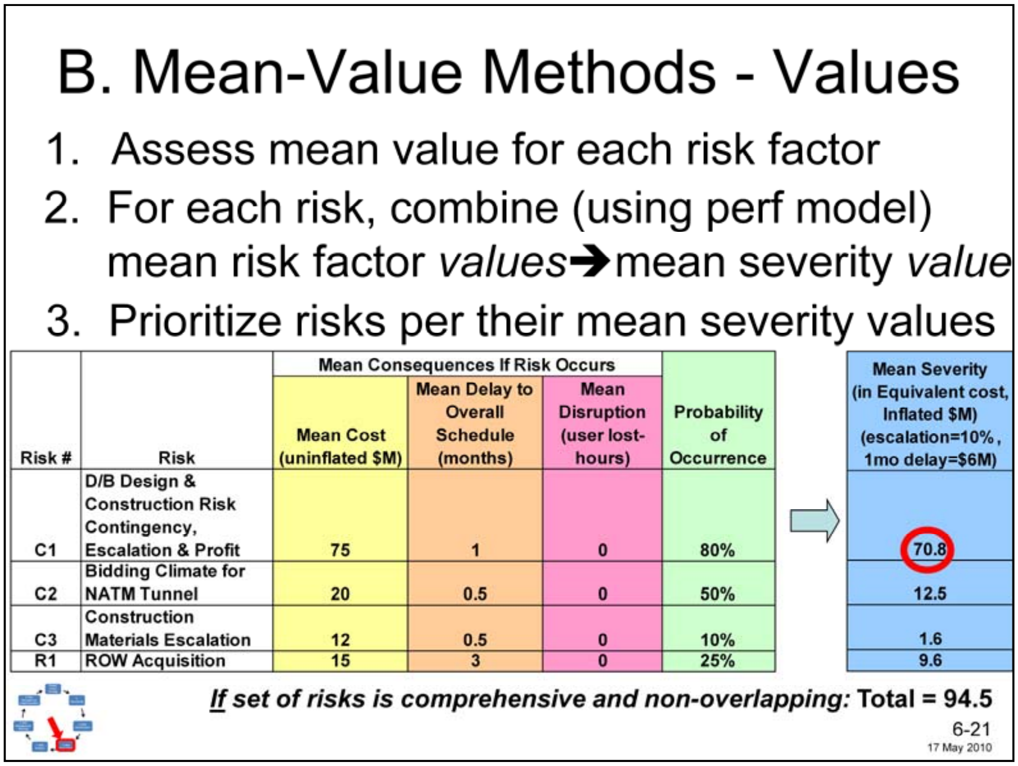


A. Mean-Value Methods - Ratings

2. Assess rating for each risk factor
3. For each risk:
   - 3.1 translate risk factor ratings to mean *values*
   - *3.2 combine* ➔ approximate mean severity *value*
   - 3.3 translate mean severity *value* back to *rating*
4. Prioritize risks per mean severity ratings

Risk #	Risk	Impact Rating			Probability Rating	Mean Severity Rating (equivalent cost in inflated $M)
		Cost	Schedule	Disruption		
C1	D/B Design & Construction Risk Contingency, Escalation & Profit	H	L	VL	VH	VH
C2	Bidding Climate for NATM Tunnel	M	VL	VL	H	H
C3	Construction Materials Escalation	M	VL	VL	L	L
R1	ROW Acquisition	M	M	VL	M	M

- Once the factor rating scales have been quantitatively defined, the following steps are done for each risk:
  1. rate each risk factor (i.e., conditional cost impact, conditional schedule impact, conditional disruption impact and probability of occurrence) using the corresponding category ratings (e.g., L, M, H), as defined in previous slide
  2. translate each risk factor rating into a mean value (using the factor rating definitions – see in previous slide)
  3. Combine (using a model) the mean values across risk factors to get very approximate mean value of risk (combining consequence types ultimately into equivalent cost)
  4. Translate back into a <u>mathematically-correct</u> *mean risk rating* (e.g., L, M, H) for each risk; the mean risk rating considers all consequence types
- Once the factor ratings have been defined in the template, and the risk factors have been assessed per those factor rating definitions and documented in the course template for each identified risk, steps 2 - 4 are done automatically in the template.
- Such mean risk ratings can subsequently be used to prioritize risks in terms of ratings.



B. Mean-Value Methods - Values

1. Assess mean value for each risk factor
2. For each risk, combine (using perf model) mean risk factor *values*➔mean severity *value*
3. Prioritize risks per their mean severity values

Risk #	Risk	Mean Consequences If Risk Occurs			Probability of Occurrence	Mean Severity (in Equivalent cost, Inflated $M) (escalation=10%, 1mo delay=$6M)
		Mean Cost (uninflated $M)	Mean Delay to Overall Schedule (months)	Mean Disruption (user lost-hours)		
C1	D/B Design & Construction Risk Contingency, Escalation & Profit	75	1	0	80%	70.8
C2	Bidding Climate for NATM Tunnel	20	0.5	0	50%	12.5
C3	Construction Materials Escalation	12	0.5	0	10%	1.6
R1	ROW Acquisition	15	3	0	25%	9.6

***If** set of risks is comprehensive and non-overlapping:* **Total = 94.5**

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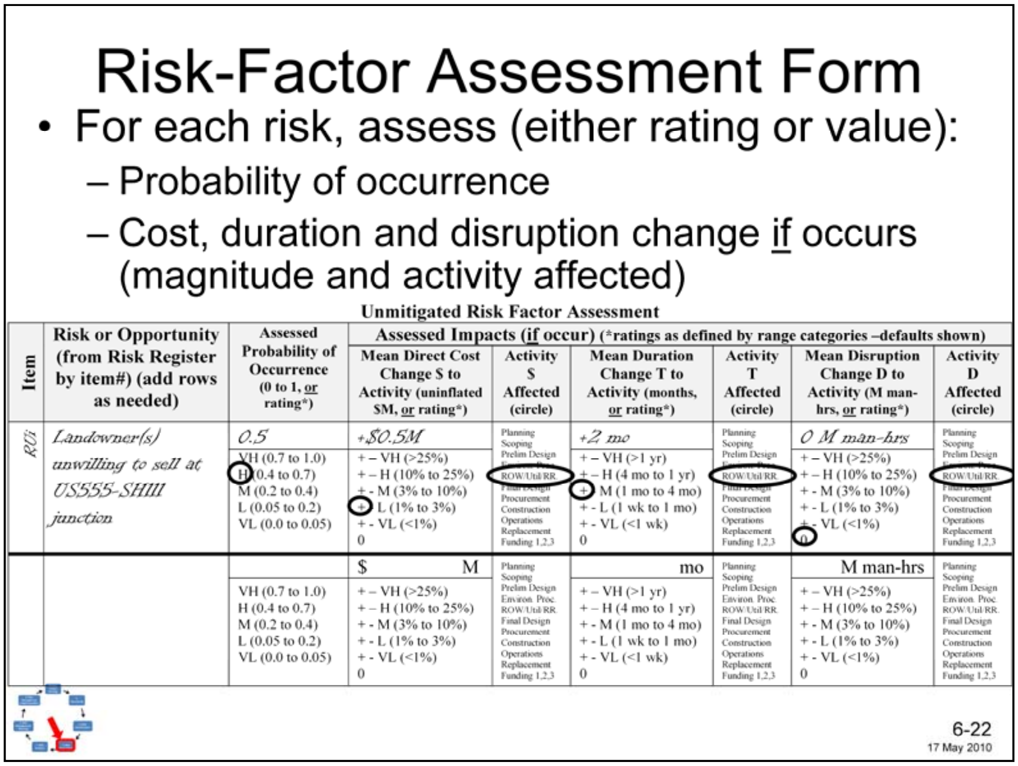
For each risk:

1. each risk factor is defined and assessed directly in terms of the units of interest:
    - Probability of the risk's occurrence (e.g., in %)
    - Mean value for each consequence type if the risk occurs; for example:
        - Additional direct unescalated cost ($) to specific activity
        - Delay (months) to specific activity
        - Additional disruption (lost-hours) to specific activity
2. In analysis
    - Translate into project performance measures: project delay (critical path analysis) and longevity (combine post-construction cost, schedule ad disruption impacts)
    - can combine the performance measures into a single equivalent performance measure ("severity")
        - Escalation – in above example escalation is 10%
        - Convert schedule delay into equivalent cost from delay and additional inflation – in above example, used $6M in equivalent cost per month of delay
        - Convert additional disruption into equivalent cost
        - Convert longevity impact into equivalent cost
    - calculate the *mean severity value*
        - Mean severity ($) = Probability * Mean equivalent cost ($)
        - Mean equivalent cost ($) = Direct cost ($) * Esc (%) + Delay (mo) * {OH ($/mo) + Esc ($/mo)} + Disruption (hrs) * Value ($/hr) + Longevity ($) * Value ($/$)

          For example, if total base cost (unescalated) is $30M and escalation rate is 4%/yr, then increased escalation due to schedule delay is $1.2M/yr or $0.1M/mo.
    - For consequences that are additive, and if the set of risks is comprehensive and non-overlapping, can add across all risks to get total mean risk for project (e.g., mean cost risk in equivalent $). However, we do not recommend budgeting based on this mean value of risk, because the chance of exceeding it would be too high (e.g., 40 to 50%), which is generally not conservative enough. Instead, the budget should be established at a higher percentile value (e.g., 80th percentile), which in turn requires a complete uncertainty analysis, as subsequently described in Module 7.

Note: In the template for this course, as noted above, additional unescalated direct costs, delays and additional disruption are assigned to specific activities. A simple performance model is used to determine the mean project (as opposed to activity) schedule, disruption, longevity and escalated cost impact.



Risk-Factor Assessment Form

- For each risk, assess (either rating or value):
  - – Probability of occurrence
  - – Cost, duration and disruption change <u>if</u> occurs (magnitude and activity affected)

Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, <u>or</u> rating*)	Assessed Impacts (<u>if</u> occur) (*ratings as defined by range categories –defaults shown)					
			Mean Direct Cost Change $ to Activity (uninflated $M, <u>or</u> rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, <u>or</u> rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, <u>or</u> rating*)	Activity D Affected (circle)
RUi	Landowner(s) unwilling to sell at US555-SHIII junction	0.5	+$0.5M	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3
		VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0		+ – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]	
			$ M	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0		+ – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	

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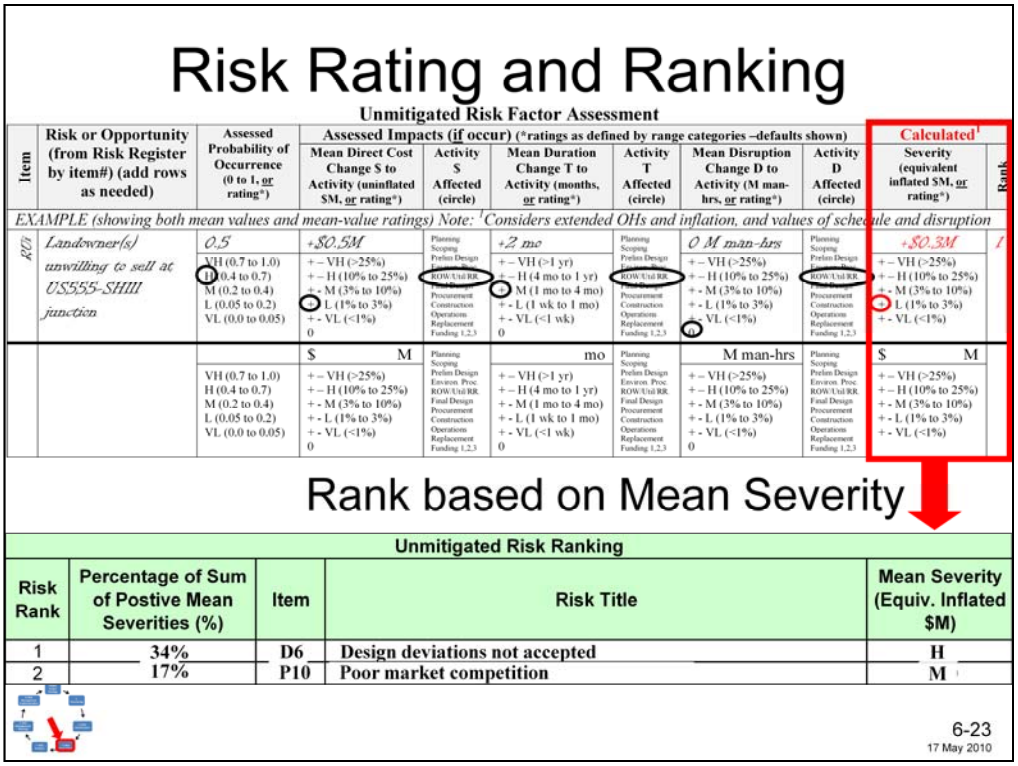
A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

This information will eventually be input into an MS Excel workbook template developed for this course (provided on CD and presented in Module 12) – in fact, the template is designed to be filled in directly (on the fly) during the workshop, bypassing the paper form.

Inputs include:

- Probability of risk event occurrence
- Cost impact <u>if</u> risk event occurs in terms of cost change to particular activity (per major project activities in standard flow chart – specify through drop down box)
- Schedule impact <u>if</u> risk event occurs in terms of duration change to particular activity (per major project activities in standard flow chart – specify through drop down box)
- Disruption impact <u>if</u> risk event occurs in terms of user lost-hours change to particular activity (per major project activities in standard flow chart – specify through drop down box)

Can use either ratings or values for each risk factor. If using ratings, <u>must</u> use specified list and first specify rating definitions (in terms of ranges and expected values for each category). The rating definitions can be documented on a hard copy (which is presented in App E of the *Guide*, with the MS Word file contained on the CD) or in the MS Excel template developed for this course (provided on CD and presented in Module 12).



Risk Rating and Ranking

Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur) (*ratings as defined by range categories –defaults shown)						Calculated[1]	
			Mean Direct Cost Change $ to Activity (uninflated $M, or rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, or rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, or rating*)	Activity D Affected (circle)	Severity (equivalent inflated $M, or rating*)	Rank
EXAMPLE (showing both mean values and mean-value ratings) Note: [1]Considers extended OHs and inflation, and values of schedule and disruption										
R01	*Landowner(s) unwilling to sell at US555-SHIII junction*	*0.5*	*+$0.5M*	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	*+2 mo*	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	*0 M man-hrs*	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	*+$0.3M*	*1*
		VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] L (1% to 3%) + - VL (<1%) 0		+ – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] L (1% to 3%) + - VL (<1%)	
			$ M	Planning Scoping Prelim Design Environ. Proc. ROW/Util RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo	Planning Scoping Prelim Design Environ. Proc. ROW/Util RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs	Planning Scoping Prelim Design Environ. Proc. ROW/Util RR Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0		+ – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	

Rank based on Mean Severity

Unmitigated Risk Ranking

Risk Rank	Percentage of Sum of Postive Mean Severities (%)	Item	Risk Title	Mean Severity (Equiv. Inflated $M)
1	34%	D6	Design deviations not accepted	H
2	17%	P10	Poor market competition	M

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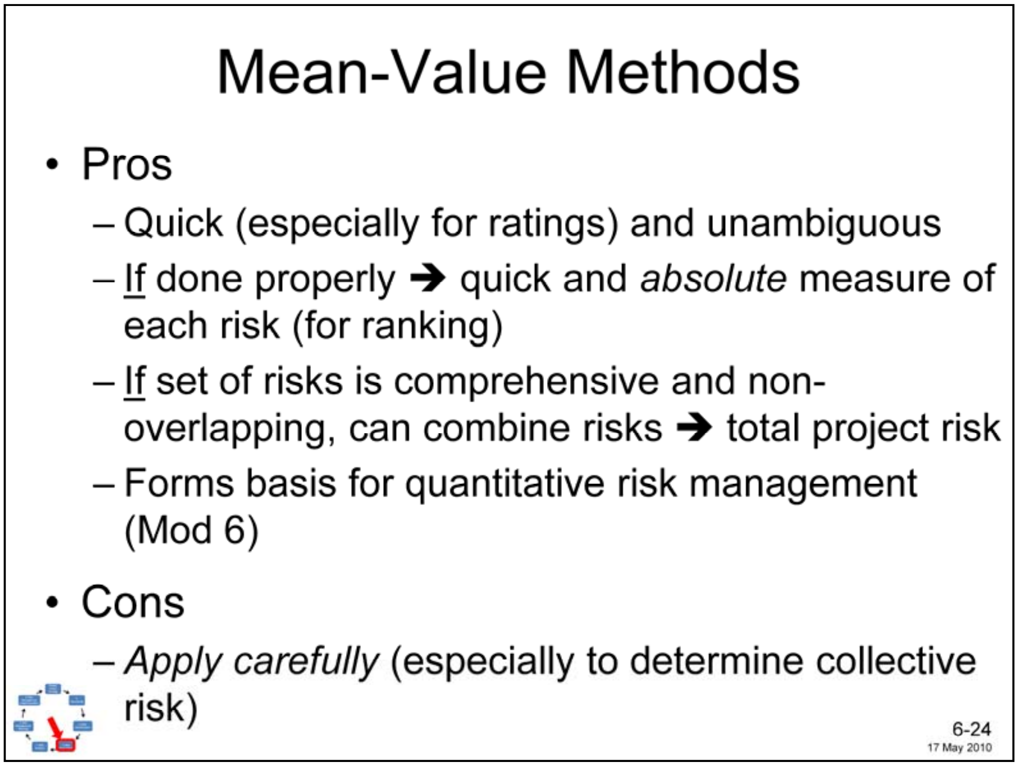
In the template for this course, the mean value or rating is determined automatically for each risk and the ranking is also done automatically.

- Once the risk factors have been assessed and documented in the course template for each identified risk, the mean severity (either rating or value) is determined automatically for each risk. The template determines the mean change in unescalated cost, in duration and in disruption for each activity due to that risk. The mean change in project schedule is determined by comparing the mean change in duration to the activity's base float (see Module 4). The mean change in longevity is determined by comparing the combined post-construction cost, schedule and disruption with and without the risk. The increased unescalated cost due to cost risks, which is escalated, increased escalation of the base cost and risk cost due to schedule risks, and extended overheads due to schedule risks are all determined automatically in terms of mean values based on the standard flow chart (appropriately considering critical path and float), escalation rates and extended OH rates, so that the mean risk is in terms of mean additional escalated cost.

- The collective mean escalated risk costs for groups of risks (including the total for the project) are also computed automatically – however, they are only appropriate if the set of risks is comprehensive and non-overlapping. The template determines the mean change in unescalated cost, in disruption, and in duration for each activity due to all the risks affecting that activity, appropriately considering overlap among schedule delays. The mean total unescalated cost, total disruption and total duration for each activity are then determined, based on these risk factor assessments, in conjunction with baseline project description (including activity base costs and durations). The mean total project schedule, disruption and cost (both unescalated and escalated) are then determined based on these activity total unescalated costs and durations, in conjunction with the standard flow chart (appropriately considering critical path and float), escalation rates and extended OH rates, from which additional unescalated cost (extended OHs) and then additional escalation are determined, so that the mean risk is in terms of mean additional escalated cost. This integrated cost and schedule model is essentially the same as used for the baseline in Module 4 and as subsequently described in Module 7, although for mean values only (ignoring uncertainty and thus significant dependency/correlations).



Mean-Value Methods

- Pros
  - Quick (especially for ratings) and unambiguous
  - If done properly ➔ quick and *absolute* measure of each risk (for ranking)
  - If set of risks is comprehensive and non-overlapping, can combine risks ➔ total project risk
  - Forms basis for quantitative risk management (Mod 6)
- Cons
  - *Apply carefully* (especially to determine collective risk)

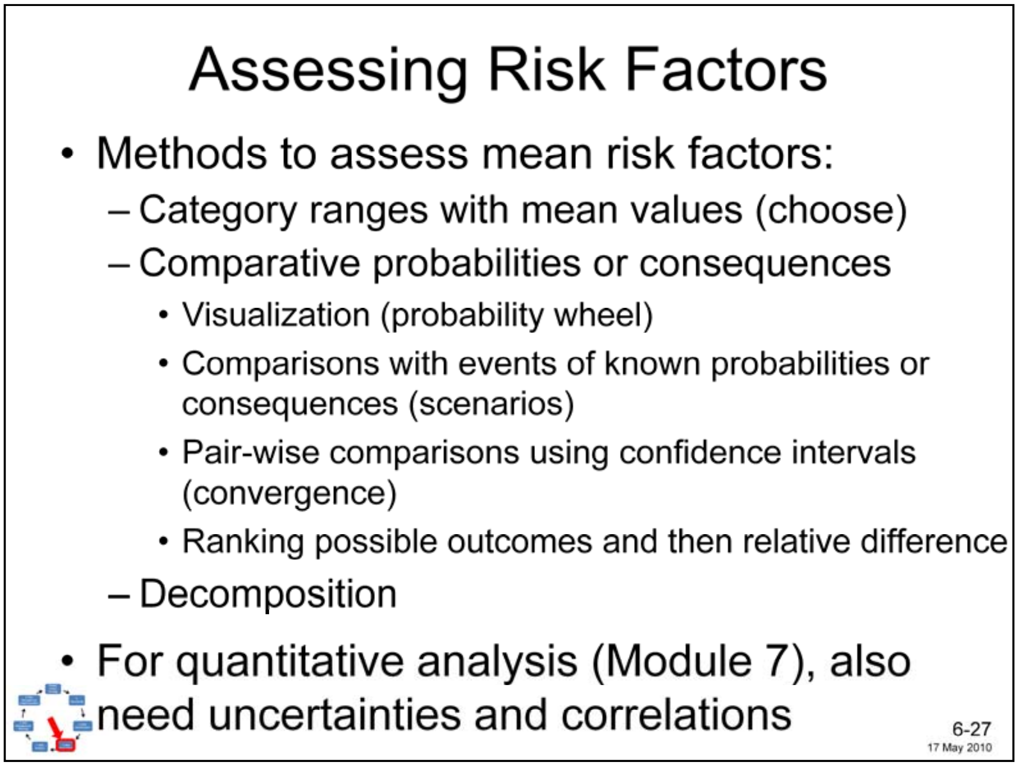
- Pros
  - Quick way to provide a mean-value measure of risk
  - No ambiguity in, or subjectivity in, how to combine likelihoods and consequences
  - Can rank risks appropriately based on their mean values
  - For monetary (additive) consequences, can add over all risks to get a total mean risk (and convert all consequences to common scale in order to combine) if the set of risks are comprehensive and non-overlapping
  - Forms basis for quantitative risk mitigation
- Cons
  - *Must be applied carefully, especially if computing total project risks (summing over the set of risks)*
    - Must avoid overlapping (double-counting) risks
    - Must have a comprehensive set of risks if objective is to get total mean value for all project risks
  - Does not include:
    - Uncertainty in, or correlation among, consequences of event occurrence
    - Dependencies among occurrence of events
- Implemented in template for this course.

Risk Assessment

- Learning Objectives
- Available Methods
  - Process
  - Guidance
- ➢ **Assessing Risk Factors**
- Practical Exercise
- Summary

Assessing Risk Factors

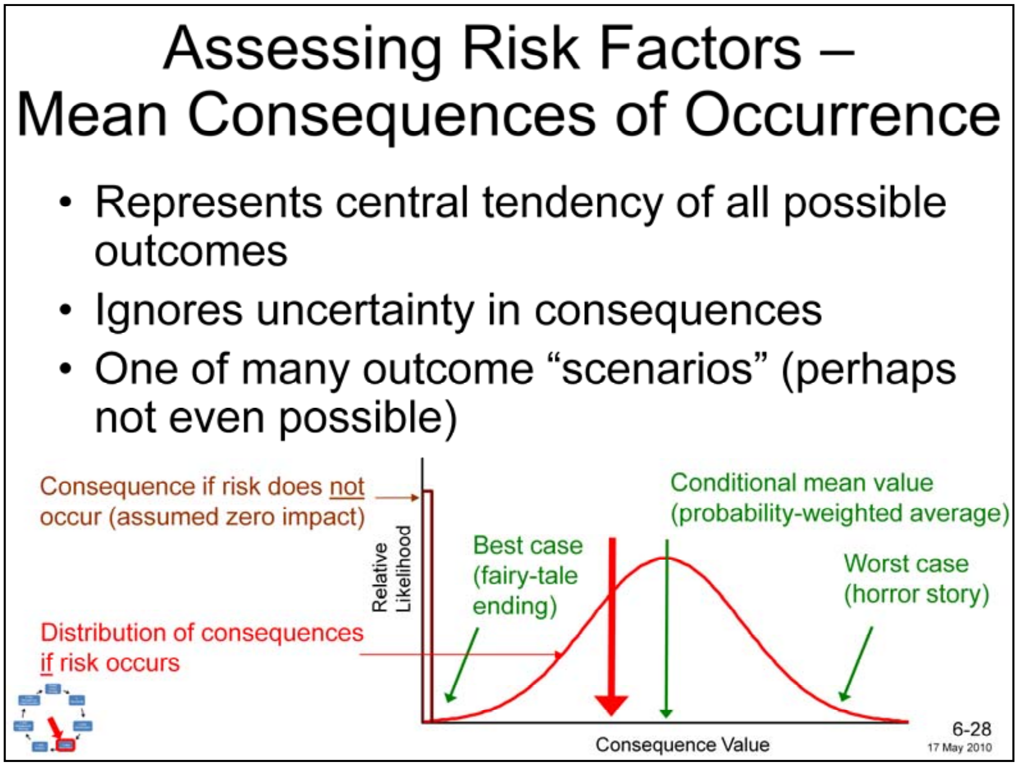
- Use *relevant* historical information
- Adequate “data” set does not usually exist
- Rely on “subjective assessment” of expert opinion/judgment (including experience)
- Subjective assessments
  - Widely accepted (e.g., NRC, EPA, DOE, DOD)
  - Must be developed appropriately
  - Best available approach



Assessing Risk Factors

- Methods to assess mean risk factors:
  - – Category ranges with mean values (choose)
  - – Comparative probabilities or consequences
    - Visualization (probability wheel)
    - Comparisons with events of known probabilities or consequences (scenarios)
    - Pair-wise comparisons using confidence intervals (convergence)
    - Ranking possible outcomes and then relative difference
  - – Decomposition
- For quantitative analysis (Module 7), also need uncertainties and correlations

- Category ranges previously discussed
- Comparative probabilities, ranking and decomposition are discussed subsequently
- Probability (or lottery) wheel can be used to visualize magnitude of probability
- Pair-wise comparisons using confidence intervals can be expressed, for example, as:
  - "Does event have more or less than 50% chance of occurring?"
  - "Is the consequence of occurrence more than $2M? – if so, is it less than $5M? – etc."



Assessing Risk Factors – Mean Consequences of Occurrence

- Represents central tendency of all possible outcomes
- Ignores uncertainty in consequences
- One of many outcome “scenarios” (perhaps not even possible)

Consequence if risk does not occur (assumed zero impact)

Distribution of consequences if risk occurs

Best case (fairy-tale ending)

Conditional mean value (probability-weighted average)

Worst case (horror story)

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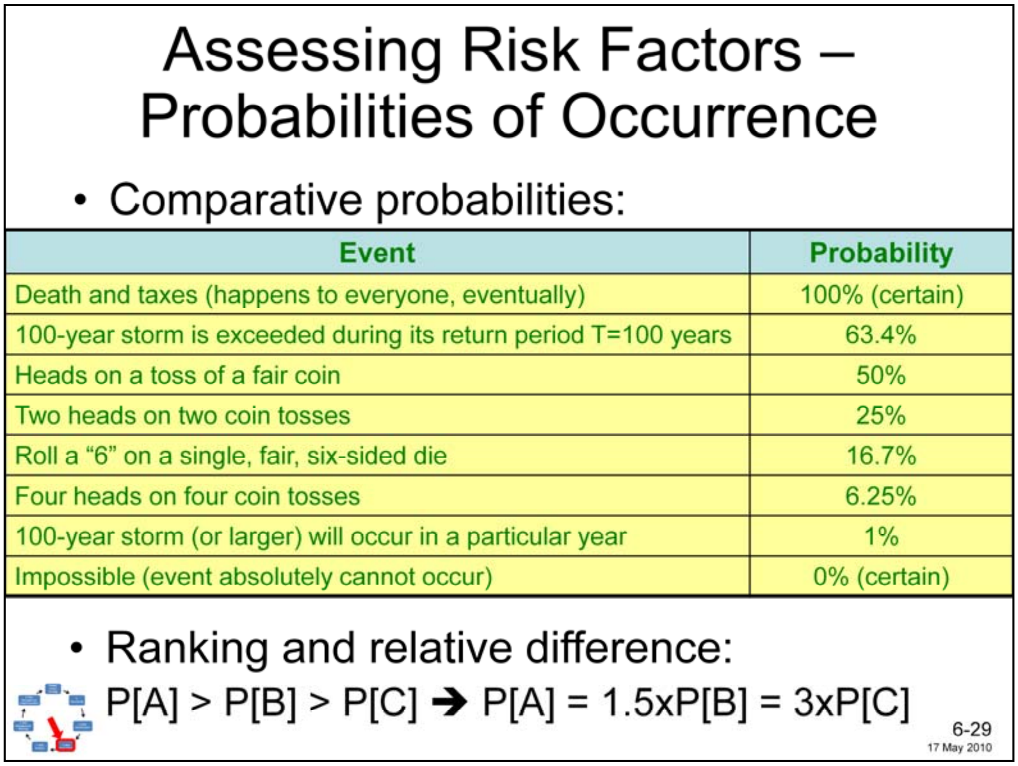

Assessing Risk Factors – Probabilities of Occurrence

- Comparative probabilities:

Event	Probability
Death and taxes (happens to everyone, eventually)	100% (certain)
100-year storm is exceeded during its return period T=100 years	63.4%
Heads on a toss of a fair coin	50%
Two heads on two coin tosses	25%
Roll a "6" on a single, fair, six-sided die	16.7%
Four heads on four coin tosses	6.25%
100-year storm (or larger) will occur in a particular year	1%
Impossible (event absolutely cannot occur)	0% (certain)

- Ranking and relative difference:

P[A] > P[B] > P[C] ➔ P[A] = 1.5xP[B] = 3xP[C]

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Comparative probabilities table provides some events with known probabilities, which can be useful for eliciting probabilities for other events *by comparison (e.g., more or less likely).*

Probability for outcome of interest can be determined by comparing to all the other possible outcomes – ranking and then assessing relative difference:

1. First, rank the possible outcomes qualitatively; e.g.,

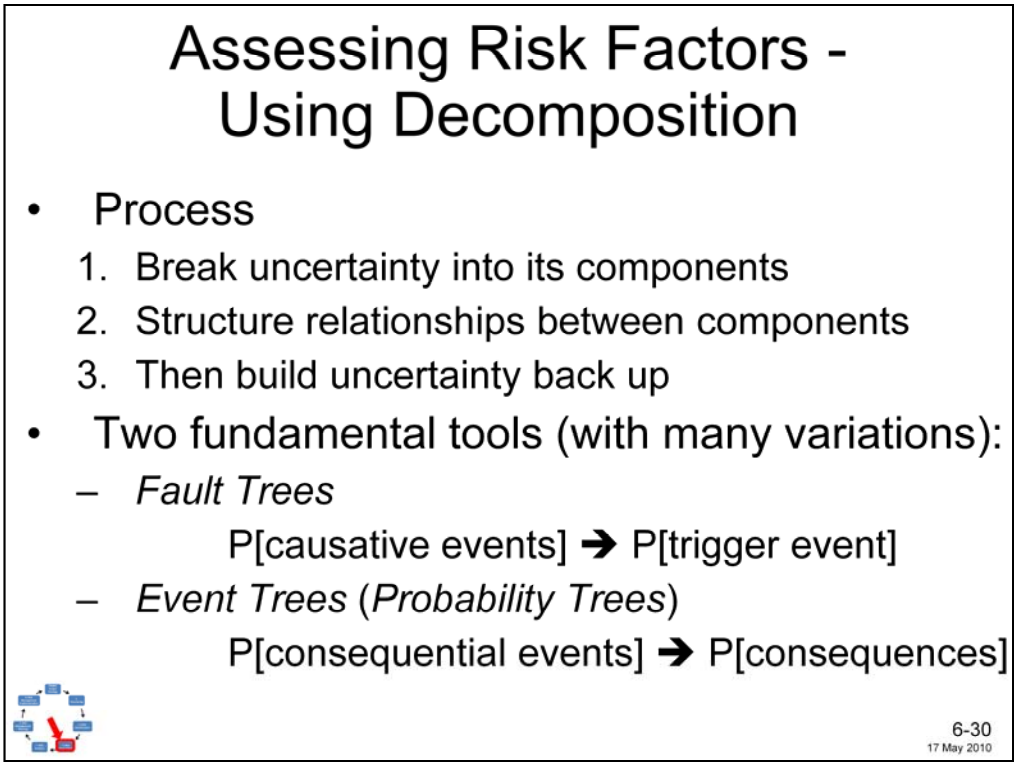
   A more likely than **B**, which is more likely than **C**

2. Then, quantify consecutive pairs in terms of their relative likelihood; e.g.,

   Likelihood of **A** versus likelihood of **B** is **3:2; B** vs. **C** is **2:1**

3. Then, reduce the relative likelihoods for all possible outcomes so that the total of all probabilities equals 1.0; e.g.,

   Total = 3+2+1 = 6; **P(A)** = 3/6; **P(B)** = 2/6; **P(C)** = 1/6



Assessing Risk Factors - Using Decomposition

- Process
  1. Break uncertainty into its components
  2. Structure relationships between components
  3. Then build uncertainty back up
- Two fundamental tools (with many variations):
  - *Fault Trees*

    P[causative events] ➔ P[trigger event]
  - *Event Trees* (*Probability Trees*)

    P[consequential events] ➔ P[consequences]

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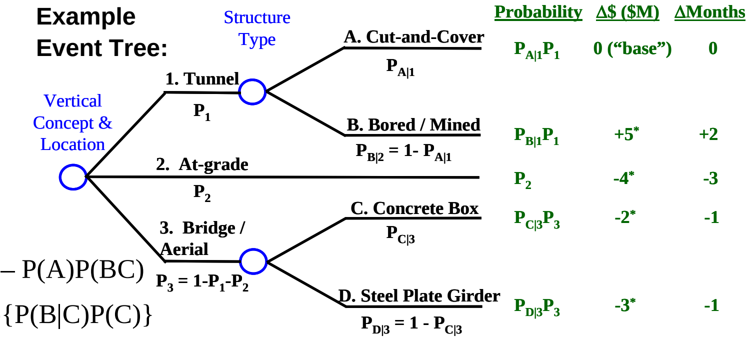
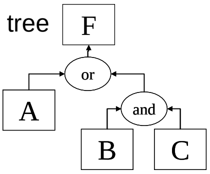
- "Decomposition" techniques break an uncertainty into its components or factors, structure the relationships (conditionality/correlation) between the components or factors, then build the uncertainty back up.
- Two fundamental tools (with many variations):
  - *Fault Trees*
    - Identify possible combinations of events (and their probabilitities) that lead to the occurrence of a "failure" or "trigger" event, which in turn leads to significant consequences
    - Often used to calculate the probability of a "trigger" event occurring
  - *Event trees (Probability trees)*
    - Starting with the occurrence of a "trigger" event, depicts the sequence and combination of possible follow-on, or "consequential," events (and their probabilities) that might occur, resulting in measurable consequences (e.g., $, time)
    - Often used to identify possible outcomes, the probability of the outcomes, and consequences of the outcomes, *given* the occurrence of the "trigger" event

These techniques used to be a mainstay of risk analysis; today they're still very useful for structuring risk assessments

Example Event Tree:

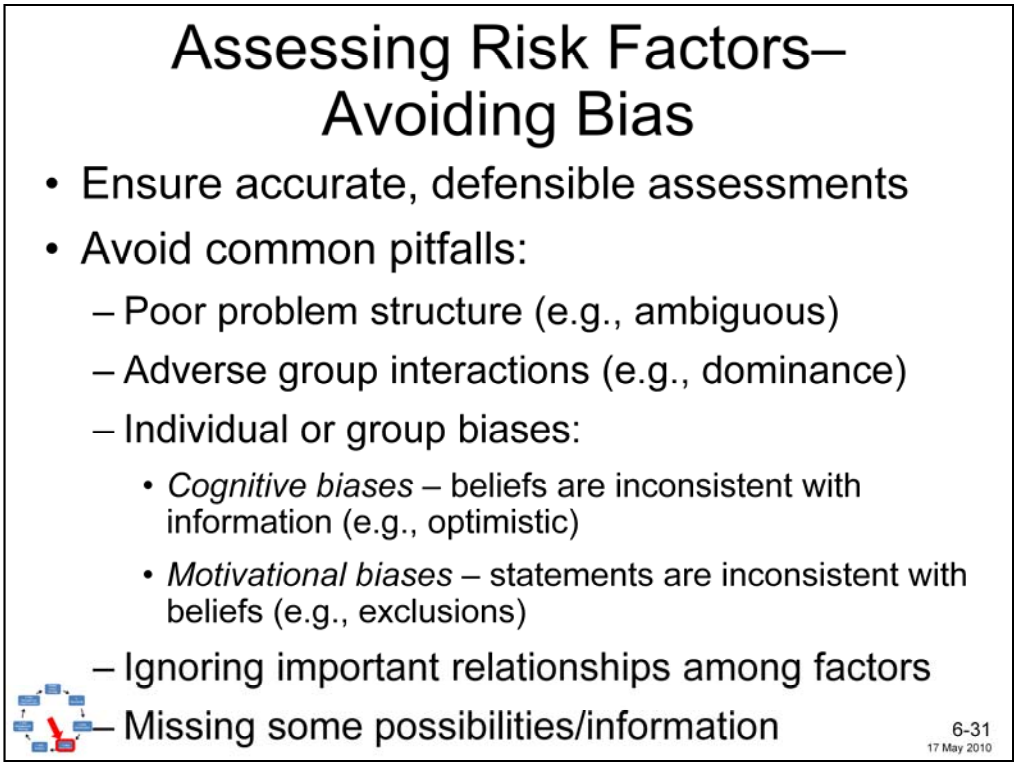


Example fault tree



$$P(F) = P(A\text{u}(BC)) = P(A) + P(BC) – P(A)P(BC)$$

$$= P(A) + \{P(B|C)P(C)\} – P(A)\{P(B|C)P(C)\}$$



Assessing Risk Factors– Avoiding Bias

- Ensure accurate, defensible assessments
- Avoid common pitfalls:
  - – Poor problem structure (e.g., ambiguous)
  - – Adverse group interactions (e.g., dominance)
  - – Individual or group biases:
    - *Cognitive biases* – beliefs are inconsistent with information (e.g., optimistic)
    - *Motivational biases* – statements are inconsistent with beliefs (e.g., exclusions)
  - – Ignoring important relationships among factors
  - – Missing some possibilities/information

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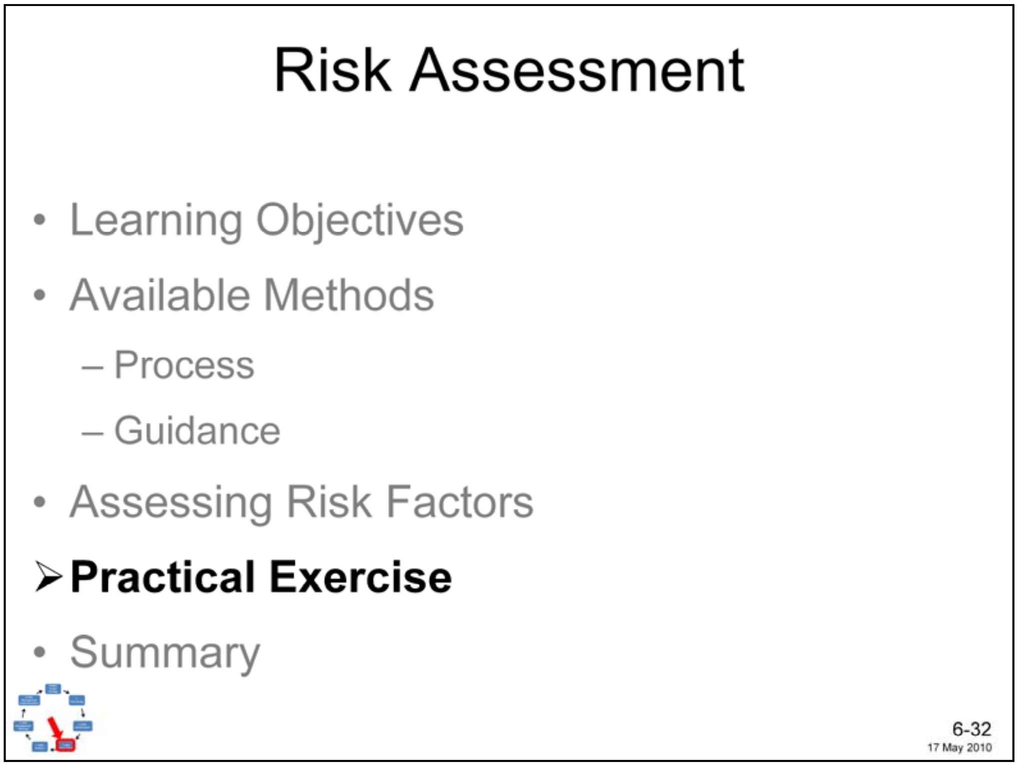
- Must avoid common pitfalls related to subjective assessment:
  - Avoid poor problem structure: make sure to define clearly the factors to be assessed and all related assumptions
  - Mitigate adverse group interactions (e.g., defuse difficult or dominant personalities; ensure all credible opinions are given fair “airtime”)
  - Identify and mitigate individual or group biases:
    - Cognitive biases – beliefs are inconsistent with the information
      - *Anchoring* - focus on starting point (e.g., neglect extremes)
      - *Overconfidence* - ignore unlikely possibilities
      - *Coherence/Conjunctive Distortions* - ignore components (combinations: e.g., $P[x] = \Pi_y P[y]$)
      - *Availability* - focus on easily recalled info
      - *Base Rate* - focus on most specific info (neglect data-based frequency of occurrence)
      - *Representativeness* - ignore relevance of different types of info (treat all equally)
    - Motivational biases – statements are inconsistent with beliefs
      - *Management* – tell them what they want to hear
      - *Expert* – want to appear knowledgeable
      - *Conflict* - self-serving
      - *Conservative* - err on the “safe” side
      - *Peer pressure* - go with the crowd

    ➔ *Utilizing independent subject-matter expertise (balanced perspective) can help immensely, but recognizing and mitigating bias is always a challenge!*
  - Recognize and characterize important relationships among factors
  - identify and appropriately consider <u>all</u> possible outcomes and information
- Qualified facilitator can also help immensely.

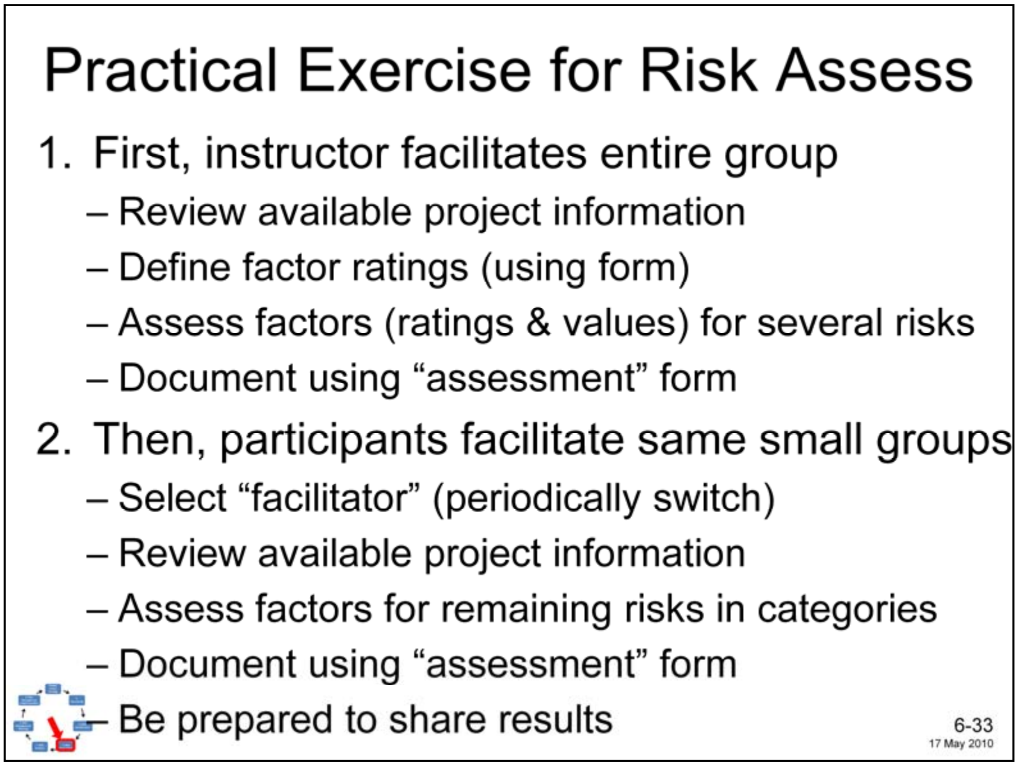


Risk Assessment

- Learning Objectives
- Available Methods
  - Process
  - Guidance
- Assessing Risk Factors

➢ **Practical Exercise**

- Summary



Practical Exercise for Risk Assess

1. First, instructor facilitates entire group
   - Review available project information
   - Define factor ratings (using form)
   - Assess factors (ratings & values) for several risks
   - Document using “assessment” form
2. Then, participants facilitate same small groups
   - Select “facilitator” (periodically switch)
   - Review available project information
   - Assess factors for remaining risks in categories
   - Document using “assessment” form
   - Be prepared to share results

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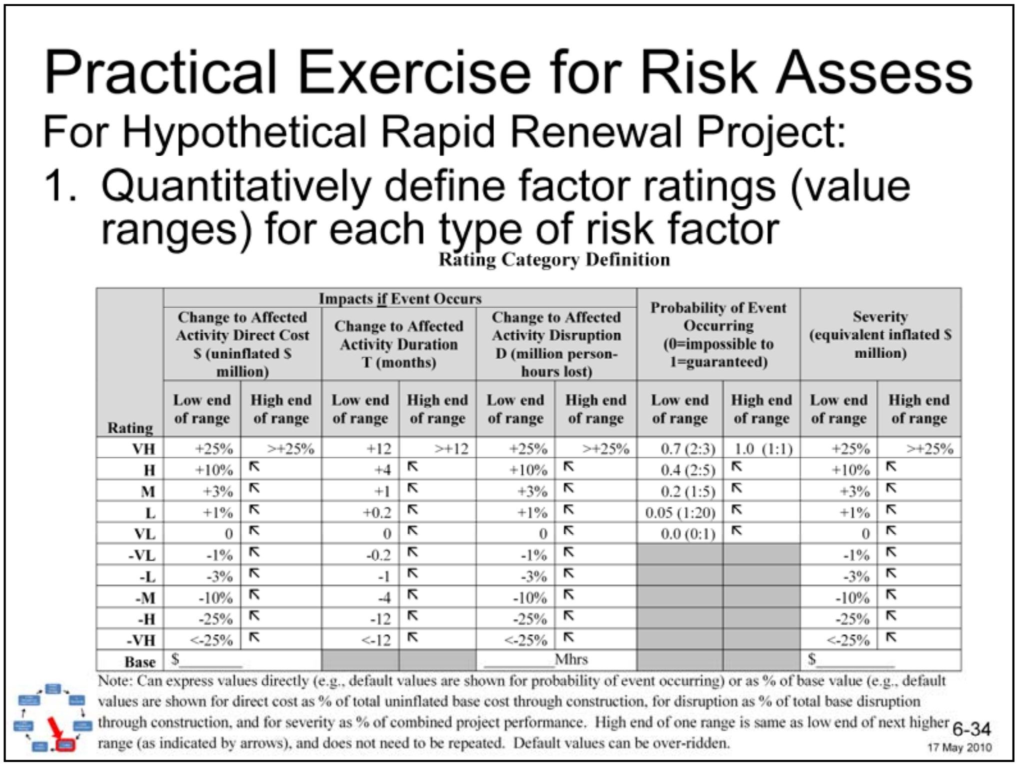
Regarding the hypothetical rapid renewal project presented in Appendix F of the *Guide*, which was described in Module 3, structured in Module 4 and for which risks were identified in Module 5, QDOT initially decided that assessing the risks primarily in terms of mean-value ratings (e.g., L, M, and H) would be sufficient for its intended use of the risk assessment results (i.e., prioritizing the risks for proactive individual risk reduction). Following the principles and process outlined in Chapter 6 of the *Guide*, the group first defined mean-value rating scales (see next slide) for:

- each of the three types (cost, schedule, and disruption) of impacts of occurrence (e.g., a Medium (M) cost impact was defined to correspond to a value between 3% and 10% of the base project cost, in uninflated dollars);
- the probability of occurrence (e.g., a Medium (M) probability corresponded to a probability of occurrence between 0.2 and 0.4), and
- the “severity” of combined impacts (considering the probability of occurrence and tradeoffs) (e.g., a Medium (M) severity was defined to correspond to a value between 3% and 10% of the base combined project performance, in equivalent inflated dollars)

The group then discussed each of the identified risks in the risk register and quantified each of them in terms of mean-value ratings for: a) the cost, schedule, and disruption impacts (and the affected activity) if the risk occurs; and b) the probability of occurrence.

QDOT then used these assessments to determine (using an appropriate risk model, e.g., the template that incorporates the algorithms presented in Chapter 6 of the *Guide*): a) the approximate mean-value impact of each risk to the project objectives of cost, schedule, and disruption; and b) by combining with QDOT’s established “value trade-offs” among the objectives, a mean-value “severity” for each risk, based on which the risks were ranked.

As will subsequently be discussed, for quantitative risk analysis (Module 7), the assessments and the analyses are conducted in more detail.



Practical Exercise for Risk Assess

For Hypothetical Rapid Renewal Project:

1. Quantitatively define factor ratings (value ranges) for each type of risk factor

Rating Category Definition

Rating	Impacts *if* Event Occurs						Probability of Event Occurring (0=impossible to 1=guaranteed)		Severity (equivalent inflated $ million)	
	Change to Affected Activity Direct Cost S (uninflated $ million)		Change to Affected Activity Duration T (months)		Change to Affected Activity Disruption D (million person-hours lost)					
	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range
VH	+25%	>+25%	+12	>+12	+25%	>+25%	0.7 (2:3)	1.0 (1:1)	+25%	>+25%
H	+10%	↖	+4	↖	+10%	↖	0.4 (2:5)	↖	+10%	↖
M	+3%	↖	+1	↖	+3%	↖	0.2 (1:5)	↖	+3%	↖
L	+1%	↖	+0.2	↖	+1%	↖	0.05 (1:20)	↖	+1%	↖
VL	0	↖	0	↖	0	↖	0.0 (0:1)	↖	0	↖
-VL	-1%	↖	-0.2	↖	-1%	↖			-1%	↖
-L	-3%	↖	-1	↖	-3%	↖			-3%	↖
-M	-10%	↖	-4	↖	-10%	↖			-10%	↖
-H	-25%	↖	-12	↖	-25%	↖			-25%	↖
-VH	<-25%	↖	<-12	↖	<-25%	↖			<-25%	↖
Base	$________				________Mhrs				$________	

Note: Can express values directly (e.g., default values are shown for probability of event occurring) or as % of base value (e.g., default values are shown for direct cost as % of total uninflated base cost through construction, for disruption as % of total base disruption through construction, and for severity as % of combined project performance. High end of one range is same as low end of next higher range (as indicated by arrows), and does not need to be repeated. Default values can be over-ridden.

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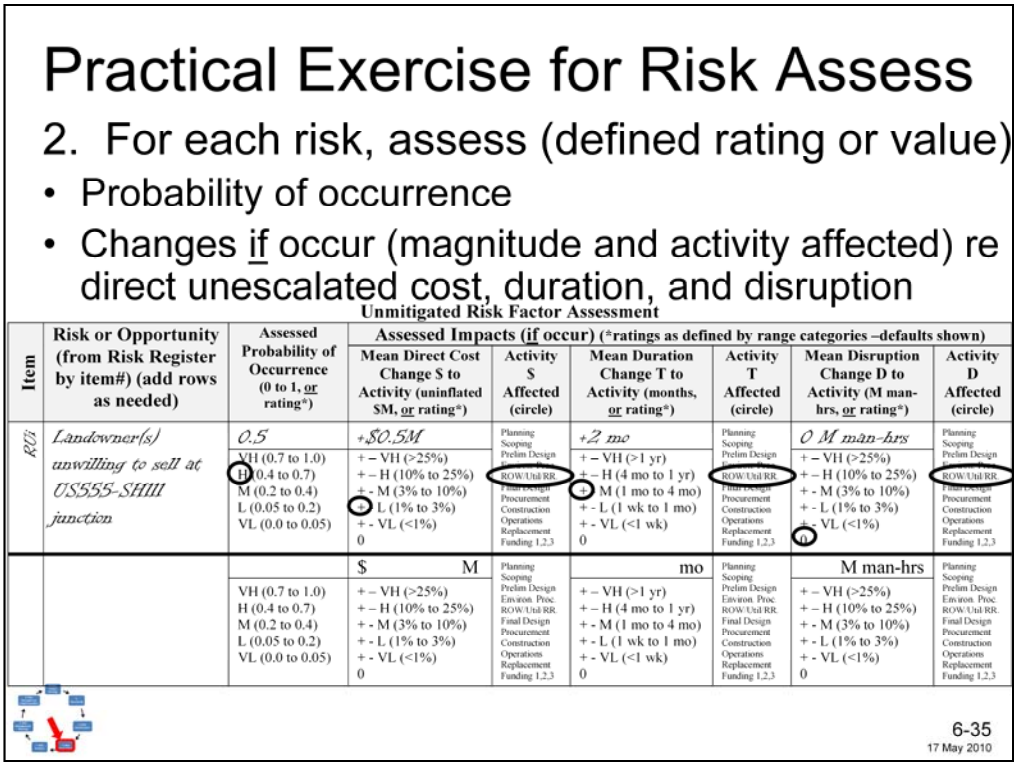
Regarding the hypothetical rapid renewal project presented in Appendix F of the *Guide*, QDOT first had to define the ratings (in terms of ranges). A copy of this form is at the end of this module.



Practical Exercise for Risk Assess

2. For each risk, assess (defined rating or value)

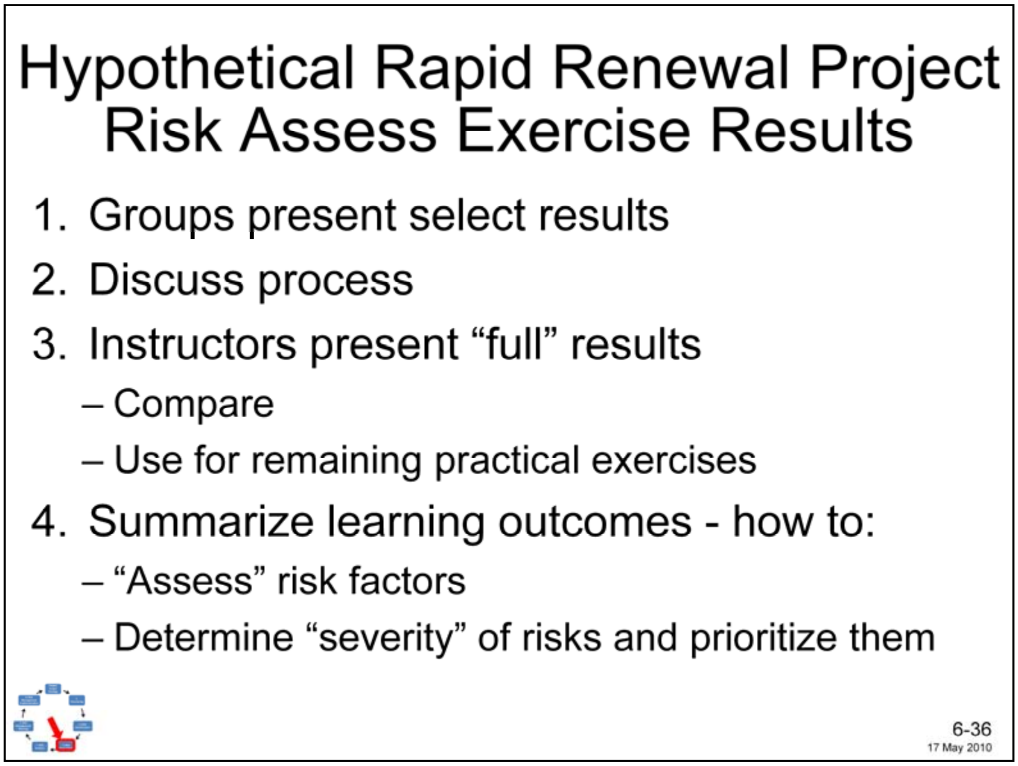
- Probability of occurrence
- Changes <u>if</u> occur (magnitude and activity affected) re direct unescalated cost, duration, and disruption

Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, <u>or</u> rating*)	Assessed Impacts (<u>if</u> occur) (*ratings as defined by range categories –defaults shown)					
			Mean Direct Cost Change $ to Activity (uninflated $M, <u>or</u> rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, <u>or</u> rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, <u>or</u> rating*)	Activity D Affected (circle)
RUi	Landowner(s) unwilling to sell at US555-SHIII junction	0.5 VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+$0.5M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo + – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3

Regarding the hypothetical rapid renewal project presented in Appendix F of the *Guide*, which was described in Module 3, structured in Module 4 and for which risks were identified in Module 5, QDOT assessed (generally in terms of mean ratings, using the previously defined risk category definitions) the various factors for each of the risks using the principles discussed in this module and the Unmitigated Risk Factor Assessment form to document those assessments. A blank copy of this form is at the end of this module.

This information will eventually be input into the MS Excel workbook template developed for this course, which will automatically determine the mean severity for each risk, as well as the mean change in performance for each risk and for groups of risks; however, the <u>collective</u> mean change in performance is only appropriate <u>if</u> the set of risks is comprehensive and non-overlapping. The risks are subsequently ranked based on their severity, but this ranking should be checked for reasonableness.



Hypothetical Rapid Renewal Project Risk Assess Exercise Results

1. Groups present select results
2. Discuss process
3. Instructors present “full” results
   - Compare
   - Use for remaining practical exercises
4. Summarize learning outcomes - how to:
   - “Assess” risk factors
   - Determine “severity” of risks and prioritize them

Instructors’ results will be handed out after participants’ results have been presented and discussed. These results, which will be used for remaining practical exercises, should be inserted in Appendix F of the *Guide* for future reference.

Risk Assessment

- Learning Objectives
- Available Methods
  - Process
  - Guidance
- Assessing Risk Factors
- Practical Exercise

➢ **Summary**

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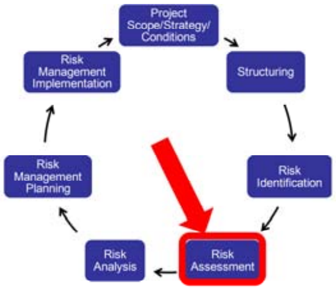
Summary – Risk Assessment



- ✓Risk assessment for:
  - Severity of project risks
  - Risk management planning
  - Quantitative risk analysis
- ✓Various methods available
  - Qualitative – inaccurate and limited usefulness
  - Quantitative – more accurate and more useful
    - Statistical basis – limited applicability
    - Subjective basis – facilitate to mitigate bias
  - Detail (factors + model)

➔ appropriate accuracy, defensibility, effort

Rating Category Definition

Rating	Impacts if Event Occurs						Probability of Event Occurring (0=impossible to 1=guaranteed)		Severity (equivalent inflated $ million)	
	Change to Affected Activity Direct Cost $ (uninflated $ million)		Change to Affected Activity Duration T (months)		Change to Affected Activity Disruption D (million person-hours lost)					
	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range	Low end of range	High end of range
VH	+25%	>+25%	+12	>+12	+25%	>+25%	0.7 (2:3)	1.0 (1:1)	+25%	>+25%
H	+10%	↖	+4	↖	+10%	↖	0.4 (2:5)	↖	+10%	↖
M	+3%	↖	+1	↖	+3%	↖	0.2 (1:5)	↖	+3%	↖
L	+1%	↖	+0.2	↖	+1%	↖	0.05 (1:20)	↖	+1%	↖
VL	0	↖	0	↖	0	↖	0.0 (0:1)	↖	0	↖
-VL	-1%	↖	-0.2	↖	-1%	↖			-1%	↖
-L	-3%	↖	-1	↖	-3%	↖			-3%	↖
-M	-10%	↖	-4	↖	-10%	↖			-10%	↖
-H	-25%	↖	-12	↖	-25%	↖			-25%	↖
-VH	<-25%	↖	<-12	↖	<-25%	↖			<-25%	↖
Base	$________				_________Mhrs				$__________	

Note: Can express values directly (e.g., default values are shown for probability of event occurring) or as % of base value (e.g., default values are shown for direct cost as % of total uninflated base cost through construction, for disruption as % of total base disruption through construction, and for severity as % of combined project performance. High end of one range is same as low end of next higher range (as indicated by arrows), and does not need to be repeated. Default values can be over-ridden.

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Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur) (*ratings as defined by range categories –defaults shown)						Calculated[1]	Rank
			Mean Direct Cost Change $ to Activity (uninflated $M, or rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, or rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, or rating*)	Activity D Affected (circle)	Severity (equivalent inflated $M, or rating*)	
EXAMPLE (showing both mean values and mean-value ratings) Note: [1]Considers extended OHs and inflation, and values of schedule and disruption										
RU1	Landowner(s) unwilling to sell at US555-SH111 junction	0.5 VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+$0.5M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo + – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+$0.3M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%)	1
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	

Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur) (*ratings as defined by range categories –defaults shown)						Calculated[1]	Rank
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RUi	Landowner(s) unwilling to sell at US555-SH111 junction	0.5 VH (0.7 to 1.0) [✓ H] (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	+$0.5M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo + – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]	Planning Scoping Prelim Design Environ. Proc. [✓ ROW/Util/RR.] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+$0.3M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%)	1
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
		VH (0.7 to 1.0) H (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) VL (0.0 to 0.05)	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	mo + – VH (>1 yr) + – H (4 mo to 1 yr) + - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	M man-hrs + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	$ M + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%)	
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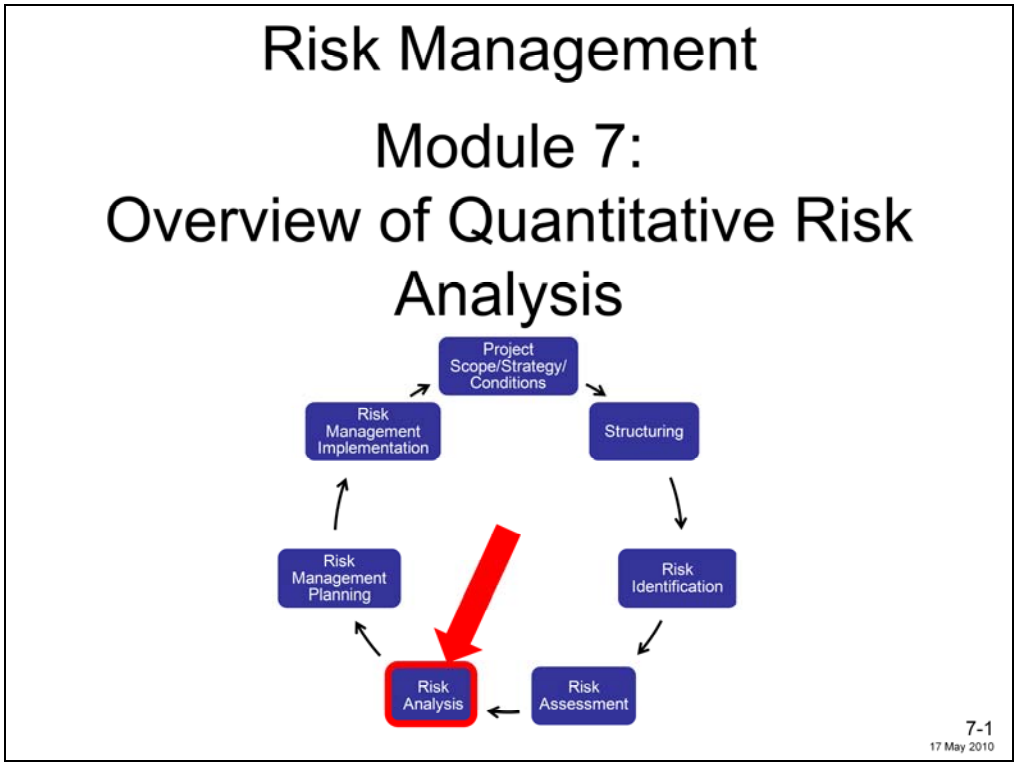


Risk Management

Module 7: Overview of Quantitative Risk Analysis

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

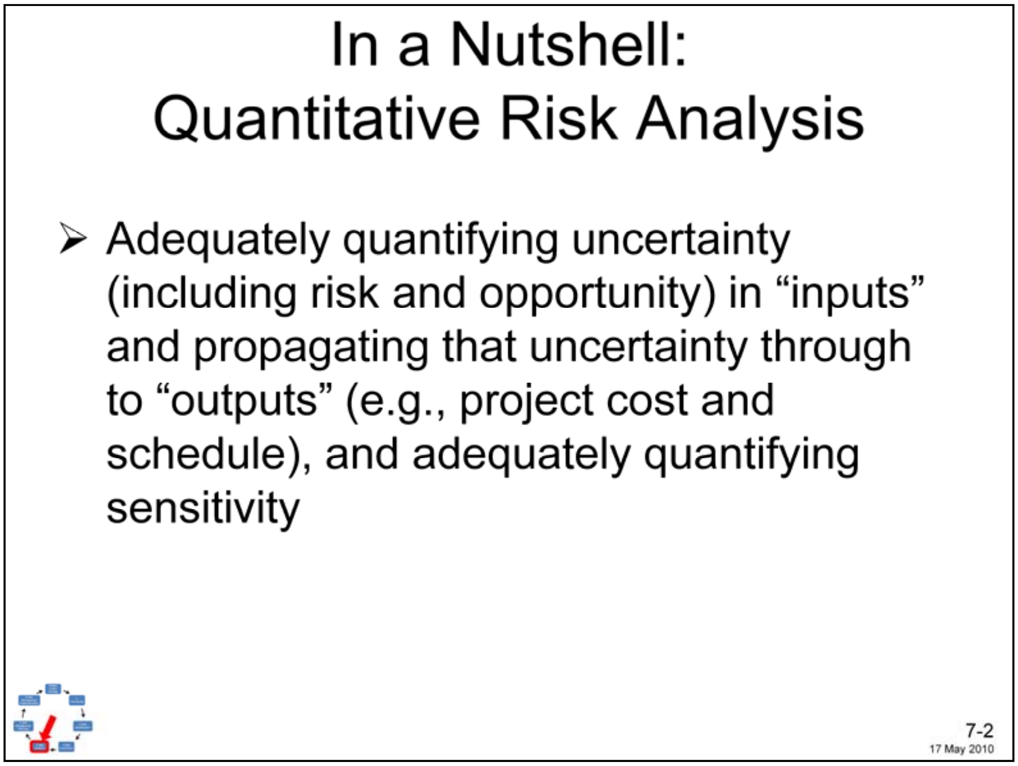
Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

Overview only. No training provided because special skills are needed by participants.



In a Nutshell: Quantitative Risk Analysis

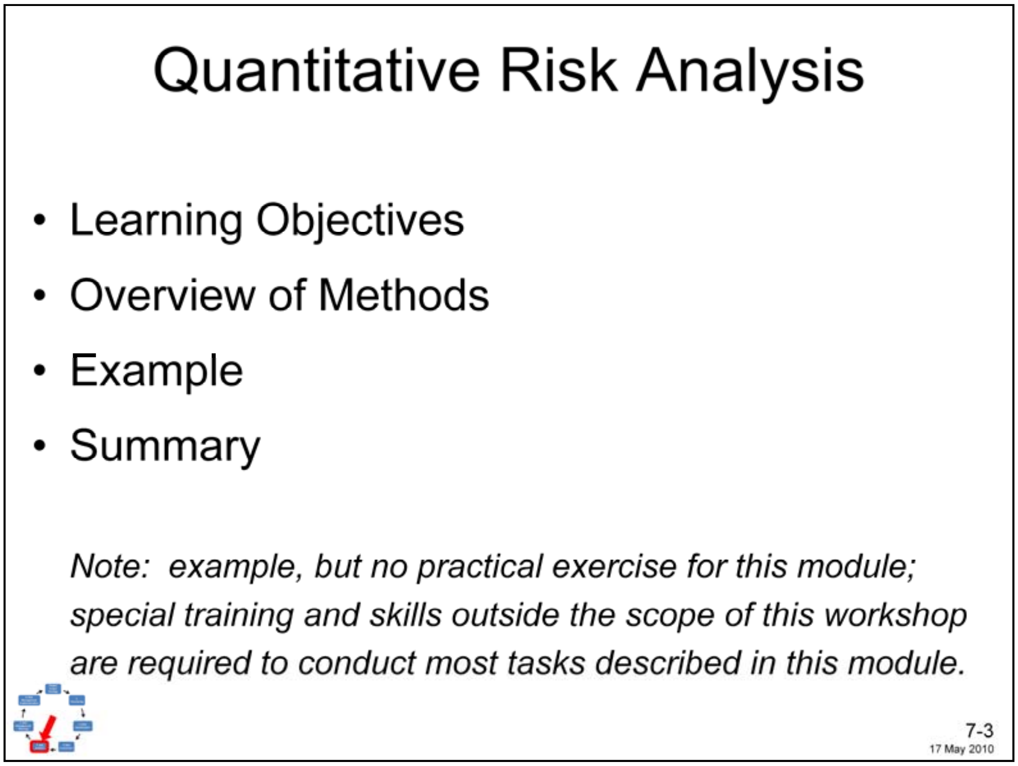
- Adequately quantifying uncertainty (including risk and opportunity) in “inputs” and propagating that uncertainty through to “outputs” (e.g., project cost and schedule), and adequately quantifying sensitivity

Project performance measures could include:

- “Costs”, such as:
    - Capital cost
    - Completion schedule
    - Disruptions during construction
    - Longevity (post-construction)
    - Safety
    - Environmental impacts
- “Benefits”, such as:
    - Revenue
    - Improved level of service

In this module, we’re focusing on project monetary cost and schedule, although this can be extended to disruption and longevity (as discussed elsewhere).

Quantifying uncertainty in project performance aids project decision making.

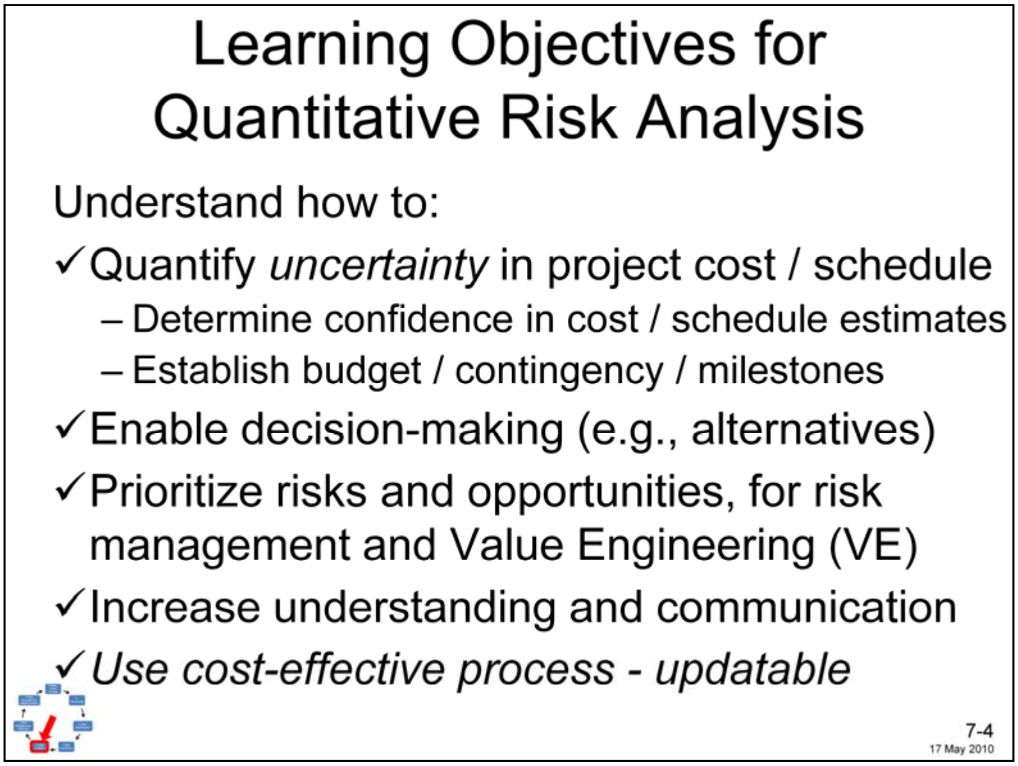


Quantitative Risk Analysis

- Learning Objectives
- Overview of Methods
- Example
- Summary

Note: example, but no practical exercise for this module; special training and skills outside the scope of this workshop are required to conduct most tasks described in this module.

Quantitative risk analysis requires special skills, which might not be cost-effective for a DOT to develop since such analyses can usually be cost-effectively outsourced. However, the DOT needs to understand what's involved so that they can appropriately evaluate the results.



Learning Objectives for Quantitative Risk Analysis

Understand how to:

- ✓ Quantify *uncertainty* in project cost / schedule
  - – Determine confidence in cost / schedule estimates
  - – Establish budget / contingency / milestones
- ✓ Enable decision-making (e.g., alternatives)
- ✓ Prioritize risks and opportunities, for risk management and Value Engineering (VE)
- ✓ Increase understanding and communication
- ✓ *Use cost-effective process - updatable*

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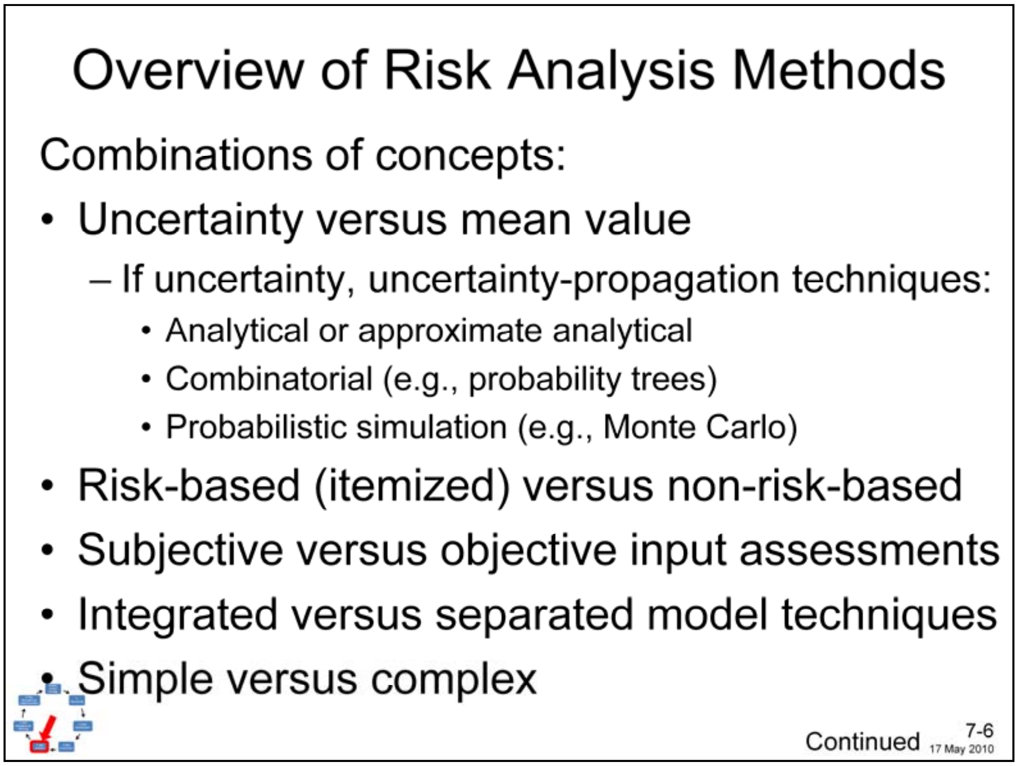
- Quantify uncertainty in project cost, schedule, and perhaps other measures (e.g., within an integrated cost/schedule framework)
  - Increase confidence in the cost and schedule estimates
  - Establish reasonable budget / contingency and milestones
- Enable defensible project and program decision-making
- Identify and prioritize critical risks and key opportunities (builds on results from Modules 4 and 5), to enable Risk Management and Value Engineering
- Increase project team, as well as external, understanding and communication
- Cost-effective process – otherwise could be expensive and time consuming
- Should be relatively easy to update if inputs change

Quantitative Risk Analysis

- Objectives
- ➢ **Overview of Methods**
- Example
- Summary



Overview of Risk Analysis Methods

Combinations of concepts:

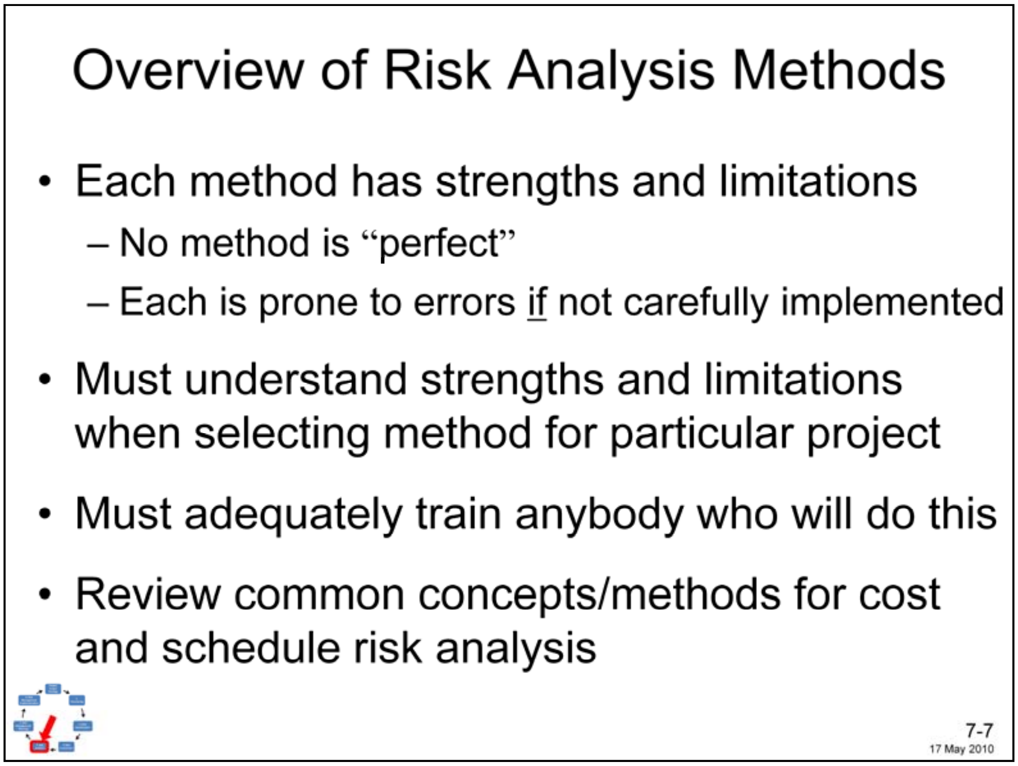
- Uncertainty versus mean value
  - If uncertainty, uncertainty-propagation techniques:
    - Analytical or approximate analytical
    - Combinatorial (e.g., probability trees)
    - Probabilistic simulation (e.g., Monte Carlo)
- Risk-based (itemized) versus non-risk-based
- Subjective versus objective input assessments
- Integrated versus separated model techniques
- Simple versus complex

Continued 7-6 17 May 2010

“Risk analysis” weaves together a number of concepts in various combinations:

- Probabilistic versus non-probabilistic (traditional deterministic)
- Quantify uncertainty versus not quantify uncertainty (i.e., use only mean values)
  - If quantify uncertainty, quantify uncertainty in, and correlations among, input parameters
  - If quantify uncertainty, numerous uncertainty-propagation techniques, including:
    - Analytical or approximate analytical
    - Combinatorial (e.g., probability trees)
    - Probabilistic simulation (e.g., Monte Carlo)
- Risk-based versus non-risk-based
  - Bottom-up (identify and assess individual risks and other uncertainties), such as in a “base + risk” approach – need comprehensive and non-overlapping set of risks and other uncertainties, which is difficult to achieve without qualified facilitation; otherwise, underestimate uncertainty in outputs
  - Top-down (don’t identify individual risks; lump all uncertainty at a high level) – difficult to do accurately due to complicated nature of some projects
- Subjective versus objective assessment of input parameters:
  - Objective assessment from historical data (used when adequate data are available)
  - Subjective assessment from expert judgment (can be combined with objective) – see discussion of biases in Module 6
- Integrated versus separated modeling techniques
  - For project cost and schedule modeling, some possibilities include:
    - Cost only
    - Schedule only
    - Ad hoc combination of separate cost and schedule models
    - Integrated cost and schedule (inflated cost = explicit function of cost, time)
- Simple versus complex – there is such a thing as too much detail, as well as not enough

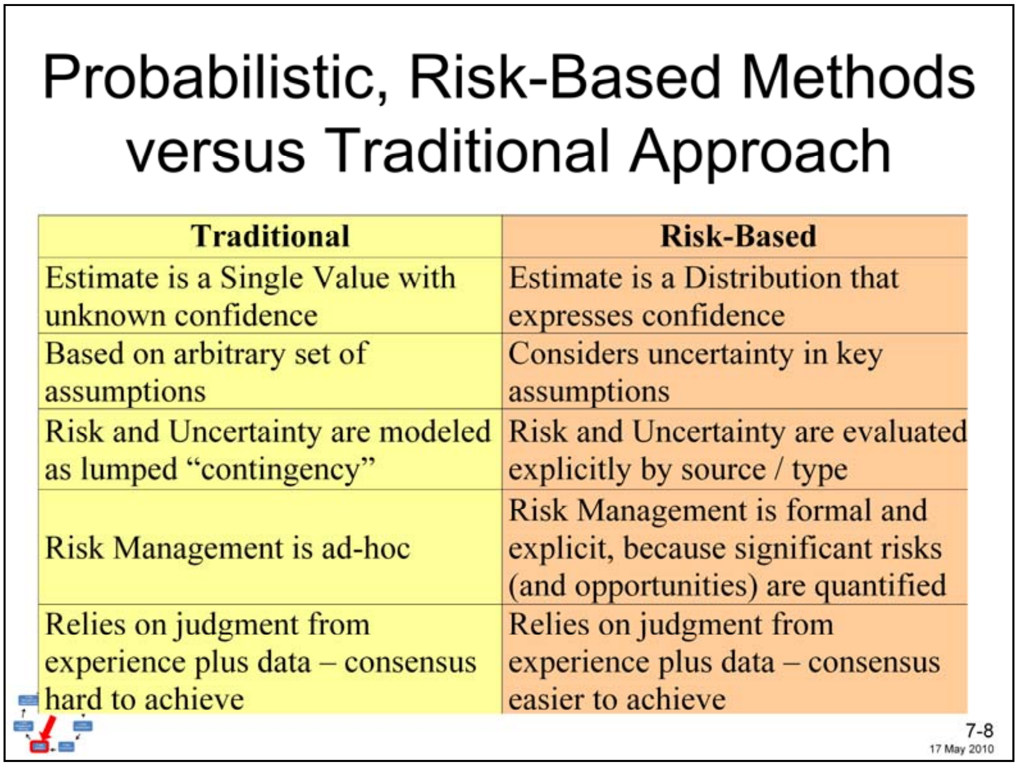
Note: Course template determines mean values of schedule and cost (unescalated and escalated), using mean values of base durations, unescalated costs and escalation rates for each activity and mean values of risk impacts (with probability of risk occurrence) in an integrated schedule and cost model.



Overview of Risk Analysis Methods

- Each method has strengths and limitations
  - No method is "perfect"
  - Each is prone to errors if not carefully implemented
- Must understand strengths and limitations when selecting method for particular project
- Must adequately train anybody who will do this
- Review common concepts/methods for cost and schedule risk analysis

Many risk analysis methods exist (e.g., probabilistic, risk-based, integrated cost and schedule). Must be carefully done to avoid misleading results.



Probabilistic, Risk-Based Methods versus Traditional Approach

Traditional	Risk-Based
Estimate is a Single Value with unknown confidence	Estimate is a Distribution that expresses confidence
Based on arbitrary set of assumptions	Considers uncertainty in key assumptions
Risk and Uncertainty are modeled as lumped "contingency"	Risk and Uncertainty are evaluated explicitly by source / type
Risk Management is ad-hoc	Risk Management is formal and explicit, because significant risks (and opportunities) are quantified
Relies on judgment from experience plus data – consensus hard to achieve	Relies on judgment from experience plus data – consensus easier to achieve

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<u>Traditional approach</u> is non-probabilistic, non-risk-based (also see Module 4).

$$\text{Cost: } C_T = \sum_i C_i \qquad \text{Schedule: } D_T = \sum_i D_i \text{, where } D_i \text{ are on critical path}$$

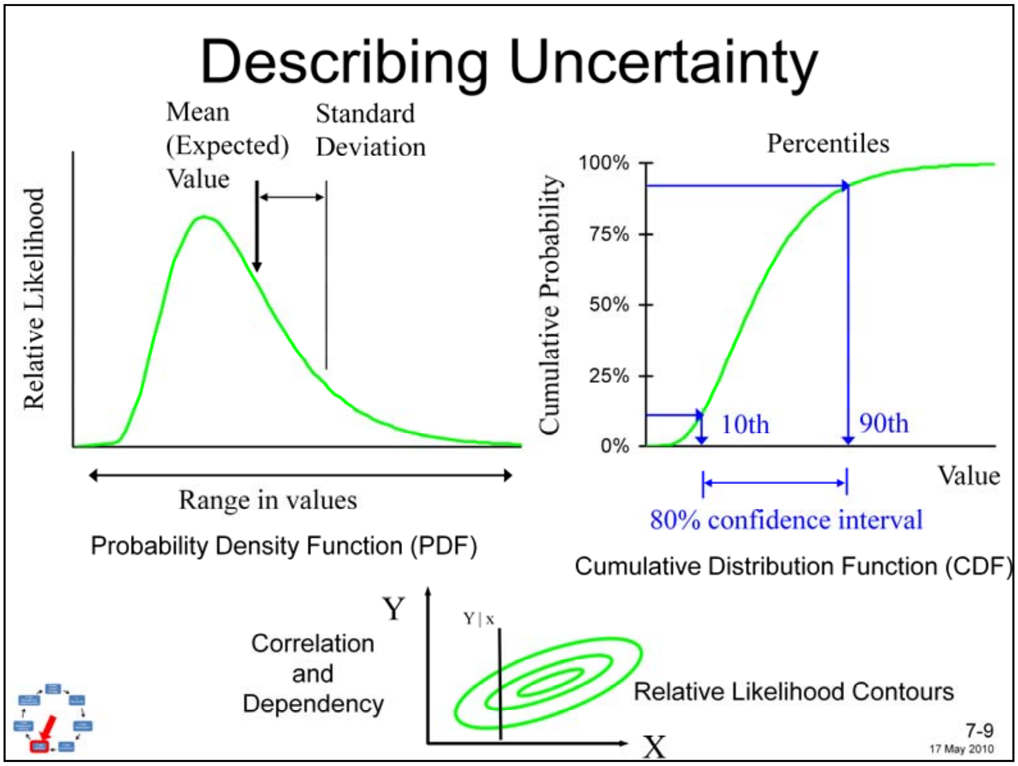
- Individual costs (C_i) and durations (D_i) are single-valued estimates (conservative estimate + lumped contingency)
- Contingency is not probabilistic or risk-based; intended to implicitly account for risks
- Result is single-valued cost and schedule estimates with unknown confidence

Example:

Project Cost Element	Estimated Cost	Contingency Factor	Cost Contingency
C_1 = Design (including Environmental Documentation)	$500,000	10%	$50,000
C_2 = Right-of-Way Acquisition	$1,000,000	40%	$400,000
C_3 = Construction (agency and contractor)	$10,000,000	20%	$2,000,000
Subtotal	$11,500,000		$2,450,000
C_T = Grand Total	$13,950,000		

Note: Most cost estimates are done in current (uninflated) dollars, and then sometimes inflated later.

Consensus is often difficult to achieve on deterministic inputs, because of uncertainty compounded by unspecified degrees of conservatism.



Describing Uncertainty

Probability Density Function (PDF)

Cumulative Distribution Function (CDF)

Correlation and Dependency

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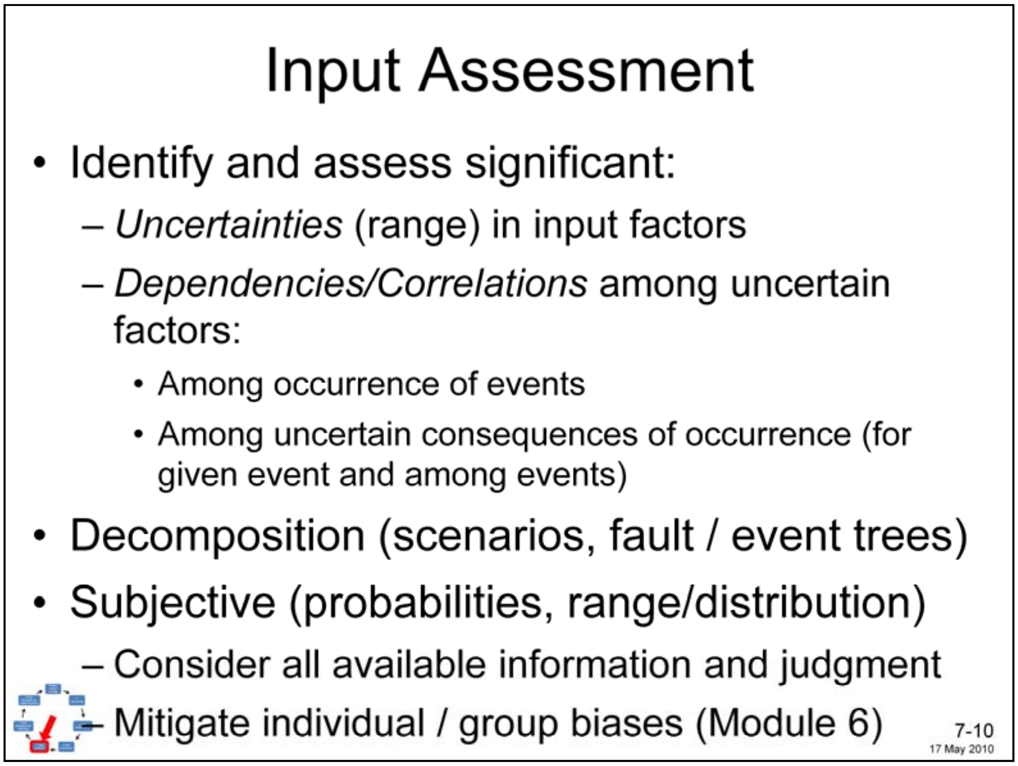
- Uncertainty in parameter value
  - Relative likelihood of any particular value being true (pdf – probability density function)
    - Mean value or expected value (probability weighted average value)
    - Standard deviation or variance
  - Probability (p_i) of each member of a comprehensive and mutually exclusive set, e.g., scenarios (pmf – probability mass function) - $\sum_{\text{all } i} p_i = 1.0$
  - Probability (P) of event (yes or no) – P = 1.0 – P'
  - Probability of not exceeding a particular value (cdf – cumulative distribution function)
    - Percentiles
    - Confidence intervals
- Uncertainty in combination of parameter values
  - Independence
  - Dependence
    - Correlation coefficient (absolute or rank)
    - Conditional distribution



Input Assessment

- Identify and assess significant:
  - *Uncertainties* (range) in input factors
  - *Dependencies/Correlations* among uncertain factors:
    - Among occurrence of events
    - Among uncertain consequences of occurrence (for given event and among events)
- Decomposition (scenarios, fault / event trees)
- Subjective (probabilities, range/distribution)
  - Consider all available information and judgment
  - Mitigate individual / group biases (Module 6)

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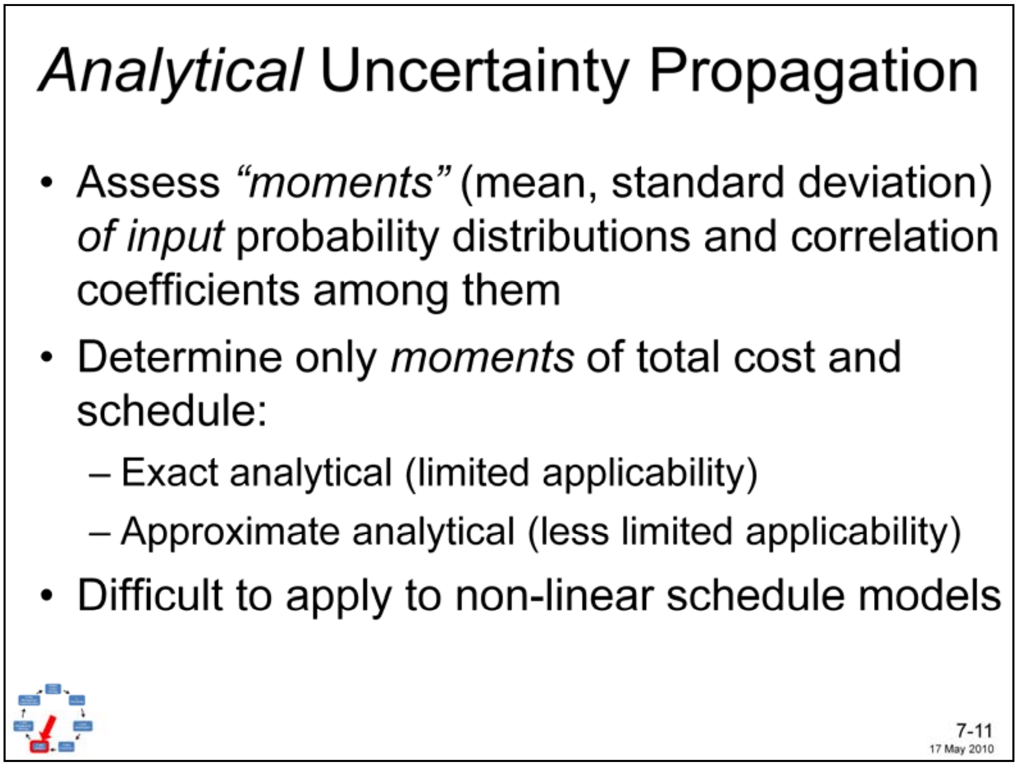
- Several methods are described briefly in Module 6
- Must identify the uncertainties (range) of possible outcomes, which means need to identify and assess significant uncertainties (range) in input factors and significant dependencies/correlations among uncertain factors:
  - Among occurrence of events
  - Among uncertain consequences of occurrence (for a given event and among events)
- There are a number of ways to model input uncertainties – more than one way might work



Analytical Uncertainty Propagation

- Assess *"moments"* (mean, standard deviation) *of input* probability distributions and correlation coefficients among them
- Determine only *moments* of total cost and schedule:
  - – Exact analytical (limited applicability)
  - – Approximate analytical (less limited applicability)
- Difficult to apply to non-linear schedule models

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$$\text{Cost}: \; C_T = \sum_i C_i \qquad \text{Schedule}: \; D_T = \sum_i D_i, \text{ where } D_i \text{ are on critical path}$$

• Component costs C_i are generally characterized probabilistically, *quantifying uncertainty in inputs via "moments" of probability distributions* (mean, standard deviation) and correlation coefficients among C_i

• May or may not specify risk separately

• *Produces moments (mean, standard deviation)* of total cost C_T and schedule D_T (note: does *not* yield entire probability distributions!)

• Several popular approaches:

- Exact analytical (see next slide; useful for sums of variables)
- Approximate analytical, for example:
  - First-Order, Second-Moment (e.g., Ang and Tang, 1975)
  - Point Estimate Method (e.g., Harr, 1986)

• Difficult to apply to schedule models if have multiple potential critical paths (the approximate methods don't handle discreteness/discontinuity well)

Moments

Exact analytical solution for the moments (mean and variance) of the sum (linear combination) of uncertain variables:

Function (e.g., cost): $C_T = \sum_i C_i$ Mean Value: $\mu_{C_T} = \sum_i \mu_{C_i}$

Variance: $\sigma^2_{C_T} = \sum_i \sum_j \rho_{C_iC_j}\sigma_{C_i}\sigma_{C_j}$ Standard deviation: $\sigma_{C_T} = \sqrt{\sigma^2_{C_T}}$

$$\mu = \text{mean value;}\ \sigma = \text{standard deviation;}$$

$$\rho_{ij} = \text{correlation coefficient between variables i and j}$$

$$\rho_{ij} = 0 \text{ if i and j are independent;} = 1 \text{ if } i = j; \text{ otherwise between -1 and 1}$$

Distribution Form

Sum of normal distributions is a normal distribution

Sum of many independent distributions (regardless of form) approaches a normal distribution

Note: Product of two log normal distributions is a log normal distribution, and product of many independent distributions (regardless of form) approaches a log normal distribution

Example (same as previous):

Analytical solution for total project cost (i.e., sum of component costs):

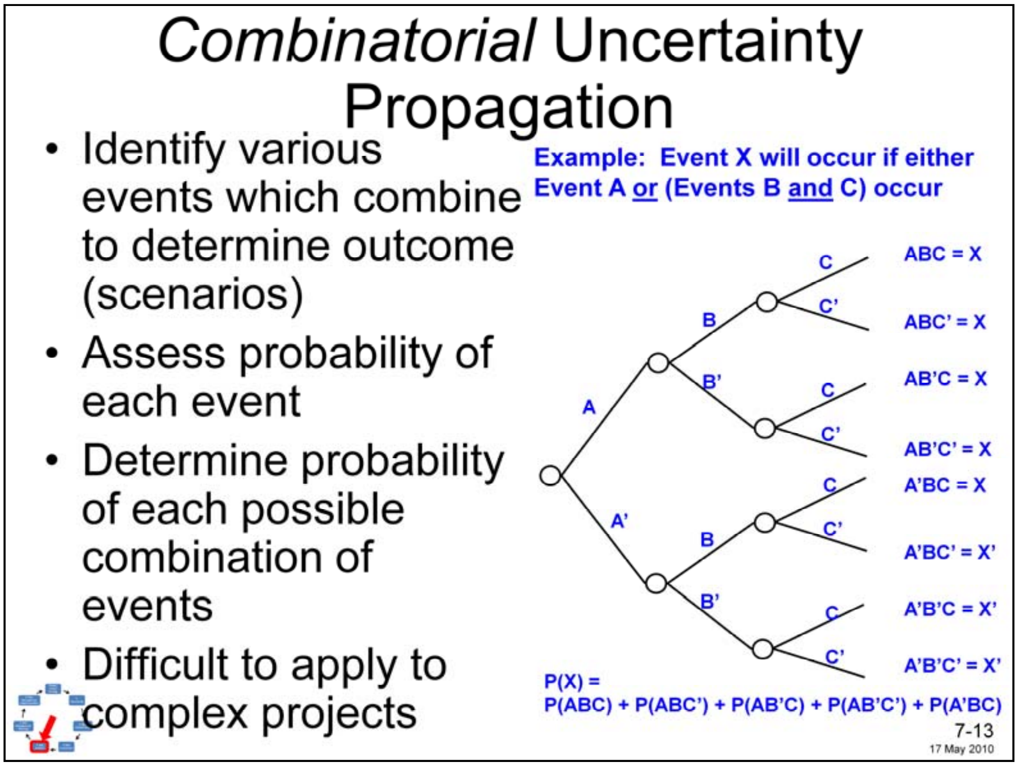
Project Cost Element (C_i)	**Mean Cost of C_i, μ_i**	**Standard Deviation of C_i, σ_i**	**Correlation Coefficients, ρ_{ij}**
C_1 = Design	\$500,000	\$50,000	ρ_{13}=ρ_{31}=0.5
C_2 = Right of Way Acquisition	\$1,000,000	\$200,000	Independent (ρ_{2j} = 0)
C_3 = Construction	\$10,000,000	\$1,000,000	ρ_{13}=ρ_{31}=0.5
C_T = Total Cost	\$11,500,000	\$1,045,225	

Moments for total cost CT:

$$\mu_{C_T} = 500{,}000 + 1{,}000{,}000 + 10{,}000{,}000 = \$11{,}500{,}000$$

$$\sigma_{C_T} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + 2\rho_{12}\sigma_1\sigma_2 + 2\rho_{13}\sigma_1\sigma_3 + 2\rho_{23}\sigma_2\sigma_3} = \$1{,}045{,}225$$

Can then assume a form for the probability distribution of C_T (e.g., Normal or Gaussian)



Combinatorial Uncertainty Propagation

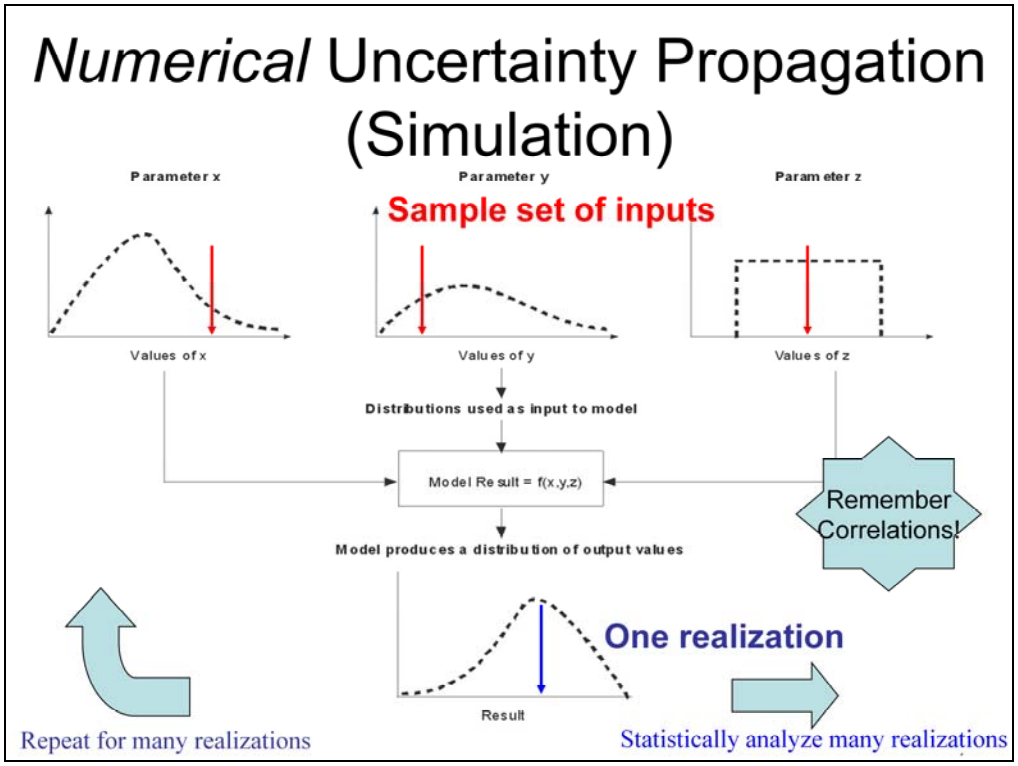
- Identify various events which combine to determine outcome (scenarios)
- Assess probability of each event
- Determine probability of each possible combination of events
- Difficult to apply to complex projects

Example: Event X will occur if either Event A <u>or</u> (Events B <u>and</u> C) occur

P(X) =
P(ABC) + P(ABC') + P(AB'C) + P(AB'C') + P(A'BC)

Probability trees are useful tools for identifying <u>combinations</u> of events and outcomes, and thus for developing discretized probability distributions for the potential outcome (e.g., project performance measure):

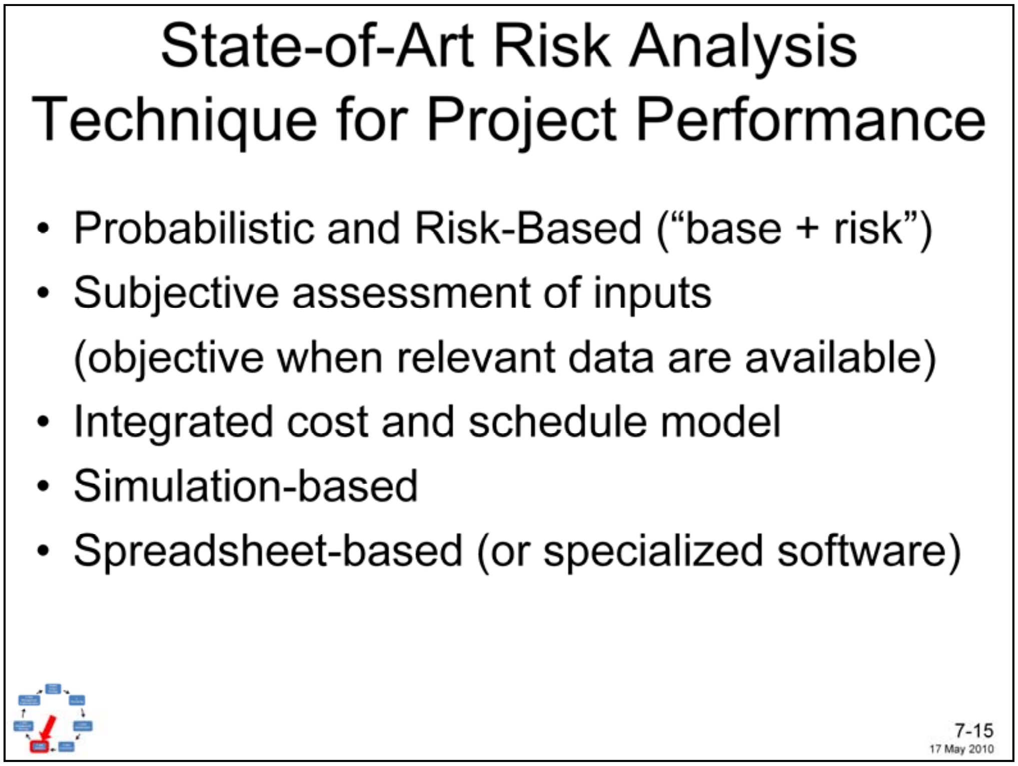
- Essentially the same as scenario analysis, and similar in construct to an event tree (possible <u>sequences</u> of events).
- Produces a comprehensive and non-overlapping set of possible outcomes, and by assessing each branch probability can determine (by multiplication) each end point probability.
- Useful for very small probabilities, which would be difficult to model with Monte Carlo simulation.



Numerical Uncertainty Propagation (Simulation)

Cost : $C_T = \sum_i C_i$ Schedule : $D_T = \sum_i D_i$, where D_i are on critical path

- Component costs C_i are generally characterized probabilistically, quantifying uncertainty in inputs via probability distributions and correlation coefficients among C_i
- Might or might not specify risk separately
- Produces probability distributions of total cost C_T and schedule D_T, and sensitivity of results to uncertain inputs
- Several popular approaches:
  - Monte Carlo simulation
  - Monte Carlo with efficiency enhancement, such as Latin Hypercube or Importance Sampling
- Very convenient for probabilistic analysis of complex models (including non-linear and discrete behavior); but has other drawbacks
- ***However*, need to be careful to only model/simulate realistic situations!**
- MS Excel (as well as MS Project and Primavera) have commercially available (3rd party) add-in packages to do Monte Carlo simulation.



State-of-Art Risk Analysis Technique for Project Performance

- Probabilistic and Risk-Based (“base + risk”)
- Subjective assessment of inputs (objective when relevant data are available)
- Integrated cost and schedule model
- Simulation-based
- Spreadsheet-based (or specialized software)

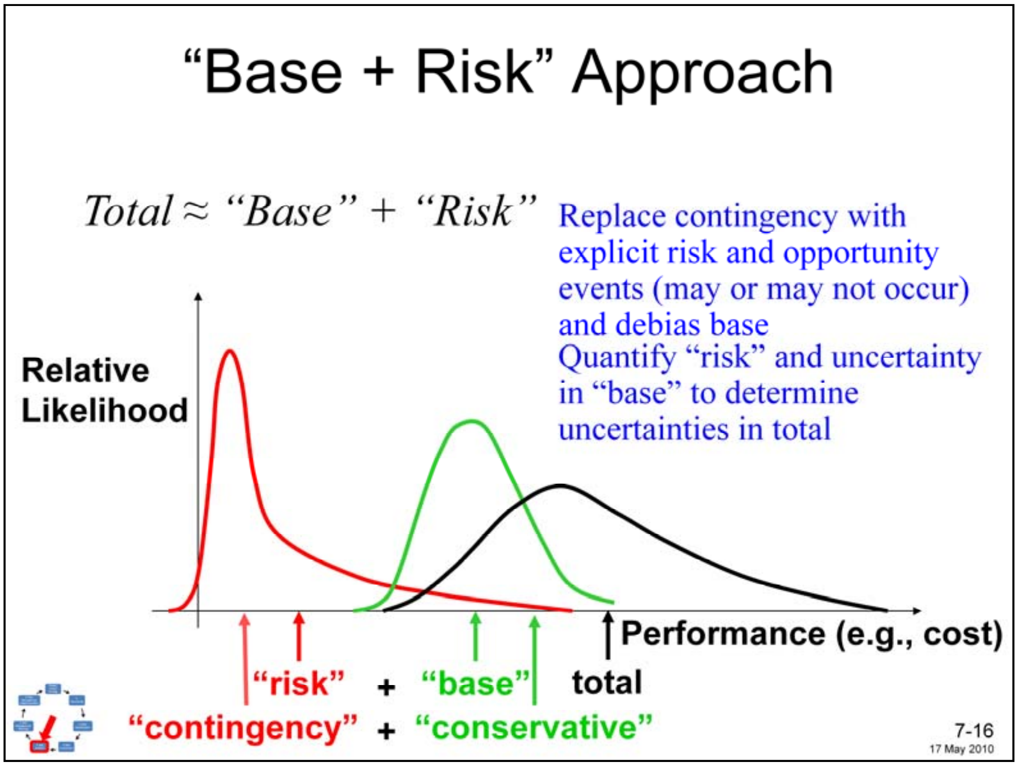
State-of-the-art is:

- Probabilistic
- Risk-Based - a “base + risk” approach
- Can include other “costs” and “benefits”
- Subjective assessment of inputs, supplemented by objective when relevant data are available
- Integrated cost and schedule model (explicitly captures relationship between cost and schedule)
- Simulation-based (assuming valid logic, can handle complex functional relationships as needed)
- Can be done in spreadsheets (e.g., MS Excel with @Risk) or with specialized software

Note: Course <u>template</u> is:

- Simplified
- Mean value
- Risk-based
- Integrated cost and schedule model
- <u>Not</u> simulation based
- Done in spreadsheet

Variance in outputs could be determined in a similar way (based on variances of, and correlations among, inputs) and an assumption could be made regarding the form of the distribution of the outputs.



“Base + Risk” Approach

$Total \approx \text{“Base”} + \text{“Risk”}$

Replace contingency with explicit risk and opportunity events (may or may not occur) and debias base

Quantify “risk” and uncertainty in “base” to determine uncertainties in total

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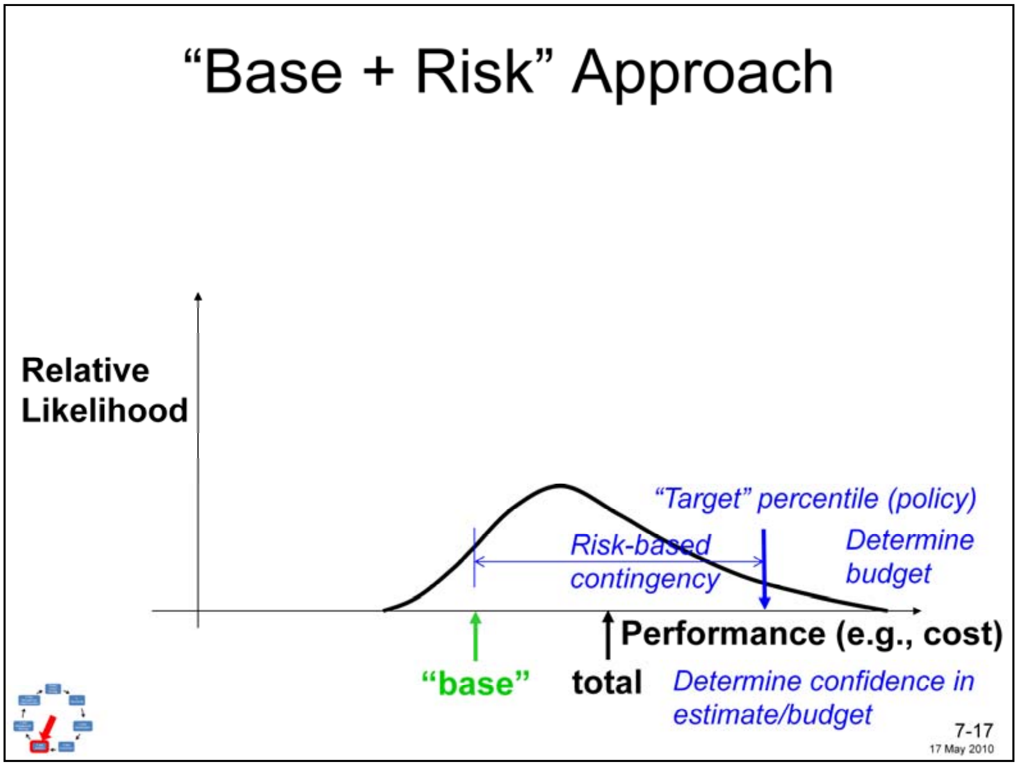
Uncertainty in performance will be function of uncertainties in base and uncertainties due to risks.

If quantity performance uncertainty, then can determine: a) confidence in the estimate or in the budget, i.e., the probability of meeting (or exceeding) that value; or b) appropriate budget (and thus contingency) to meet a target percentile or level of confidence.

Base uncertainties will vary with project development, generally decreasing as decisions are made and design evolves (although the mean value will also vary). Risks will also vary as they are resolved (i.e., they eventually either happen or do not happen). Hence, performance uncertainty (and contingency to cover that uncertainty) will generally decrease as the project develops.



“Base + Risk” Approach

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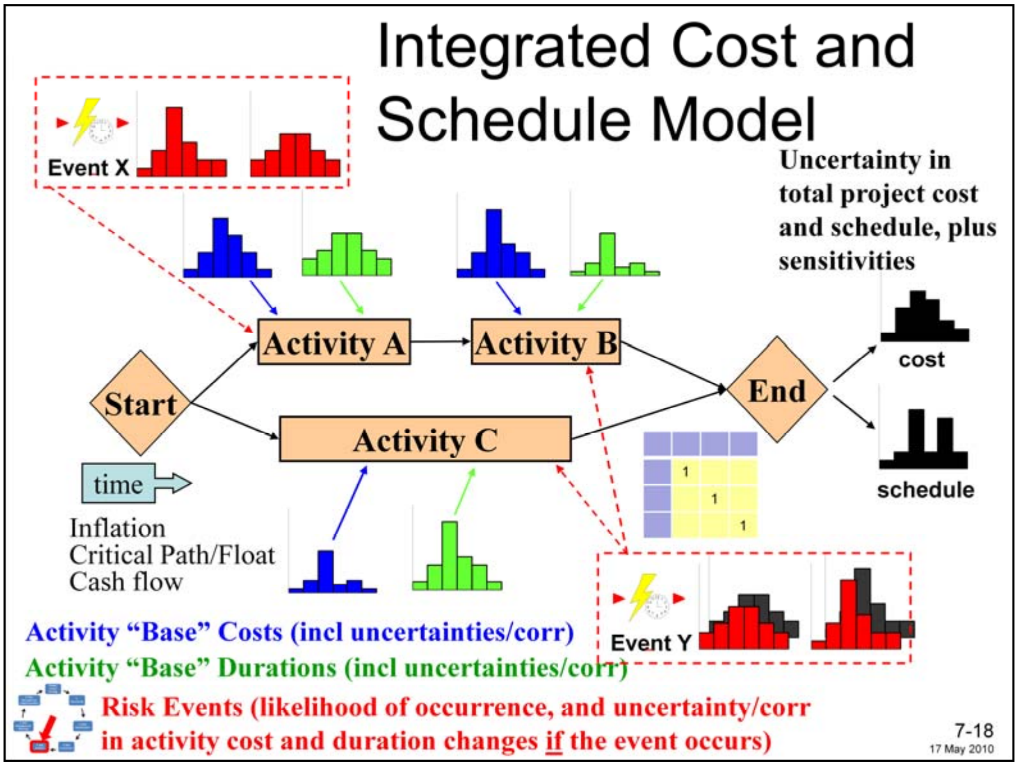


Integrated Cost and Schedule Model

Uncertainty in total project cost and schedule, plus sensitivities

Activity “Base” Costs (incl uncertainties/corr)

Activity “Base” Durations (incl uncertainties/corr)

Risk Events (likelihood of occurrence, and uncertainty/corr in activity cost and duration changes if the event occurs)

- Flowchart is typically more complicated (more activities), but still easy to model critical path. Also, there are typically many more risks.
- Need to assess significant correlations/dependencies
- Can simplify many of the less significant distributions to expected values, thereby reducing the number of correlations to be assessed.
- Can also model “decision nodes”, e.g., “triggered” risks (as in recovery plans). For example, delays due to cash flow constraints, or premiums to accelerate work due to earlier delays.
- Cost estimate (which is typically not in same terms as flowchart) will have to be “allocated” to the activities (e.g., 50% of a cost item goes to one activity and the other 50% goes to another activity).

Note: Course template simply uses mean values for all activity base durations, base unescalated cost and escalation rates, and mean values for risk impacts.

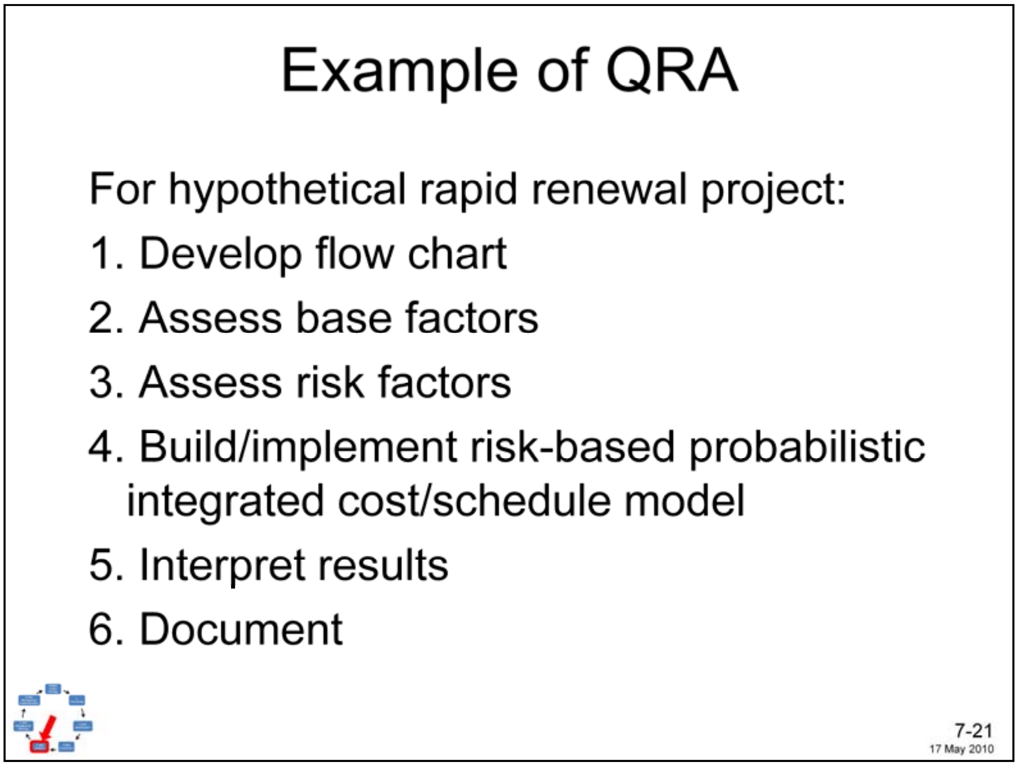
Could add disruption in a similar way as for cost, and combine various performance measures (e.g., capital cost and disruption using tradeoffs, e.g., to determine “user costs”) into “longevity” and ultimately combined performance (to determine risk “severity”).

Risk Analysis Process

1. Identify scope of risk analysis
2. Select method / approach
3. Define performance model (inputs, outputs)
4. Define project “base” (exclusive of risks)
5. Identify risks (relative to base)
6. Quantify “inputs” (base / risk uncertainties)
7. Implement model to determine:
    1. uncertainty in outputs
    2. sensitivity of outputs to inputs
8. Document/check and update (as needed)

Quantitative Risk Analysis

- Learning Objectives
- Overview of Methods
- **Example**
- Summary



Example of QRA

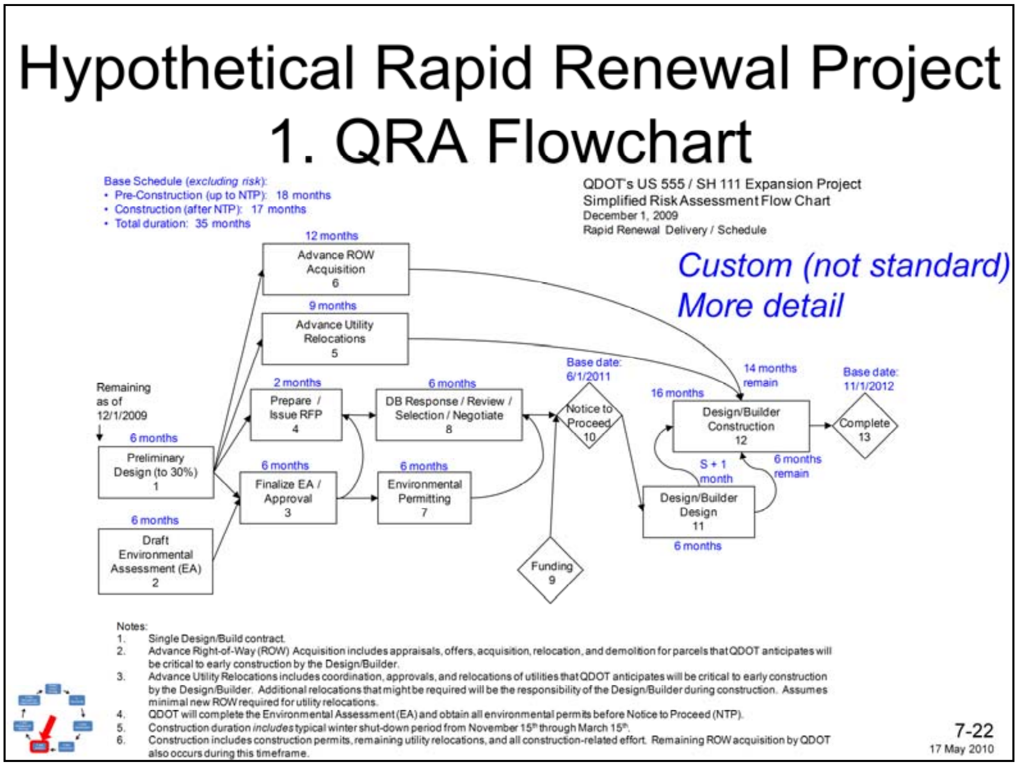
For hypothetical rapid renewal project:

1. Develop flow chart
2. Assess base factors
3. Assess risk factors
4. Build/implement risk-based probabilistic integrated cost/schedule model
5. Interpret results
6. Document

Several weeks after the risk identification and rating effort described previously, QDOT decided to conduct full, integrated, probabilistic modelling of the cost and schedule to help them establish reasonable project budgets (including contingency) and milestones, as well as to better prioritize the risks and other uncertainties. Following the principles and process outlined in Chapter 7 of the *Guide*, QDOT's risk consultant worked with the original group to:

- expand upon the simplified project flow chart to facilitate probabilistic cost and schedule modelling
- expand the group’s earlier mean-value ratings into full probabilistic assessments for cost and schedule impacts through construction, identifying the activities in the revised flowchart affected by each risk
- assess uncertainties in (and correlations among) the base cost and base schedule, and their relationship to the revised flowchart activities.

An integrated schedule and cost risk model was then developed (using a previously developed template) and used (via Monte Carlo simulation) to combine the base cost, base schedule, base uncertainties, and the complete probabilistic risk register to determine the uncertainty in project schedule (e.g., in terms of date of substantial completion of construction) and in cost (e.g., in terms of total project cost through construction, both uninflated and inflated), as well as the approximate contribution of each factor to specific target percentiles of inflated project cost and completion date.



Hypothetical Rapid Renewal Project
1. QRA Flowchart

Base Schedule (*excluding risk*):
- Pre-Construction (up to NTP): 18 months
- Construction (after NTP): 17 months
- Total duration: 35 months

QDOT's US 555 / SH 111 Expansion Project
Simplified Risk Assessment Flow Chart
December 1, 2009
Rapid Renewal Delivery / Schedule

Custom (not standard)
More detail

Notes:
1. Single Design/Build contract.
2. Advance Right-of-Way (ROW) Acquisition includes appraisals, offers, acquisition, relocation, and demolition for parcels that QDOT anticipates will be critical to early construction by the Design/Builder.
3. Advance Utility Relocations includes coordination, approvals, and relocations of utilities that QDOT anticipates will be critical to early construction by the Design/Builder. Additional relocations that might be required will be the responsibility of the Design/Builder during construction. Assumes minimal new ROW required for utility relocations.
4. QDOT will complete the Environmental Assessment (EA) and obtain all environmental permits before Notice to Proceed (NTP).
5. Construction duration *includes* typical winter shut-down period from November 15th through March 15th.
6. Construction includes construction permits, remaining utility relocations, and all construction-related effort. Remaining ROW acquisition by QDOT also occurs during this timeframe.

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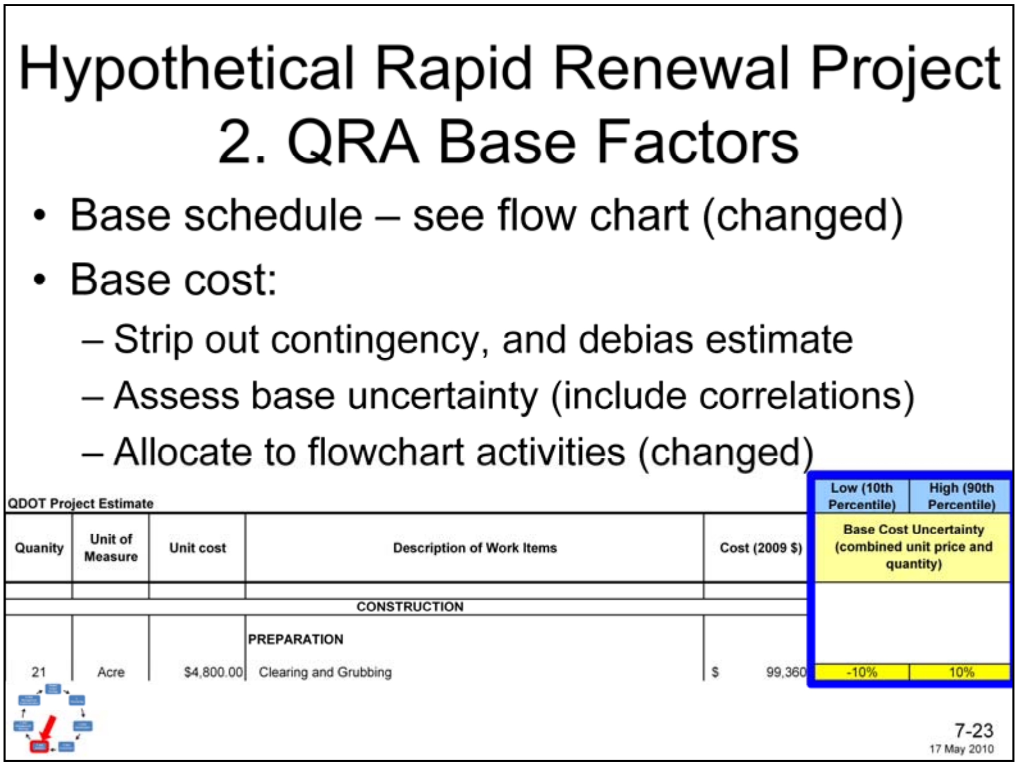
This shows a slightly more-detailed, custom developed flow chart for the project



Hypothetical Rapid Renewal Project
2. QRA Base Factors

- Base schedule – see flow chart (changed)
- Base cost:
  - Strip out contingency, and debias estimate
  - Assess base uncertainty (include correlations)
  - Allocate to flowchart activities (changed)

QDOT Project Estimate

Quanity	Unit of Measure	Unit cost	Description of Work Items	Cost (2009 $)	Low (10th Percentile)	High (90th Percentile)
					Base Cost Uncertainty (combined unit price and quantity)	
			CONSTRUCTION			
			PREPARATION			
21	Acre	$4,800.00	Clearing and Grubbing	$ 99,360	-10%	10%

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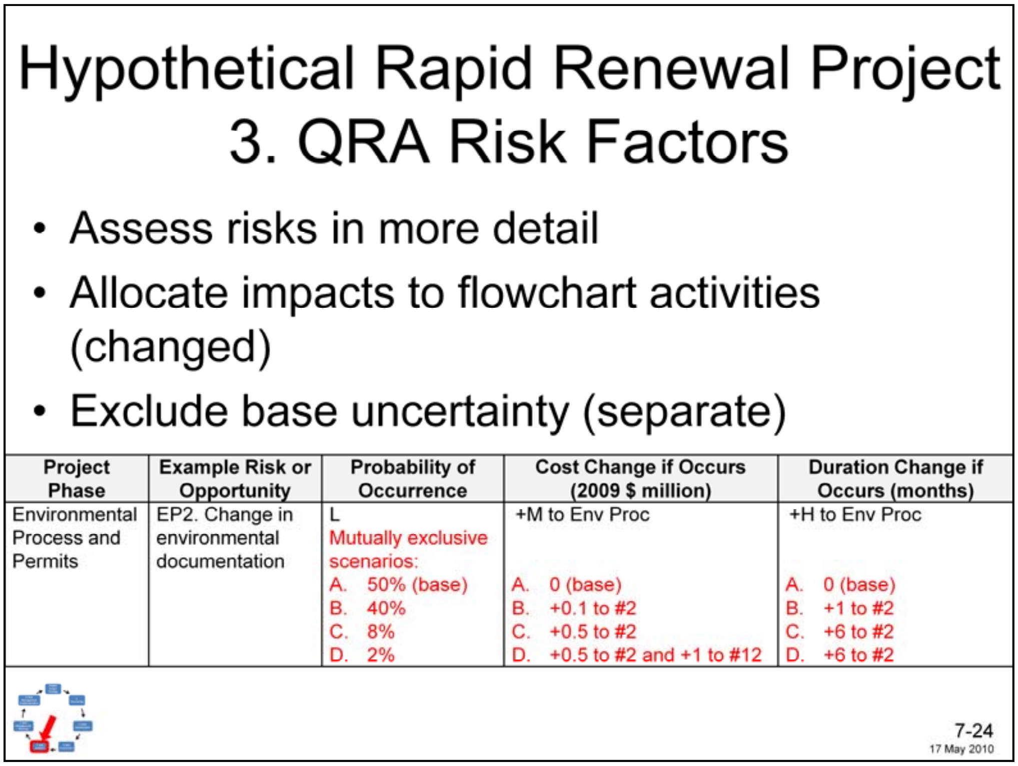
QDOT Project Estimate

Quanity	Unit of Measure	Unit cost	Description of Work Items	Cost (2009 $)		Deterministic Base Cost 2009 $M	Note to Travis on Base Uncertainty due to quantity (high, med or low)	Low (10th Percentile)	High (90th Percentile)
								Base Cost Uncertainty (combined unit price and quantity)	
			CONSTRUCTION						
			PREPARATION						
21	Acre	$4,800.00	Clearing and Grubbing	$ 99,360		0.10		-10%	10%
26,397	S.Y.	$8.40	Removing Cement Conc. Pavement	$ 221,735		0.22	med	-10%	10%
26,397	S.Y.	$4.80	Removing Asphalt Conc. Pavement	$ 126,706		0.13	med	-10%	10%
			GRADING						
33,393	C.Y.	$9.60	Roadway Excavation Incl. Haul	$ 320,573		0.32	high	-20%	20%
27,960	C.Y.	$4.20	Common Borrow incl. Haul	$ 117,432		0.12	high	-20%	20%
3,107	C.Y.	$14.40	Gravel Borrow Incl. Haul	$ 44,741		0.04	high	-20%	20%
31,067	C.Y.	$1.20	Embankment Compaction	$ 37,280		0.04	high	-20%	20%
			DRAINAGE						
42	Each	$2,160.00	Grate Inlet Type 1 or 2	$ 90,720		0.09	low	-5%	5%
6	Each	$3,600.00	Drop Inlet Type 1	$ 21,600		0.02	low	-5%	5%
21,120	L.F.	$78.00	Plain St. Culv. Pipe 0.109 In. Thick 36 In. Diam.	$ 1,647,360		1.65	low	-5%	5%
50	L.F.	$1,800.00	St. Stru. Pipe Arch 8 Guage 20 Ft. 0 In. Span	$ 89,100		0.09	low	-5%	5%
			STRUCTURE						
3,972	S.F.	$145.00	Bridge No. (easy bridge)	$ 575,940		0.58		-20%	20%
8,673	S.F.	$22.00	Concrete Retaining Wall	$ 190,806		0.19		-10%	10%
			SURFACING						
27,047	Ton	$12.00	Crushed Surfacing Bace Course	$ 324,564		0.32	med	-10%	10%
			CEMENT CONC. PAVEMENT						
16,696	C.Y.	$110.00	Cement Conc. Pavement	$ 1,836,560		1.84	med	-10%	10%
882	S.Y.	$146.00	Bridge Approach Slab	$ 128,772		0.13	med	-10%	10%
			ASPHALT CONCRETE PAVEMENT						
1,100	Ton	$36.00	Miscellaneous Asphalt Conc. Pavement	$ 39,600		0.04		-10%	10%
			EROSION CONTROL AND PLANTING						
2	Acre	$2,400.00	Seeding, Fertilizing and Mulching	$ 4,800		0.00		-10%	10%
1	EST.	$85,000.00	Temporary Water Pollution/Erosion Control	$ 85,000		0.09		-10%	10%
1,564	C.Y.	$13.20	Topsoil Type B	$ 20,645		0.02		-10%	10%
1	EST.	$150,000.00	Miscellaneous Landscaping						
			TRAFFIC						
15,840	L.F.	$120.00	Special Conc. Barrier Type 5	$ 1,900,800		1.90		-10%	10%
8	Each	$14,400.00	Permanent Impact Attenuator	$ 115,200		0.12		-10%	10%
214,000	L.F.	$0.12	Paint Line	$ 25,680		0.03		-10%	10%
1	L.S.	$24,000.00	Permanent Sigining	$ 24,000		0.02		-10%	10%
			OTHER ITEMS						
4,000	L.F.	$18.00	Temporary Barrier Glare Screen	$ 72,000		0.07		-10%	10%
1	EST.	$12,000.00	Roadside Cleanup	$ 12,000		0.01		-10%	10%
1	EST.	$6,000.00	Trimming and Cleanup	$ 6,000		0.01		-10%	10%
			CONSTRUCTION SUBTOTAL "A" (before Mob, Traffic Control and Other Misc. Items)	$ 8,178,973					
1	L.S.	$408,948.66	Mobilization	$ 408,949	5.0%		high	-10%	20%
1	L.S.	$601,154.53	Traffic Control (at 7% of subtotal A + Mob)	$ 601,155	7.0%			0%	50%
1	EST.	$1,030,550.62	Other Miscelleaneous Items (12% of subtotal A + Mob)	$ 1,030,551	12.0%			-10%	20%
			CONSTRUCTION SUBTOTAL "B" (including Mob, Traffic Control and Other Misc. Items)	$ 10,219,627					
			DESIGN-BUILDER DESIGN FEES (10% of "B")	$ 1,021,963	10.0%			-10%	10%
			DESIGN-BUILD CONSTRUCTION TOTAL "C"	$ 11,241,590					
			CONSTRUCTION ADMINSTRATION (8% of "C")	$ 899,327	8.0%			-10%	20%
			AGENCY DESIGN, ENV, PERMITTING, AND PROCUREMENT (10% of "C" + C. Admin) (includes previous costs of $200,000)	$ 1,214,092	10.0%			-10%	10%
			RIGHT OF WAY	$ 2,000,000		2.00		-20%	20%
			UTILITY RELOCATIONS	$ 1,000,000		1.00		-20%	20%
			PROJECT SUBTOTAL "D" (Before Contingency)	$ 16,355,009					
			CONTINGENCY (30% of Project SubTotal "D")	$ -	zeroed out for base cost				
			TOTAL	$ 16,355,009					



Hypothetical Rapid Renewal Project
3. QRA Risk Factors

- Assess risks in more detail
- Allocate impacts to flowchart activities (changed)
- Exclude base uncertainty (separate)

Project Phase	Example Risk or Opportunity	Probability of Occurrence	Cost Change if Occurs (2009 $ million)	Duration Change if Occurs (months)
Environmental Process and Permits	EP2. Change in environmental documentation	L Mutually exclusive scenarios: A. 50% (base) B. 40% C. 8% D. 2%	+M to Env Proc A. 0 (base) B. +0.1 to #2 C. +0.5 to #2 D. +0.5 to #2 and +1 to #12	+H to Env Proc A. 0 (base) B. +1 to #2 C. +6 to #2 D. +6 to #2

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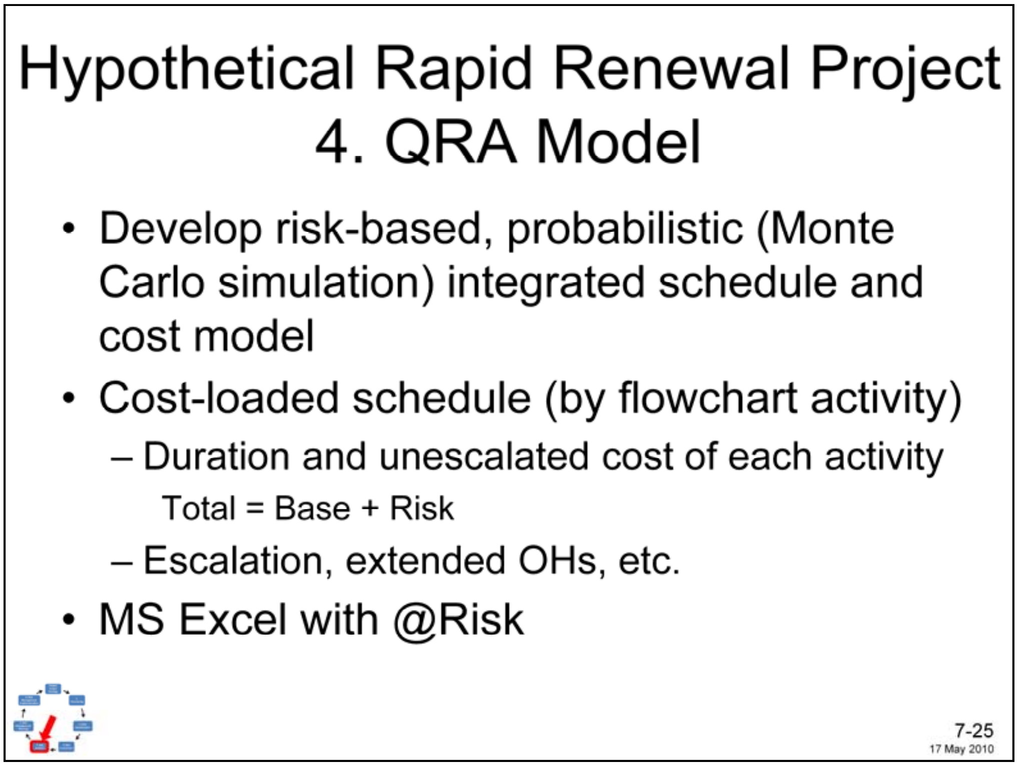
The group's earlier mean-value ratings were expanded into full probabilistic assessments for cost and schedule impacts through construction, identifying the activities in the revised flowchart affected by each risk. This is an excerpt from the resulting probabilistic risk register, and shows the probabilistic assessment for an example risk that relates specifically to rapid renewal elements of the project.

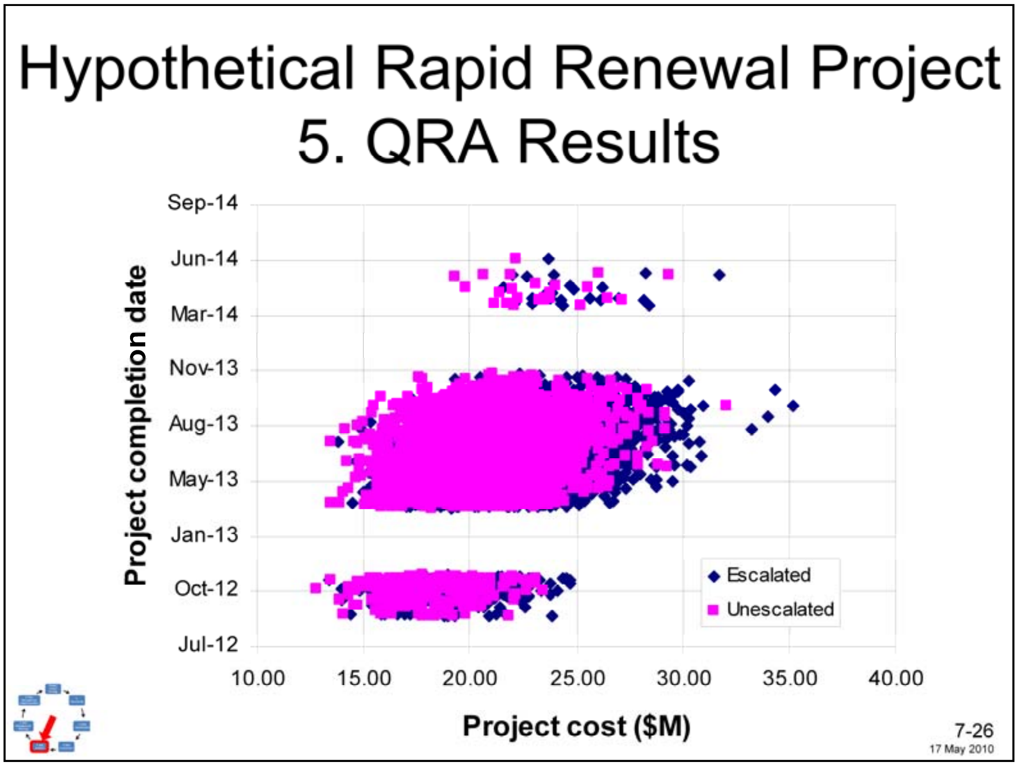


Hypothetical Rapid Renewal Project
4. QRA Model

- Develop risk-based, probabilistic (Monte Carlo simulation) integrated schedule and cost model
- Cost-loaded schedule (by flowchart activity)
  - Duration and unescalated cost of each activity

    Total = Base + Risk
  - Escalation, extended OHs, etc.
- MS Excel with @Risk

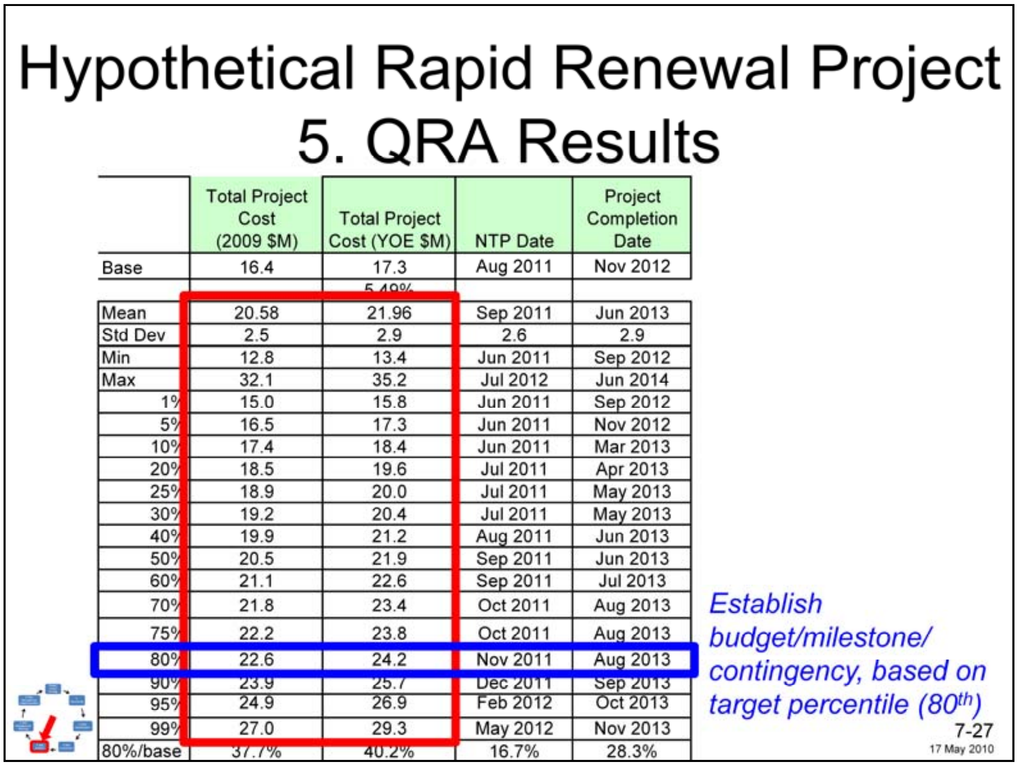
An integrated schedule and cost risk model was developed (using a previously developed template) and used (via Monte Carlo simulation) to combine the base cost, base schedule, base uncertainties, and the complete probabilistic risk register to determine the uncertainty in project schedule (e.g., in terms of date of substantial completion of construction) and in cost (e.g., in terms of total project cost through construction, both uninflated and inflated), as well as the approximate contribution of each factor to specific target percentiles of inflated project cost and completion date.



Hypothetical Rapid Renewal Project
5. QRA Results

7-26
17 May 2010

This shows “raw” results of 5000 possible outcomes (in terms of project completion date and uninflated and inflated project cost) from Monte Carlo simulation, which shows the correlation between inflated cost and project completion date. Note that this correlation between cost and schedule results from the structure of the flow chart and the assessed uncertainty in, and correlation between, individual base uncertainties and risk factors.



Hypothetical Rapid Renewal Project

5. QRA Results

	Total Project Cost (2009 $M)	Total Project Cost (YOE $M)	NTP Date	Project Completion Date
Base	16.4	17.3	Aug 2011	Nov 2012
		5.49%		
Mean	20.58	21.96	Sep 2011	Jun 2013
Std Dev	2.5	2.9	2.6	2.9
Min	12.8	13.4	Jun 2011	Sep 2012
Max	32.1	35.2	Jul 2012	Jun 2014
1%	15.0	15.8	Jun 2011	Sep 2012
5%	16.5	17.3	Jun 2011	Nov 2012
10%	17.4	18.4	Jun 2011	Mar 2013
20%	18.5	19.6	Jul 2011	Apr 2013
25%	18.9	20.0	Jul 2011	May 2013
30%	19.2	20.4	Jul 2011	May 2013
40%	19.9	21.2	Aug 2011	Jun 2013
50%	20.5	21.9	Sep 2011	Jun 2013
60%	21.1	22.6	Sep 2011	Jul 2013
70%	21.8	23.4	Oct 2011	Aug 2013
75%	22.2	23.8	Oct 2011	Aug 2013
80%	22.6	24.2	Nov 2011	Aug 2013
90%	23.9	25.7	Dec 2011	Sep 2013
95%	24.9	26.9	Feb 2012	Oct 2013
99%	27.0	29.3	May 2012	Nov 2013
80%/base	37.7%	40.2%	16.7%	28.3%

Establish budget/milestone/ contingency, based on target percentile (80th)

7-27

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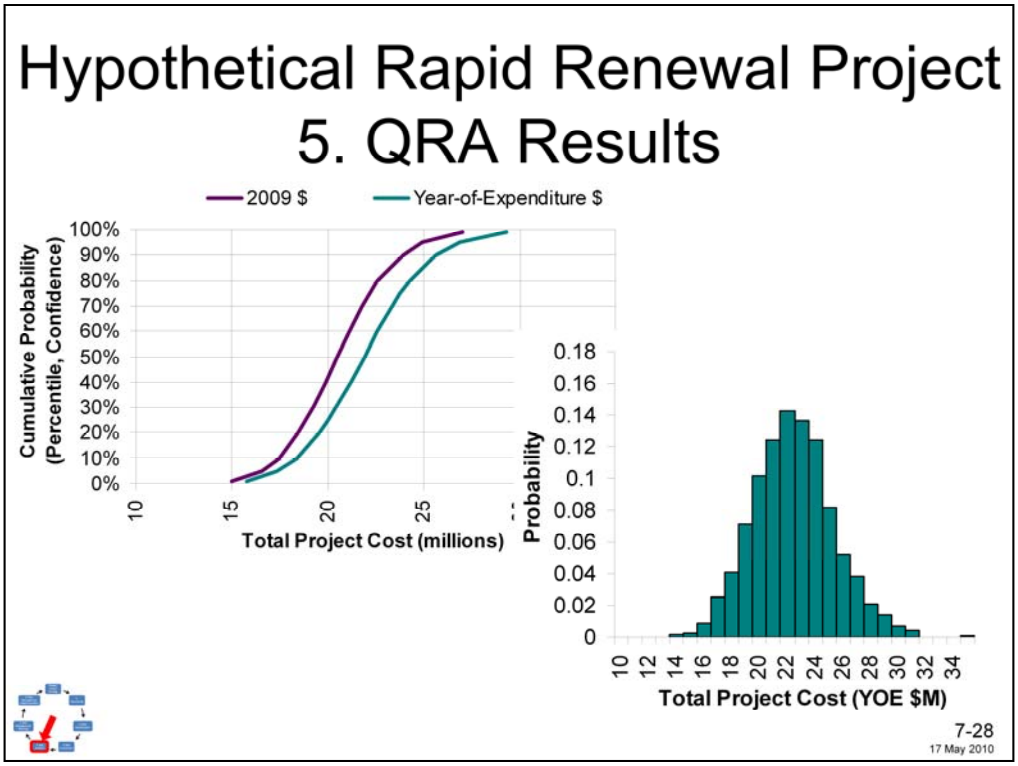
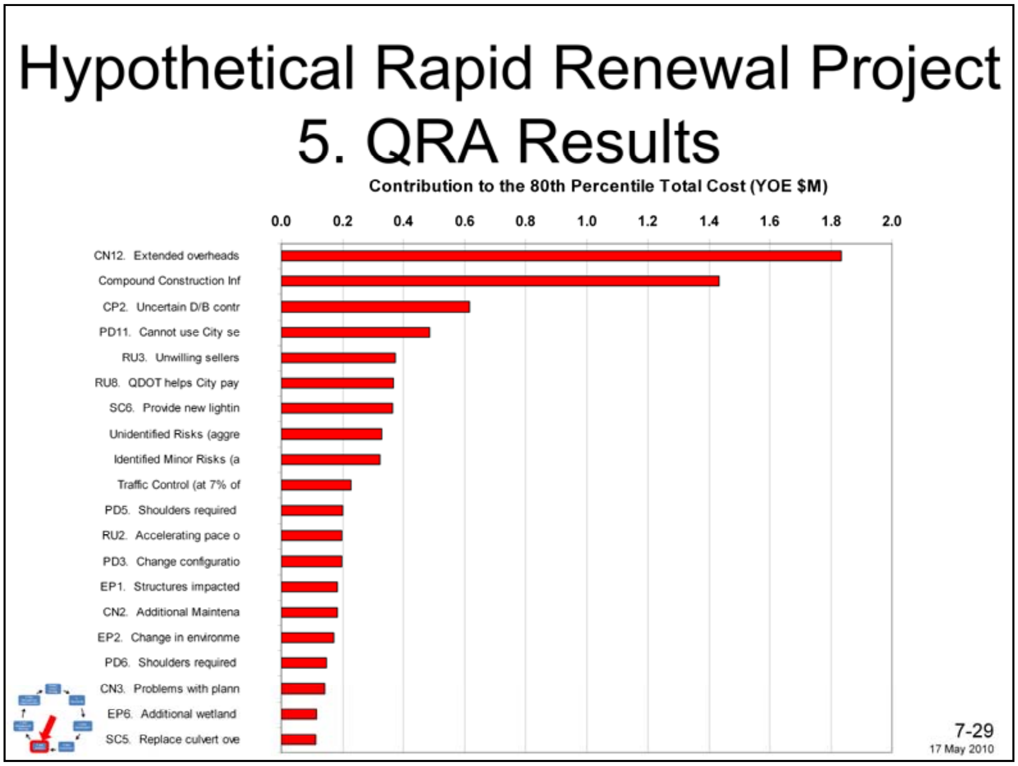
This shows probability distributions for project performance (tabular), derived from raw results. Probability distributions (graphical) are subsequently developed for the various performance measures (e.g., uninflated and inflated cost).

Budgets/milestones (and thereby contingencies) are established at a particular confidence level (target percentile), typically around 80%.



Hypothetical Rapid Renewal Project
5. QRA Results

This shows cumulative probability distribution for uninflated and inflated project cost, and probability distribution for inflated project cost, derived from raw results (consistent with tabular results); similar distributions were developed for uninflated cost, as well as project schedule.



Hypothetical Rapid Renewal Project
5. QRA Results

7-29
17 May 2010

This shows the approximate contribution of each uncertain factor to the 80th percentile of inflated project cost; similar relationships were developed for contribution to the 80th percentile of project completion date. These sensitivities are derived from Monte Carlo simulation results, and do not require separate analyses.

Hypothetical Rapid Renewal Project
6. QRA Documentation

In *Risk Management Plan*, document:

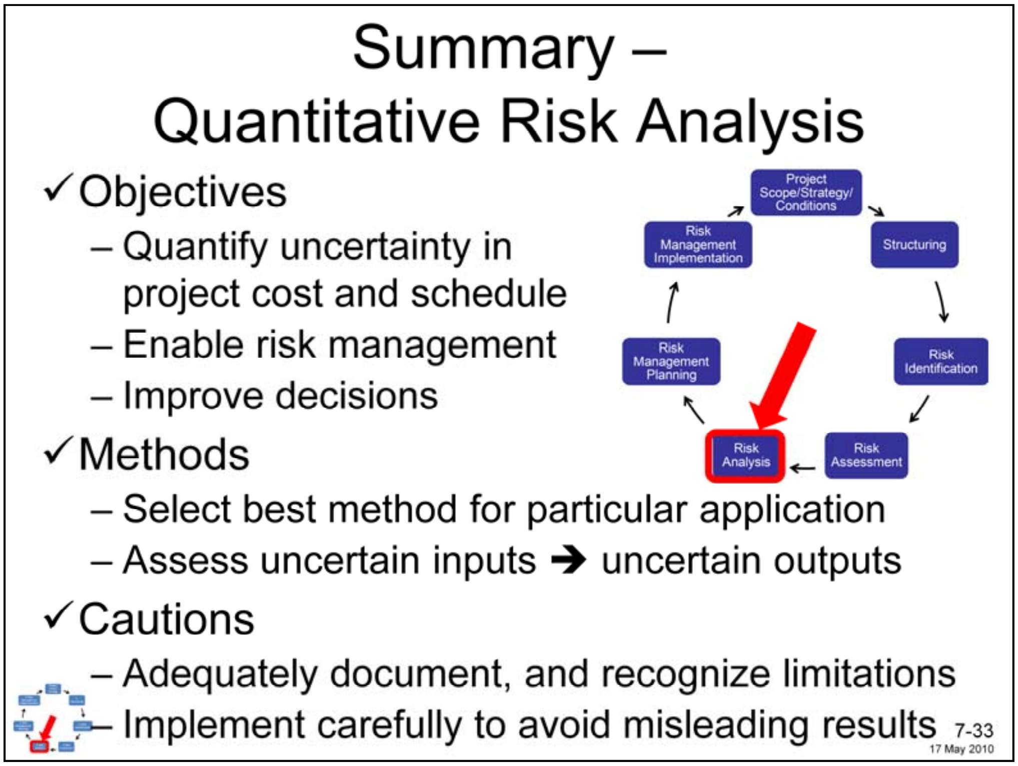
- Project description (including cost and schedule estimates)
- Project abstraction (flowchart activities/logic)
- Base schedule and cost factors (uncertainties)
- Risks and risk factors (in *Risk Register*)
- Model
- Results (performance and sensitivity)

Hypothetical Rapid Renewal Project QRA Discussion

- Why do QRA?
- Value of results?
- Additional effort involved?
- Additional skills involved?
- Limitations?
- Recommendations?

Quantitative Risk Analysis

- Learning Objectives
- Overview of Methods
- Example
- **Summary**



Summary – Quantitative Risk Analysis

✓Objectives

- Quantify uncertainty in project cost and schedule
- Enable risk management
- Improve decisions

✓Methods

- Select best method for particular application
- Assess uncertain inputs ➔ uncertain outputs

✓Cautions

- Adequately document, and recognize limitations
- Implement carefully to avoid misleading results

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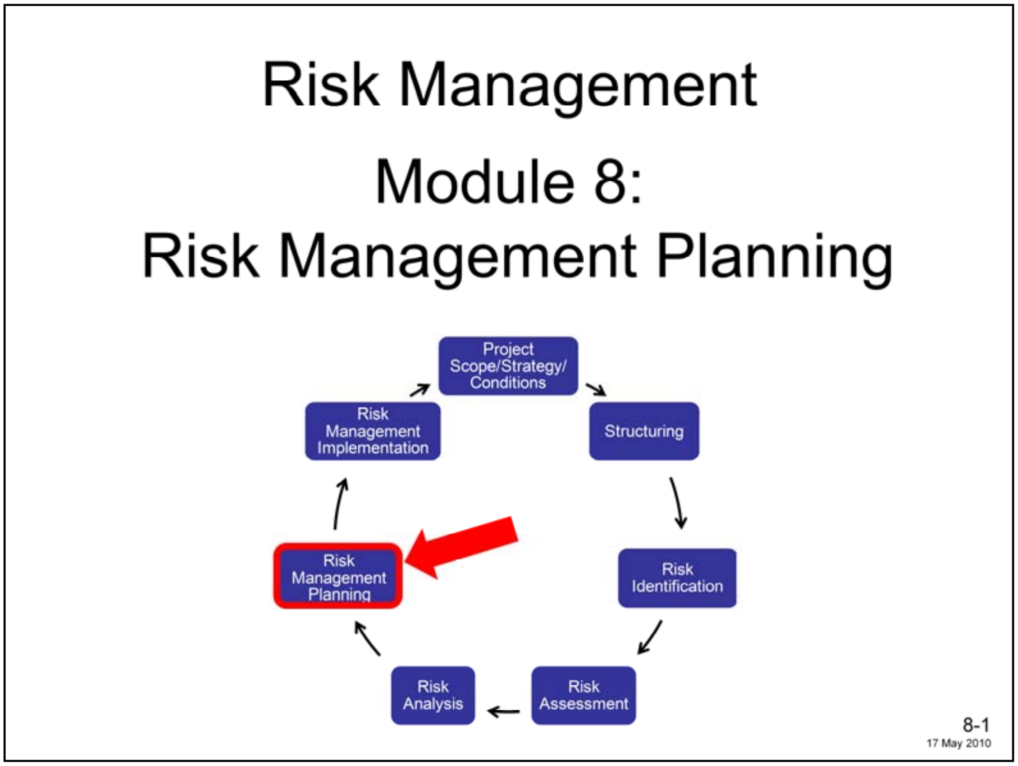
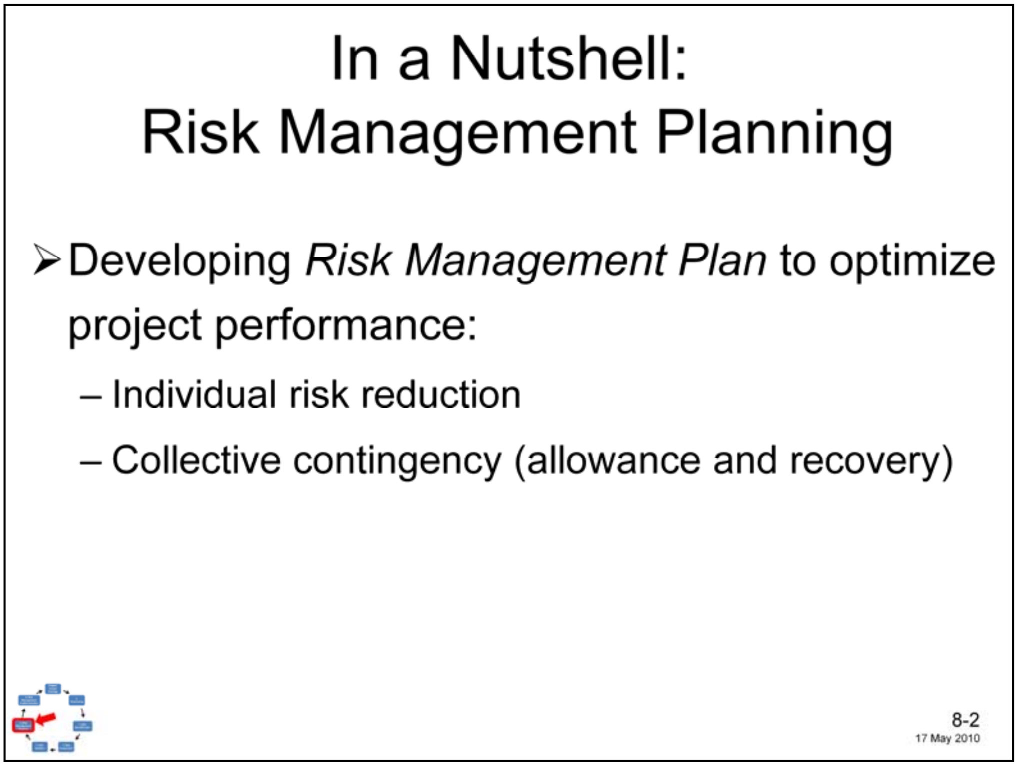


Risk Management

Module 8:
Risk Management Planning

Identification and assessment of the severity of project risks were discussed in Modules 5 and 6, and more detailed evaluation of the severity of risks was discussed in Module 7.
Implementation/management of risk management plans is subsequently discussed in Module 9



In a Nutshell: Risk Management Planning

- Developing *Risk Management Plan* to optimize project performance:
  - Individual risk reduction
  - Collective contingency (allowance and recovery)

8-2
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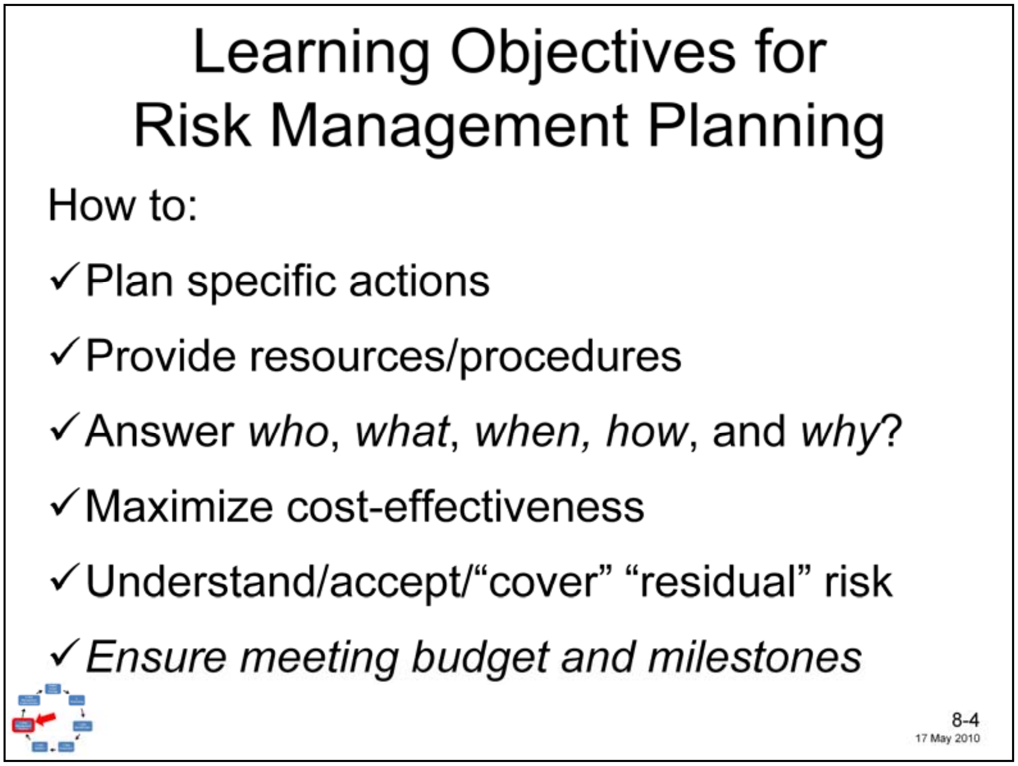
Risk Management Planning means developing plans (and a program to implement those plans) for appropriately addressing the risks early on, by reducing significant risks to the extent possible and by adequately “covering” the remaining risks (with allowances and “recovery” plans). Allocation of risks (who “owns” them) will be done preliminarily when first identified, but won’t be finalized until contract negotiations are complete.

Risk Management Planning

- Learning Objectives
- Methods
- Guidance
- Practical Exercise
- Summary



Learning Objectives for Risk Management Planning

How to:

✓Plan specific actions

✓Provide resources/procedures

✓Answer *who*, *what*, *when, how*, and *why*?

✓Maximize cost-effectiveness

✓Understand/accept/“cover” “residual” risk

✓*Ensure meeting budget and milestones*

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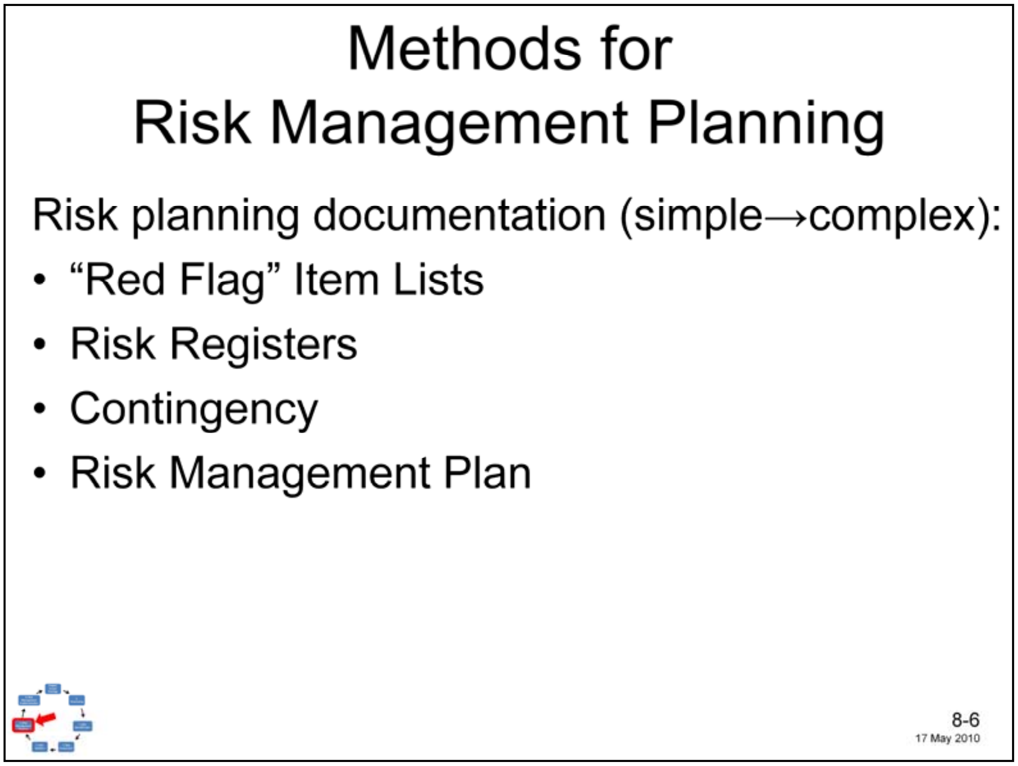
17 May 2010

- The objectives of risk management planning can be summarized as planning specific actions, and providing adequate resources/procedures (i.e., “program”) to successfully implement those actions.
- The following questions should be considered when planning:
    - Who is responsible?
    - What can be done and what options are available?
    - When can they be done?
    - How can they be done and what is needed?
    - What are the tradeoffs in terms of all costs, benefits, and risks among the available options?
    - What are the impacts of current decisions on future options?
    - Why is it being done (defensible)?
- The process of risk management planning often involves an analysis of tradeoffs to maximize the cost-effectiveness of reduction options.
- However, even with the best risk-reduction planning, some risks will remain. The process will also allow for: a) a better understanding of the remaining risks that must be accepted by the owner; and b) development of appropriate contingency (allowances and recovery plans).

Risk Management Planning

- Learning Objectives
- **Methods**
- Guidance
- Practical Exercise
- Summary



Methods for Risk Management Planning

Risk planning documentation (simple→complex):

- “Red Flag” Item Lists
- Risk Registers
- Contingency
- Risk Management Plan

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Ranging from simple to complex:

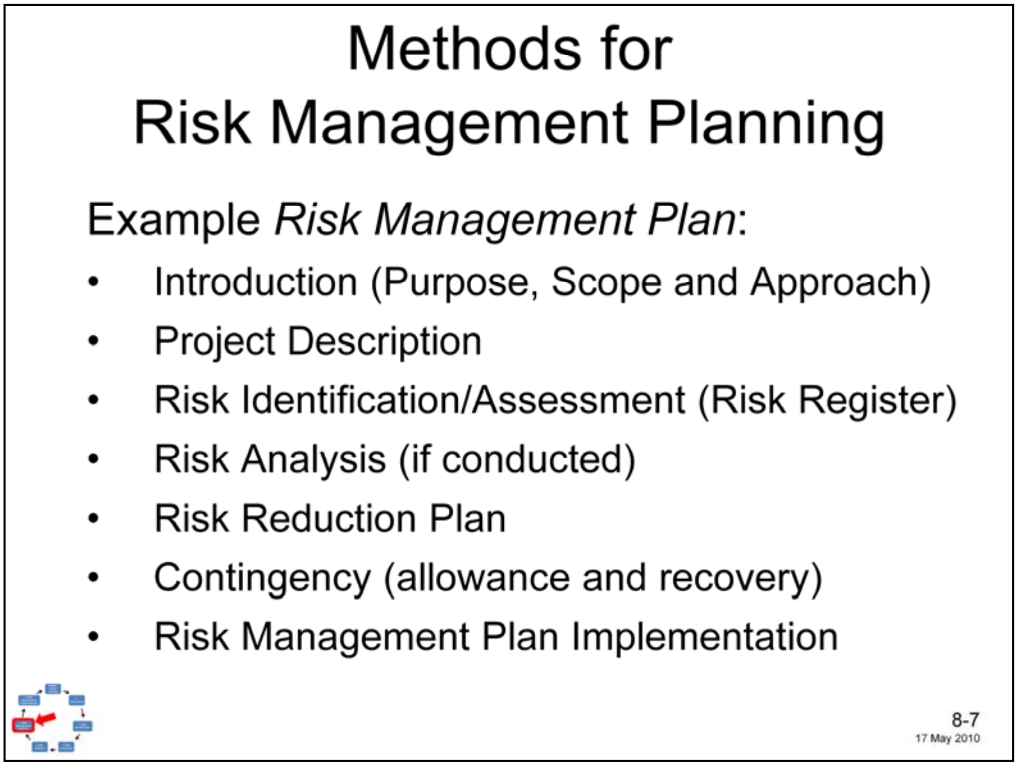
• “Red Flag” Items Lists (developed through methods discussed in Modules 5 and 6, e.g., “Red/Yellow/Green” method) are simple and straight forward to create and use (including monitoring/updating) – they simply keep the key risks in mind in guiding risk management. However, they do not typically involve explicit determination of cost-effectiveness of risk-reduction actions, nor do they address contingency.

• Risk Registers provide more detail than simple Red Flag Item Lists, but otherwise have similar limitations. Also, without maintenance and updating, their usefulness is even more limited.

• Contingency is typically an allowance to cover remaining risks and other uncertainties, e.g., expressed as a percentage of base cost, which varies with project development – as risks are realized (and added to the base) or retired, the contingency required to cover them decreases. Traditionally, contingency is determined via judgment, consistent with industry experience and guidance. However: a) such subjective direct assessment (such as for costs) is difficult to do accurately; and b) as previously shown, traditionally-derived contingency is, on average, inadequate.

• Recovery (or contingency planning) involves actions that can be taken to reduce cost or accelerate schedule (if needed). For cost, this might involve non-essential scope deferral (e.g., through contract options). For schedule, this might include working additional crews and/or additional shifts.

• A Risk Management Plan is typically used on only the largest projects. They should be part of the Project Management Plan that FHWA requires on large projects. They help to clearly assign risk management responsibilities on the project team. However, without adequate implementation (including monitoring/maintenance and updating – see Module 9), they have limited usefulness.



Methods for Risk Management Planning

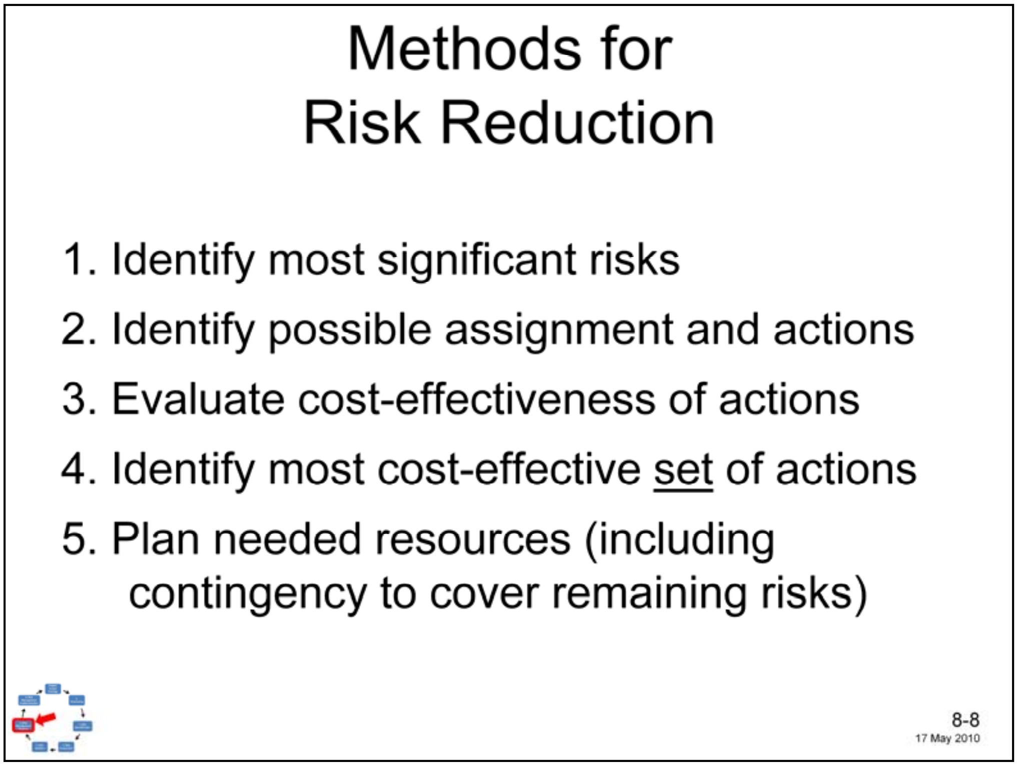
Example *Risk Management Plan*:

- Introduction (Purpose, Scope and Approach)
- Project Description
- Risk Identification/Assessment (Risk Register)
- Risk Analysis (if conducted)
- Risk Reduction Plan
- Contingency (allowance and recovery)
- Risk Management Plan Implementation

Risk management includes:

- planning proactive actions to take now to cost-effectively reduce individual risks
- managing contingency funds to reasonably cover residual risks collectively, and recovery (or contingency) plans to provide additional assurance of covering residual risks
- Implementation (including monitoring/updating), which is discussed in Module 9, requires:
  - Risk Management Organization
  - Risk Management Information System, Documentation and Reports

The Risk Management Plan contains the risk assessment (including the project description and Risk Register) and, if conducted, risk analysis, on which the plan is based.



Methods for Risk Reduction

1. Identify most significant risks
2. Identify possible assignment and actions
3. Evaluate cost-effectiveness of actions
4. Identify most cost-effective <u>set</u> of actions
5. Plan needed resources (including contingency to cover remaining risks)

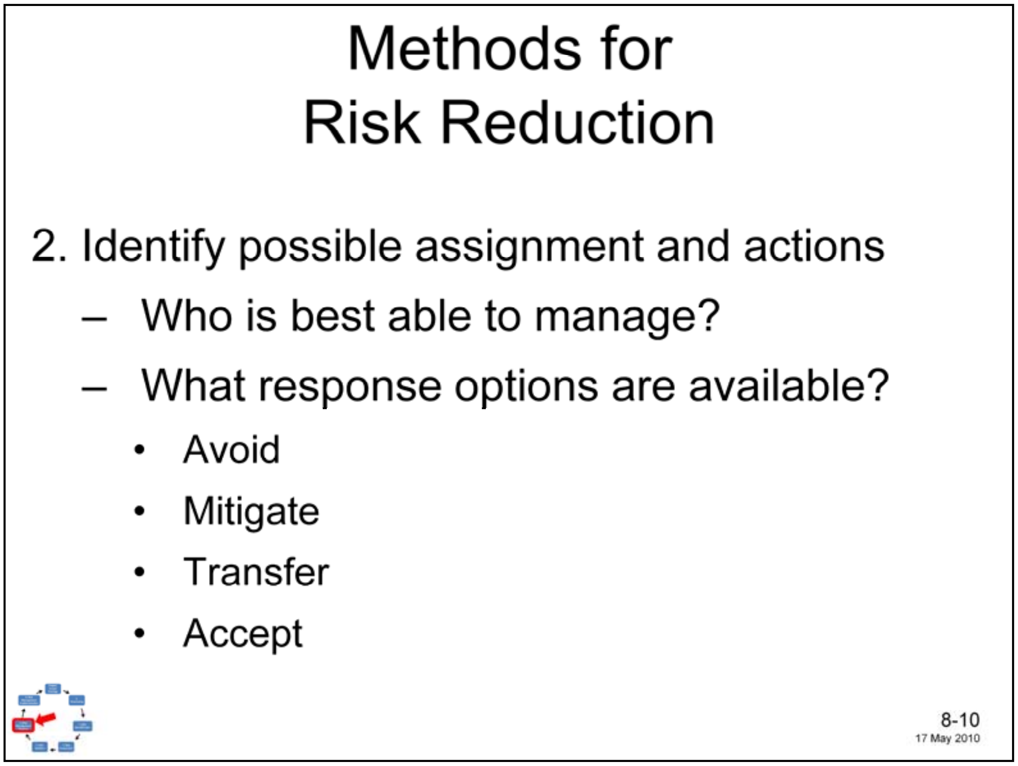
The risk mitigation and planning process contains five basic steps:

1. Identify most significant risks (see Module 6 or 7)
2. Identify possible ownership and actions for each risk (see separate generic list)
3. Evaluate cost-effectiveness of each action individually
4. Identify most cost-effective <u>set</u> of actions, considering combinations – develop “Plan”
5. Identify resources needed to implement Plan (“Program”), which includes contingency fund and plan to cover remaining risks – see Module 9.

While additional steps may be needed on large, unique, or highly uncertain projects, these five steps constitute the basic framework for risk reduction planning. A key to success is making a comprehensive and quantitatively-based evaluation in steps 3 and 4 when making tradeoffs for risk reduction options.

Methods for Risk Reduction

1. Identify most significant risks
    - Rank based on risk rating / assessment (Module 6 or 7)
    - Start with short list (highest risks) and expand (as time allows)



Methods for Risk Reduction

2. Identify possible assignment and actions
   - Who is best able to manage?
   - What response options are available?
     - Avoid
     - Mitigate
     - Transfer
     - Accept

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Avoidance – redesign or change project strategy (possibly at some additional cost or delay) to avoid a particular risk – reduce probability of occurrence (“prevention”)

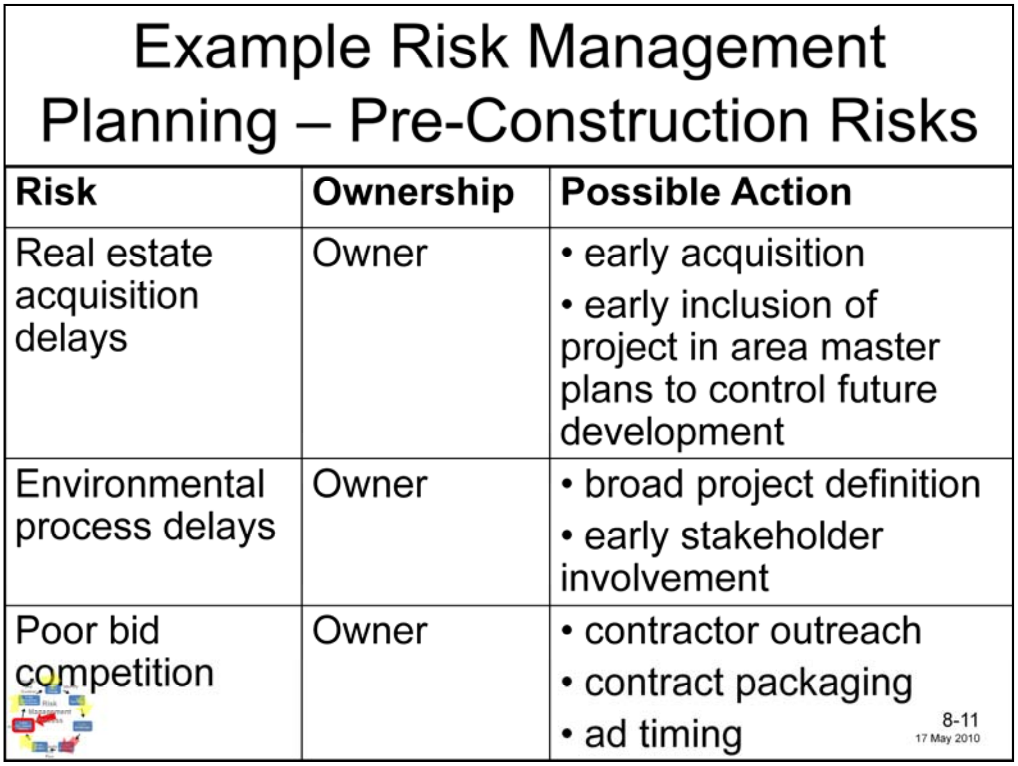
Mitigation – take action (generally at some additional cost or delay) to reduce the impacts of a particular risk if it does occur

Transference – transfer (generally at some price) responsibility for impacts of a particular risk to someone else (e.g., contractor, insurance, etc. – see next slide), who is better able to manage it - Transferring a risk will be discussed in more depth in the following discussion on risk allocation.

Acceptance – do nothing to change a particular risk and accept the possibility that it will happen with the assessed impacts, for which contingencies are needed

Note: Uncertainties will generally reduce over time as the project develops (decisions are made) and more information is obtained; e.g., risks will eventually either happen or not. However, this uncertainty reduction will not necessarily result in cost, schedule or disruption reductions, unless it might result in less conservative design. For example, if a conservative foundation design has been adopted because of the substantial uncertainty in geotechnical conditions, additional information on those geotechnical conditions (i.e., through site investigations) might confirm better geotechnical conditions than assumed for design, allowing for a less conservative design – conversely, the additional information could confirm that the actual geotechnical conditions are as bad as assumed for design, so that, even though the uncertainty has been reduced, there is no change in design.

Note: Several examples are shown on following slides (see Appendix D.3 of the *Guide*).

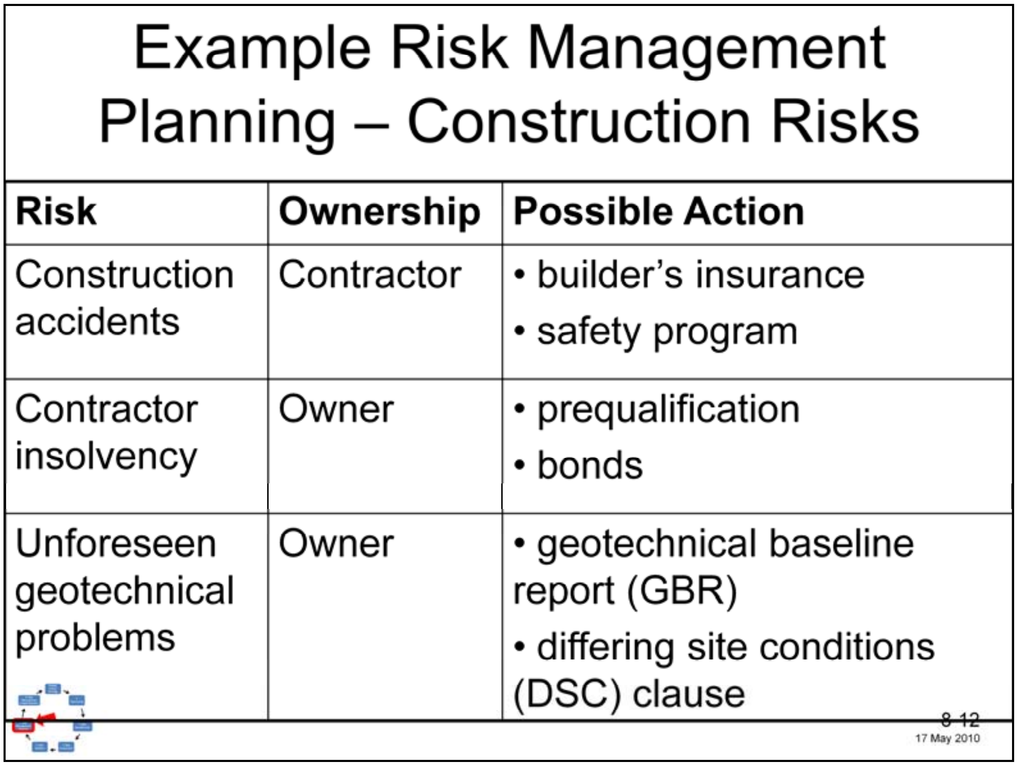


Example Risk Management Planning – Pre-Construction Risks

Risk	Ownership	Possible Action
Real estate acquisition delays	Owner	• early acquisition • early inclusion of project in area master plans to control future development
Environmental process delays	Owner	• broad project definition • early stakeholder involvement
Poor bid competition	Owner	• contractor outreach • contract packaging • ad timing

AASHTO Design-Build Risk Allocation Example (* can be shared):

Design-Build Risks	Owner*	Design-Builder*
Design		
Definition of Scope		
Project Definition		
Establishing Performance Requirement		
Geotech Investigation - based on preliminary design in RFP		
Geotech Investigation - based on proposal		
Initial project Geotechnical Analysis /Report based on preliminary design		



Example Risk Management Planning – Construction Risks

Risk	Ownership	Possible Action
Construction accidents	Contractor	• builder's insurance • safety program
Contractor insolvency	Owner	• prequalification • bonds
Unforeseen geotechnical problems	Owner	• geotechnical baseline report (GBR) • differing site conditions (DSC) clause

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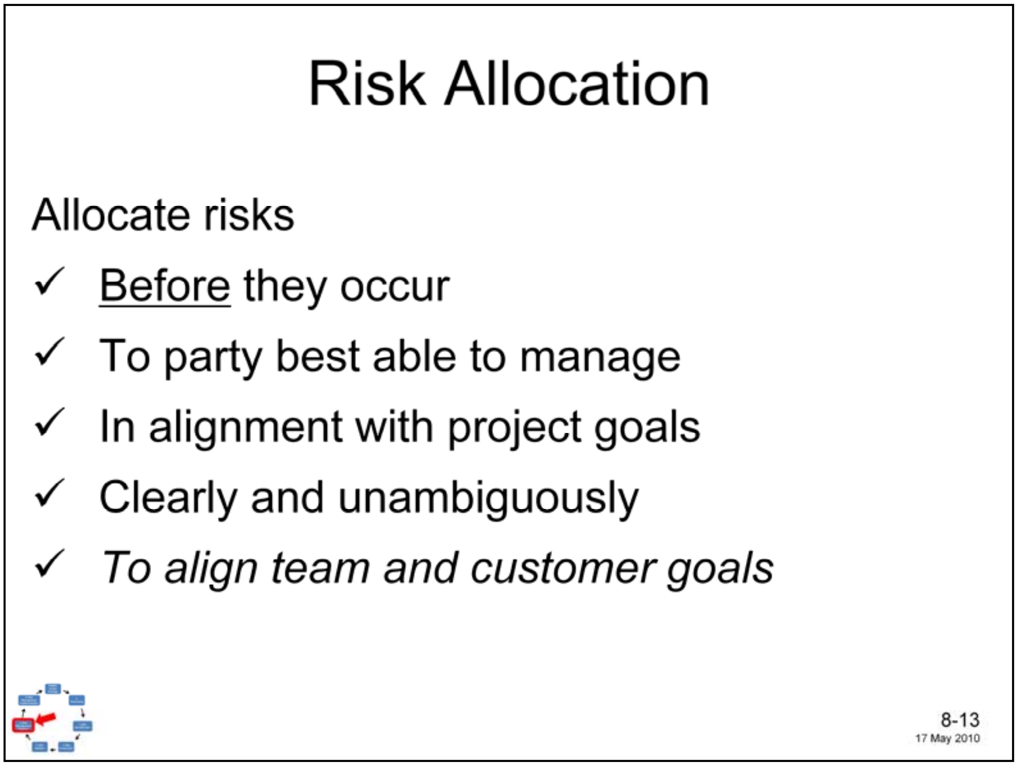
ACEC/AGC Example:

Risk	Party Recommended to Assume Risk	How is Risk Assigned or Managed
Site Access	Owner	Advanced planning or acquisition
Means and Methods of Construction	Contractor	Specific contract clause
Site Conditions	Owner	Geotechnical investigation and contract clause
Weather; Acts of God	Shared (owner assumes delay risk, contractor assumes dollar risk)	Contract clause



Risk Allocation

Allocate risks

- ✓ <u>Before</u> they occur
- ✓ To party best able to manage
- ✓ In alignment with project goals
- ✓ Clearly and unambiguously
- ✓ *To align team and customer goals*

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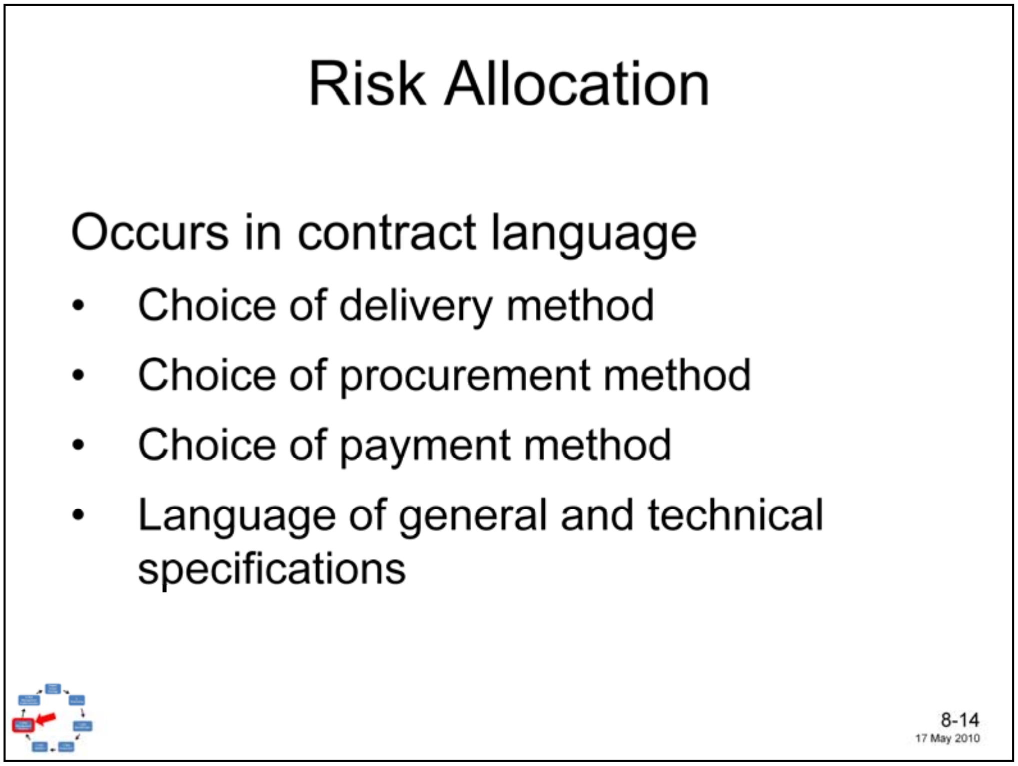
Risk Allocation means <u>contractually</u> assigning the residual risks to a specific party ("transfer"). Although typically assumed early on as part of risk management, such contractual assignment is done later in the process than much of the other proactive risk management. This assignment (and the associated price) is negotiated between the owner and the contractor.

- Allocate risks <u>before</u> they occur to the party that is best able manage them.
- Allocate risks in alignment with project goals.
- Allocate risks clearly and unambiguously to reduce disagreements.
- There is an option to share risks when appropriate to accomplish project goals.
- Ultimately seek to allocate risks to promote team alignment with customer-oriented performance goals.



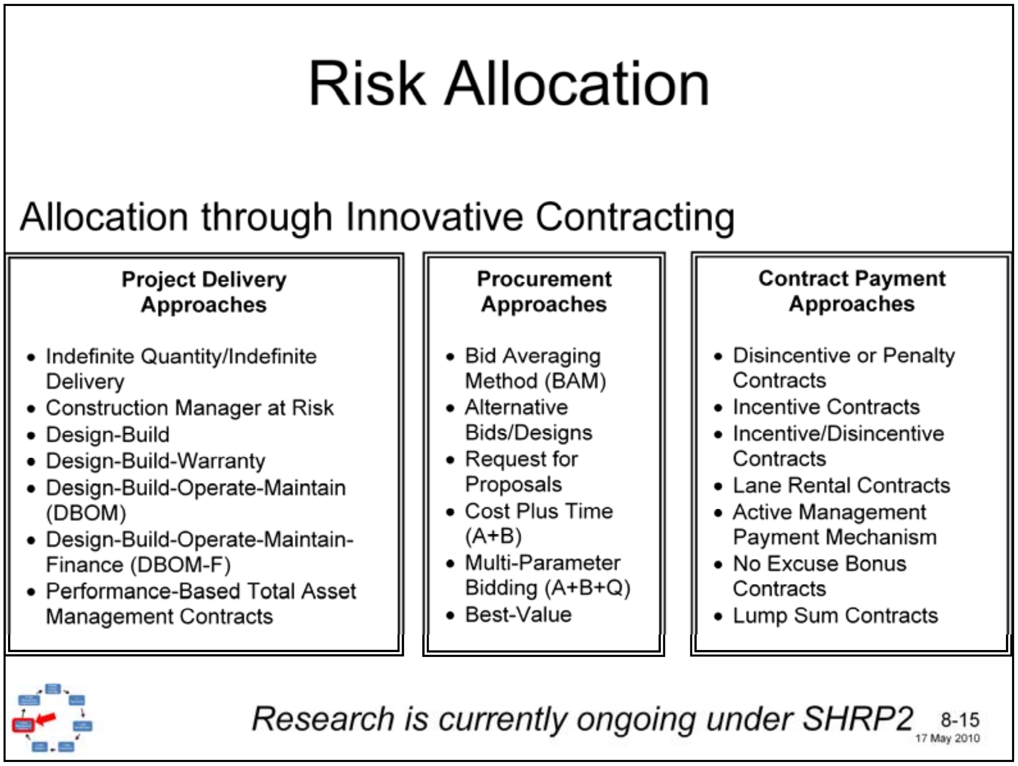
Risk Allocation

Occurs in contract language

- Choice of delivery method
- Choice of procurement method
- Choice of payment method
- Language of general and technical specifications

Risk allocation occurs in choice of delivery method and the final language of the contract documents:

- Choice of delivery method (i.e., design/build, design/bid/build, etc.)
- Choice of procurement method (i.e., low bid, best-value, etc.)
- Choice of payment method (i.e., lump sum, unit price, escalation clause, etc.)
- Language of general and technical specifications (i.e., who is allocated the risk for undiscovered conditions)



Risk Allocation

Allocation through Innovative Contracting

Project Delivery Approaches

- Indefinite Quantity/Indefinite Delivery
- Construction Manager at Risk
- Design-Build
- Design-Build-Warranty
- Design-Build-Operate-Maintain (DBOM)
- Design-Build-Operate-Maintain-Finance (DBOM-F)
- Performance-Based Total Asset Management Contracts

Procurement Approaches

- Bid Averaging Method (BAM)
- Alternative Bids/Designs
- Request for Proposals
- Cost Plus Time (A+B)
- Multi-Parameter Bidding (A+B+Q)
- Best-Value

Contract Payment Approaches

- Disincentive or Penalty Contracts
- Incentive Contracts
- Incentive/Disincentive Contracts
- Lane Rental Contracts
- Active Management Payment Mechanism
- No Excuse Bonus Contracts
- Lump Sum Contracts

Research is currently ongoing under SHRP2

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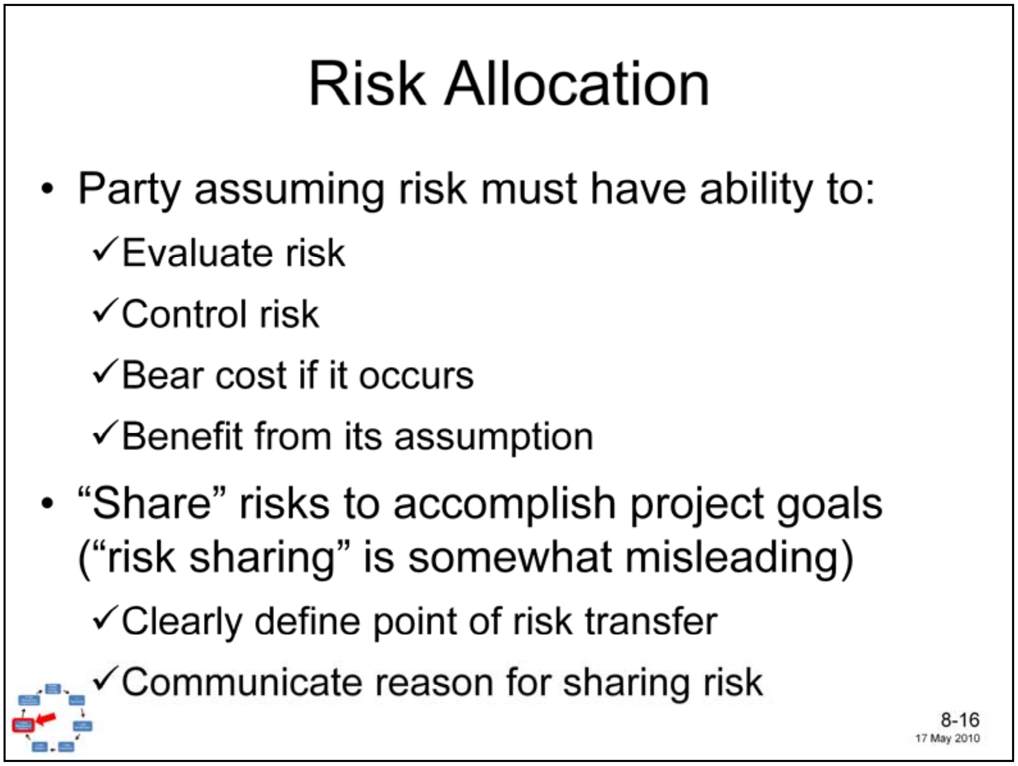
Industry review of proposed project delivery methods (and associated risk allocation) is often useful to identify potential problems (risks) beforehand, and thereby avoid them.

For more information, please see the following sources:

• The Federal Highway Administration's Construction Administration group maintains a website on Innovative Contracting. It is an excellent source of information. The Website can be found at <http://www.fhwa.dot.gov/programadmin/contracts/>.

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



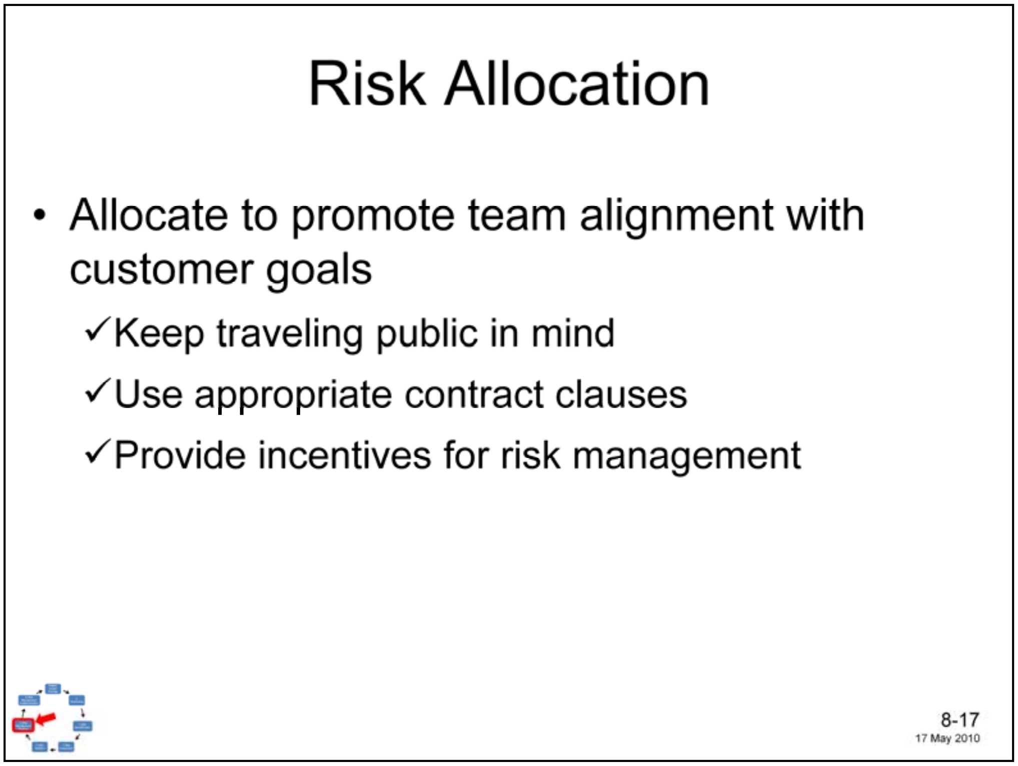
Risk Allocation

- Party assuming risk must have ability to:
  - ✓Evaluate risk
  - ✓Control risk
  - ✓Bear cost if it occurs
  - ✓Benefit from its assumption
- “Share” risks to accomplish project goals (“risk sharing” is somewhat misleading)
  - ✓Clearly define point of risk transfer
  - ✓Communicate reason for sharing risk

For example:

- the following risks are best borne by the contractor:
  - an inadequate labor force
  - a breakdown in equipment
  - using a specific construction technique
- the risk of securing project funds or project site availability would be best borne by the agency.

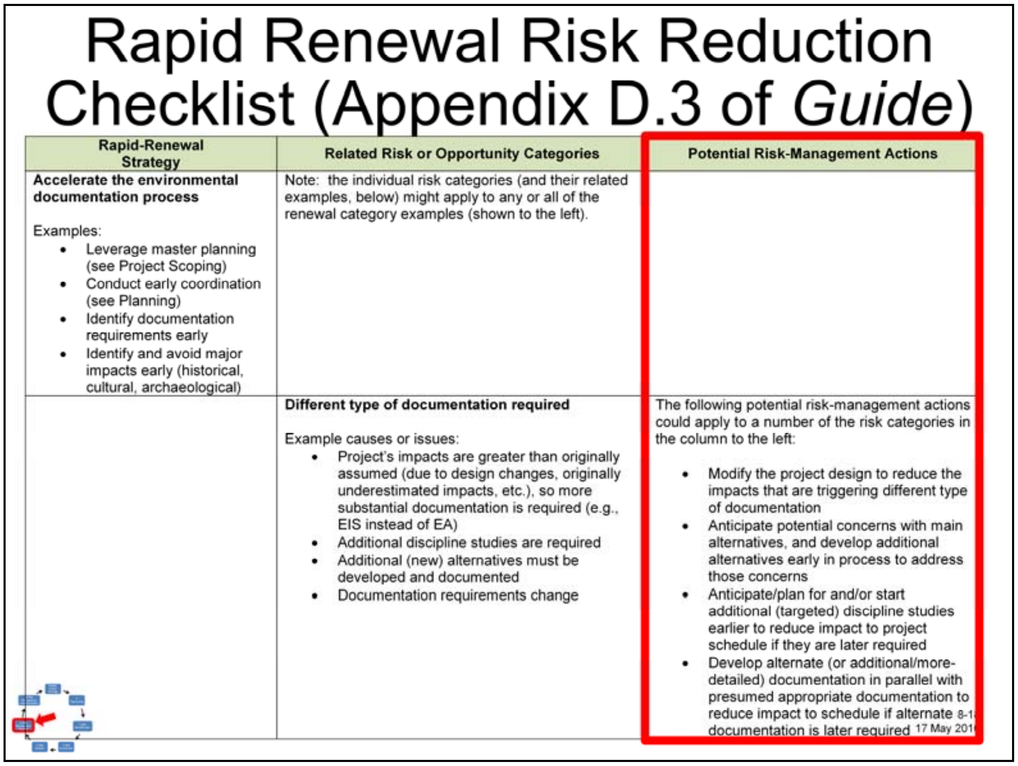
The cost of the risk, if it occurs, might be covered by insurance or by contingency.



Risk Allocation

- Allocate to promote team alignment with customer goals
  - ✓Keep traveling public in mind
  - ✓Use appropriate contract clauses
  - ✓Provide incentives for risk management

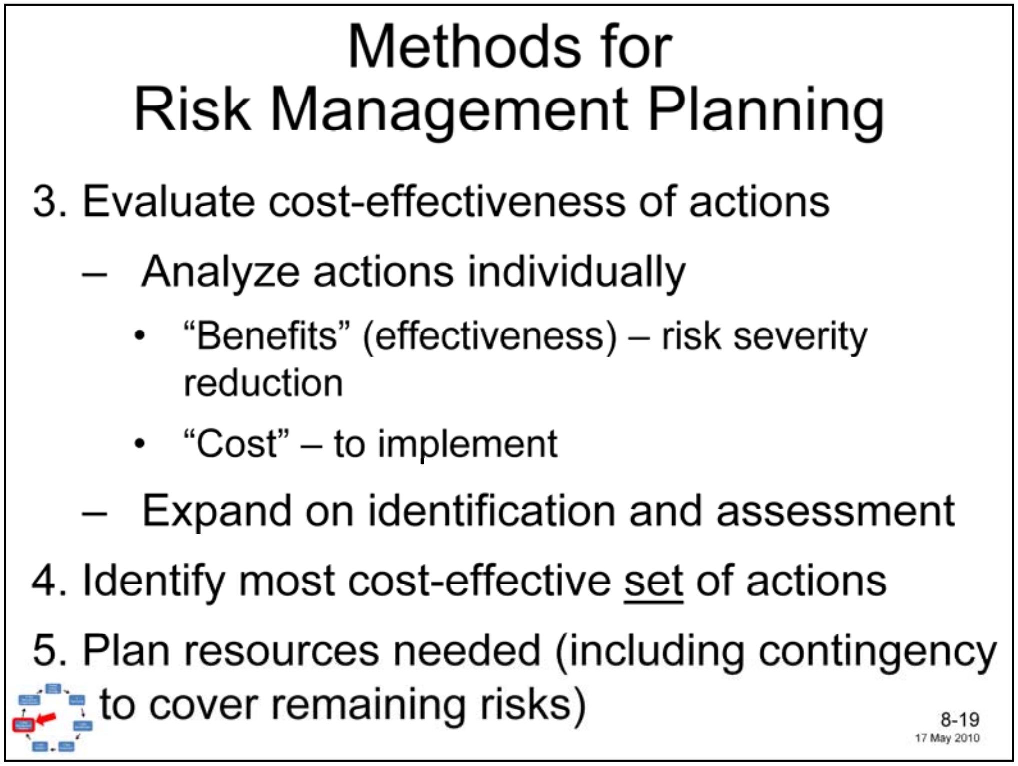
For example, when doing work under traffic, the public (e.g. the customer) would like the work done as quickly as possible. The use of project delivery techniques (e.g. design/build, etc), procurement mechanisms (e.g. A+B bidding, etc.) and contracting mechanisms (e.g. lump sum payments, etc.) can all be used to allocate risks in alignment with the public’s goal of getting the work done quickly with minimal impact.



Rapid Renewal Risk Reduction Checklist (Appendix D.3 of *Guide*)

Rapid-Renewal Strategy	Related Risk or Opportunity Categories	Potential Risk-Management Actions
Accelerate the environmental documentation process Examples: - Leverage master planning (see Project Scoping) - Conduct early coordination (see Planning) - Identify documentation requirements early - Identify and avoid major impacts early (historical, cultural, archaeological)	Note: the individual risk categories (and their related examples, below) might apply to any or all of the renewal category examples (shown to the left).	
	Different type of documentation required Example causes or issues: - Project's impacts are greater than originally assumed (due to design changes, originally underestimated impacts, etc.), so more substantial documentation is required (e.g., EIS instead of EA) - Additional discipline studies are required - Additional (new) alternatives must be developed and documented - Documentation requirements change	The following potential risk-management actions could apply to a number of the risk categories in the column to the left: - Modify the project design to reduce the impacts that are triggering different type of documentation - Anticipate potential concerns with main alternatives, and develop additional alternatives early in process to address those concerns - Anticipate/plan for and/or start additional (targeted) discipline studies earlier to reduce impact to project schedule if they are later required - Develop alternate (or additional/more-detailed) documentation in parallel with presumed appropriate documentation to reduce impact to schedule if alternate documentation is later required

Potential risk reduction actions have been identified for each of the generic list of rapid renewal risk categories. This is simply one example from Appendix D.3 of the *Guide*.



Methods for Risk Management Planning

3. Evaluate cost-effectiveness of actions
   - Analyze actions individually
     - “Benefits” (effectiveness) – risk severity reduction
     - “Cost” – to implement
   - Expand on identification and assessment
4. Identify most cost-effective set of actions
5. Plan resources needed (including contingency to cover remaining risks)

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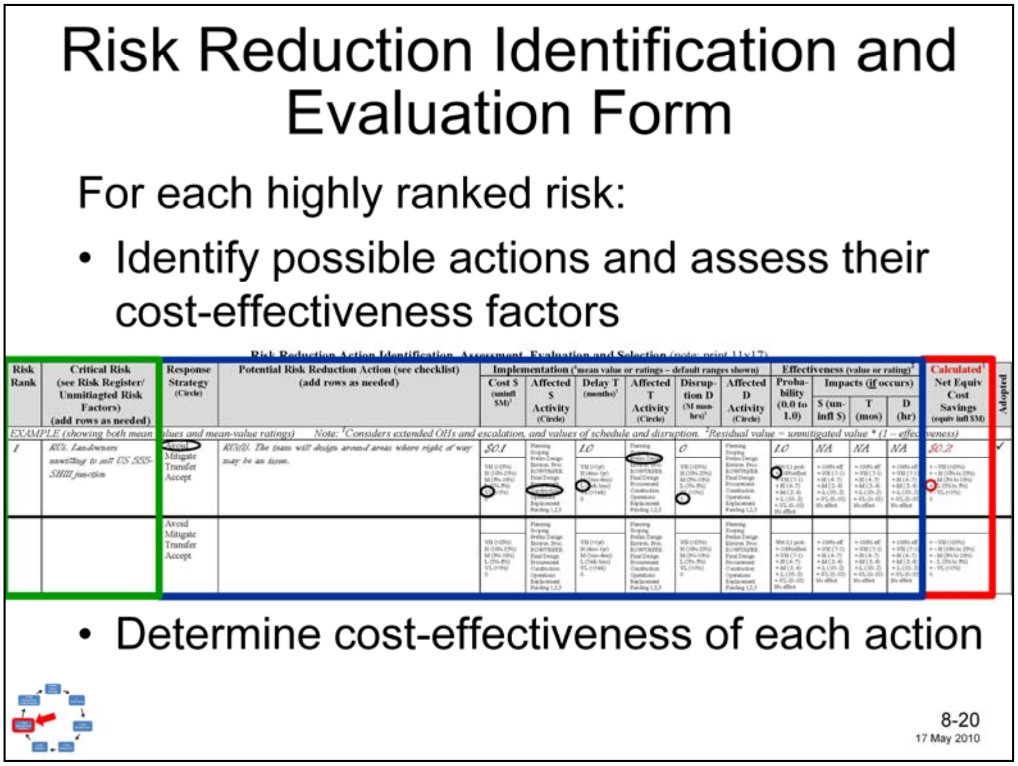
- Determine cost-effectiveness of each possible action. For each feasible action to reduce a particular risk, assess:
  - Project cost (including transfer price), and possibly delay and/or disruption to implement that action
  - Risk reduction if that action is implemented
    - Change in likelihood of that risk occurring
    - Change in impacts (cost, schedule, disruption, by activity) if that risk occurs
  - Depends on method used to assess/rate risks (Module 6 or 7)
- Identify and select most cost-effective actions (in terms of either net-benefit or benefit-to-cost ratio).



Risk Reduction Identification and Evaluation Form

For each highly ranked risk:

- Identify possible actions and assess their cost-effectiveness factors

Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)	Response Strategy (Circle)	Potential Risk Reduction Action (see checklist) (add rows as needed)	Implementation ([1]mean value or ratings – default ranges shown)						Effectiveness (value or rating)[2]				Calculated[1] Net Equiv Cost Savings (equiv infl $M)	Adopted
				Cost $ (uninfl $M)[1]	Affected $ Activity (Circle)	Delay T (months)[1]	Affected T Activity (Circle)	Disruption D (M man-hrs)[1]	Affected D Activity (Circle)	Probability (0.0 to 1.0)	Impacts (if occurs)				
											$ (un-infl $)	T (mos)	D (hr)		
EXAMPLE (showing both mean values and mean-value ratings) Note: [1]Considers extended OHs and escalation, and values of schedule and disruption. [2]Residual value = unmitigated value * (1 – effectiveness)															
1	RU1. Landowners unwilling to sell US 555-SHIII junction	Avoid Mitigate Transfer Accept	RU1(1). The team will design around areas where right of way may be an issue.	$0.1		1.0		0		1.0	NA	NA	NA	$0.2	✓
		Avoid Mitigate Transfer Accept													

- Determine cost-effectiveness of each action

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A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

This information will eventually be input into an MS Excel workbook template developed for this course (provided on CD and presented in Module 12) – in fact, the template is designed to be filled in directly (on the fly) during the workshop, bypassing the paper form.

- From previous forms, list the risks in rank order.
- Inputs include:
  - *Type of mitigation (from drop down box)*
  - *Short descriptive title*
  - *Implementation consequences (values or ratings, although template uses values only)*
    - *Mean implementation cost (unescalated) and affected activity*
    - *Mean schedule impact and affected activity*
    - *Mean disruption impact and affected activity*
  - *Effectiveness (%) in reducing risk factors*
    - *Probability of occurrence*
    - *Cost impact of occurrence*
    - *Schedule impact of occurrence*
    - *Disruption impact of occurrence*

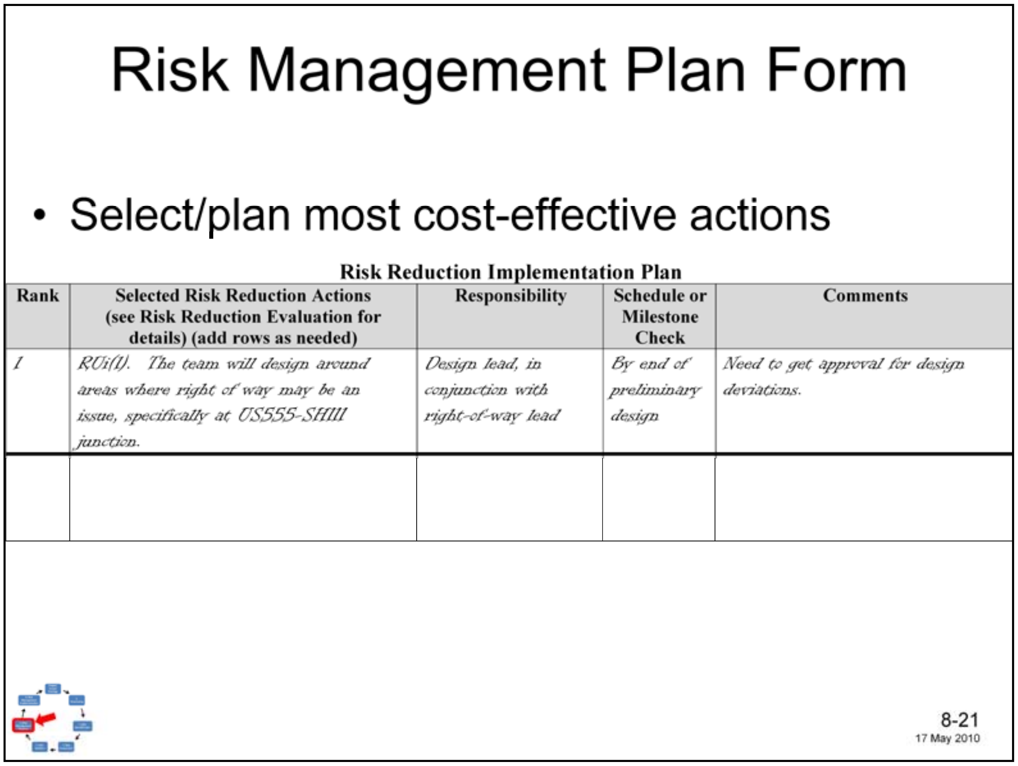
Note: *0% effectiveness = no change in risk factor*

100% effectiveness = risk factor goes to zero.

For opportunities, -100% effectiveness = probability increase to 1.0 or impact increase by 100% (impact changes can exceed 100%)

Note: The template for this course does the following:

- Risk rankings are generated automatically from Risk Assessment sheet and are carried over to Risk Reduction Identification and Evaluation sheet – default risk management of no action is automatically considered for each risk (a check list of possible actions for each type of risk is provided in App D.3 of the *Guide*).
- The reduction in risk severity, as well as the cost-effectiveness (in terms of a ratio or net difference), for each identified risk management action is computed automatically.



Risk Management Plan Form

- Select/plan most cost-effective actions

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	*RUi(1). The team will design around areas where right of way may be an issue, specifically at US555-SH111 junction.*	*Design lead, in conjunction with right-of-way lead*	*By end of preliminary design*	*Need to get approval for design deviations.*

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A hard copy of this form is presented in Appendix E of the Guide, and the MS Word file is contained on the CD.

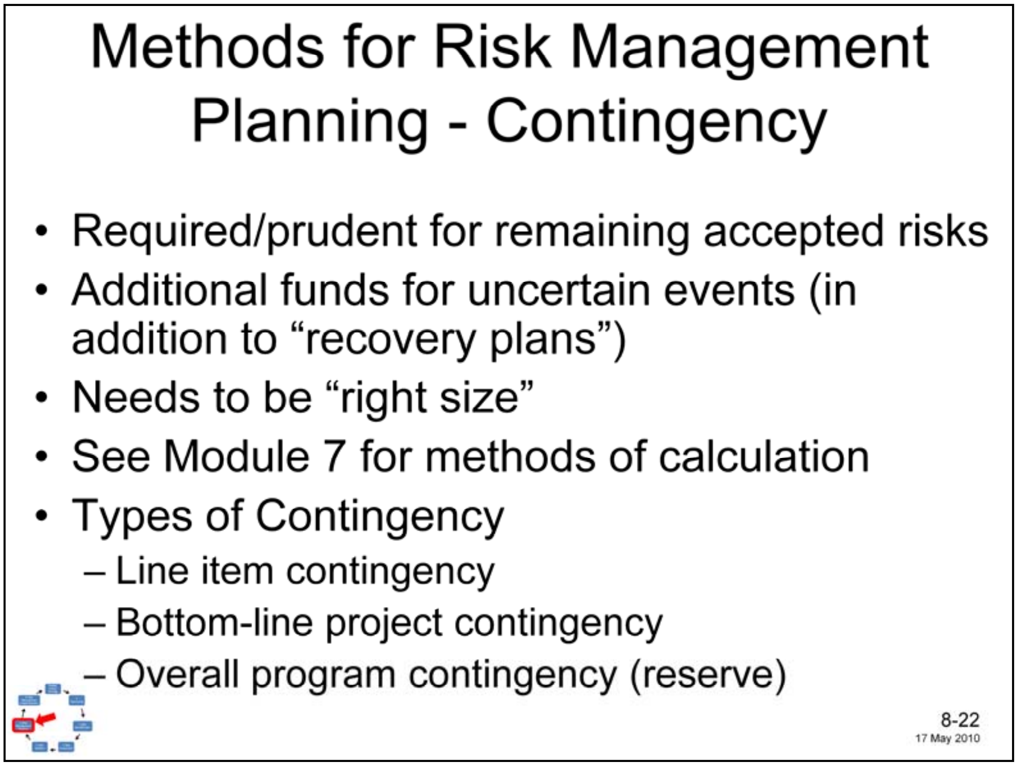
This information will eventually be input into an MS Excel workbook template developed for this course (provided on CD and presented in Module 12) – in fact, the template is designed to be filled in directly (on the fly) during the workshop, bypassing the paper form.

Once the cost-effectiveness of each possible action has been determined (based on the assessments in the previous form), select the most cost-effective risk management action for each significant risk. These are then translated to the Risk Management Plan form, which also requires input of:

- Who’s responsible for action
- The schedule for implementing the action
- The current status / progress of that action (update)

This set of selected actions constitutes part of the Risk Management Plan.

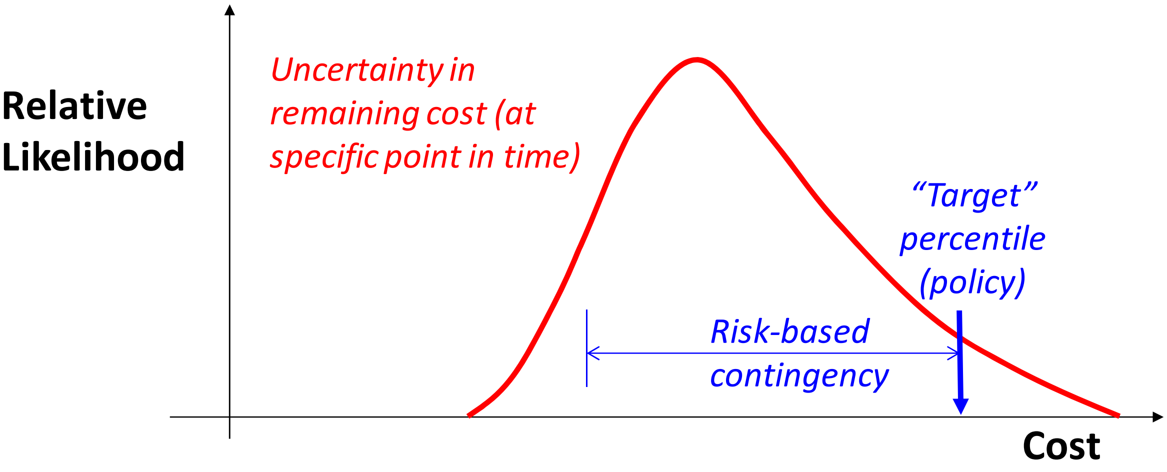
Note: The risk reduction and residual risks, if this Risk Management Plan is implemented, are computed automatically by the course template.

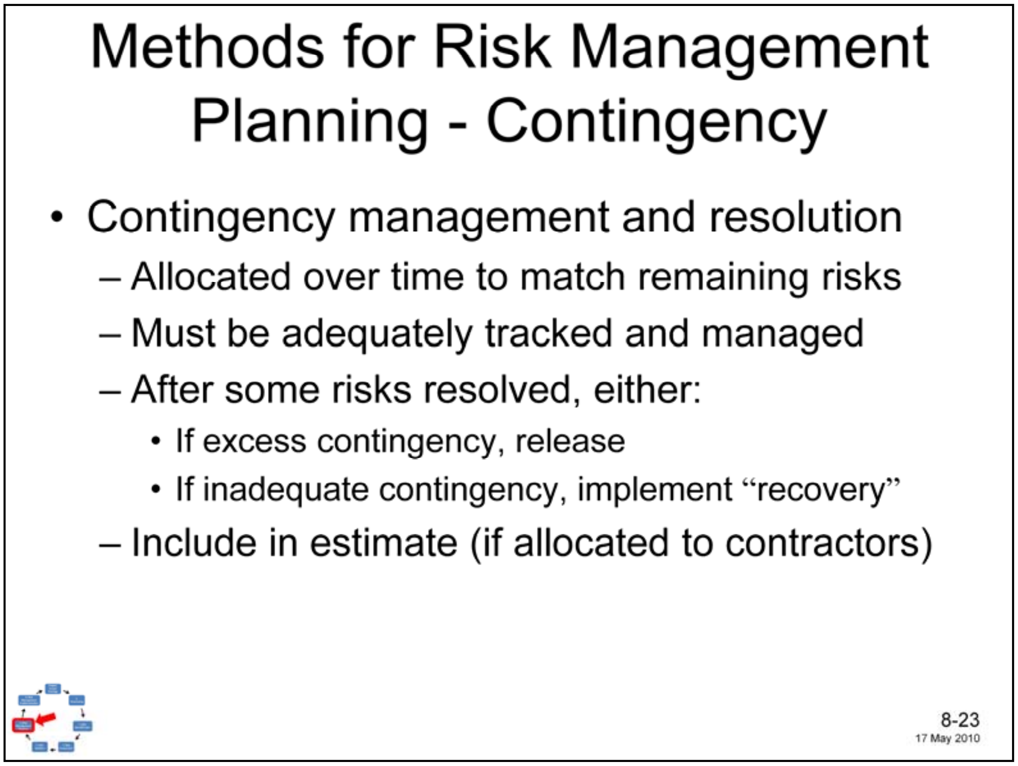


Methods for Risk Management Planning - Contingency

- Required/prudent for remaining accepted risks
- Additional funds for uncertain events (in addition to “recovery plans”)
- Needs to be “right size”
- See Module 7 for methods of calculation
- Types of Contingency
  - Line item contingency
  - Bottom-line project contingency
  - Overall program contingency (reserve)

- Contingency is used to cover remaining risks and other uncertainties, and is comprised of:
  - Available additional funds
  - Contingency (“recovery”) plans (triggered)
    - Scope reduction / deferral
    - Obtain additional funds
    - Accelerate schedule
- Needs to be
  - Adequate to provide appropriate confidence in meeting project budget and milestones, but
  - Not too large (which would obligate funds that could otherwise be used for other projects and could encourage higher project costs)
- Best determined through quantitative risk assessment, (Module 7) from which the DOT can make a policy decision as to which level of confidence they want to budget for (see below). The remaining costs or time (including remaining risks) from various points in project development can be analyzed to determine contingency drawdown requirements.





Methods for Risk Management Planning - Contingency

- Contingency management and resolution
  - Allocated over time to match remaining risks
  - Must be adequately tracked and managed
  - After some risks resolved, either:
    - If excess contingency, release
    - If inadequate contingency, implement “recovery”
  - Include in estimate (if allocated to contractors)

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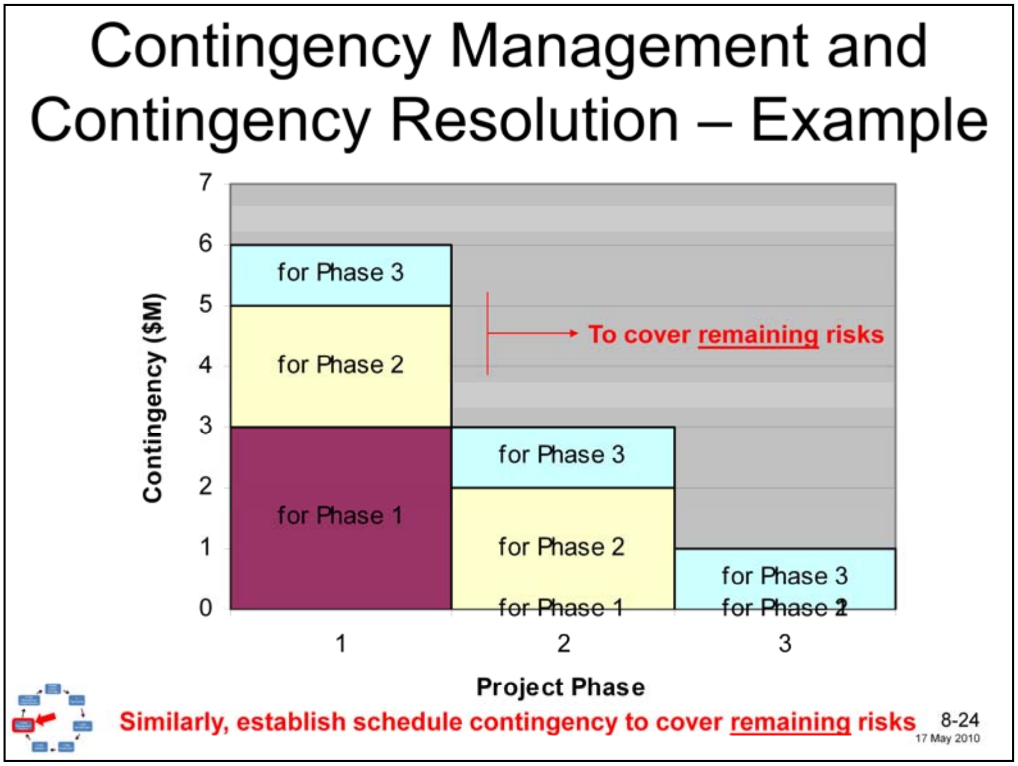
- Contingency is allocated over time to match the exposure to the remaining underlying risks
- Need system for tracking and managing the contingency funds in same way as other budget items to keep unnecessary costs down. For example, might manage to a very low budget, with some contingency relatively easily available as needed and the rest much more difficult to get access to.
- Once risk is resolved, remaining contingency (if any) for that item is removed to avoid the temptation of spending it elsewhere, or, if contingency is inadequate, implement recovery plan
- Allocation of risk to contractors costs money (they will include in their bid, often assuming risk will occur)



Contingency Management and Contingency Resolution – Example

Similarly, establish schedule contingency to cover remaining risks

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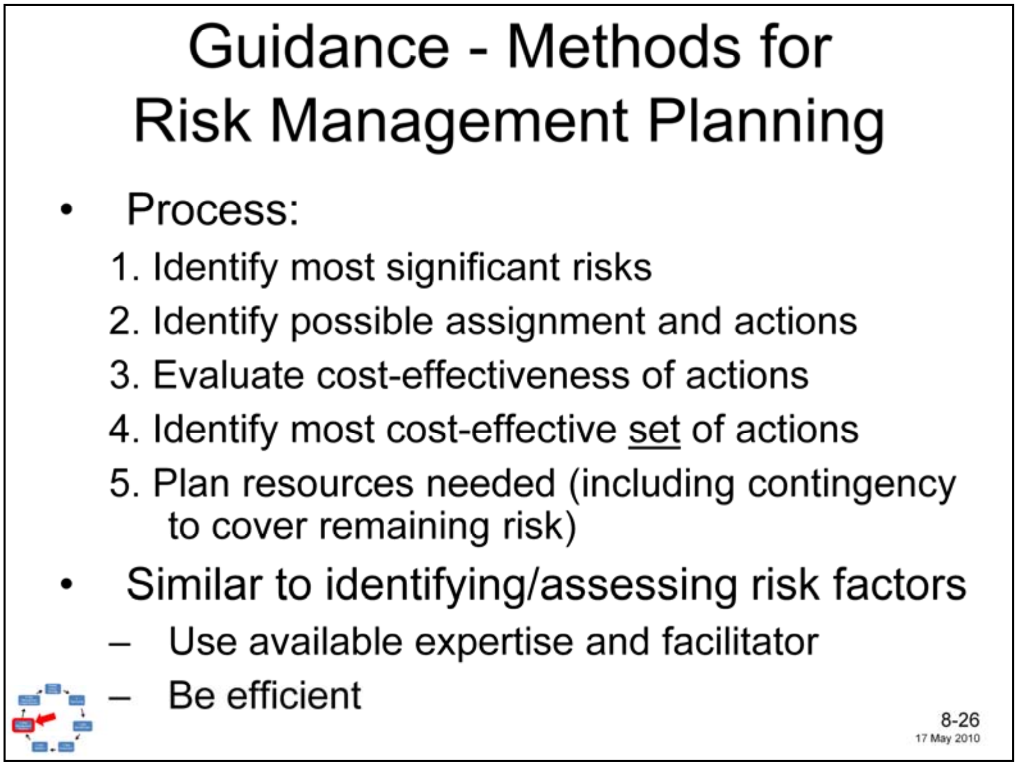
The contingency for the last phase is determined. The contingency for the next to the last phase can be determined as the difference between the total contingency needed to complete minus the contingency needed for the last phase. And so on.

Risk Management Planning

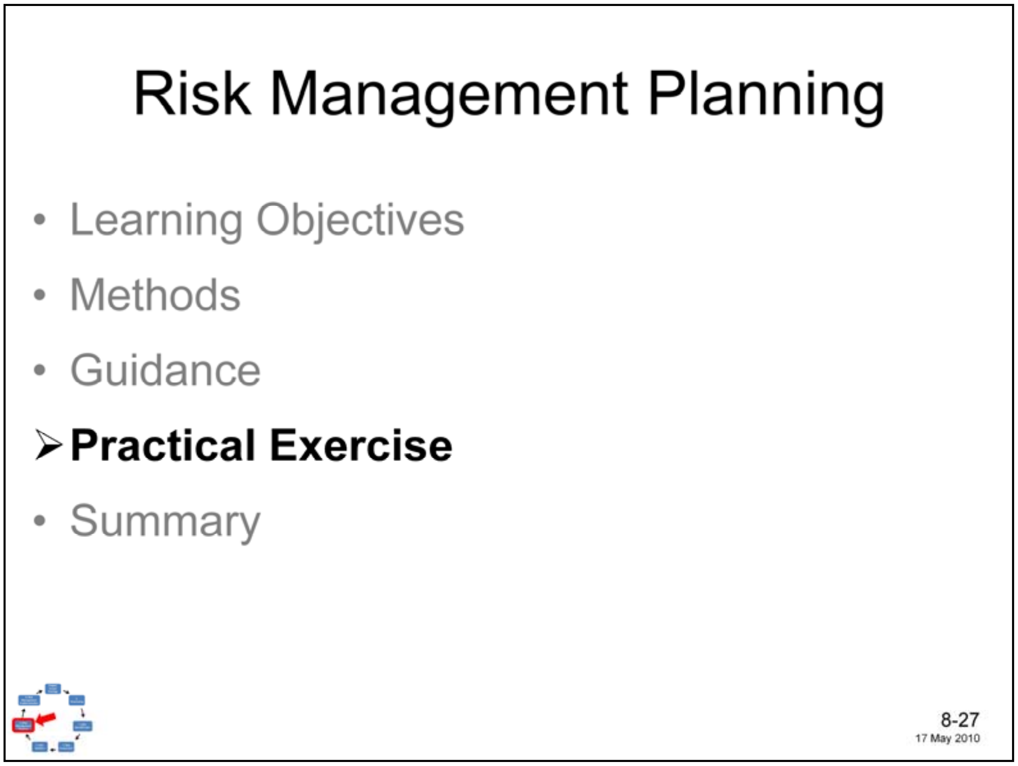
- Learning Objectives
- Methods
- **Guidance**
- Practical Exercise
- Summary



Guidance - Methods for Risk Management Planning

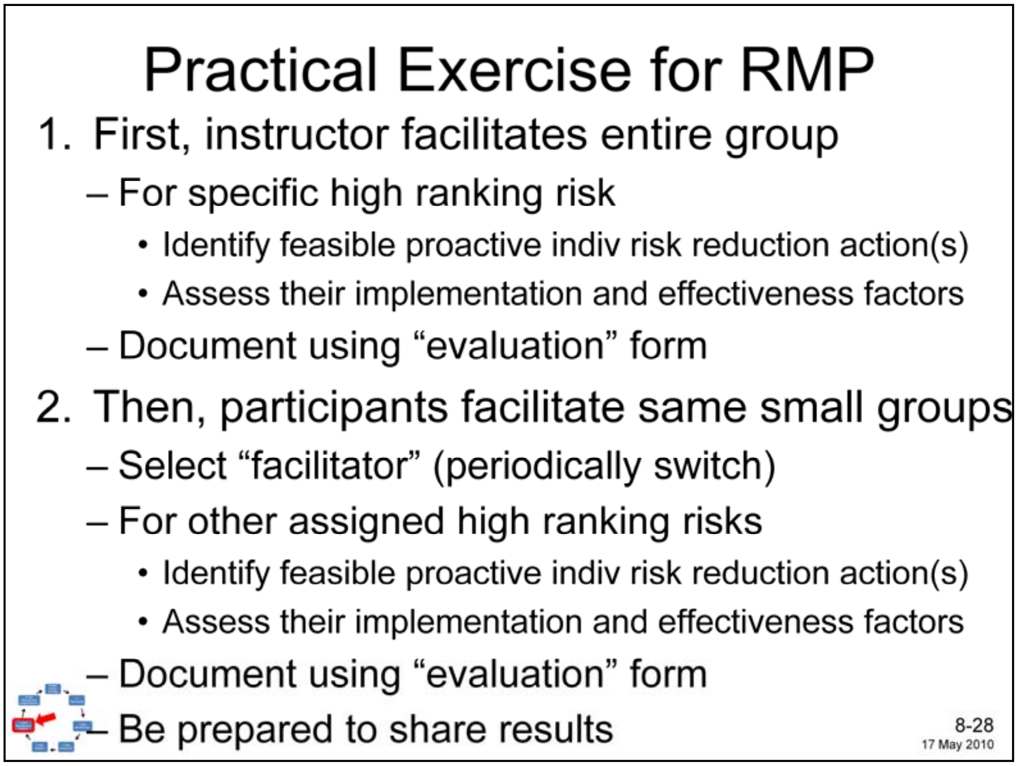
- Process:
  1. Identify most significant risks
  2. Identify possible assignment and actions
  3. Evaluate cost-effectiveness of actions
  4. Identify most cost-effective set of actions
  5. Plan resources needed (including contingency to cover remaining risk)
- Similar to identifying/assessing risk factors
  - Use available expertise and facilitator
  - Be efficient

The process is as previously discussed.. The identification of actions, and the subsequent assessment of their cost-effectiveness factors, is done in a very similar was as the identification of risks (Module 5) and assessment of their factors (Module 6). Also, similar tot eh evaluation of risk severity (Module 6), the course template (Module 12) facilitates evaluations of possible risk reduction actions, in terms of their cost-effectiveness, and determines the residual project risk if a particular risk management program is adopted.



Risk Management Planning

- Learning Objectives
- Methods
- Guidance
- ➢ **Practical Exercise**
- Summary



Practical Exercise for RMP

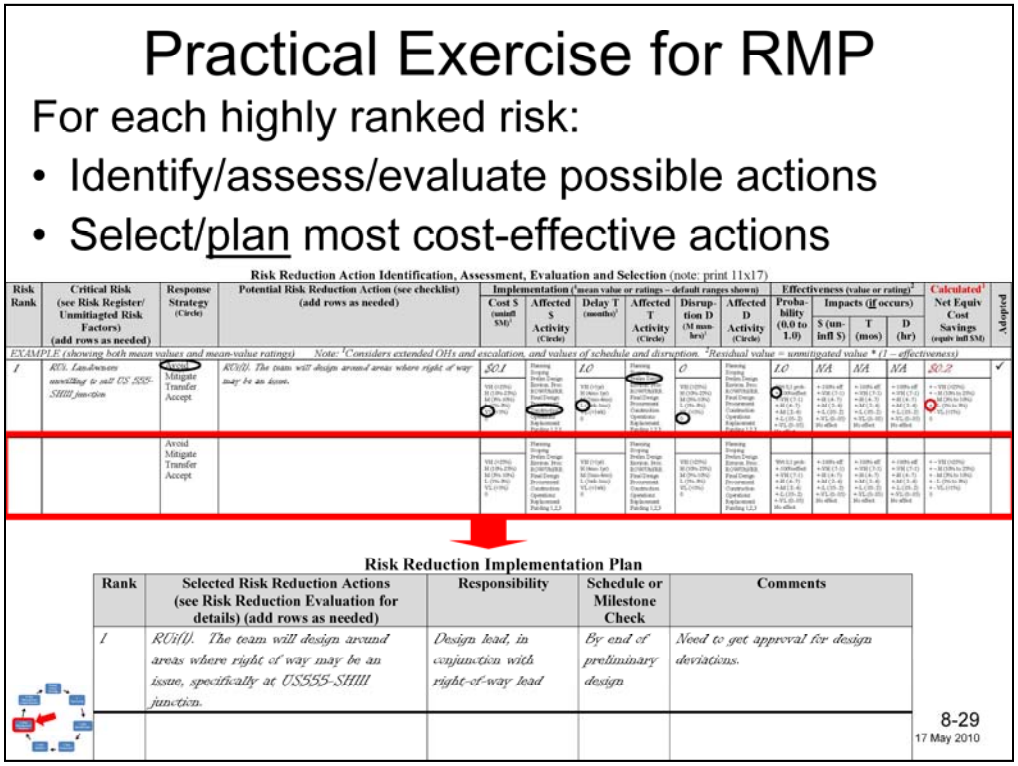
1. First, instructor facilitates entire group
   - For specific high ranking risk
     - Identify feasible proactive indiv risk reduction action(s)
     - Assess their implementation and effectiveness factors
   - Document using “evaluation” form
2. Then, participants facilitate same small groups
   - Select “facilitator” (periodically switch)
   - For other assigned high ranking risks
     - Identify feasible proactive indiv risk reduction action(s)
     - Assess their implementation and effectiveness factors
   - Document using “evaluation” form
   - Be prepared to share results

Regarding the hypothetical rapid renewal project presented in Appendix F of the *Guide*, which was described in Module 3, structured in Module 4 and for which risks were identified in Module 5 and assessed in Module 6, QDOT followed the principles and process outlined in Chapter 8 of the *Guide* to identify and plan specific risk-management actions to address the key risks to its project objectives (as identified through risk assessment and subsequently risk analysis). QDOT focused on identifying cost-effective actions, for the highest-rated (i.e., highest-priority) risks first. QDOT also considered synergy between multiple risk-management actions as appropriate.

Several of the rapid-renewal risks rated high on the list of mean-value risks and were eventually targeted for improvement through risk management. The complete project Risk Management Plan consisted of: 1) proactive risk-reduction plans, 2) contingency-management actions per QDOT procedure (by project phase), and 3) recovery plans (by project phase). The complete *Risk Management Plan* for this hypothetical rapid renewal project is presented in Appendix F of the *Guide*.

For each of the high ranking risks, the following was done: a) possible proactive risk-management actions were identified; b) the estimated mean cost, schedule and/or disruption (by activity) to implement each action was assessed; c) the anticipated mean effectiveness of each action in reducing each risk factor was assessed; and d) the overall cost-effectiveness (in terms of reduction in “severity”) for each action was calculated (using the template). Cost-effective actions were then selected, and responsibility for implementing those actions, and follow-up criteria, were established. Note that risk management actions were also planned for other high-priority, non-rapid-renewal risks in the risk register.

As noted previously, QDOT ultimately performed a full probabilistic evaluation of project cost and schedule. After the risk-management planning effort, QDOT updated this probabilistic risk analysis to account for the proactive risk-reduction plans and therefore better quantify the benefits of the planned actions on project cost and schedule. Using these “mitigated” probability distributions for inflated cost and schedule, QDOT determined the cost and schedule corresponding to its “target” project reliability (e.g., 80th percentile), then compared these values to the corresponding “base” cost and schedule (without risk), and therefore established its equivalent cost and schedule contingencies.



Practical Exercise for RMP

For each highly ranked risk:

- Identify/assess/evaluate possible actions
- Select/plan most cost-effective actions

Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)	Response Strategy (Circle)	Potential Risk Reduction Action (see checklist) (add rows as needed)	Implementation (¹mean value or ratings – default ranges shown)						Effectiveness (value or rating)²				Calculated¹	Adopted
				Cost $ (uninfl $M)¹	Affected $ Activity (Circle)	Delay T (months)¹	Affected T Activity (Circle)	Disruption D (M man-hrs)¹	Affected D Activity (Circle)	Probability (0.0 to 1.0)	Impacts (if occurs) $ (un-infl $)	T (mos)	D (hr)	Net Equiv Cost Savings (equiv infl $M)	
EXAMPLE (showing both mean values and mean-value ratings) Note: ¹Considers extended OHs and escalation, and values of schedule and disruption. ²Residual value = unmitigated value * (1 – effectiveness)															
1	RUi. Landowners unwilling to sell US 555-SHIII junction	[✓ Avoid] Mitigate Transfer Accept	RUi(I). The team will design around areas where right of way may be an issue.	$0.1		1.0		0		1.0	NA	NA	NA	$0.2	✓
		Avoid Mitigate Transfer Accept													

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	RUi(I). The team will design around areas where right of way may be an issue, specifically at US555-SHIII junction.	Design lead, in conjunction with right-of-way lead	By end of preliminary design	Need to get approval for design deviations.

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Regarding the hypothetical rapid renewal project presented in Appendix F of the *Guide*, which was described in Module 3, structured in Module 4 and for which risks were identified in Module 5 and assessed in Module 6, fill in *Risk Reduction Identification and Evaluation* form and *Risk Management* form for hypothetical project. A blank copy of this form is at the end of this module.

For each high ranking risk, input

- *Type of mitigation (select one)*
- *Short descriptive title*
- *Implementation consequences (values only)*
  - *Mean implementation cost (unescalated) and affected activity*
  - *Mean schedule impact and affected activity*
  - *Mean disruption impact and affected activity*
- *Effectiveness (%) in reducing risk factors*
  - *Probability of occurrence*
  - *Cost impact of occurrence*
  - *Schedule impact of occurrence*
  - *Disruption impact of occurrence*

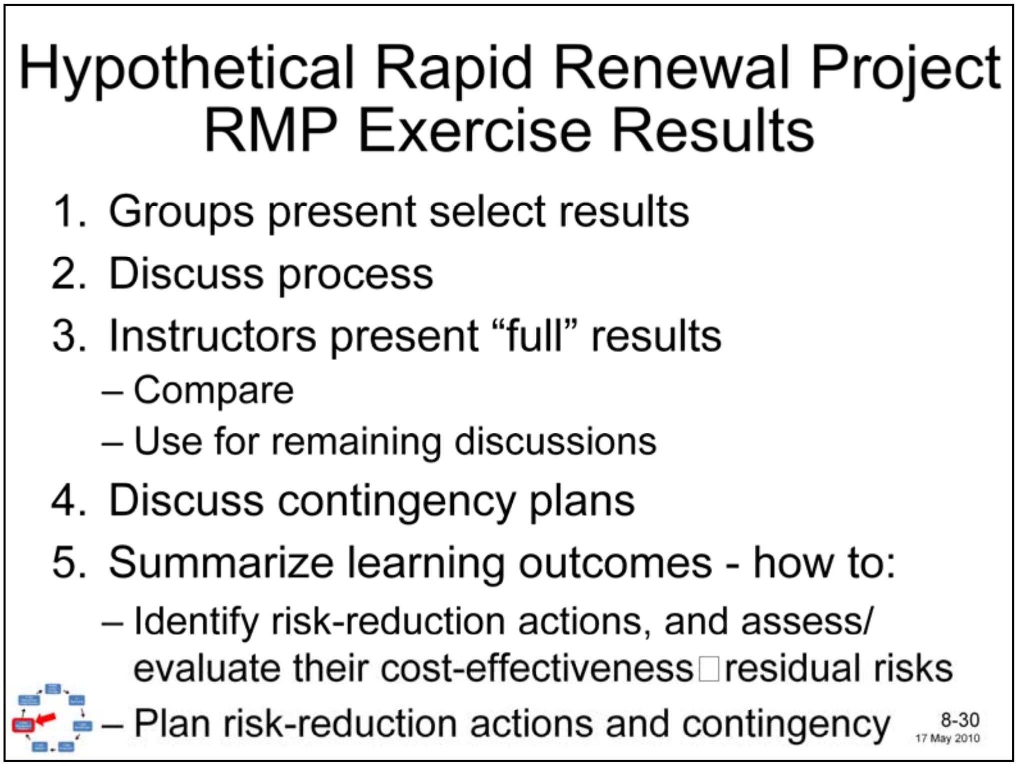
Note: *0% effectiveness = no change in risk factor*

100% effectiveness = risk factor goes to zero.

For opportunities, -100% effectiveness = probability increase to 1.0 or impact increase by 100% (impact changes can exceed 100%)

- Evaluation: approximately in terms of the reduction in mean severity, as well as the cost-effectiveness (in terms of a ratio or net difference), for each identified risk management action. This is done automatically in the MS Excel workbook template developed for this course.
- Select the most cost-effective risk management action for each significant risk. These are translated to the Risk Management Plan, which also requires input of:
  - Who's responsible for action
  - The schedule for implementing the action
  - The current status / progress of that action (update)

This set of selected actions constitutes one part of the *Risk Management Plan*. The other part relates to contingency (allowances and recovery plans) to cover remaining risks.



Hypothetical Rapid Renewal Project RMP Exercise Results

1. Groups present select results
2. Discuss process
3. Instructors present “full” results
   - Compare
   - Use for remaining discussions
4. Discuss contingency plans
5. Summarize learning outcomes - how to:
   - Identify risk-reduction actions, and assess/ evaluate their cost-effectiveness□residual risks
   - Plan risk-reduction actions and contingency

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Instructors’ results will be handed out after participants’ results have been presented and discussed. These results, which will be used for remaining discussions, should be inserted in Appendix F of the *Guide* for future reference.

Risk Management Planning

- Learning Objectives
- Methods
- Guidance
- Practical Exercise

➢ **Summary**

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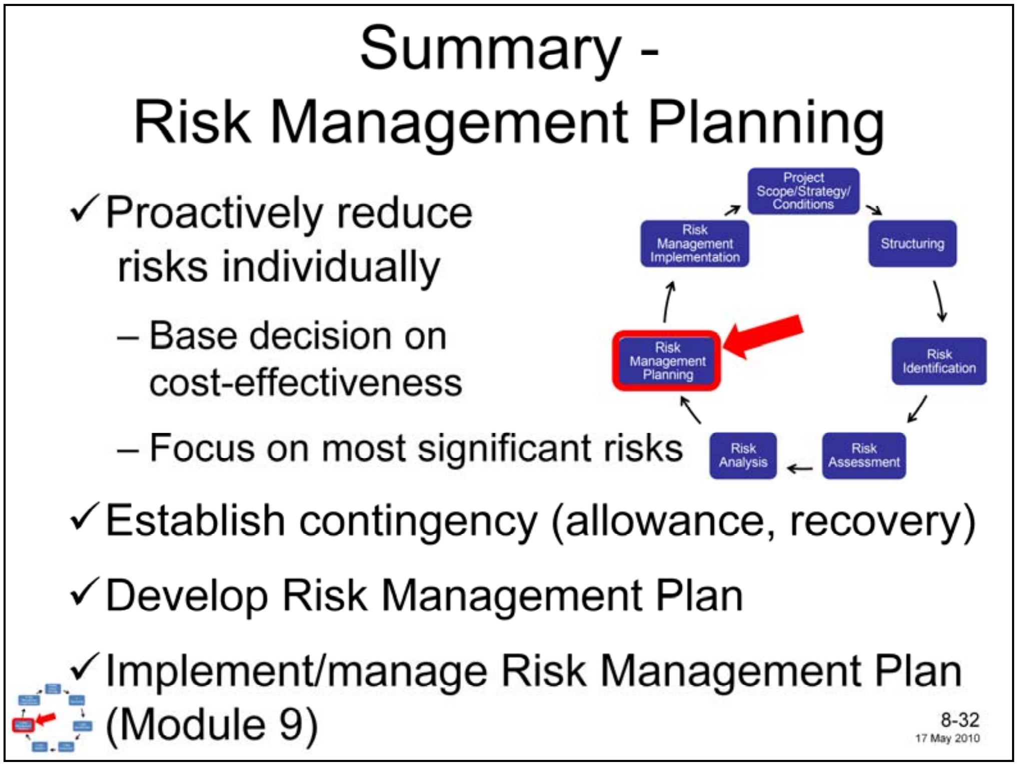

Summary - Risk Management Planning

- ✓Proactively reduce risks individually
  - – Base decision on cost-effectiveness
  - – Focus on most significant risks
- ✓Establish contingency (allowance, recovery)
- ✓Develop Risk Management Plan
- ✓Implement/manage Risk Management Plan (Module 9)

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• Many (but not all) risks can be proactively reduced in various ways by various project participants, with varying cost-effectiveness

  • Decisions on risk reduction should be based on cost-effectiveness. For example, at contract time, contractually allocate risks to the party that most cost-effectively manage them (considering their "risk transfer" price) and seek alignment with the end user's goals.

  • Focus on most significant risks, both individually and collectively (combinations)

• Develop and manage contingency to adequately cover remaining risks.

• Develop Risk Management Plan to document the process

• Develop Risk Management Program (System) to implement that plan, which in turn will involve additional resources and costs (Module 9)

Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)	Response Strategy (Circle)	Potential Risk Reduction Action (see checklist) (add rows as needed)	Implementation ([1]mean value or ratings – default ranges shown)						Effectiveness (value or rating)[2]				Calculated[1] Net Equiv Cost Savings (equiv infl $M)	Adopted
				Cost $ (uninfl $M)[1]	Affected $ Activity (Circle)	Delay T (months)[1]	Affected T Activity (Circle)	Disruption D (M man-hrs)[1]	Affected D Activity (Circle)	Probability (0.0 to 1.0)	Impacts (if occurs)				
											$ (un-infl $)	T (mos)	D (hr)		
*EXAMPLE (showing both mean values and mean-value ratings) Note: [1]Considers extended OHs and escalation, and values of schedule and disruption. [2]Residual value = unmitigated value * (1 – effectiveness)*															
1	RUi. Landowners unwilling to sell US 555-SH111 junction	[✓ Avoid] Mitigate Transfer Accept	RUi(1). The team will design around areas where right of way may be an issue.	$0.1 VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) [✓ VL] (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement [✓ Construction] Operations Replacement Funding 1,2,3	1.0 VH (>1yr) H (4mo-1yr) M (1mo-4mo) [✓ L] (1wk-1mo) VL (<1wk) 0	Planning Scoping [✓ Prelim Design] Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) [✓ 0]	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	1.0 Wrt 0,1 prob: [✓ +]-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	NA +-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	NA +-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	NA +-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	$0.2 + – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0	✓
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
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		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	

Risk Reduction Action Identification, Assessment, Evaluation and Selection (note: print 11x17)

Risk Rank	Critical Risk (see Risk Register/ Unmitiagted Risk Factors) (add rows as needed)	Response Strategy (Circle)	Potential Risk Reduction Action (see checklist) (add rows as needed)	Implementation ([1]mean value or ratings – default ranges shown)						Effectiveness (value or rating)[2]				Calculated[1] Net Equiv Cost Savings (equiv infl $M)	Adopted
				Cost $ (uninfl $M)[1]	Affected $ Activity (Circle)	Delay T (months)[1]	Affected T Activity (Circle)	Disruption D (M man-hrs)[1]	Affected D Activity (Circle)	Probability (0.0 to 1.0)	Impacts (if occurs)				
											$ (un-infl $)	T (mos)	D (hr)		
*EXAMPLE (showing both mean values and mean-value ratings) Note: [1]Considers extended OHs and escalation, and values of schedule and disruption. [2]Residual value = unmitigated value * (1 – effectiveness)*															
1	RUi. Landowners unwilling to sell US 555-SH111 junction	[✓ Avoid] Mitigate Transfer Accept	RUi(1). The team will design around areas where right of way may be an issue.	$0.1	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement [✓ Construction] Operations Replacement Funding 1,2,3	1.0	Planning Scoping [✓ Prelim Design] Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	0	Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3	1.0	NA	NA	NA	$0.2	✓
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) [✓ VL (<1%)] 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) [✓ L (1wk-1mo)] VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) [✓ 0]		Wrt 0,1 prob: [✓ +-100%effect] +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ + - L (1% to 3%)] + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	
		Avoid Mitigate Transfer Accept			Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3		Planning Scoping Prelim Design Environ. Proc. ROW/Util/RR. Final Design Procurement Construction Operations Replacement Funding 1,2,3						
				VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		VH (>1yr) H (4mo-1yr) M (1mo-4mo) L (1wk-1mo) VL (<1wk) 0		VH (>25%) H (10%-25%) M (3%-10%) L (1%-3%) VL (<1%) 0		Wrt 0,1 prob: +-100%effect +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+-100% eff +-VH (.7-1) +-H (.4-.7) +-M (.2-.4) +-L (.05-.2) +-VL (0-.05) No effect	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) 0	

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	RUi(1). The team will design around areas where right of way may be an issue, specifically at US555-SH111 junction.	Design lead, in conjunction with right-of-way lead	By end of preliminary design	Need to get approval for design deviations.

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	RUi(1). The team will design around areas where right of way may be an issue, specifically at US555-SH111 junction.	Design lead, in conjunction with right-of-way lead	By end of preliminary design	Need to get approval for design deviations.

Risk Management

Module 9:
Implementing the
Risk Management Plan

Project Scope/Strategy/ Conditions

Structuring

Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

In a Nutshell: Implementing the *Risk Management Plan*

Adequately and efficiently implementing the *Risk Management Plan:*

- Proactively reduce individual risks
- Address changing conditions (monitor and reassess existing risks, retire expired risks, identify new risks)
- Establish, track, and control contingency
- Decide on “recovery” (if needed)

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17 May 2010

The *Risk Management Plan* must be successfully implemented to affect project performance.

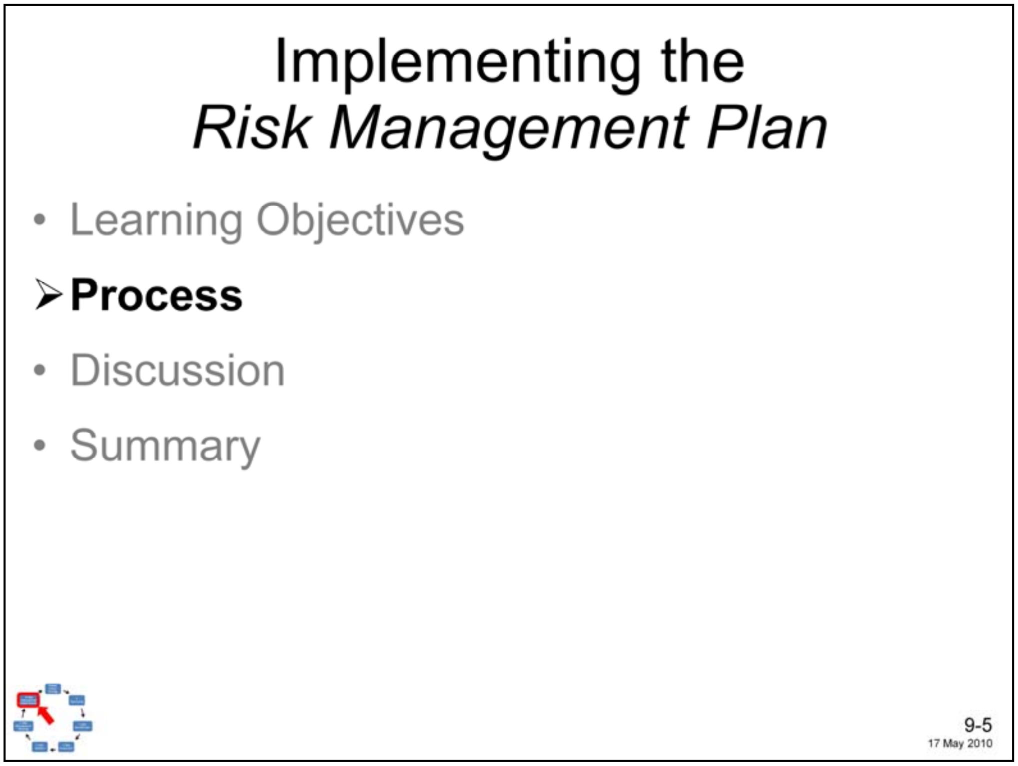
Implementing the *Risk Management Plan*

- Learning Objectives
- Process
- Discussion
- Summary

Learning Objectives for Implementing Risk Management Plan

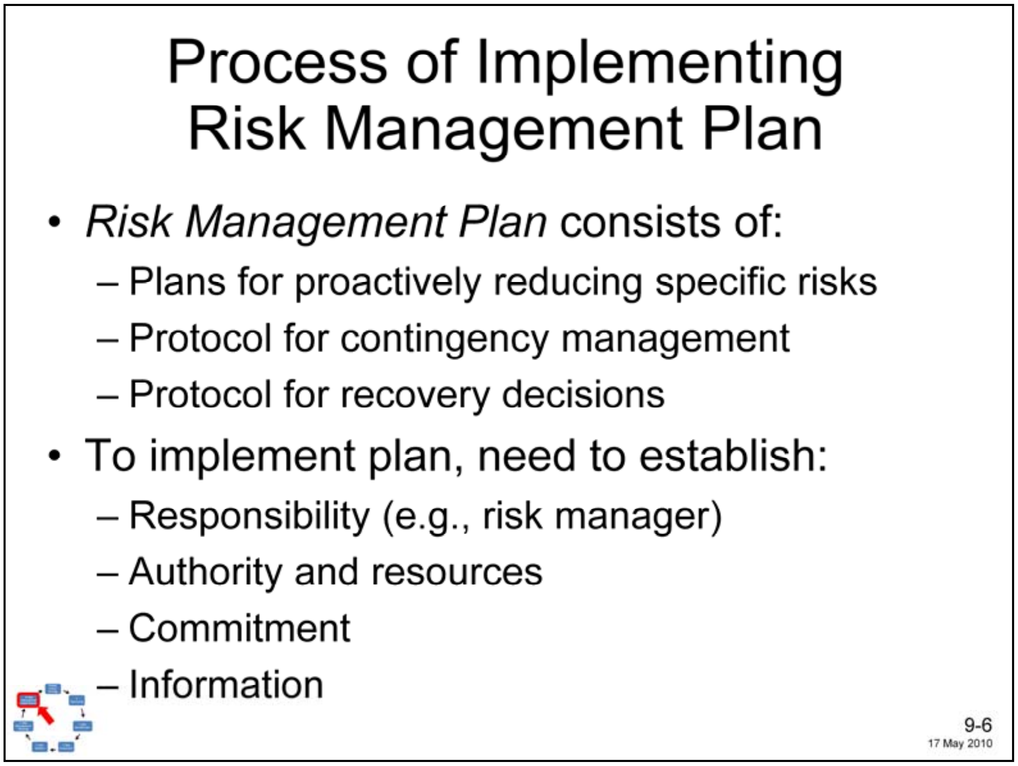
How to:

- ✓Optimize project performance
- ✓Implement Risk Management Plan
- ✓Accommodate changing project conditions
- ✓Actively manage contingencies
- ✓Implement adequately but efficiently



Implementing the *Risk Management Plan*

- Learning Objectives
- **Process**
- Discussion
- Summary

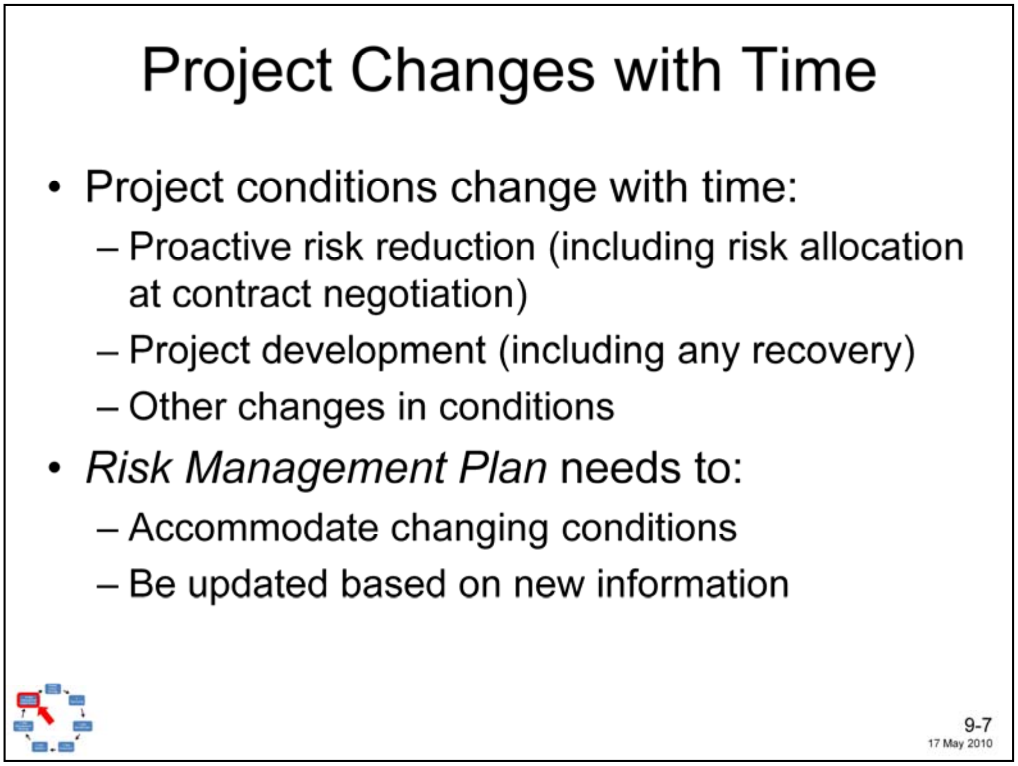


Process of Implementing Risk Management Plan

- *Risk Management Plan* consists of:
  - – Plans for proactively reducing specific risks
  - – Protocol for contingency management
  - – Protocol for recovery decisions
- To implement plan, need to establish:
  - – Responsibility (e.g., risk manager)
  - – Authority and resources
  - – Commitment
  - – Information

Successful implementation requires the following (at a minimum):

- Responsibility – assignment of a risk manager and “owners” of significant individual risks;
- Commitment – the organization has to commit to the plan;
- Resources – adequate resources (funding and staff) have to be provided to carry out the plan;
- Authority– specific individuals have to be given adequate authority, as well as resources, for carrying out their assigned plan responsibilities; and
- Information – relevant information must be gathered and distributed in timely fashion.



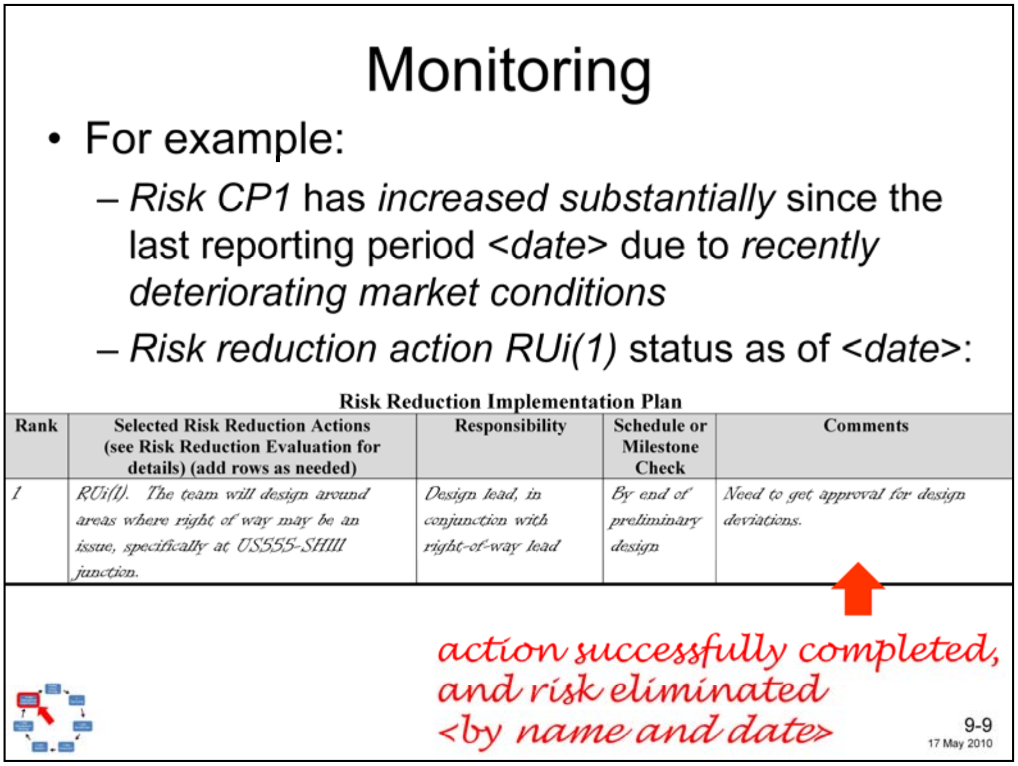
Project Changes with Time

- Project conditions change with time:
  - Proactive risk reduction (including risk allocation at contract negotiation)
  - Project development (including any recovery)
  - Other changes in conditions
- *Risk Management Plan* needs to:
  - Accommodate changing conditions
  - Be updated based on new information

A unique feature of the *Risk Management Plan*, unlike most plans, is that it is actually an evolving document, with the expectation that it will be adjusted to reflect changes in the project as that project develops. This means that those project actions and conditions must be monitored, and the plan periodically updated to reflect observed changes.

Monitoring

- Monitor (distinct from update) changing project conditions:
  - – Project development status
  - – Risk reduction action status and results
  - – Existing risks
  - – Contingency and recovery plans
- Monitor periodically, at secondary milestones, and at moderate project changes
- Adequately document (e.g., in memo or in risk register)



Monitoring

- For example:
  - *Risk CP1* has *increased substantially* since the last reporting period <*date*> due to *recently deteriorating market conditions*
  - *Risk reduction action RUi(1)* status as of <*date*>:

Risk Reduction Implementation Plan

Rank	Selected Risk Reduction Actions (see Risk Reduction Evaluation for details) (add rows as needed)	Responsibility	Schedule or Milestone Check	Comments
1	*RUi(1). The team will design around areas where right of way may be an issue, specifically at US555-SHIII junction.*	*Design lead, in conjunction with right-of-way lead*	*By end of preliminary design*	*Need to get approval for design deviations.*

action successfully completed,
and risk eliminated
<by name and date>

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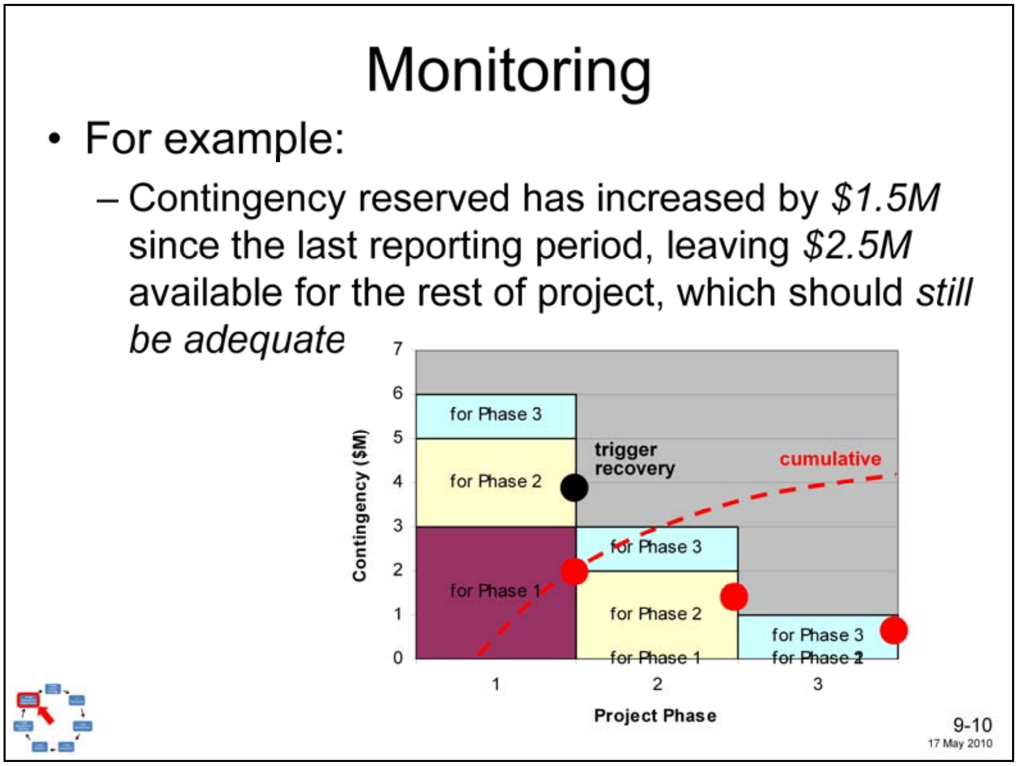
In this example, the project team has determined that it will be more cost effective to design around an area with a significant right-of-way risk. The management actions provide an estimate of the resources, an estimate of the risk reduction, and a person who is responsible for verifying that the risk plan has been implemented by a key milestone. Status updates can then be documented on this form.



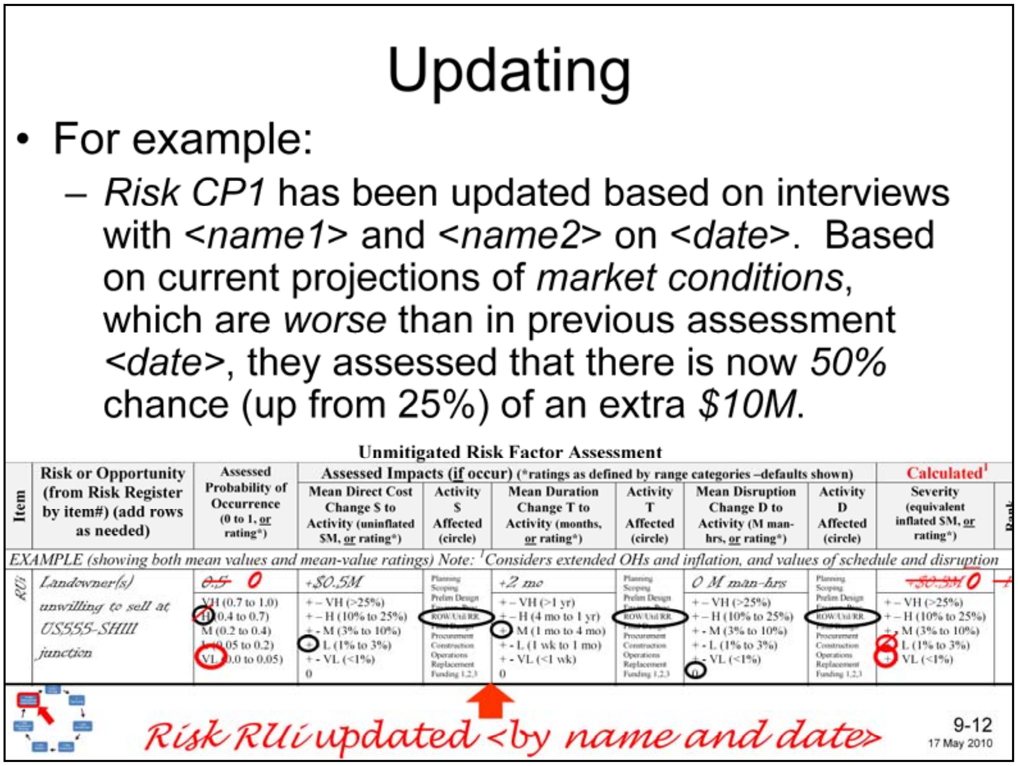
Monitoring

- For example:
  - Contingency reserved has increased by *$1.5M* since the last reporting period, leaving *$2.5M* available for the rest of project, which should *still be adequate*

Contingencies are typically allocated to, and tracked by, the different phases of the project. For the case shown in red in this example, the contingency actually spent in each phase (and thus cumulatively) was less than that budgeted – after each phase, unused contingency could be released. For the case shown in black, the contingency spent in the first phase was higher than that budgeted for that phase, which triggers recovery. DOTs typically have established protocols for approving and tracking contingency expenditure and releases, with approvals generally required at higher organizational levels as the amounts increase.

Updating

- Update (reassess and reanalyze, if needed):
  - Base
  - Risks (update/retire existing risks, add new risks)
  - Contingency and recovery plan requirements
- Update periodically at primary milestones and at major project changes (e.g., indicated by monitoring)
- Adequately document (in risk register and in *Risk Management Plan*)



Updating

- For example:
  - *Risk CP1* has been updated based on interviews with <*name1*> and <*name2*> on <*date*>. Based on current projections of *market conditions*, which are *worse* than in previous assessment <*date*>, they assessed that there is now *50%* chance (up from 25%) of an extra *$10M*.

Unmitigated Risk Factor Assessment

Item	Risk or Opportunity (from Risk Register by item#) (add rows as needed)	Assessed Probability of Occurrence (0 to 1, or rating*)	Assessed Impacts (if occur) (*ratings as defined by range categories –defaults shown)						Calculated[1]	
			Mean Direct Cost Change $ to Activity (uninflated $M, or rating*)	Activity $ Affected (circle)	Mean Duration Change T to Activity (months, or rating*)	Activity T Affected (circle)	Mean Disruption Change D to Activity (M man-hrs, or rating*)	Activity D Affected (circle)	Severity (equivalent inflated $M, or rating*)	Rank
EXAMPLE (showing both mean values and mean-value ratings) Note: [1]Considers extended OHs and inflation, and values of schedule and disruption										
RUi	*Landowner(s) unwilling to sell at US555-SHIII junction*	~~0.5~~ 0	+$0.5M	Planning Scoping Prelim Design [illegible] [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	+2 mo	Planning Scoping Prelim Design [illegible] [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	0 M man-hrs	Planning Scoping Prelim Design [illegible] [✓ ROW/Util/RR] Final Design Procurement Construction Operations Replacement Funding 1,2,3	~~+$0.3M~~ 0	
		VH (0.7 to 1.0) ~~[✓ H]~~ (0.4 to 0.7) M (0.2 to 0.4) L (0.05 to 0.2) [✓ VL] (0.0 to 0.05)	+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) [✓ +] - L (1% to 3%) + - VL (<1%) 0		+ – VH (>1 yr) + – H (4 mo to 1 yr) [✓ +] - M (1 mo to 4 mo) + - L (1 wk to 1 mo) + - VL (<1 wk) 0		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) + - L (1% to 3%) + - VL (<1%) [✓ 0]		+ – VH (>25%) + – H (10% to 25%) + - M (3% to 10%) ~~[✓ +]~~ - L (1% to 3%) [✓ +] - VL (<1%)	

Risk RUi updated <by name and date>

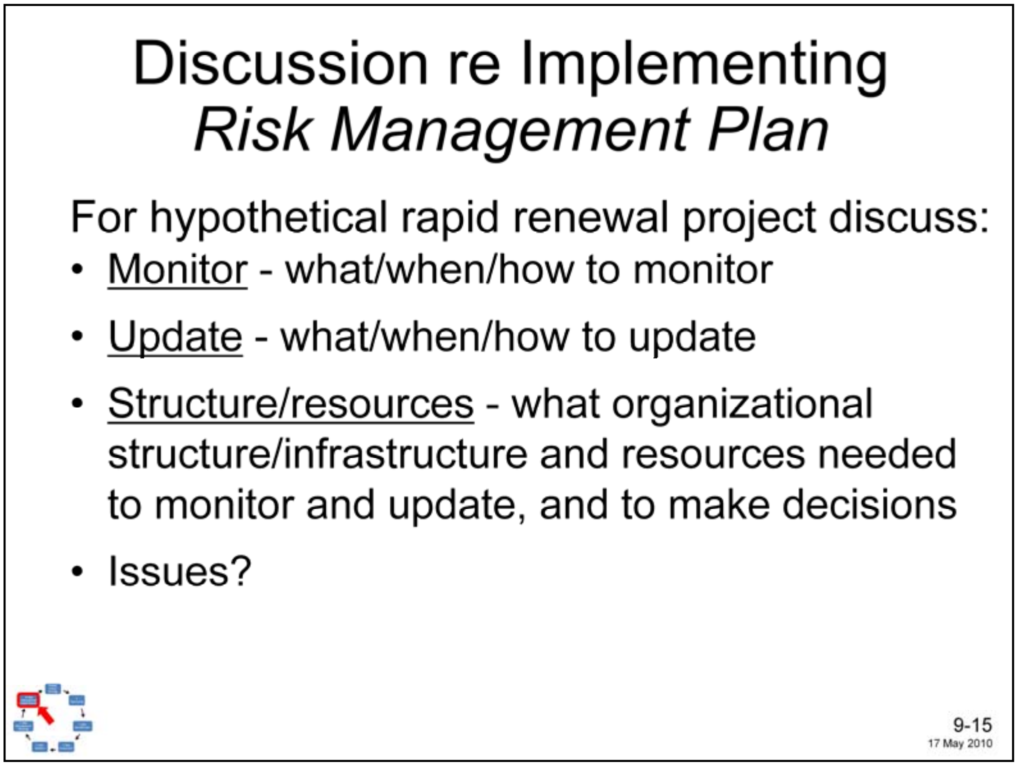
This example, which is related to the previous example, shows a case where there was a risk of a landowner being unwilling to sell a parcel needed to construct a project. When it was first identified, there was a high probability (50%) that the owner would not be willing sell and the impact of this risk was $500,000 and 2-month delay, with an "expected value" of about $300,000 (including increased escalation and extended OHs) and 1 month (critical path). As seen in the previous example, the management action was successfully taken to avoid this risk by designing around the parcel, at a cost of about $100,000 ($150,000 including increased escalation and extended OHs) and 1 month delay. The resulting reduction in risk meant that about $300,000 and 1 month less contingency was required; however, the resulting cost ($150,000) and delay (1 month) of the mitigation effort had to be added to the base cost and schedule. Based on such updates of the various inputs, the contingency requirements (and recovery requirements) could be recalculated.

Updating

- For example:
  - Contingency required for the remainder of the project was reanalyzed on <*date*>, based on updated inputs. The contingency required is now *$5M*, which is *$2M less* than previously <*date*> - *$1M* of that *$2M* has been reserved, leaving *$1M* excess. This *excess* contingency *can be released*.

Implementing the *Risk Management Plan*

- Learning Objectives
- Process
- ➢ **Discussion**
- Summary



Discussion re Implementing *Risk Management Plan*

For hypothetical rapid renewal project discuss:

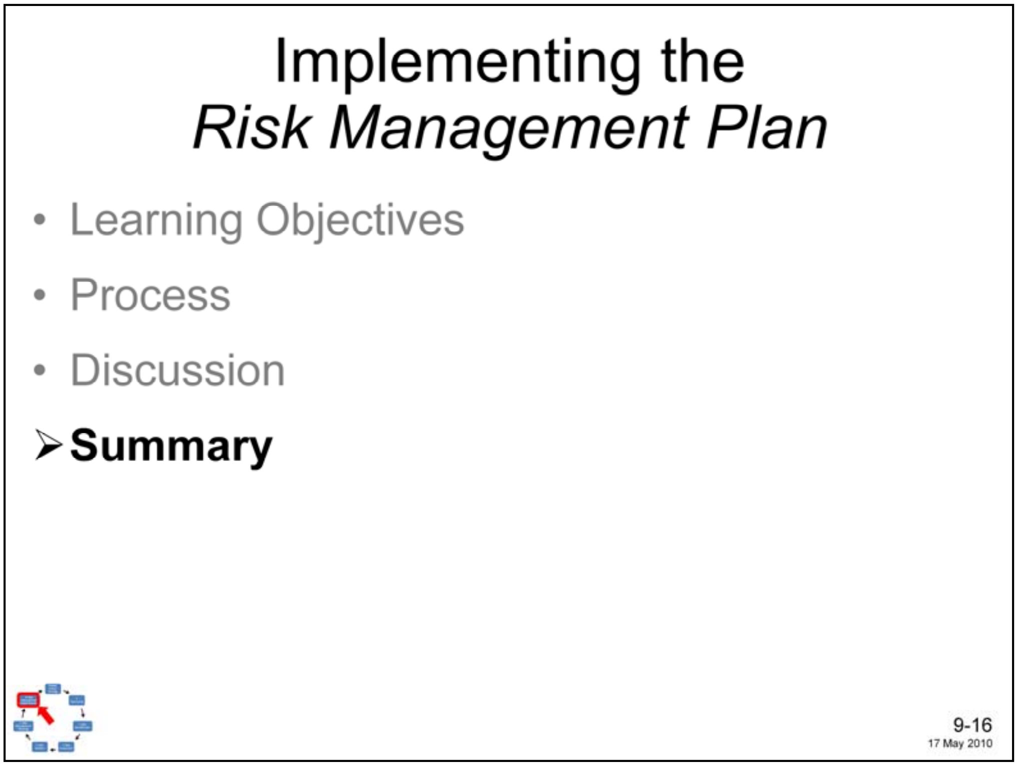
- Monitor - what/when/how to monitor
- Update - what/when/how to update
- Structure/resources - what organizational structure/infrastructure and resources needed to monitor and update, and to make decisions
- Issues?

9-15
17 May 2010

The Risk Management Plan for the hypothetical rapid renewal project is contained in Appendix F of the *Guide*. It must be successfully implemented to improve project performance.

After QDOT developed the *Risk Management Plan*, the project's Risk Manager successfully implemented that plan, including:

- Proactively and cost-effectively reducing individual risks that were within QDOT's control, including monitoring and updating the risks and the plan as time progressed;
- Monitoring and controlling contingency expenditure (to cover actual risk occurrences as needed) and releasing excess contingency; and
- Implementing recovery plans as needed when remaining contingency was not sufficient.



Implementing the *Risk Management Plan*

- Learning Objectives
- Process
- Discussion

➢ **Summary**

Summary - Implementing the *Risk Management Plan*

Successful implementation of the *Risk Management Plan*:

- ✓ Optimizes project performance
- ✓ Involves monitoring and periodic updating of
  - Status of proactive risk reduction activities
  - Residual risks
  - Contingency
- ✓ Requires adequate resources
  - Responsibility/authority
  - Commitment/resources
  - Information
- ✓ Is efficient

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Risk Management

Module 10:
Implementing this *Guide*

Project Scope/Strategy/ Conditions

Structuring

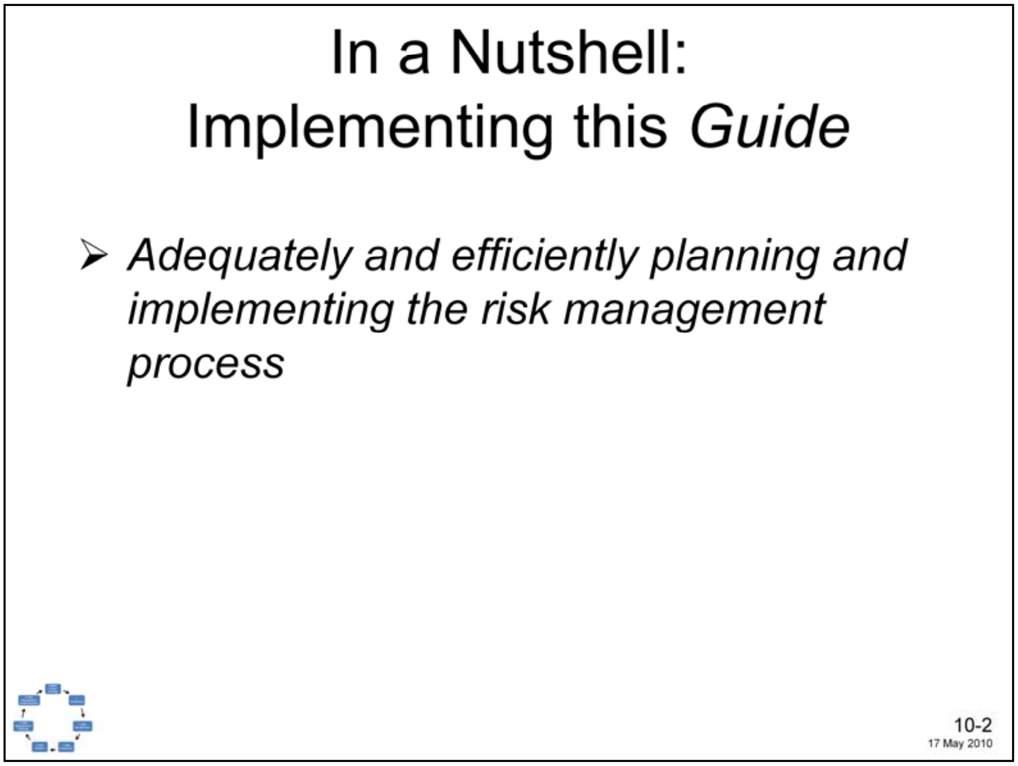
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



In a Nutshell: Implementing this *Guide*

- *Adequately and efficiently planning and implementing the risk management process*

17 May 2010

Adequate planning, appropriate resources, careful coordination, and integration into continuous project management processes are keys to successful risk management implementation. Initiate the risk management process early in the project's life cycle, and then update as appropriate. Engage the appropriate participants and provide them with relevant information for each of the risk management process steps. Ultimately, adequately plan and resource the meetings, workshops, and project management staff throughout the process to ensure an efficient and effective process. A good planner and a qualified facilitator are keys to successful implementation.

Implementing this *Guide*

- Learning Objectives
- Logistics
- Discussion
- Summary

Learning Objectives for Implementing this *Guide*

Understand:

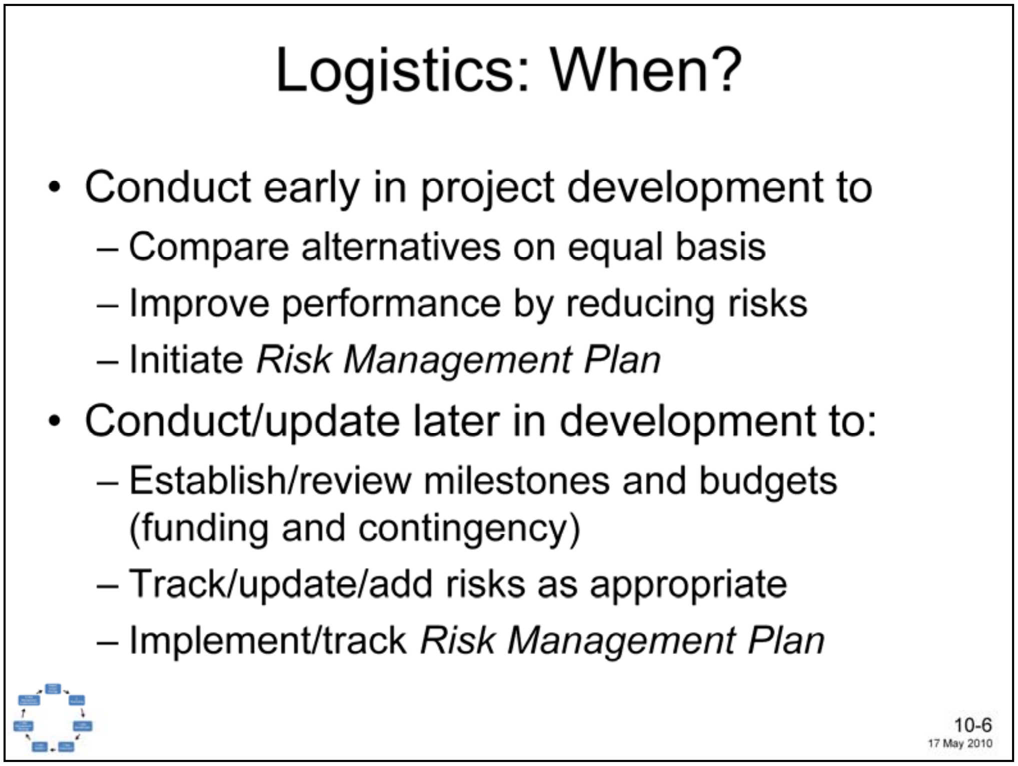
✓*When?*

✓*Who?*

✓*How?*

Implementing this *Guide*

- Learning Objectives
- **Logistics**
- Discussion
- Summary



Logistics: When?

- Conduct early in project development to
  - Compare alternatives on equal basis
  - Improve performance by reducing risks
  - Initiate *Risk Management Plan*
- Conduct/update later in development to:
  - Establish/review milestones and budgets (funding and contingency)
  - Track/update/add risks as appropriate
  - Implement/track *Risk Management Plan*

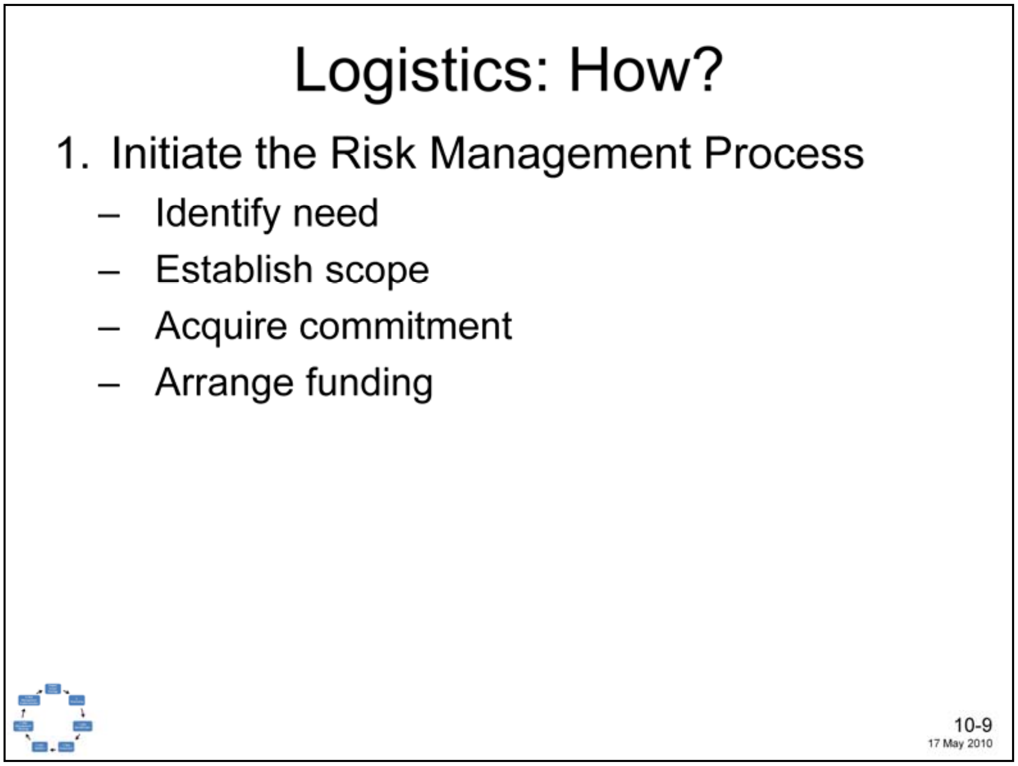
Risk management is beneficial in all phases of project development. In general, the earlier risk management is started, the more time the project team has to react to the identified risks and the easier the risks are to manage, and thus the more benefits the project will realize from risk management. Once a project’s purpose and overall scope have started to take shape, various elements of the risk management process can be applied to maximize benefits.

Logistics: Who?

- Participants
  - *DOT management and project leader* – provide active support, authority, and resources, plus ultimate responsibility
  - *Facilitator/analyst* – guides and manages development of *Risk Management Plan*
  - *Workshop attendees* – project management, project technical staff, and subject matter experts (SMEs, e.g., same as for VE) provide input
- Need *planner* to organize participants

Logistics: How?

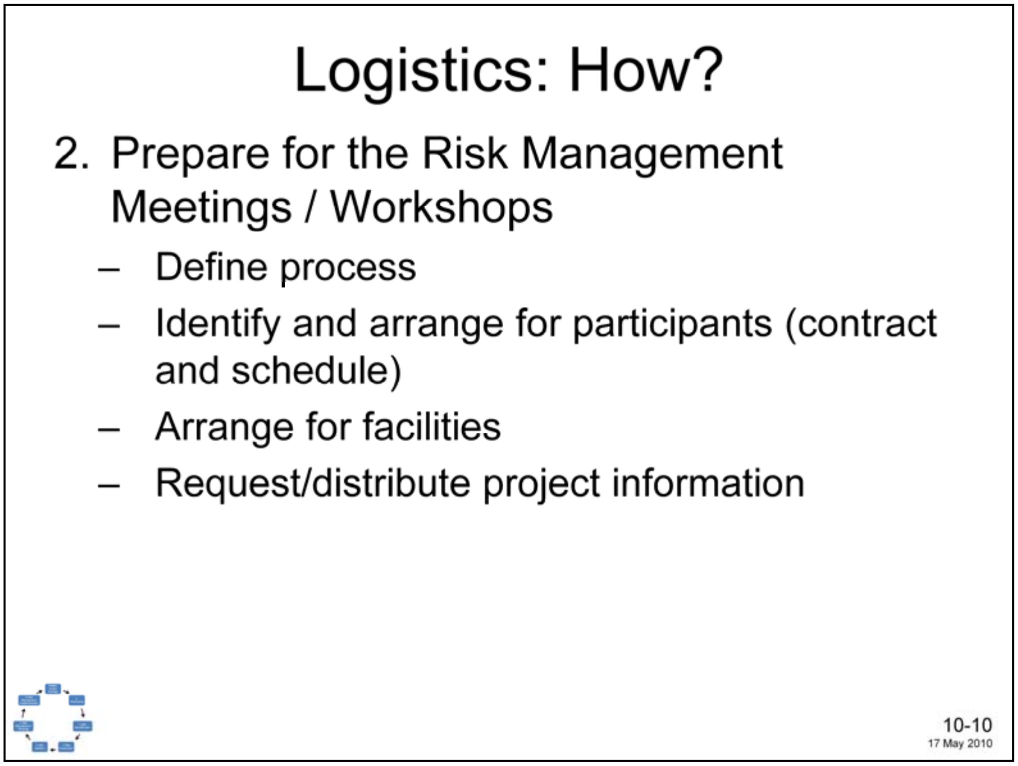
1. Initiate the Risk Management Process
2. Prepare for the Risk Management Meetings / Workshops
3. Conduct the Risk Management Meetings / Workshops (*Modules 4-8*)
4. Document Risk Management Process and Results (*Risk Management Plan*)
5. Implement Risk Management Plan (*Module 9*)



Logistics: How?

1. Initiate the Risk Management Process
   - Identify need
   - Establish scope
   - Acquire commitment
   - Arrange funding

Coordinate with project team. Consider tying risk management and VE processes together at key milestones. Determine if qualitative or quantitative analyses are needed (e.g., to quantify project performance uncertainty, from which appropriate budget and contingency can be determined).

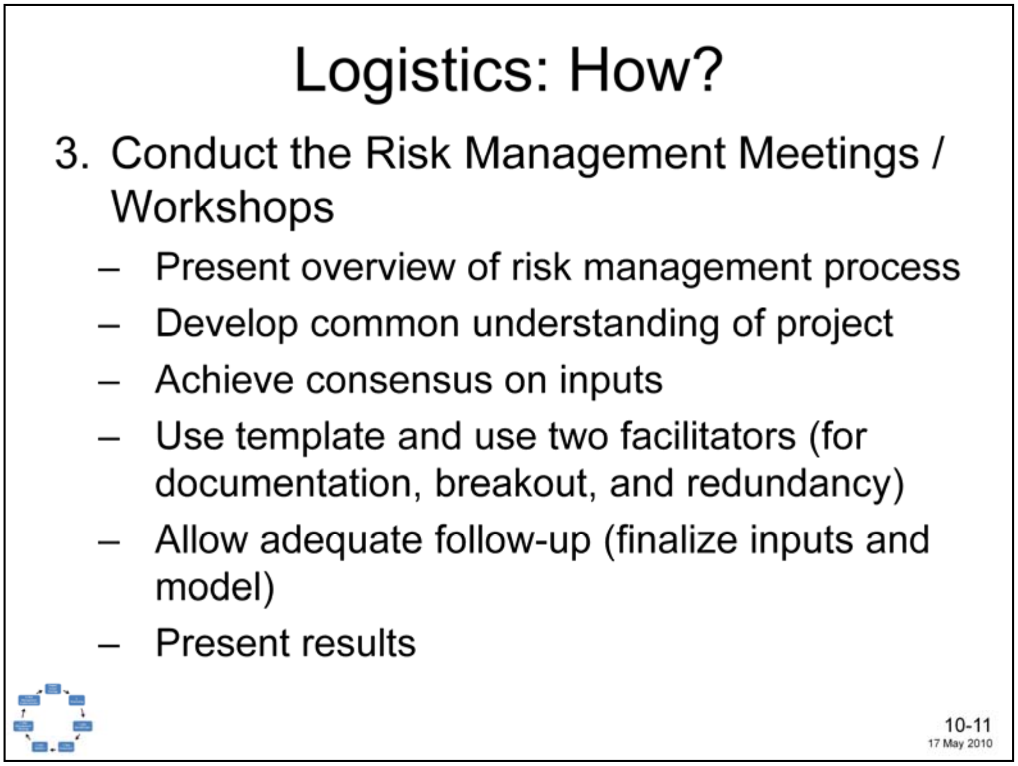


Logistics: How?

2. Prepare for the Risk Management Meetings / Workshops
   - Define process
   - Identify and arrange for participants (contract and schedule)
   - Arrange for facilities
   - Request/distribute project information

10-10
17 May 2010

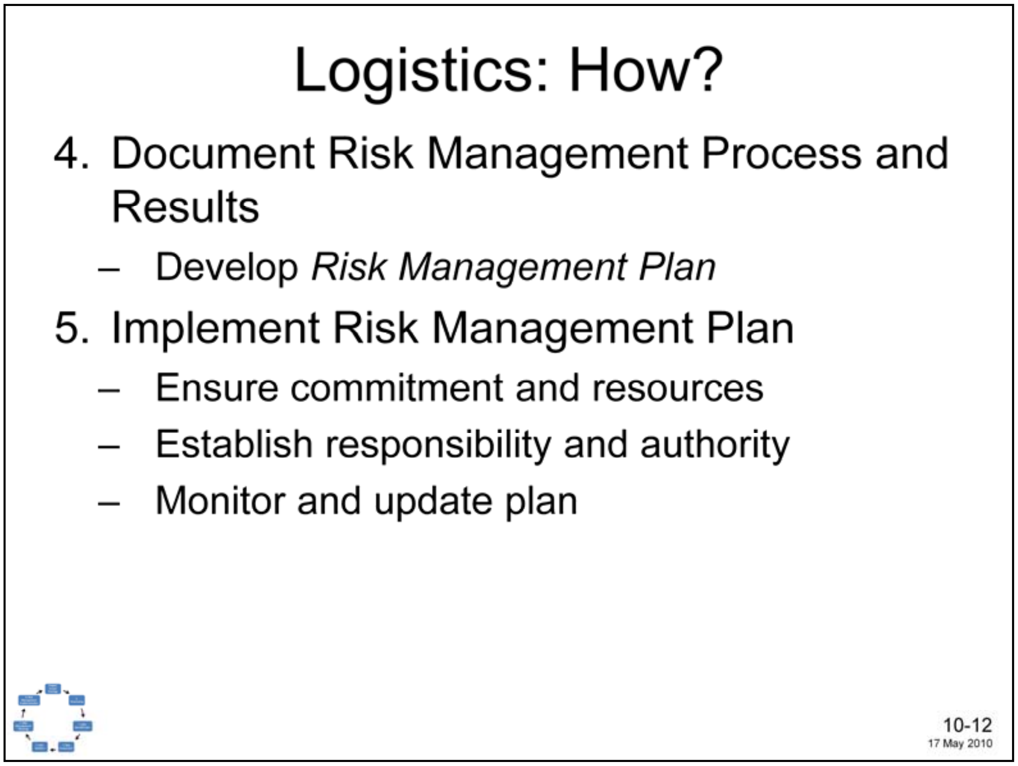
Consider implementing a number of risk management process steps in one meeting (e.g., structuring, risk identification, risk assessment, and risk management planning), or have separate meetings, to suit the project needs. Consider tying risk management and VE together, and/or conduct separate prep session upfront to plan subsequent workshops and meetings, including identification of participants.



Logistics: How?

3. Conduct the Risk Management Meetings / Workshops
   - Present overview of risk management process
   - Develop common understanding of project
   - Achieve consensus on inputs
   - Use template and use two facilitators (for documentation, breakout, and redundancy)
   - Allow adequate follow-up (finalize inputs and model)
   - Present results

A set of slides has been developed specifically for the facilitator to present an appropriate overview of the risk management process at the beginning of the workshop. A hard copy of this presentation is presented in Appendix E of the Guide, and the MS PowerPoint file is contained on the CD.



Logistics: How?

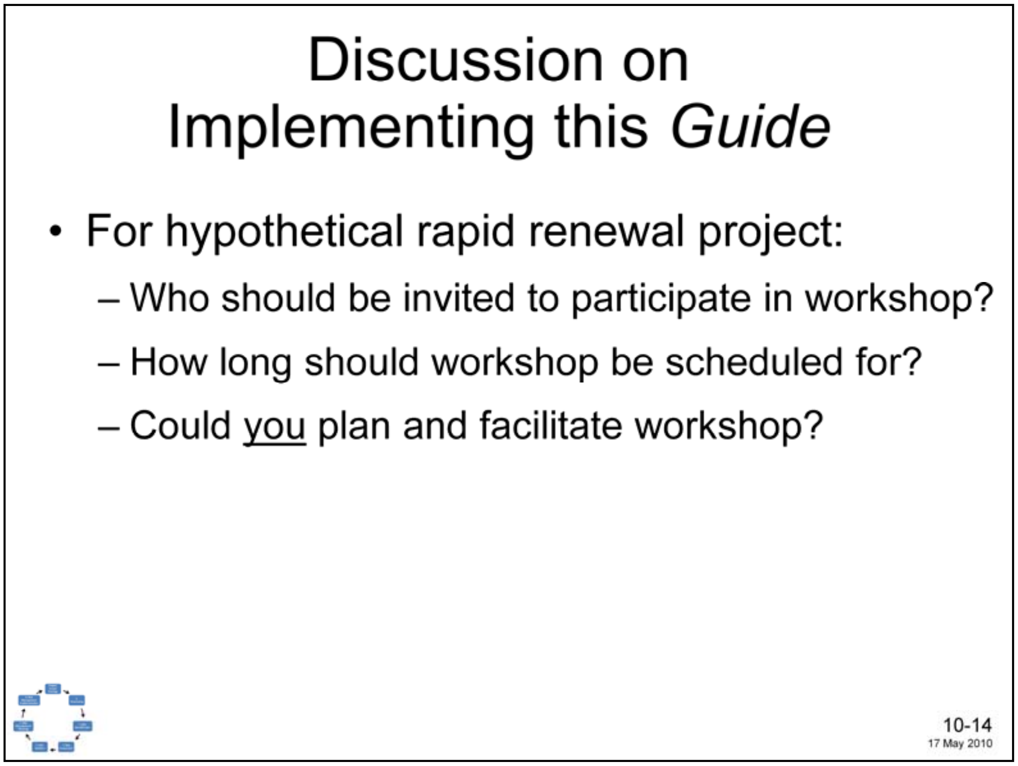
4. Document Risk Management Process and Results
   - Develop *Risk Management Plan*
5. Implement Risk Management Plan
   - Ensure commitment and resources
   - Establish responsibility and authority
   - Monitor and update plan

10-12
17 May 2010

A *Risk Management Plan* for the hypothetical rapid renewal project is presented in Appendix F of the *Guide*.

Implementing this *Guide*

- Learning Objectives
- Logistics
- ➢ **Discussion**
- Summary



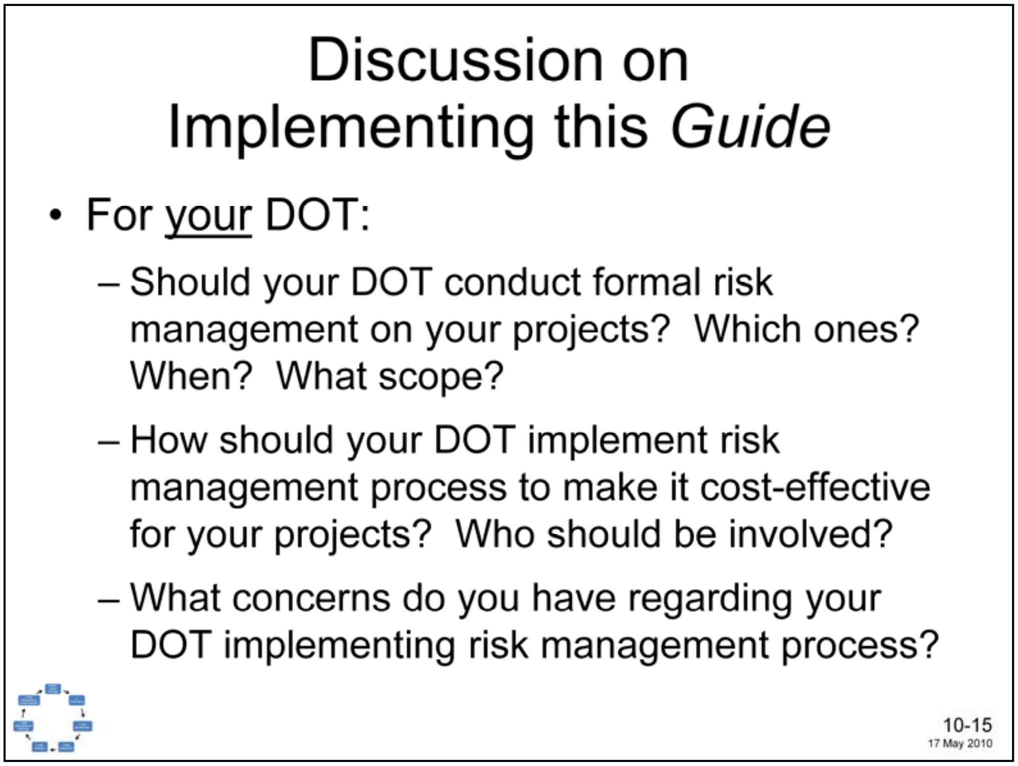
Discussion on Implementing this *Guide*

- For hypothetical rapid renewal project:
  - – Who should be invited to participate in workshop?
  - – How long should workshop be scheduled for?
  - – Could <u>you</u> plan and facilitate workshop?

To implement the risk management process (as described in Chapters 2-9 of the *Guide* and in Modules 2-9) on the hypothetical rapid renewal project (as described in Appendix F of the *Guide*), QDOT did the following (as described in Chapter 10 of the *Guide*):

- assembled relevant project information (i.e., regarding scope, strategy/status, conditions/assumptions, cost estimate, schedule, etc.);
- convened a group of key project-team staff and independent subject-matter experts from the key project disciplines, facilitated by a qualified risk elicitor/analyst, to conduct risk assessment and risk management planning (consistent with the principles, processes and guidance described throughout the *Guide*), culminating in a *Risk Management Plan*; and
- assigned a Risk Manager (with appropriate authority and resources) to implement the resulting *Risk Management Plan*, including monitoring, updating, and controlling.

Construction of the QDOT project was successfully completed on <date> at an inflated cost of <$M> (with <$M> remaining contingency), with few unanticipated problems – several of the risks actually occurred, but most did not (relatively consistent with their assessed probabilities of occurrence, e.g., about one out of ten risks that had 10% probability actually occurred, and about half the risks that had 50% probability actually occurred).



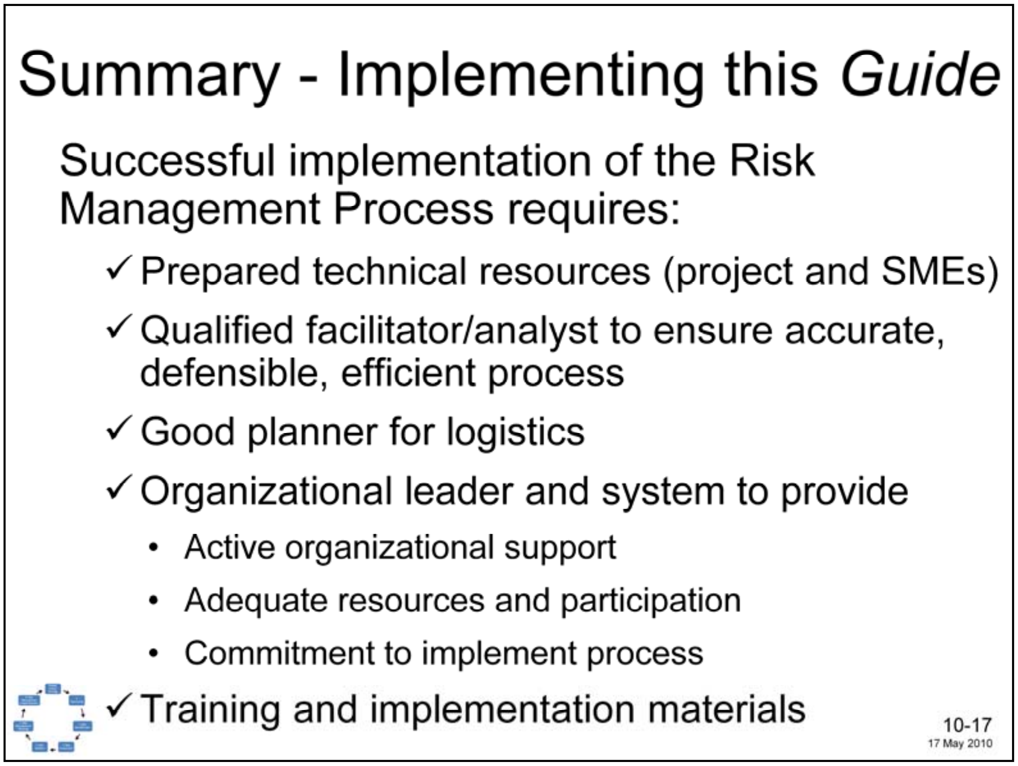
Discussion on Implementing this *Guide*

- For <u>your</u> DOT:
  - – Should your DOT conduct formal risk management on your projects? Which ones? When? What scope?
  - – How should your DOT implement risk management process to make it cost-effective for your projects? Who should be involved?
  - – What concerns do you have regarding your DOT implementing risk management process?

17 May 2010

Implementing this *Guide*

- Learning Objectives
- Logistics
- Discussion
- ➢ **Summary**



Summary - Implementing this *Guide*

Successful implementation of the Risk Management Process requires:

- ✓ Prepared technical resources (project and SMEs)
- ✓ Qualified facilitator/analyst to ensure accurate, defensible, efficient process
- ✓ Good planner for logistics
- ✓ Organizational leader and system to provide
  - Active organizational support
  - Adequate resources and participation
  - Commitment to implement process
- ✓ Training and implementation materials

Useful implementation materials (which have been provided) includes introductory overview slides, forms, template, and checklists.

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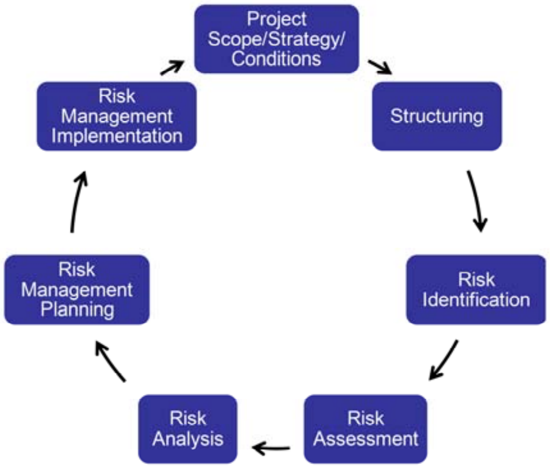
Risk Management

Module 11: Conclusion



Project Scope/Strategy/ Conditions

Structuring

Risk Identification

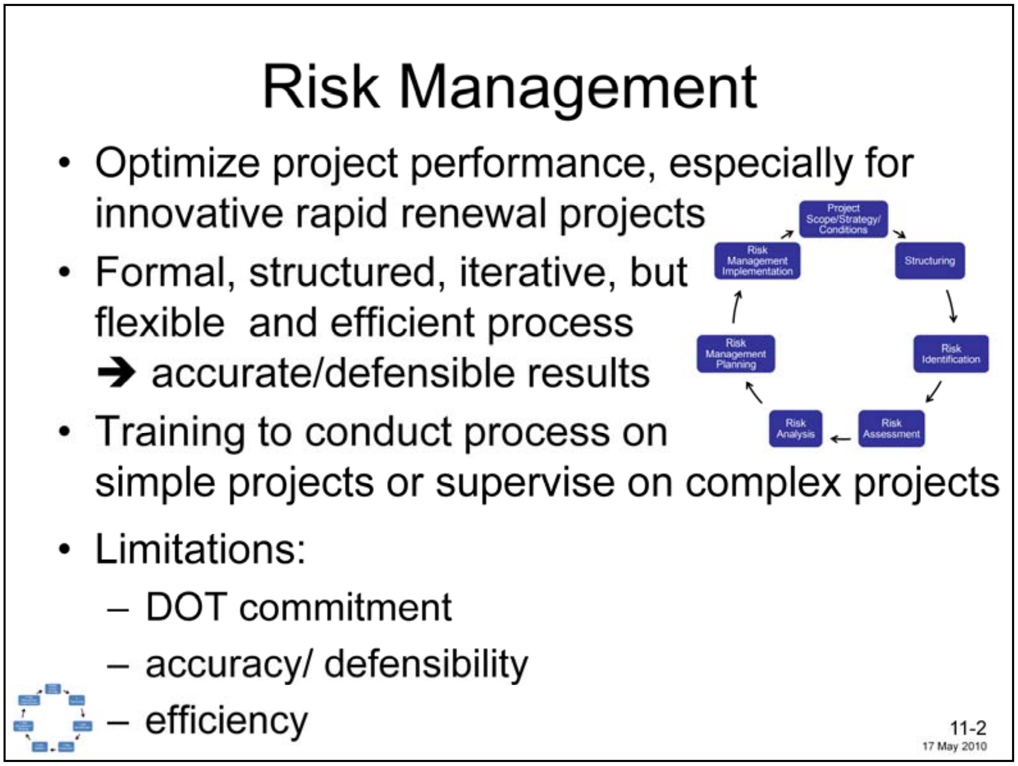
Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation

17 May 2010

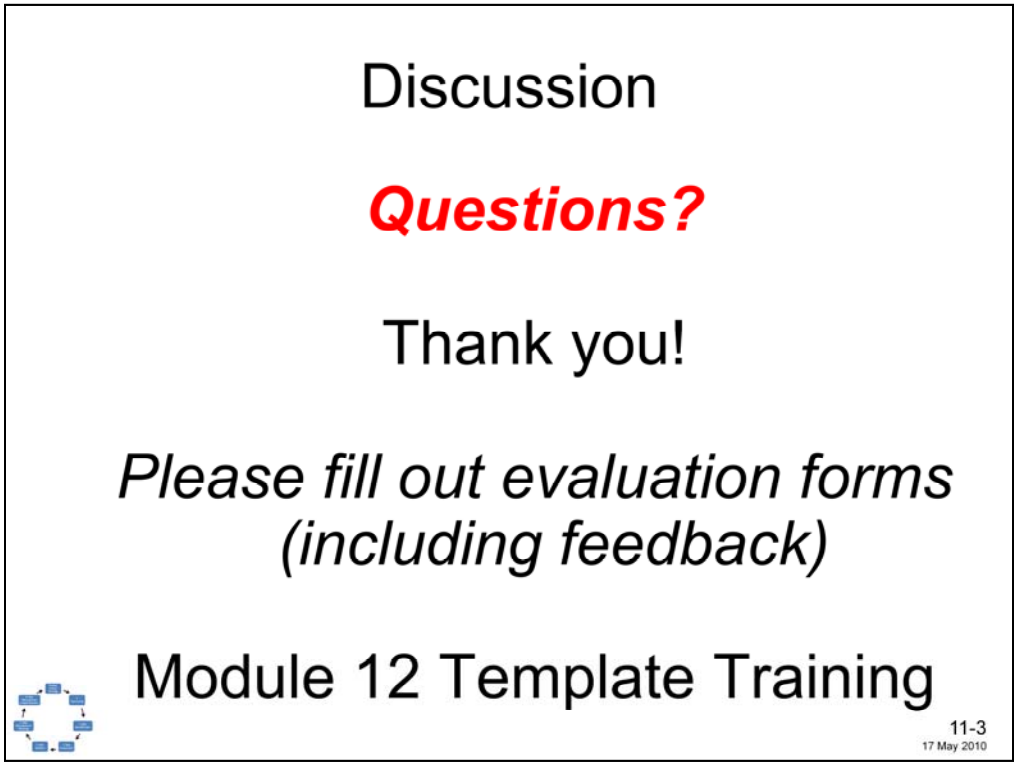


Risk Management

- Optimize project performance, especially for innovative rapid renewal projects
- Formal, structured, iterative, but flexible and efficient process
  ➔ accurate/defensible results
- Training to conduct process on simple projects or supervise on complex projects
- Limitations:
  - DOT commitment
  - accuracy/ defensibility
  - efficiency

11-2
17 May 2010

See syllabus (at front of notebook) and Chapter 11. Conclusions in *Guide.*



Discussion

Questions?

Thank you!

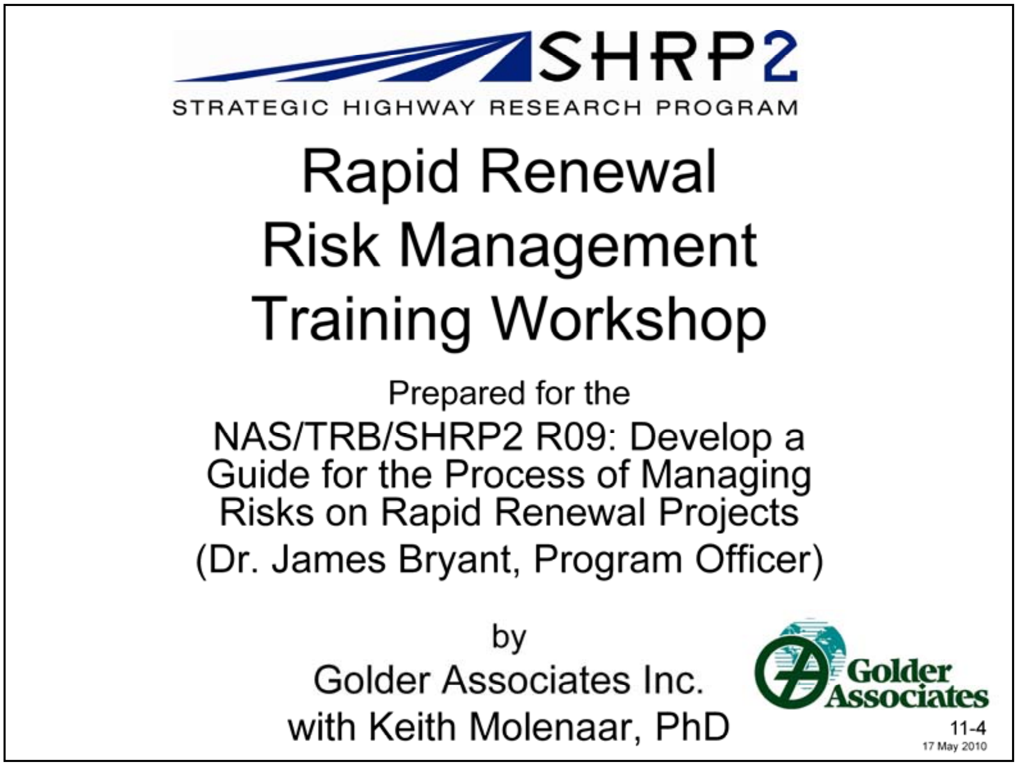
Please fill out evaluation forms (including feedback)

Module 12 Template Training

Any questions?

Please fill out the evaluation form, which is behind the syllabus at the from of the notebook.

After the break, for those who are interested, we'll conduct training on the template that documents and automatically does the calculations discussed in previous modules.



SHRP2
STRATEGIC HIGHWAY RESEARCH PROGRAM

Rapid Renewal Risk Management Training Workshop

Prepared for the
NAS/TRB/SHRP2 R09: Develop a Guide for the Process of Managing Risks on Rapid Renewal Projects
(Dr. James Bryant, Program Officer)

by
Golder Associates Inc.
with Keith Molenaar, PhD

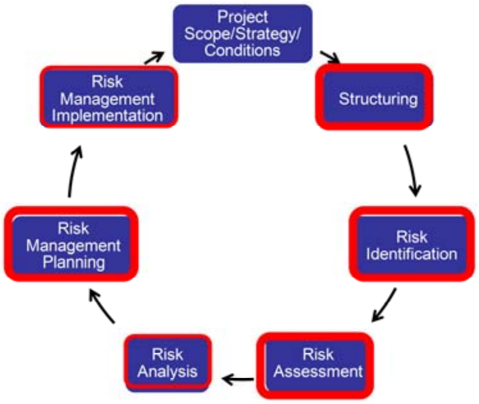
Golder Associates

11-4
17 May 2010

This course provides training to DOTs to implement the recently developed Guide for the Process of Managing Risks on Rapid Renewal Projects (“*Guide*”).

Risk Management

Module 12:
Template Training



Project Scope/Strategy/ Conditions

Structuring

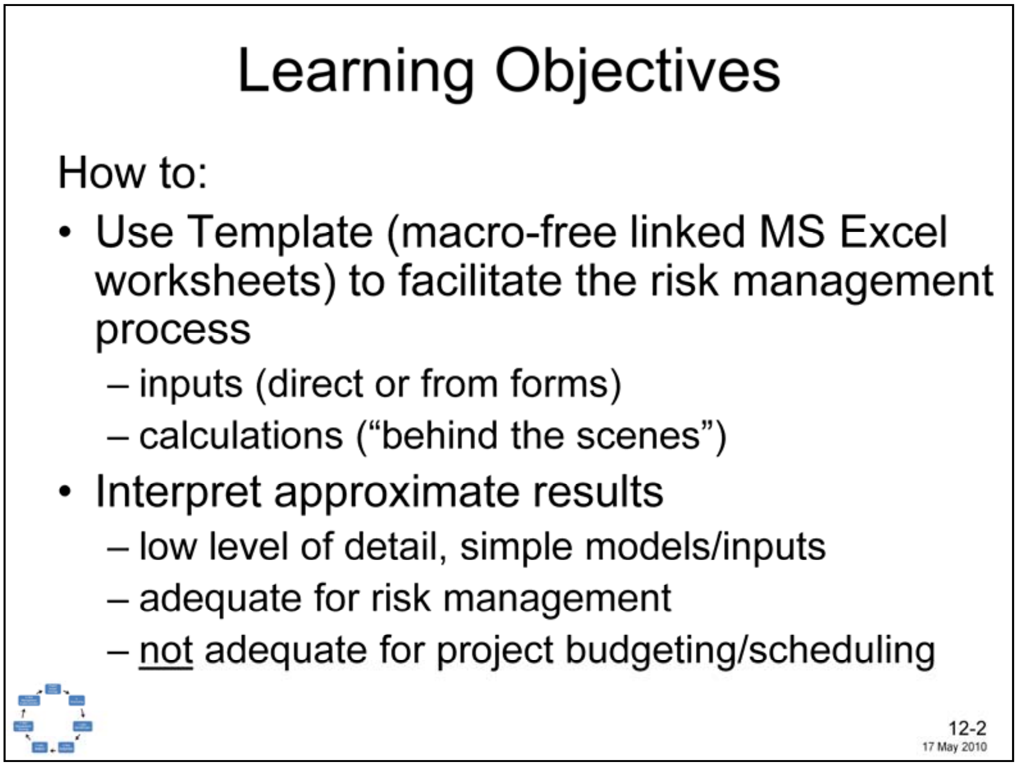
Risk Identification

Risk Assessment

Risk Analysis

Risk Management Planning

Risk Management Implementation



Learning Objectives

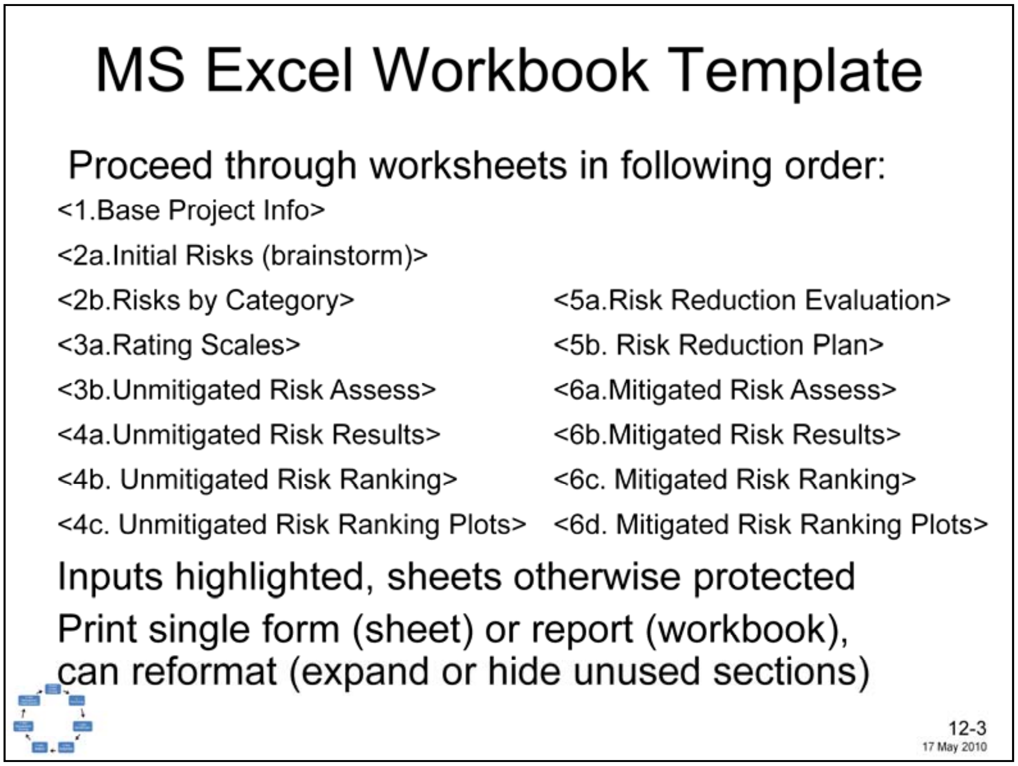
How to:

- Use Template (macro-free linked MS Excel worksheets) to facilitate the risk management process
  - inputs (direct or from forms)
  - calculations (“behind the scenes”)
- Interpret approximate results
  - low level of detail, simple models/inputs
  - adequate for risk management
  - <u>not</u> adequate for project budgeting/scheduling

12-2
17 May 2010

•MS Excel workbook template has been developed to facilitate parts of the risk management process for relatively simple rapid renewal projects, as presented in this course. Template is contained on CD, and User’s Guide for Template is provided in Appendix E of *Guide*.

- The template consists of linked MS Excel worksheets (without macros), in which assessed inputs are entered (either directly as they are assessed or from forms) and appropriate calculations are performed “behind the scenes” – inputs are highlighted and the rest of the spreadsheets are protected and hidden to prevent inadvertent changes
- The results are approximate due to low level of detail and simplifications in the models and in the inputs - adequate for risk management purposes, but generally <u>not</u> for project budgeting/scheduling
- Provides documentation of assessments/inputs, as well as of outputs.



MS Excel Workbook Template

Proceed through worksheets in following order:

- <1.Base Project Info>
- <2a.Initial Risks (brainstorm)>
- <2b.Risks by Category>
- <3a.Rating Scales>
- <3b.Unmitigated Risk Assess>
- <4a.Unmitigated Risk Results>
- <4b. Unmitigated Risk Ranking>
- <4c. Unmitigated Risk Ranking Plots>
- <5a.Risk Reduction Evaluation>
- <5b. Risk Reduction Plan>
- <6a.Mitigated Risk Assess>
- <6b.Mitigated Risk Results>
- <6c. Mitigated Risk Ranking>
- <6d. Mitigated Risk Ranking Plots>

Inputs highlighted, sheets otherwise protected

Print single form (sheet) or report (workbook), can reformat (expand or hide unused sections)

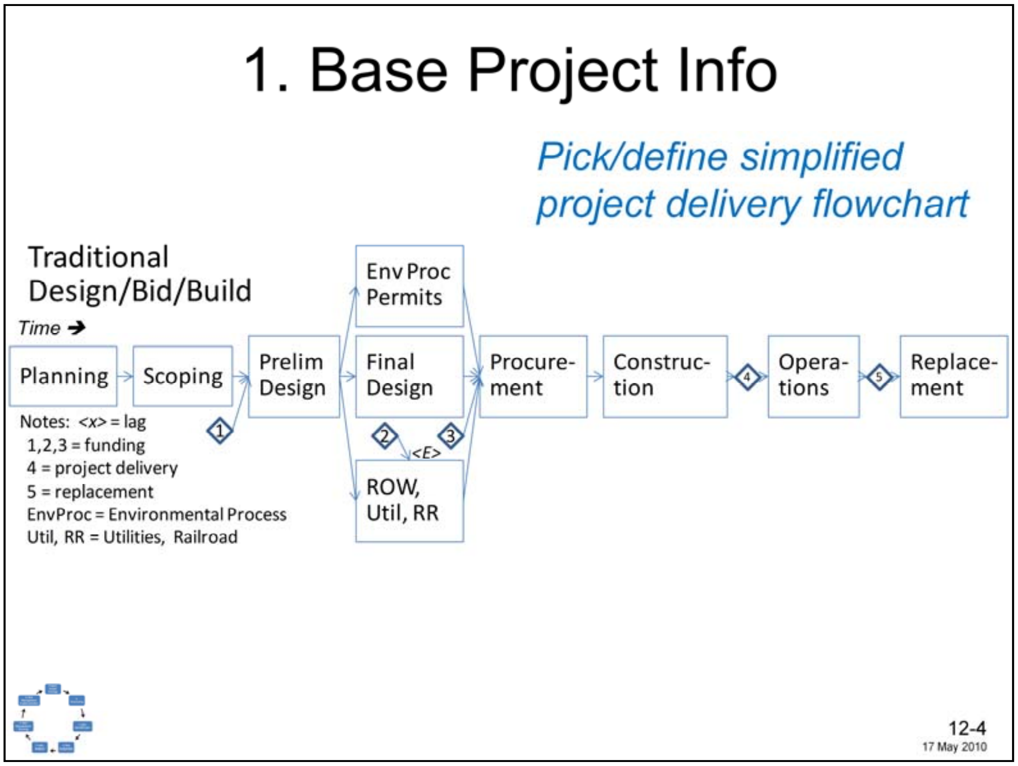
12-3
17 May 2010

On your computer, insert CD and open MS Excel workbook <Rapid Renewal Risk Management Planning Template (Beta 22Mar2010)> - this is the blank template. Save a working copy under a different file name. The first worksheet (“0.Instructions”) in that workbook contains general instructions. A complete, more extensive User’s Guide for the template is provided in Appendix E of the *Guide*.

Generally the input worksheets look similar to the hard copy forms also contained in Appendix E. The worksheets must be filled in order.

Inputs are highlighted (in yellow), and the rest of the worksheet is protected to prevent inadvertent changes and resulting errors –the parts of the worksheet that do the intermediate calculations are hidden to minimize confusion.

The user can reformat worksheets (e.g., to see wrapped text, or to hide unused portions), and can print individual worksheets or the entire workbook (the print area is preset).



1. Base Project Info

Pick/define simplified project delivery flowchart

Traditional Design/Bid/Build

Time ➔

Planning

Scoping

Prelim Design

Env Proc Permits

Final Design

ROW, Util, RR

Procure-ment

Construc-tion

Opera-tions

Replace-ment

1

2

<*E*>

3

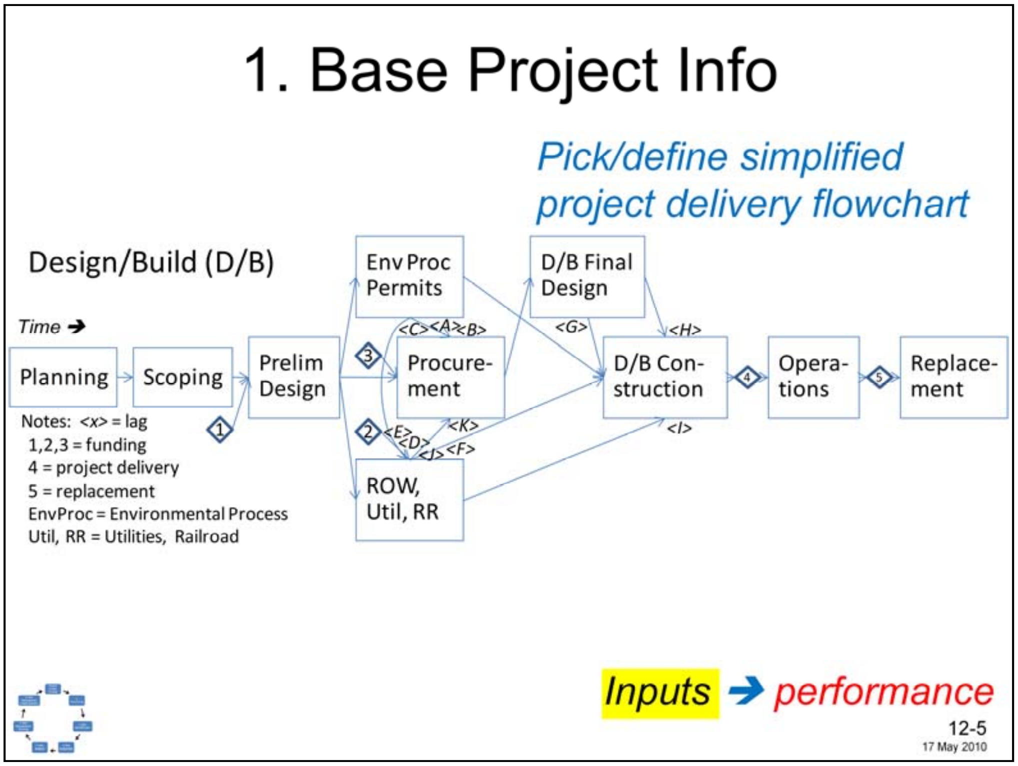
4

5

Notes: <*x*> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

17 May 2010

On the second worksheet <*1.Base Project Info*> of the template, one of the first inputs is to select the standard simplified flowchart that will be used: one represents traditional linear design/bid/build (D/B/B) project delivery whereas the other represents a more complicated, non-linear design/build (D/B) project delivery. However, if these flowcharts do not adequately represent the project, the user can redefine the activities so that they better represent their project, e.g., D/B Final Design might include some environmental permits acquired by the D/B contractor. Such redefinitions will have to be noted as inserted comments in the worksheet. Again, inputs (as highlighted in yellow) will be assessed for these activities (which are the same for the two flow charts, only their sequence is different), and the template will automatically do the appropriate calculations to determine performance.



1. Base Project Info

Pick/define simplified project delivery flowchart

Design/Build (D/B)

Time ➔

Planning

Scoping

Prelim Design

Env Proc Permits

Procure-ment

ROW, Util, RR

D/B Final Design

D/B Con-struction

Opera-tions

Replace-ment

<A> <B> <C> <D> <E> <F> <G> <H> <I> <J> <K>

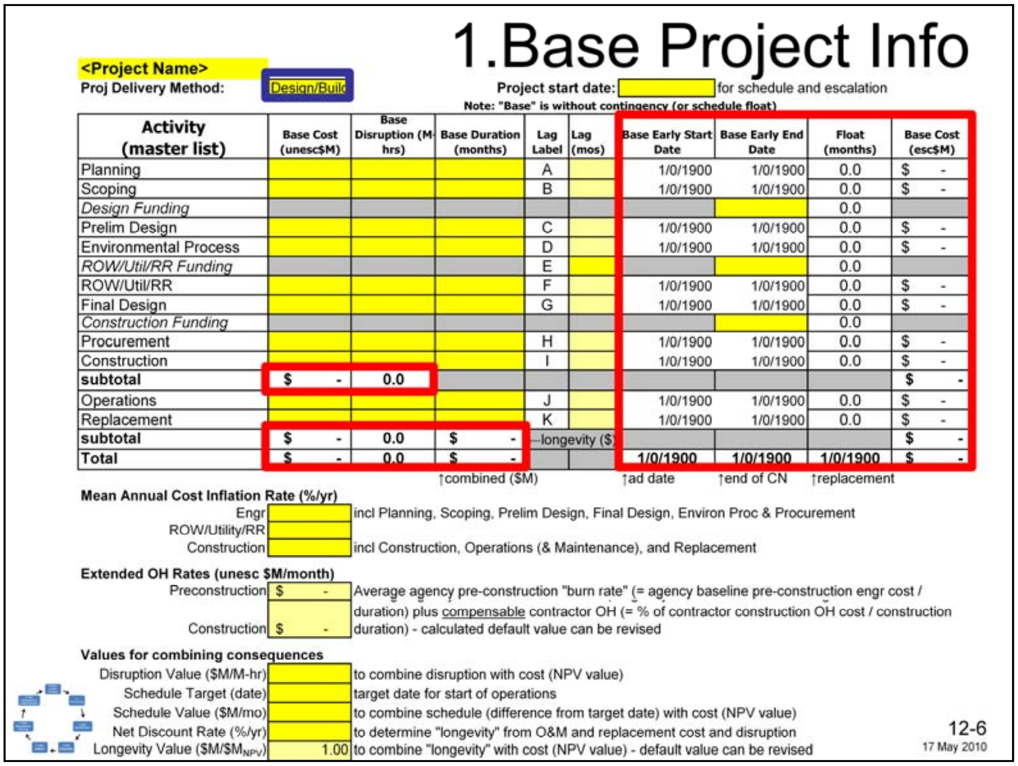
① ② ③ ④ ⑤

Notes: <*x*> = lag
1,2,3 = funding
4 = project delivery
5 = replacement
EnvProc = Environmental Process
Util, RR = Utilities, Railroad

Inputs ➔ *performance*

12-5
17 May 2010

On the second worksheet <*1.Base Project Info*> of the template, one of the first inputs is to select the standard simplified flowchart that will be used: one represents traditional linear design/bid/build (D/B/B) project delivery whereas the other represents a more complicated, non-linear design/build (D/B) project delivery. However, if these flowcharts do not adequately represent the project, the user can redefine the activities so that they better represent their project, e.g., D/B Final Design might include some environmental permits acquired by the D/B contractor. Such redefinitions will have to be noted as inserted comments in the worksheet. Again, inputs (as highlighted in yellow) will be assessed for these activities (which are the same for the two flow charts, only their sequence is different), and the template will automatically do the appropriate calculations to determine performance.



1.Base Project Info

<Project Name>

Proj Delivery Method: Design/Build

Project start date: for schedule and escalation

Note: "Base" is without contingency (or schedule float)

Activity (master list)	**Base Cost (unesc$M)**	**Base Disruption (M-hrs)**	**Base Duration (months)**	**Lag Label**	**Lag (mos)**	**Base Early Start Date**	**Base Early End Date**	**Float (months)**	**Base Cost (esc$M)**
Planning				A		1/0/1900	1/0/1900	0.0	$ -
Scoping				B		1/0/1900	1/0/1900	0.0	$ -
Design Funding								0.0	
Prelim Design				C		1/0/1900	1/0/1900	0.0	$ -
Environmental Process				D		1/0/1900	1/0/1900	0.0	$ -
ROW/Util/RR Funding				E				0.0	
ROW/Util/RR				F		1/0/1900	1/0/1900	0.0	$ -
Final Design				G		1/0/1900	1/0/1900	0.0	$ -
Construction Funding								0.0	
Procurement				H		1/0/1900	1/0/1900	0.0	$ -
Construction				I		1/0/1900	1/0/1900	0.0	$ -
subtotal	$ -	0.0							**$ -**
Operations				J		1/0/1900	1/0/1900	0.0	$ -
Replacement				K		1/0/1900	1/0/1900	0.0	$ -
subtotal	$ -	0.0	$ -	—longevity ($)					**$ -**
Total	$ -	0.0	$ -			**1/0/1900**	**1/0/1900**	**1/0/1900**	**$ -**
			↑combined ($M)			↑ad date	↑end of CN	↑replacement	

Mean Annual Cost Inflation Rate (%/yr)

Engr		incl Planning, Scoping, Prelim Design, Final Design, Environ Proc & Procurement
ROW/Utility/RR		
Construction		incl Construction, Operations (& Maintenance), and Replacement

Extended OH Rates (unesc $M/month)

Preconstruction	$ -	Average agency pre-construction "burn rate" (= agency baseline pre-construction engr cost / duration) plus compensable contractor OH (= % of contractor construction OH cost / construction duration) - calculated default value can be revised
Construction	$ -	

Values for combining consequences

Disruption Value ($M/M-hr)		to combine disruption with cost (NPV value)
Schedule Target (date)		target date for start of operations
Schedule Value ($M/mo)		to combine schedule (difference from target date) with cost (NPV value)
Net Discount Rate (%/yr)		to determine "longevity" from O&M and replacement cost and disruption
Longevity Value ($M/$M$_{NPV}$)	1.00	to combine "longevity" with cost (NPV value) - default value can be revised

12-6
17 May 2010

Also on the second worksheet <*1.Base Project Info*> of the Template, the “base” (before considering risks) project information for *the selected “standard” flow charts is documented.* Typically, this information would first be developed using the Project Description & Baseline Form (paper), which is then transferred manually to this template.

Inputs (yellow cells only) include:

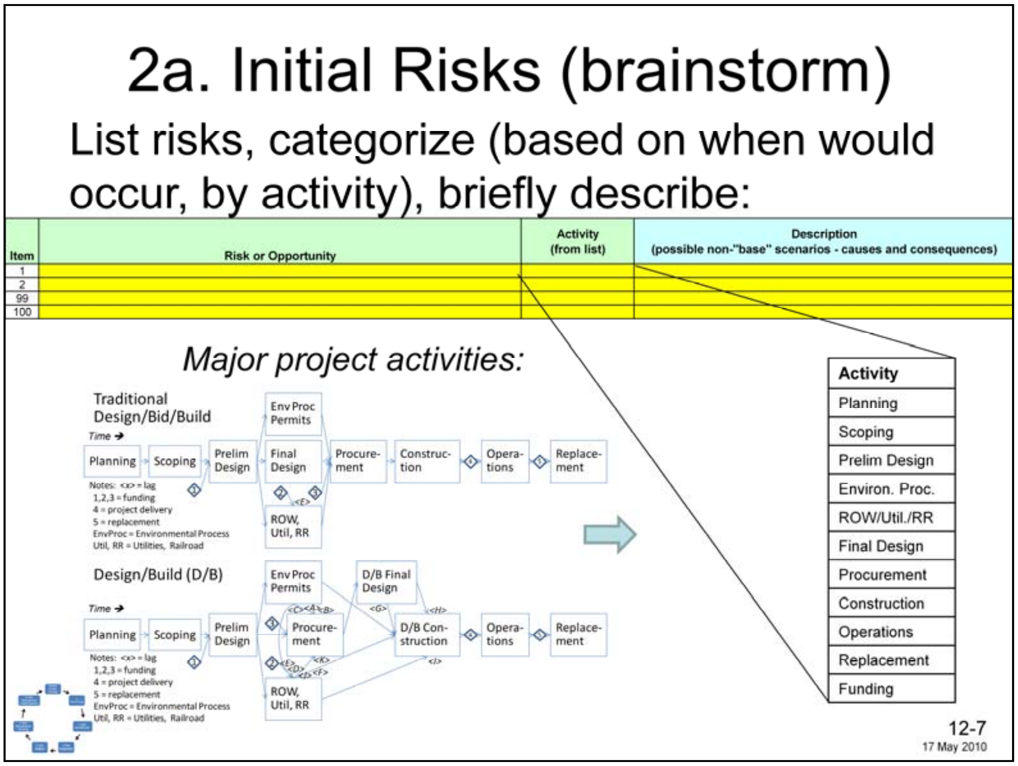
- Project start date (from which schedule and escalation are derived)
- “Base” unescalated cost, duration and disruption (exclusive of risk, contingency, float) for each major project activity, and lags (if any) for several activities – might need separate matrix to allocate cost items in the cost estimate to flowchart activities
- Funding availability milestone dates
- Average annual escalation rates (over appropriate time periods) for various types of activities.

  Note: Extended OH rates for preconstruction delays and for construction delays are determined automatically in terms of average “burn” rates, but can be over-ridden. Also “values” for subsequent tradeoffs are entered, including net discount rate for post-construction costs and “values” of disruption, schedule and longevity.

- The total base project costs (unescalated and escalated), base activity schedule dates, base activity float, base activity escalated costs, base disruption and base longevity are computed automatically in the worksheet, based on selected standard flow chart, early activity starts, and escalation to each activity midpoint at its specified escalation rate. The schedule is determined through standard critical path methods.

Note: These are only <u>base</u> costs, schedule, and disruption without consideration of risk. Total cost (including escalation and extended OHs), schedule and disruption will be determined once risks are added in – see later spreadsheets

- If “expected values” (probability-weighted average values) are used for inputs, then the outputs are also approximately expected values. However, there will generally be significant uncertainty in the outputs due to significant uncertainties in the inputs, which will <u>not</u> be assessed or considered when using this template.
- The base factor values might change as the project evolves. Document any changes (e.g., observed during periodic monitoring/updates) with inserted comments .



2a. Initial Risks (brainstorm)

List risks, categorize (based on when would occur, by activity), briefly describe:

Item	Risk or Opportunity	Activity (from list)	Description (possible non-"base" scenarios - causes and consequences)
1			
2			
99			
100			

Major project activities:

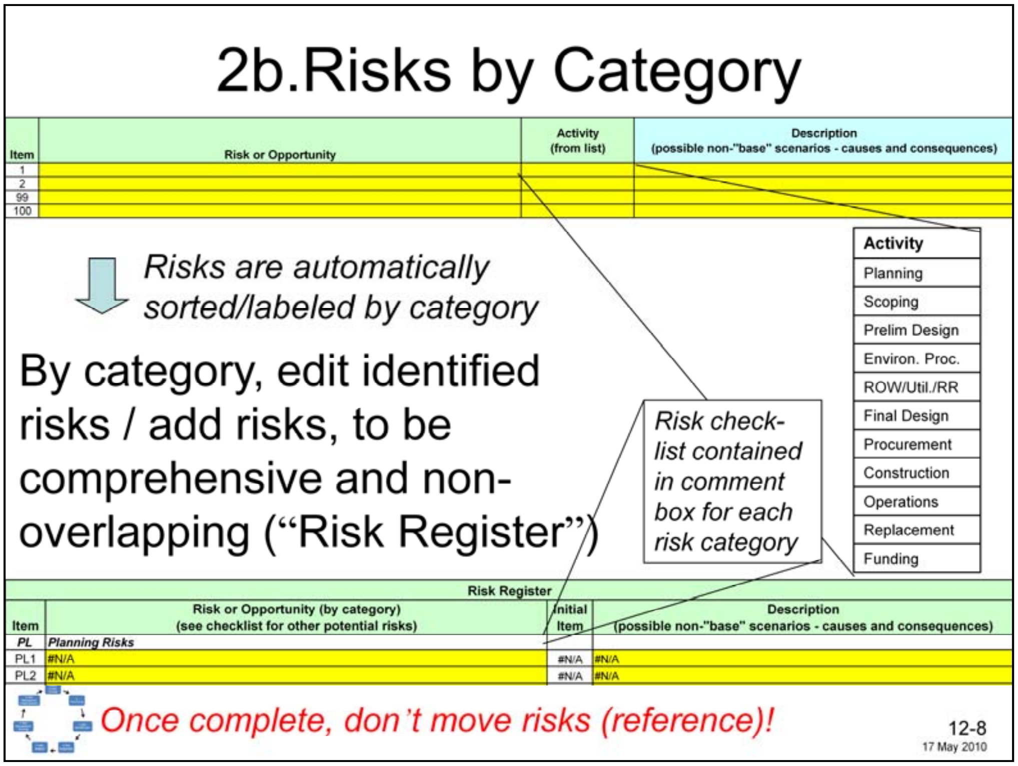
Activity
Planning
Scoping
Prelim Design
Environ. Proc.
ROW/Util./RR
Final Design
Procurement
Construction
Operations
Replacement
Funding

12-7
17 May 2010

On the third spreadsheet *<2a. Initial Risks (brainstorm)>* of the Template, the initial list of risks identified by workshop participants is documented, generally in the order they are identified as they are identified. This is the first step in developing the Risk Register. Typically, this information would be developed through brainstorming and input directly "on the fly" in a workshop, although it could be developed first in hard copy on the Risk Identification Form, and then transferred manually to this template.

Inputs (yellow cells only) include:

- Risk (or opportunity) short, descriptive title
- Risk category (per major project activity during which it is most likely to occur, and after which it is unlikely to occur – e.g., poor market competition would occur during procurement, after which it has either happened or not) – drop down box
- More detailed description



2b.Risks by Category

Item	Risk or Opportunity	Activity (from list)	Description (possible non-"base" scenarios - causes and consequences)
1			
2			
99			
100			

Risks are automatically sorted/labeled by category

By category, edit identified risks / add risks, to be comprehensive and non-overlapping ("Risk Register")

Risk check-list contained in comment box for each risk category

Activity
Planning
Scoping
Prelim Design
Environ. Proc.
ROW/Util./RR
Final Design
Procurement
Construction
Operations
Replacement
Funding

Risk Register

Item	Risk or Opportunity (by category) (see checklist for other potential risks)	Initial Item	Description (possible non-"base" scenarios - causes and consequences)
PL	*Planning Risks*		
PL1	#N/A	#N/A	#N/A
PL2	#N/A	#N/A	#N/A

Once complete, don't move risks (reference)!

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17 May 2010

On the fourth worksheet <*2b. Risks by Category*> of the Template, the risks in <*2a. Initial Risks (brainstorm)*> are automatically resorted by their specified category and then the initial risks in each category are edited and new risks are added to ensure that collectively they are comprehensive, as well as non-overlapping. This is an interim step in developing the Risk Register. Typically, this information would be developed and input directly "on the fly" in a workshop, although it could be developed first in hard copy on the Risk Register Form, and then transferred manually to this template.

Inputs (yellow cells only) include:

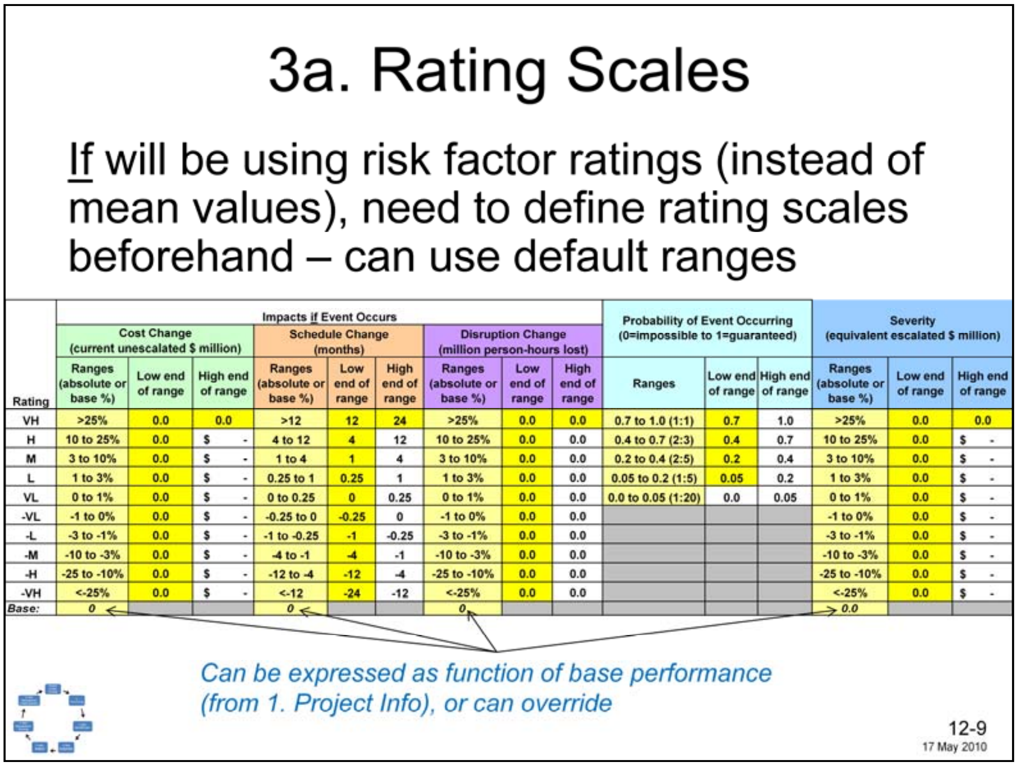
• Risk (or opportunity) short descriptive title (which is initially carried over from <*2a. Initial Risks (brainstorm)*>)

• More detailed description (which is initially carried over from <*2a.Initial Risks (brainstorm)*>)

Note that this sheet supersedes <*2a. Initial Risks (brainstorm)*>, i.e., if an entry is edited or added in this sheet it wipes out the link to the risk identification sheet. Hence, after the first risk list is generated in <*2a. Initial Risks (brainstorm)*>, then all other risk entries must be done in this sheet and no changes should be made in <*2a. Initial Risks (brainstorm)*> – the transferred risks can be "fixed" (immune to changes in <*2a. Initial Risks (brainstorm)*>) by copying them and then pasting special) their values in the same cells.

Note: Risks can be edited and new risks can be added as new information becomes available (and they will be carried forward to subsequent worksheets), but risks cannot be moved once assessments start in subsequent worksheets. For example, the base factors might change. Document changes with inserted comments

<eventually, the risk check list for each category will be contained in a comment box for each risk category>



3a. Rating Scales

If will be using risk factor ratings (instead of mean values), need to define rating scales beforehand – can use default ranges

	Impacts if Event Occurs									Probability of Event Occurring (0=impossible to 1=guaranteed)			Severity (equivalent escalated $ million)		
	Cost Change (current unescalated $ million)			Schedule Change (months)			Disruption Change (million person-hours lost)								
Rating	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range	Ranges	Low end of range	High end of range	Ranges (absolute or base %)	Low end of range	High end of range
VH	>25%	0.0	0.0	>12	12	24	>25%	0.0	0.0	0.7 to 1.0 (1:1)	0.7	1.0	>25%	0.0	0.0
H	10 to 25%	0.0	$ -	4 to 12	4	12	10 to 25%	0.0	0.0	0.4 to 0.7 (2:3)	0.4	0.7	10 to 25%	0.0	$ -
M	3 to 10%	0.0	$ -	1 to 4	1	4	3 to 10%	0.0	0.0	0.2 to 0.4 (2:5)	0.2	0.4	3 to 10%	0.0	$ -
L	1 to 3%	0.0	$ -	0.25 to 1	0.25	1	1 to 3%	0.0	0.0	0.05 to 0.2 (1:5)	0.05	0.2	1 to 3%	0.0	$ -
VL	0 to 1%	0.0	$ -	0 to 0.25	0	0.25	0 to 1%	0.0	0.0	0.0 to 0.05 (1:20)	0.0	0.05	0 to 1%	0.0	$ -
-VL	-1 to 0%	0.0	$ -	-0.25 to 0	-0.25	0	-1 to 0%	0.0	0.0				-1 to 0%	0.0	$ -
-L	-3 to -1%	0.0	$ -	-1 to -0.25	-1	-0.25	-3 to -1%	0.0	0.0				-3 to -1%	0.0	$ -
-M	-10 to -3%	0.0	$ -	-4 to -1	-4	-1	-10 to -3%	0.0	0.0				-10 to -3%	0.0	$ -
-H	-25 to -10%	0.0	$ -	-12 to -4	-12	-4	-25 to -10%	0.0	0.0				-25 to -10%	0.0	$ -
-VH	<-25%	0.0	$ -	<-12	-24	-12	<-25%	0.0	0.0				<-25%	0.0	$ -
Base:	*0*			*0*			*0*						*0.0*		

Can be expressed as function of base performance (from 1. Project Info), or can override

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17 May 2010

On the fifth worksheet <*3a.Ratinmg Scales*> of the Template, the rating scales (if used) are defined. This step is n*eeded only if will be using ratings instead of mean values.* Typically, this information would be developed and input directly "on the fly" in a workshop, although it could be developed first in hard copy, and then transferred manually to this template.

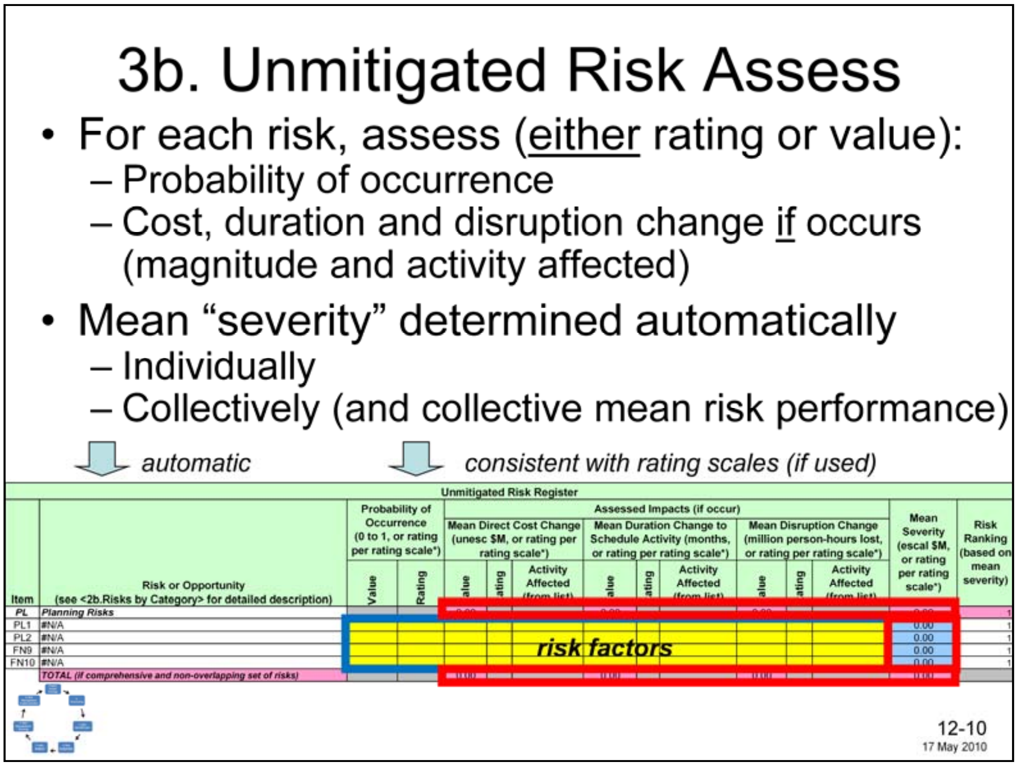
Inputs (yellow cells only) include ranges of mean factor values (which in turn define mean values of each range), associated with each rating for:

- *cost impacts* – unescalated cost change for specified activity, e.g., expressed as percentage of unescalated base cost (from <*1.Project Info*>)
- *schedule impacts* – duration change for specified activity (not necessarily to critical path)
- *disruption impacts* – disruption change for specified activity, e.g., expressed as percentage of total base disruption (from <*1.Project Info*>)
- *probability of occurrence*
- *severity* – change in mean combined project performance (including escalated cost, schedule, disruption and longevity impacts) in terms of equivalent escalated cost change , e.g., expressed as percentage of base combined project performance (from <*1.Project Info*>)

Although default values are shown, they can be revised.

For example, in the table above

- "-L" cost rating is defined by the range in cost of savings of -3% to -1% of the base unescalated project cost, with a mean value of -2%. If the base unescalated project cost was $30M, then the range of additional unescalated costs for "–L" would be -$0.9M to -$0.3M, with a mean value (which would be used for mean-value risk-ranking purposes) of -$0.6M (which would subsequently be escalated and combined with schedule impacts to determine equivalent impact).
- "H" probability rating is defined by the range in probabilities of 0.4 to 0.7, with a mean value of 0.55.



3b. Unmitigated Risk Assess

- For each risk, assess (<u>either</u> rating or value):
  - – Probability of occurrence
  - – Cost, duration and disruption change <u>if</u> occurs (magnitude and activity affected)
- Mean "severity" determined automatically
  - – Individually
  - – Collectively (and collective mean risk performance)

automatic *consistent with rating scales (if used)*

Unmitigated Risk Register

Item	Risk or Opportunity (see <2b.Risks by Category> for detailed description)	Probability of Occurrence (0 to 1, or rating per rating scale*)		Assessed Impacts (if occur)									Mean Severity (escal $M, or rating per rating scale*)	Risk Ranking (based on mean severity)
				Mean Direct Cost Change (unesc $M, or rating per rating scale*)			Mean Duration Change to Schedule Activity (months, or rating per rating scale*)			Mean Disruption Change (million person-hours lost, or rating per rating scale*)				
		Value	Rating	alue	ating	Activity Affected (from list)	alue	ating	Activity Affected (from list)	alue	ating	Activity Affected (from list)		
PL	*Planning Risks*			0.00			0.00			0.00			0.00	1
PL1	#N/A												0.00	1
PL2	#N/A												0.00	1
FN9	#N/A												0.00	1
FN10	#N/A												0.00	1
	TOTAL (if comprehensive and non-overlapping set of risks)			0.00			0.00			0.00			0.00	

risk factors

12-10
17 May 2010

On the sixth worksheet <*3b.Unmitigated Risk Assess*> of the Template, the factors defining each risk are documented. The risks by category have been automatically carried over from <*2b.Risks by Category*>; however, once start inputting factor assessments, can't move risks in <*2b. Risks by Category*>. Typically, this information would be developed and input directly "on the fly" in a workshop, although it could be developed first in hard copy on the Risk Factor Assessment Form, and then transferred manually to this template.

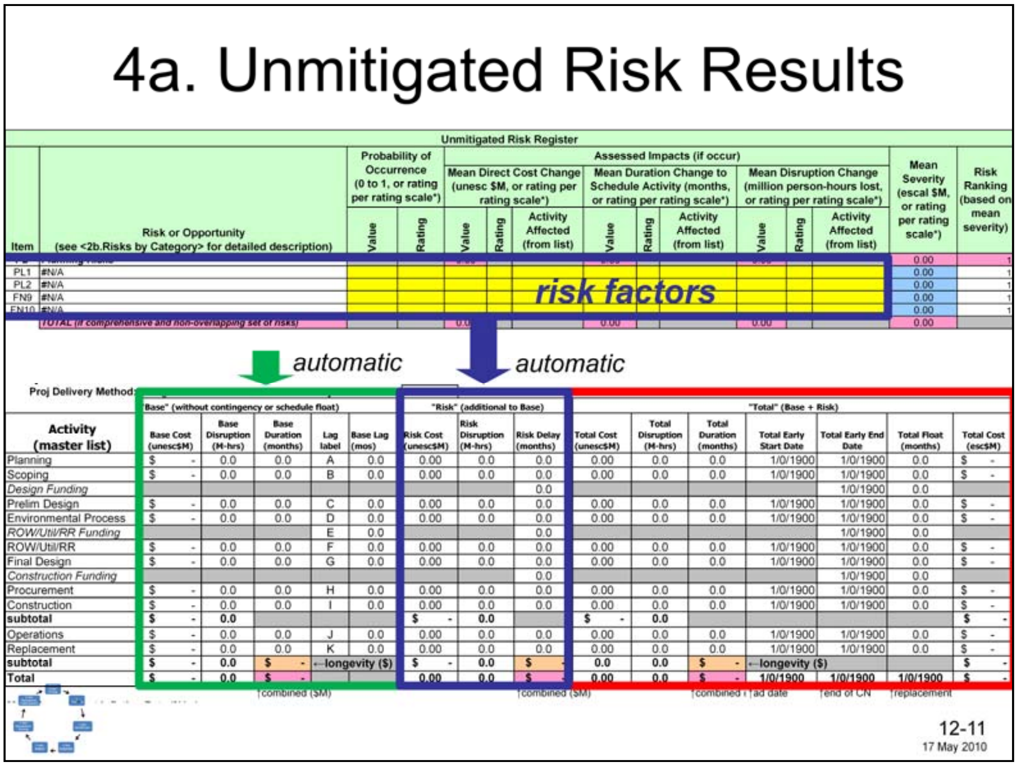
- Inputs (yellow cells only) include:
  - *Probability of risk event occurrence*
  - *Impacts (cost, disruption and/or* disruption changes) <u>if</u> risk event occurs in terms of cost change to particular activity (per major project activities in standard flow chart – specify through drop down box)

Can use <u>either</u> ratings or values for each risk factor. If using ratings, <u>must</u> use specified list (through drop down box) and first specify rating definitions (in terms of ranges and expected values for each category) – separate <*3a. Rating Scales*>. Once the risk factors have been assessed and documented in the template for each identified risk, severity (either rating or value) is determined automatically for each risk. Risk factor ratings are subsequently translated to mean values for analysis, and then back to risk ratings, using these definitions.

- The template determines the mean change in unescalated cost , duration, disruption and longevity for each activity due to that risk. The change in project schedule is determined by comparing the mean change in duration to the activity's base float (from <*1.Project Info*>). The increased unescalated cost due to cost risks, which is escalated, increased escalation of the base cost and risk cost due to schedule risks, and extended overheads due to schedule risks are all determined automatically based on the standard flow chart (appropriately considering critical path and float), escalation rates and extended OH rates, so that the severity is in terms of mean additional escalated cost.

- The collective risk for groups of risks (including total for the project) are also computed automatically – however, they are approximate and only appropriate <u>if</u> the set of risks is comprehensive and non-overlapping. The template determines the mean change in unescalated cost , duration, disruption and longevity for each activity due to <u>all</u> the risks affecting that activity, appropriately considering overlap among schedule delays. The total unescalated cost, total duration and total disruption for each activity is then determined, based on these risk factor assessments, in conjunction with baseline project description (including activity base costs, durations and disruptions). The total project schedule and cost (both unescalated and escalated) is then determined based on these activity total unescalated costs and durations, in conjunction with the standard flow chart (appropriately considering critical path and float), escalation rates and extended OH rates, from which additional unescalated cost (extended OHs) and then additional escalation is determined, so that the mean risk is in terms of mean additional escalated cost. This integrated cost and schedule model is essentially the same as used for the base in <*1.Project Info*> and as would be used for quantitative risk analysis, although for mean values only (ignoring uncertainty). Determination of either the individual or collective risk would not be feasible without this model.

Note: Risk factors can be updated as new information is obtained or as the base changes. Document through inserted comments.



4a. Unmitigated Risk Results

Unmitigated Risk Register														
		Probability of Occurrence (0 to 1, or rating per rating scale*)		Assessed Impacts (if occur)									Mean Severity (escal $M, or rating per rating scale*)	Risk Ranking (based on mean severity)
				Mean Direct Cost Change (unesc $M, or rating per rating scale*)			Mean Duration Change to Schedule Activity (months, or rating per rating scale*)			Mean Disruption Change (million person-hours lost, or rating per rating scale*)				
Item	Risk or Opportunity (see <2b.Risks by Category> for detailed description)	Value	Rating	Value	Rating	Activity Affected (from list)	Value	Rating	Activity Affected (from list)	Value	Rating	Activity Affected (from list)		
													0.00	1
PL1	#N/A												0.00	1
PL2	#N/A												0.00	1
FN9	#N/A												0.00	1
FN10	#N/A												0.00	1
	TOTAL (if comprehensive and non-overlapping set of risks)			0.00			0.00			0.00			0.00	

Proj Delivery Method:

	"Base" (without contingency or schedule float)					"Risk" (additional to Base)			"Total" (Base + Risk)							
Activity (master list)	Base Cost (unesc$M)	Base Disruption (M-hrs)	Base Duration (months)	Lag label	Base Lag (mos)	Risk Cost (unesc$M)	Risk Disruption (M-hrs)	Risk Delay (months)	Total Cost (unesc$M)	Total Disruption (M-hrs)	Total Duration (months)	Total Early Start Date	Total Early End Date	Total Float (months)	Total Cost (esc$M)
Planning	$ -	0.0	0.0	A	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Scoping	$ -	0.0	0.0	B	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Design Funding								0.0					1/0/1900	0.0	
Prelim Design	$ -	0.0	0.0	C	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Environmental Process	$ -	0.0	0.0	D	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
ROW/Util/RR Funding				E	0.0			0.0					1/0/1900	0.0	
ROW/Util/RR	$ -	0.0	0.0	F	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Final Design	$ -	0.0	0.0	G	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction Funding								0.0					1/0/1900	0.0	
Procurement	$ -	0.0	0.0	H	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction	$ -	0.0	0.0	I	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**				**$ -**	**0.0**		**$ -**	**0.0**					**$ -**
Operations	$ -	0.0	0.0	J	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Replacement	$ -	0.0	0.0	K	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**	**$ -**	**←longevity ($)**		**$ -**	**0.0**	**$ -**	**0.0**	**0.0**	**$ -**	**←longevity ($)**			**$ -**
Total	**$ -**	**0.0**	**$ -**			**0.00**	**0.0**	**$ -**	**0.00**	**0.0**	**$ -**	**1/0/1900**	**1/0/1900**	**1/0/1900**	**$ -**
			↑combined ($M)					↑combined ($M)			↑combined (	↑ad date	↑end of CN	↑replacement	

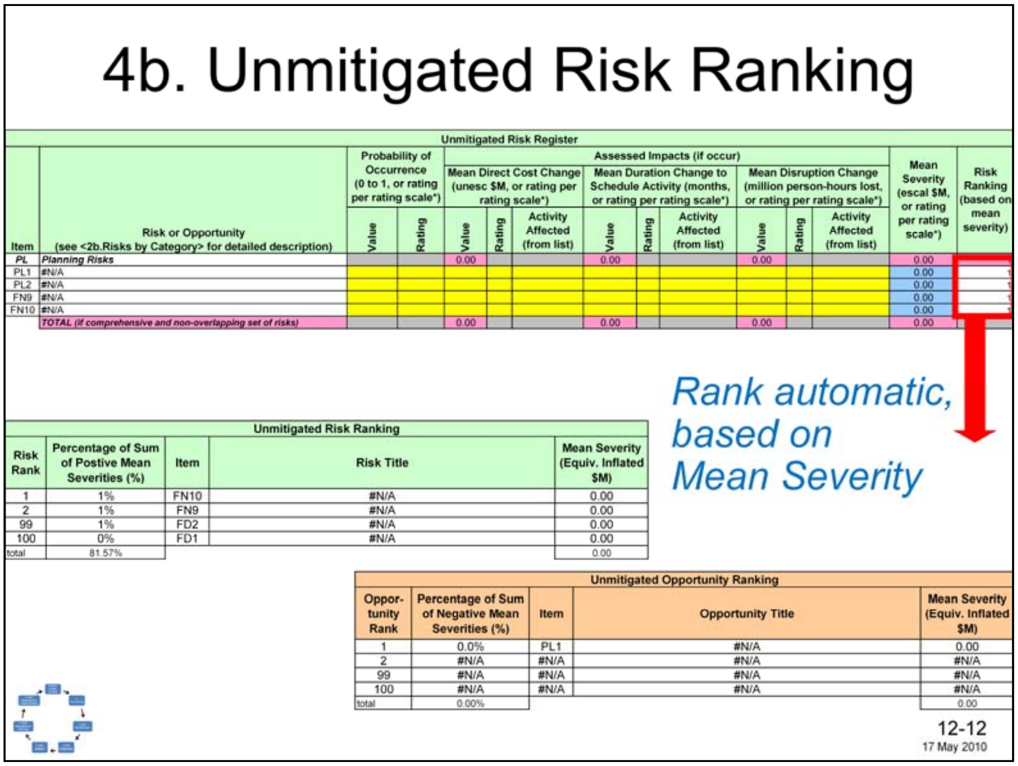
12-11

17 May 2010

On the seventh worksheet <*4a.Unmitigated Risk Assess*> of the Template, the mean base performance (cost, duration, disruption) for each activity is transferred from <*1. Project Info*> and the mean risk performance (cost, duration, disruption) for each activity is determined from <*3b. Unmitigated Risk Assess*>, by appropriately combining the mean values for all the risks affecting that activity, and then combined to determine the mean total performance (cost, duration, disruption) for each activity. The same performance model used in <*1.Project Info*> is then used to determine mean total performance (start/end dates, float, and escalated cost) for each activity, and then (combined with specified values from <*1.Project Info*>) longevity and combined project performance.

No additional inputs are required for this worksheet.

Note: The mean project performance might change if the base project info (in <*1. Project Info*>) or the risk assessment (in <*3b.Unmitigtaed Risk Assess*>) is subsequently updated.



4b. Unmitigated Risk Ranking

Unmitigated Risk Register

Item	Risk or Opportunity (see <2b.Risks by Category> for detailed description)	Probability of Occurrence (0 to 1, or rating per rating scale*)		Assessed Impacts (if occur)									Mean Severity (escal $M, or rating per rating scale*)	Risk Ranking (based on mean severity)
				Mean Direct Cost Change (unesc $M, or rating per rating scale*)			Mean Duration Change to Schedule Activity (months, or rating per rating scale*)			Mean Disruption Change (million person-hours lost, or rating per rating scale*)				
		Value	Rating	Value	Rating	Activity Affected (from list)	Value	Rating	Activity Affected (from list)	Value	Rating	Activity Affected (from list)		
PL	*Planning Risks*			0.00			0.00			0.00			0.00	
PL1	#N/A												0.00	
PL2	#N/A												0.00	
FN9	#N/A												0.00	
FN10	#N/A												0.00	
	TOTAL (if comprehensive and non-overlapping set of risks)			0.00			0.00			0.00			0.00	

Rank automatic, based on Mean Severity

Unmitigated Risk Ranking

Risk Rank	Percentage of Sum of Postive Mean Severities (%)	Item	Risk Title	Mean Severity (Equiv. Inflated $M)
1	1%	FN10	#N/A	0.00
2	1%	FN9	#N/A	0.00
99	1%	FD2	#N/A	0.00
100	0%	FD1	#N/A	0.00
total	81.57%			0.00

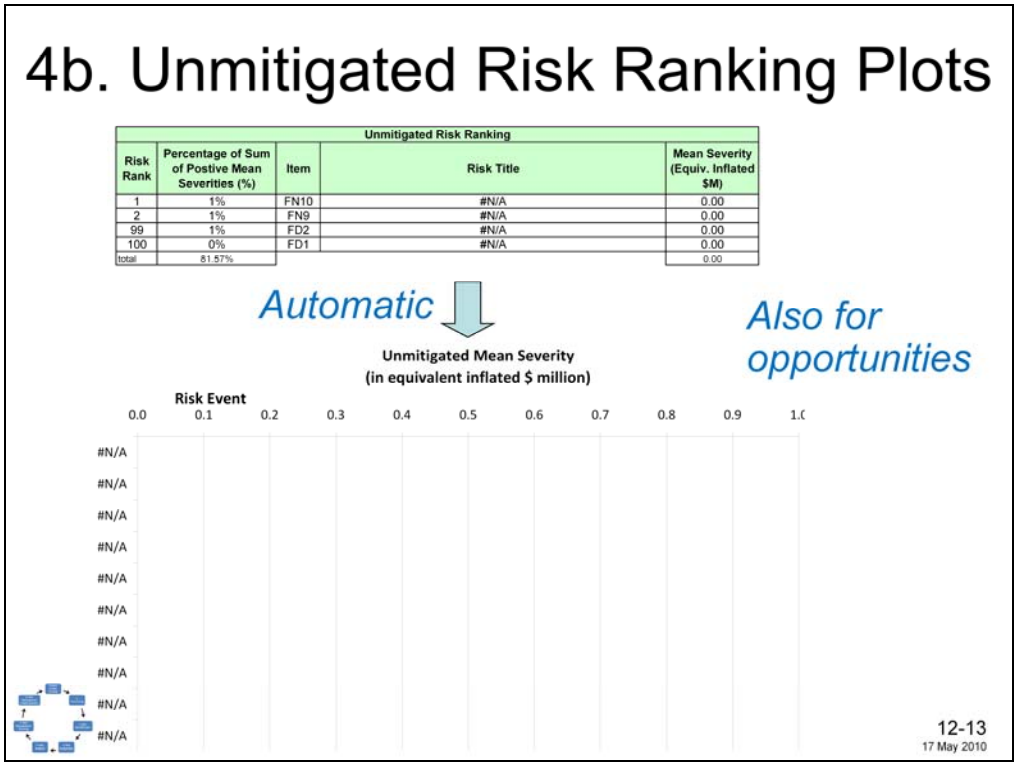
Unmitigated Opportunity Ranking

Oppor-tunity Rank	Percentage of Sum of Negative Mean Severities (%)	Item	Opportunity Title	Mean Severity (Equiv. Inflated $M)
1	0.0%	PL1	#N/A	0.00
2	#N/A	#N/A	#N/A	#N/A
99	#N/A	#N/A	#N/A	#N/A
100	#N/A	#N/A	#N/A	#N/A
total	0.00%			0.00

12-12
17 May 2010

On the eighth worksheet <*4b. Unmitigated Risk Ranking*> of the Template, the risks from <*3b. Unmitigated Risk Assess*> are automatically transferred to this worksheet and sorted by their ranking, separately for risks and opportunities. The ranking of risks in <*3b.Unmitigated Risk Assess*> is in terms of their severity, which is done automatically. No additional inputs are required for this worksheet.

Note: The ranking might change if the base project info (in <*1. Project Info*>) or the risk assessment (in <*3b. Unmitigated Risk Assess*>) is subsequently updated.



4b. Unmitigated Risk Ranking Plots

Unmitigated Risk Ranking				
Risk Rank	Percentage of Sum of Postive Mean Severities (%)	Item	Risk Title	Mean Severity (Equiv. Inflated $M)
1	1%	FN10	#N/A	0.00
2	1%	FN9	#N/A	0.00
99	1%	FD2	#N/A	0.00
100	0%	FD1	#N/A	0.00
total	81.57%			0.00

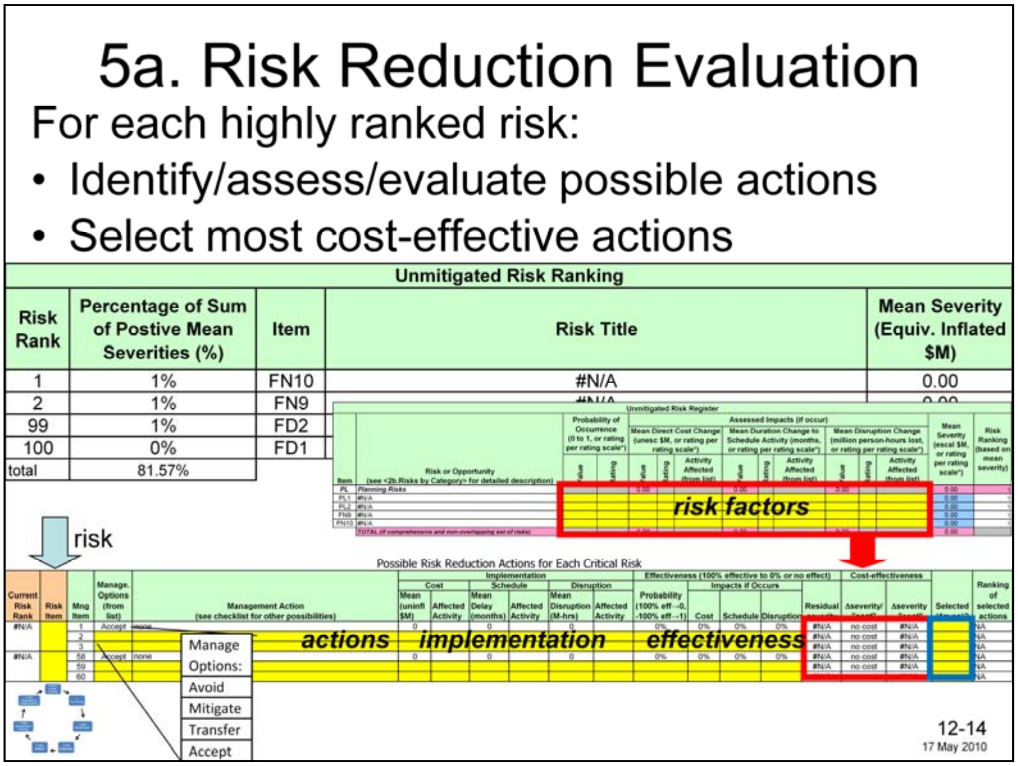
Automatic

Also for opportunities

12-13
17 May 2010

On the ninth worksheet <*4b.Unmitigated Risk Ranking Plots*> of the Template, the risk rankings from <*4a.Unmitigated Risk Ranking*> are automatically transferred to this worksheet and plotted, separately for risks and opportunities. The ranking of risks in <*4b.Unmitigated Risk Ranking Plots*> is in terms of their severity, which was determined automatically. No additional inputs are required for this worksheet.

Note: The ranking might change if the base project info (in <*1. Project Info*>) or the risk assessment (in <*3b. Unmitigated Risk Assess*>) is subsequently updated.



5a. Risk Reduction Evaluation

For each highly ranked risk:

- Identify/assess/evaluate possible actions
- Select most cost-effective actions

Unmitigated Risk Ranking				
Risk Rank	Percentage of Sum of Postive Mean Severities (%)	Item	Risk Title	Mean Severity (Equiv. Inflated $M)
1	1%	FN10	#N/A	0.00
2	1%	FN9		
99	1%	FD2		
100	0%	FD1		
total	81.57%			

12-14
17 May 2010

On the tenth worksheet <*5a. Risk Reduction Evaluation*> of the Template, for each of the high ranking risks (whose information is automatically transferred to this worksheet from <*3b. Unmitigated Risk Assess*>), various risk reduction actions are identified and evaluated in terms of their cost-effectiveness. Their cost-effectiveness is determined automatically in terms of the change in combined project performance (change in unescalated cost, change in duration and change in disruption to various activities, in combination with tradeoffs) associated with implementing the activity (regardless of effectiveness) and their effectiveness (change in severity). Typically, this information would be developed and input directly “on the fly” in a workshop, although it could be developed first in hard copy on the Risk Reduction Evaluation Form, and then transferred manually to this template.

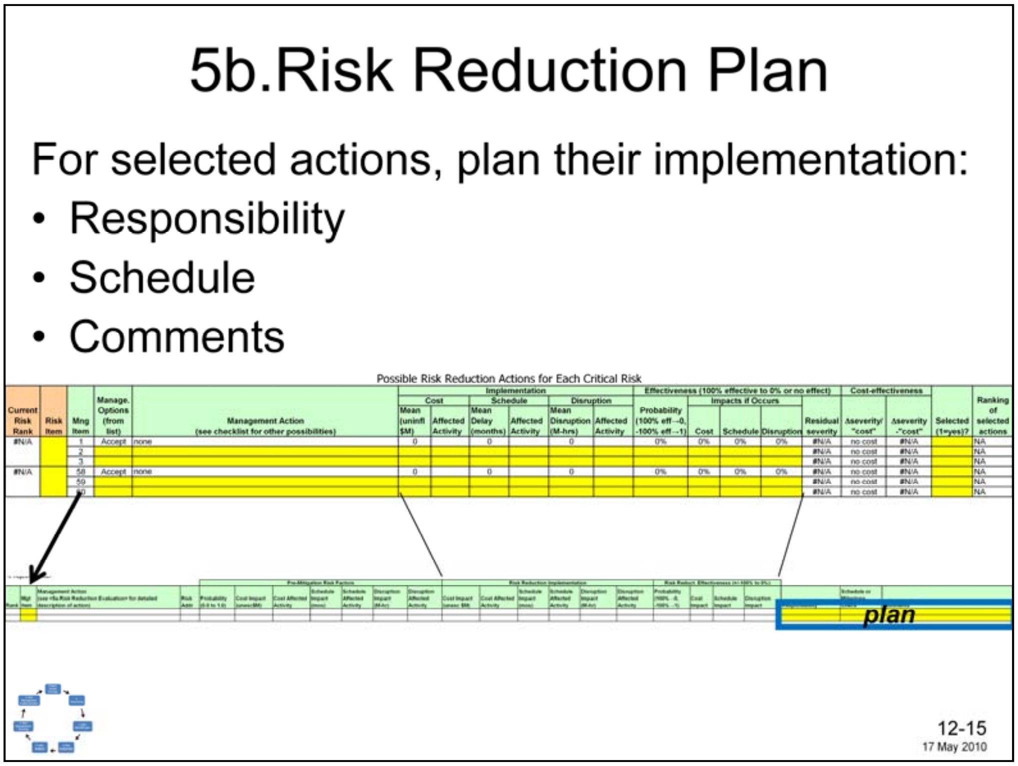
- Inputs (yellow cells only) include:
  - *Risk item* – must manually (e.g., copy/paste special) enter risk item from initial ranked list to maintain reference if ranking changes, e.g., due to updating.
  - *Type of mitigation (from drop down box)* - default risk management of no action is automatically considered for each risk <eventually, a check list of possible actions for each type of risk will be included>.
  - *Short descriptive title*
  - *Implementation consequences (values only)*
    - *Mean implementation cost (unescalated) and affected activity*
    - *Mean schedule impact and affected activity*
    - *Mean disruption impact and affected activity*
  - *Effectiveness (0% = no effect to 100% = elimination of risk factor, or -100% = increase in opportunity factor)*
    - *Probability of occurrence (+100%→0.0 prob, -100%→1.0 prob)*
    - *Cost impact of occurrence*
    - *Schedule impact of occurrence*
    - *Disruption impact of occurrence*

  Note: 0% effectiveness = no change in risk factor, whereas +100% effective = total effectiveness and risk factor goes to zero, and, for opportunity impacts, -100% effective = doubling of impact

- The reduction in risk severity, as well as the cost-effectiveness (in terms of a ratio or net difference), for each identified risk management action is computed automatically.

- Select the most cost-effective risk reduction action for each significant risk. The selected actions constitute part of the *Risk Management Plan*.

Note: The implementation and effectiveness factors for selected actions might need to be reassessed if the risks are reassessed, e.g., due to updating or changes in the base. As a result, the selection of activities might change, or other actions might be considered. Document through inserted comments.



5b.Risk Reduction Plan

For selected actions, plan their implementation:

- Responsibility
- Schedule
- Comments

Possible Risk Reduction Actions for Each Critical Risk

					Implementation						Effectiveness (100% effective to 0% or no effect)					Cost-effectiveness			
					Cost		Schedule		Disruption			Impacts if Occurs							
Current Risk Rank	Risk Item	Mng Item	Manage. Options (from list)	Management Action (see checklist for other possibilities)	Mean (uninfl $M)	Affected Activity	Mean Delay (months)	Affected Activity	Mean Disruption (M-hrs)	Affected Activity	Probability (100% eff→0, -100% eff→1)	Cost	Schedule	Disruption	Residual severity	Δseverity/ "cost"	Δseverity -"cost"	Selected (1=yes)?	Ranking of selected actions
#N/A		1	Accept	none	0		0		0		0%	0%	0%	0%	#N/A	no cost	#N/A		NA
		2													#N/A	no cost	#N/A		NA
		3													#N/A	no cost	#N/A		NA
#N/A		58	Accept	none	0		0		0		0%	0%	0%	0%	#N/A	no cost	#N/A		NA
		59													#N/A	no cost	#N/A		NA
		60													#N/A	no cost	#N/A		NA

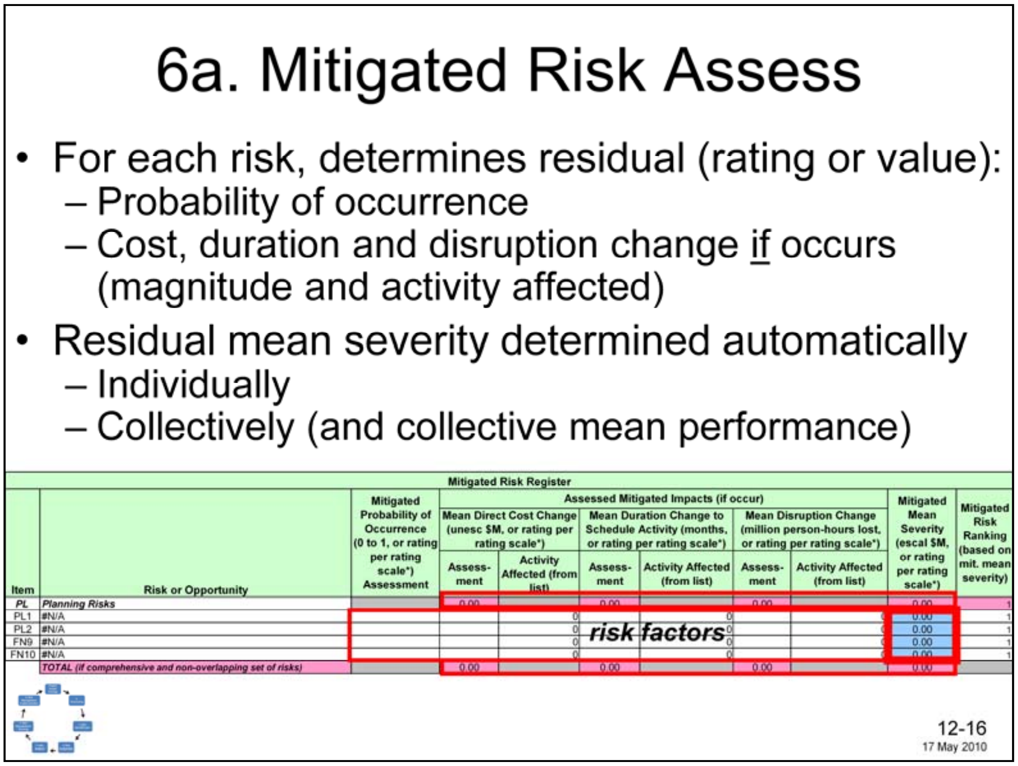
12-15
17 May 2010

On the eleventh worksheet <*5b. Risk Reduction Plan*> of the Template, the information from <*5a. Risk Reduction Evaluation*> is carried over for selected actions and action planning information (responsibility, schedule, etc.) is documented. Typically, this information would be developed and input directly "on the fly" in a workshop, although it could be developed first in hard copy on the Risk Reduction Implementation Plan Form, and then transferred manually to this template.

- The inputs (yellow cells only) include:
    - *Management item* – must manually (e.g., copy/paste special) enter management item label from initial ranked list to maintain reference if ranking changes, e.g., due to updating.
    - *Responsibility* – identify who's responsible for action
    - *Schedule/milestone* – identify the schedule for implementing the action
    - *Comments* – add any other useful information

This set of selected actions (with summaries of their implementation and effectiveness factors from <*5a.Risk Reduction Evaluation*>), and the plans for their implementation, constitutes one part of the *Risk Management Plan* (the other part of the *Risk Management Plan* relates to contingency/recovery management)

Note: This *Risk Management Plan* can be updated, as: a) base, risk and risk reduction factors are updated; b) additional actions are selected or selected actions are deleted; and c) responsibility/schedule for selected actions change – document through inserted comments.



6a. Mitigated Risk Assess

- For each risk, determines residual (rating or value):
  - – Probability of occurrence
  - – Cost, duration and disruption change <u>if</u> occurs (magnitude and activity affected)
- Residual mean severity determined automatically
  - – Individually
  - – Collectively (and collective mean performance)

Mitigated Risk Register

Item	Risk or Opportunity	Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Assessed Mitigated Impacts (if occur)						Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
			Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)			
			Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
PL	*Planning Risks*		0.00		0.00		0.00		0.00	1
PL1	#N/A			0		0		0	0.00	1
PL2	#N/A			0		0		0	0.00	1
FN9	#N/A			0		0		0	0.00	1
FN10	#N/A			0		0		0	0.00	1
	TOTAL (if comprehensive and non-overlapping set of risks)		0.00		0.00		0.00		0.00	

risk factors

12-16

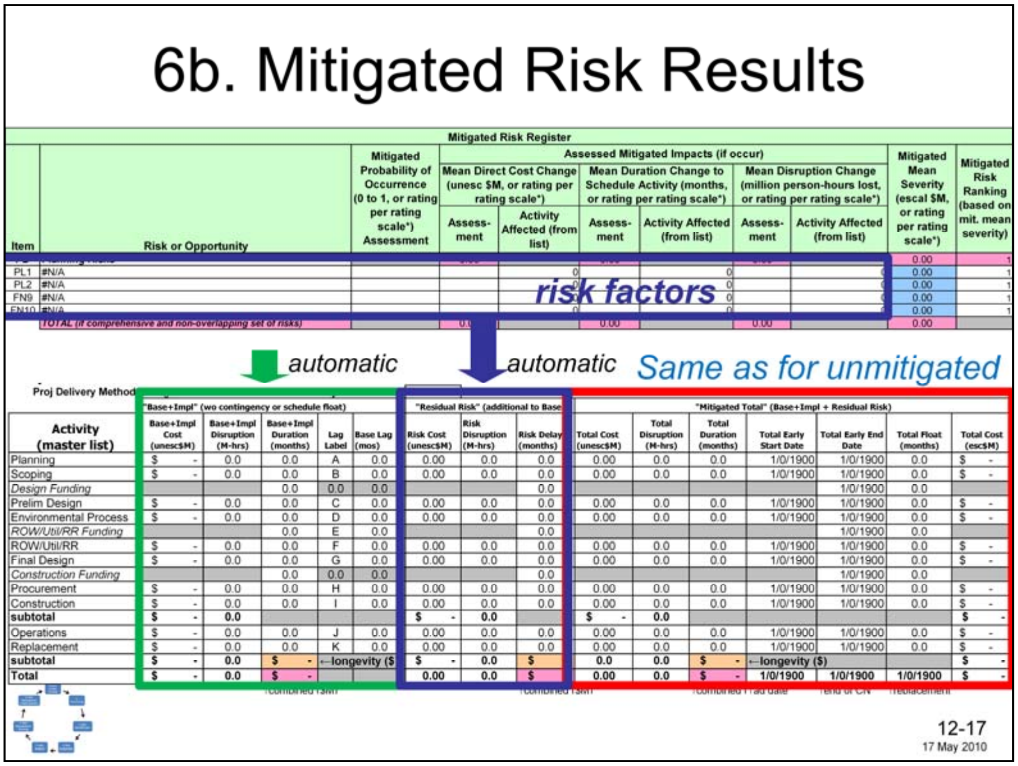
17 May 2010

On the twelfth worksheet <*6a. Mitigated Risk Assess*> of the Template, information from <*5b. Risk Reduction Plan*> and otherwise from <*3b.Unmitigated Risk Assess*> are transferred to this worksheet and used to automatically determine the mitigated risks factors and the severity (and associated ranking) for each of the residual risks. No additional inputs are required for this worksheet.

This worksheet is essentially the same as <*3b.Unmitigated Risk Assess*>, but considers selected risk reduction actions:

•The template determines the mean change in unescalated cost , duration, disruption and longevity for each activity due to that residual risk. The change in project schedule is determined by comparing the mean change in duration to the activity's base float (from <*1.Project Info*>). The increased unescalated cost due to cost risks, which is escalated, increased escalation of the base cost and risk cost due to schedule risks, and extended overheads due to schedule risks are all determined automatically based on the standard flow chart (appropriately considering critical path and float), escalation rates and extended OH rates, so that the severity is in terms of mean additional escalated cost.

• The collective residual risk for groups of risks (including total for the project) are also computed automatically – however, they are approximate and only appropriate <u>if</u> the set of risks is comprehensive and non-overlapping. The template determines the mean change in unescalated cost , duration, disruption and longevity for each activity due to <u>all</u> the residual risks affecting that activity, appropriately considering overlap among schedule delays. The total unescalated cost, total duration and total disruption for each activity is then determined, based on these risk factor assessments, in conjunction with baseline project description (including activity base costs, durations and disruptions). The total project schedule and cost (both unescalated and escalated) is then determined based on these activity total unescalated costs and durations, in conjunction with the standard flow chart (appropriately considering critical path and float), escalation rates and extended OH rates, from which additional unescalated cost (extended OHs) and then additional escalation is determined, so that the mean risk is in terms of mean additional escalated cost. This integrated cost and schedule model is essentially the same as used for the base in <*1.Project Info*> and in <4a.Unmitigated Risk Results>, and as would be used for quantitative risk analysis, although for mean values only (ignoring uncertainty). Determination of either the individual or collective risk would not be feasible without this model.



6b. Mitigated Risk Results

Mitigated Risk Register										
			Assessed Mitigated Impacts (if occur)							
		Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)		Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
Item	Risk or Opportunity		Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
									0.00	1
PL1	#N/A			0		0		0	0.00	1
PL2	#N/A			0		0		0	0.00	1
FN9	#N/A			0		0		0	0.00	1
FN10	#N/A			0		0		0	0.00	1
	TOTAL (if comprehensive and non-overlapping set of risks)		0.0		0.00		0.00		0.00	

risk factors

automatic

automatic

Same as for unmitigated

Proj Delivery Method

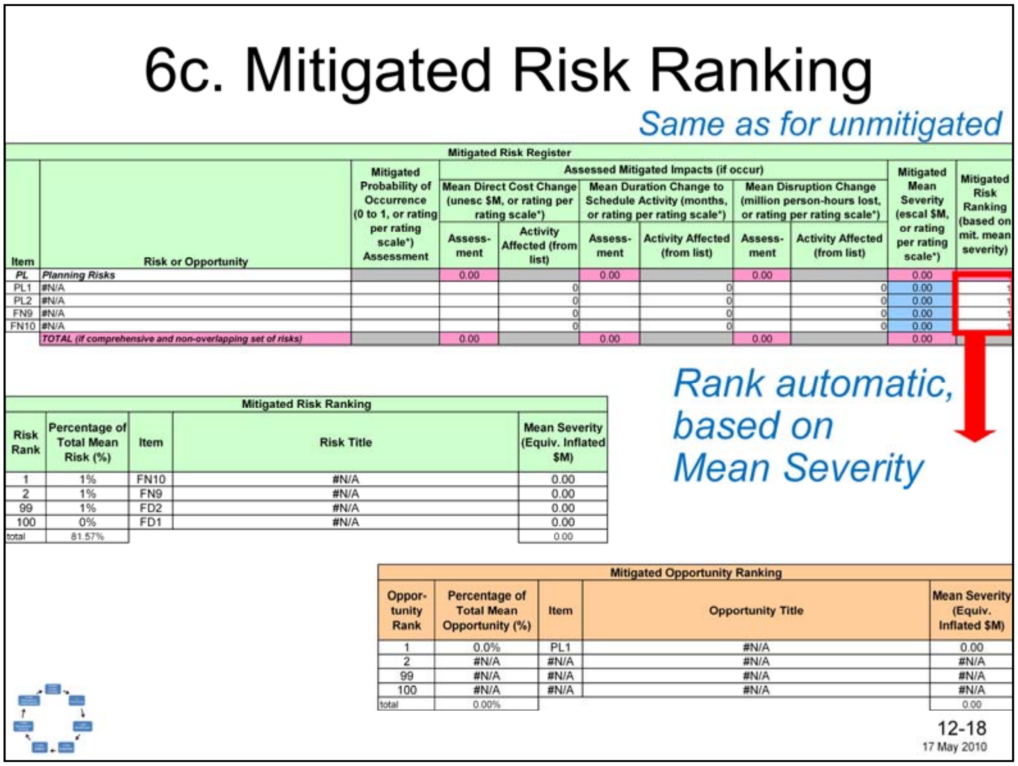
	"Base+Impl" (wo contingency or schedule float)					"Residual Risk" (additional to Base			"Mitigated Total" (Base+Impl + Residual Risk)						
Activity (master list)	Base+Impl Cost (unesc$M)	Base+Impl Disruption (M-hrs)	Base+Impl Duration (months)	Lag Label	Base Lag (mos)	Risk Cost (unesc$M)	Risk Disruption (M-hrs)	Risk Delay (months)	Total Cost (unesc$M)	Total Disruption (M-hrs)	Total Duration (months)	Total Early Start Date	Total Early End Date	Total Float (months)	Total Cost (esc$M)
Planning	$ -	0.0	0.0	A	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Scoping	$ -	0.0	0.0	B	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Design Funding			0.0	0.0	0.0			0.0					1/0/1900	0.0	
Prelim Design	$ -	0.0	0.0	C	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Environmental Process	$ -	0.0	0.0	D	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
ROW/Util/RR Funding			0.0	E	0.0			0.0					1/0/1900	0.0	
ROW/Util/RR	$ -	0.0	0.0	F	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Final Design	$ -	0.0	0.0	G	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction Funding			0.0	0.0	0.0			0.0					1/0/1900	0.0	
Procurement	$ -	0.0	0.0	H	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Construction	$ -	0.0	0.0	I	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**				**$ -**	**0.0**		**$ -**	**0.0**					**$ -**
Operations	$ -	0.0	0.0	J	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
Replacement	$ -	0.0	0.0	K	0.0	0.00	0.0	0.0	0.00	0.0	0.0	1/0/1900	1/0/1900	0.0	$ -
subtotal	**$ -**	**0.0**	**$ -**	**←longevity ($**		**$ -**	**0.0**	**$**	**0.0**	**0.0**	**$ -**	**←longevity ($)**			**$ -**
Total	**$ -**	**0.0**	**$ -**			**0.00**	**0.0**	**$**	**0.00**	**0.0**	**$ -**	**1/0/1900**	**1/0/1900**	**1/0/1900**	**$ -**

12-17
17 May 2010

On the thirteenth worksheet <*6b.Mitigated Risk Assess*> of the Template, the mean base performance (cost, duration, disruption) for each activity is determined from <*1. Project Info*> and <*5b. Risk Reduction Plan*>*, and* the mean risk performance (cost, duration, disruption) for each activity is determined from <*6a. Mitigated Risk Assess*> by appropriately combining the mean values for all the risks affecting that activity, and then combined to determine the mean total performance (cost, duration, disruption) for each activity. The same performance model used in <*1.Project Info*> *and in* <*4a. Unmitigated Risk results*> is then used to determine mean total performance (start/end dates, float, and escalated cost) for each activity, and then (combined with specified values from <*1.Project Info*>) longevity and combined project performance. No additional inputs are required for this worksheet.

This worksheet is essentially the same as <*4a. Unmitigated Risk Results*>, but considers selected risk reduction actions:

Note: The mean project performance might change if the base assessment (in <*1.Project Info*>, risk assessment (in <*3b.Unmitigtaed Risk Assess*>) or the risk reduction plan (in <*5b. Risk Reduction Plan*> is subsequently updated.



6c. Mitigated Risk Ranking

Same as for unmitigated

Mitigated Risk Register										
			Assessed Mitigated Impacts (if occur)							
		Mitigated Probability of Occurrence (0 to 1, or rating per rating scale*) Assessment	Mean Direct Cost Change (unesc $M, or rating per rating scale*)		Mean Duration Change to Schedule Activity (months, or rating per rating scale*)		Mean Disruption Change (million person-hours lost, or rating per rating scale*)		Mitigated Mean Severity (escal $M, or rating per rating scale*)	Mitigated Risk Ranking (based on mit. mean severity)
Item	Risk or Opportunity		Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)	Assess-ment	Activity Affected (from list)		
PL	*Planning Risks*		0.00		0.00		0.00		0.00	
PL1	#N/A			0		0		0	0.00	
PL2	#N/A			0		0		0	0.00	
FN9	#N/A			0		0		0	0.00	
FN10	#N/A			0		0		0	0.00	
	TOTAL (if comprehensive and non-overlapping set of risks)		0.00		0.00		0.00		0.00	

Rank automatic, based on Mean Severity

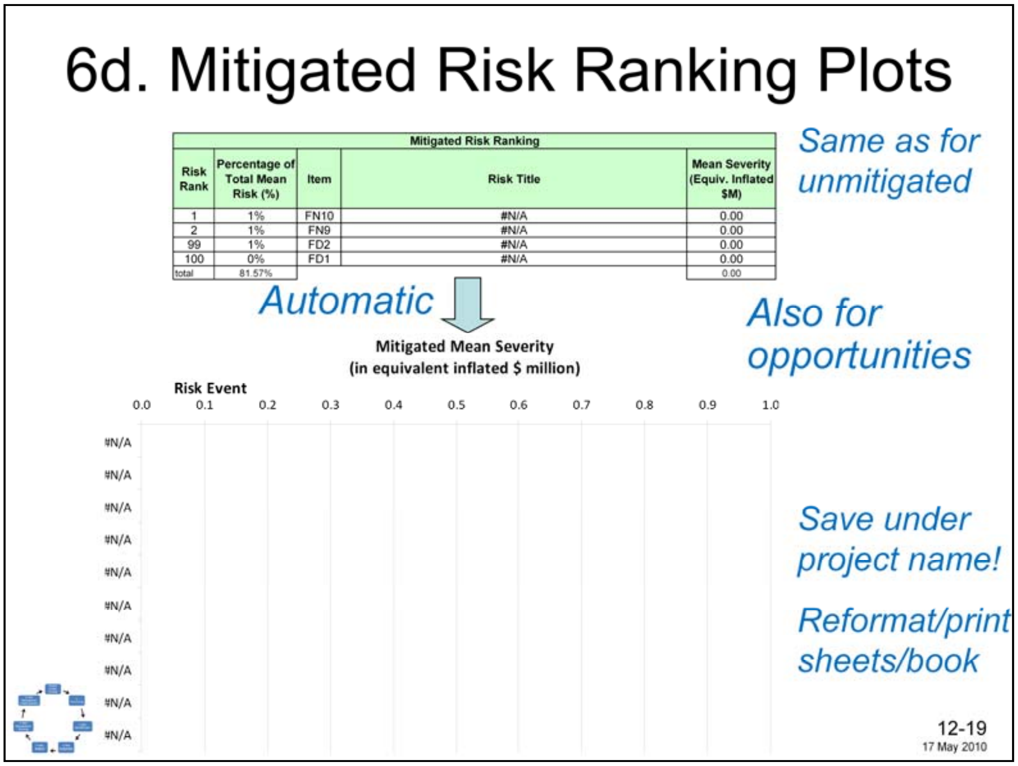
Mitigated Risk Ranking				
Risk Rank	Percentage of Total Mean Risk (%)	Item	Risk Title	Mean Severity (Equiv. Inflated $M)
1	1%	FN10	#N/A	0.00
2	1%	FN9	#N/A	0.00
99	1%	FD2	#N/A	0.00
100	0%	FD1	#N/A	0.00
total	81.57%			0.00

Mitigated Opportunity Ranking				
Oppor-tunity Rank	Percentage of Total Mean Opportunity (%)	Item	Opportunity Title	Mean Severity (Equiv. Inflated $M)
1	0.0%	PL1	#N/A	0.00
2	#N/A	#N/A	#N/A	#N/A
99	#N/A	#N/A	#N/A	#N/A
100	#N/A	#N/A	#N/A	#N/A
total	0.00%			0.00

12-18
17 May 2010

On the fourteenth worksheet <*6c.Mitigated Risk Ranking*> of the Template, the risks from <*6a.Mitigated Risk Assess*> are automatically transferred to this worksheet and sorted by their ranking, separately for risks and opportunities. The ranking of risks in <*6a.Mitigated Risk Assess*> is in terms of their severity, which is done automatically. This worksheet is essentially the same as <4b.Unmitigated Risk Ranking>, but accounts for risk reduction actions. No additional inputs are required for this worksheet.

Note: The ranking might change if the base assessment (in <*1.Project Info*>, risk assessment (in <*3b. Unmitigated Risk Assess*>) or risk reduction evaluation (in <*5a.Risk Reduction Evaluation*>) is subsequently updated.



6d. Mitigated Risk Ranking Plots

Mitigated Risk Ranking				
Risk Rank	Percentage of Total Mean Risk (%)	Item	Risk Title	Mean Severity (Equiv. Inflated $M)
1	1%	FN10	#N/A	0.00
2	1%	FN9	#N/A	0.00
99	1%	FD2	#N/A	0.00
100	0%	FD1	#N/A	0.00
total	81.57%			0.00

Same as for unmitigated

Automatic

Also for opportunities

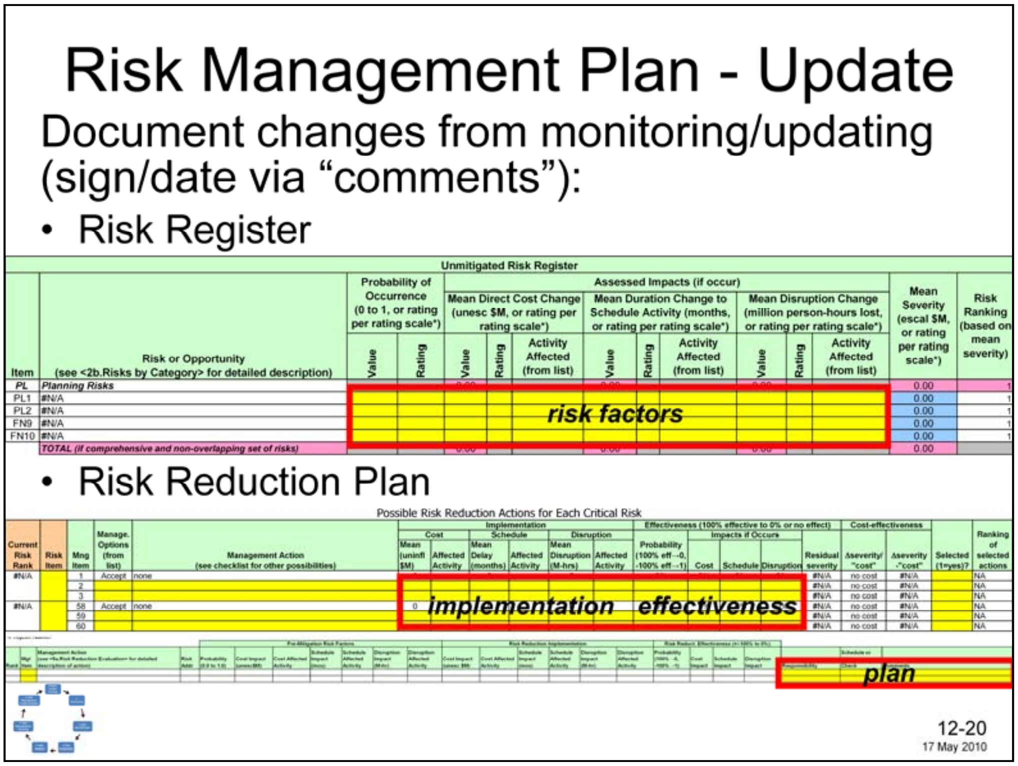
Save under project name!

Reformat/print sheets/book

12-19
17 May 2010

On the fifteenth worksheet <*6d.Mitigated Risk Ranking Plots*> of the Template, the risk rankings from <*6c.Mitigated Risk Ranking*> are automatically transferred to this worksheet and plotted, separately for risks and opportunities. The ranking of risks in <*6d.Mitigated Risk Ranking Plots*> is in terms of their severity, which was done automatically. This worksheet is essentially the same as <4c.Mitigated Risk Ranking Plots>, but accounts for risk reduction actions. No additional inputs are required for this worksheet.

Note: The ranking might change if the base assessment (in <*1.Project Info*>, risk assessment (in <*3b. Unmitigated Risk Assess*>) or risk reduction evaluation (in <*5a.Risk Reduction Evaluation*>) is subsequently updated.



Risk Management Plan - Update

Document changes from monitoring/updating (sign/date via "comments"):

- Risk Register

Unmitigated Risk Register

Item	Risk or Opportunity (see <2b.Risks by Category> for detailed description)	Probability of Occurrence (0 to 1, or rating per rating scale*) Value	Rating	Assessed Impacts (if occur) Mean Direct Cost Change (unesc $M, or rating per rating scale*) Value	Rating	Activity Affected (from list)	Mean Duration Change to Schedule Activity (months, or rating per rating scale*) Value	Rating	Activity Affected (from list)	Mean Disruption Change (million person-hours lost, or rating per rating scale*) Value	Rating	Activity Affected (from list)	Mean Severity (escal $M, or rating per rating scale*)	Risk Ranking (based on mean severity)
PL	*Planning Risks*			0.00			0.00			0.00			0.00	1
PL1	#N/A												0.00	1
PL2	#N/A												0.00	1
FN9	#N/A												0.00	1
FN10	#N/A												0.00	1
	TOTAL (if comprehensive and non-overlapping set of risks)			0.00			0.00			0.00			0.00	

risk factors

- Risk Reduction Plan

Possible Risk Reduction Actions for Each Critical Risk

Current Risk Rank	Risk Item	Mng Item	Manage. Options (from list)	Management Action (see checklist for other possibilities)	Implementation Cost Mean (uninfl $M)	Affected Activity	Schedule Mean Delay (months)	Affected Activity	Disruption Mean Disruption (M-hrs)	Affected Activity	Effectiveness (100% effective to 0% or no effect) Probability (100% eff→0, -100% eff→1)	Impacts if Occurs Cost	Schedule	Disruption	Residual severity	Cost-effectiveness Δseverity/"cost"	Δseverity -"cost"	Selected (1=yes)?	Ranking of selected actions
#N/A		1	Accept	none											#N/A	no cost	#N/A		NA
		2													#N/A	no cost	#N/A		NA
		3													#N/A	no cost	#N/A		NA
#N/A		58	Accept	none	0										#N/A	no cost	#N/A		NA
		59													#N/A	no cost	#N/A		NA
		60													#N/A	no cost	#N/A		NA

implementation ***effectiveness***

plan

12-20

17 May 2010

As previously noted, the *Risk Register* and *Risk Management Plan* can and should be monitored and updated as new information is obtained (through tracking and monitoring on a scheduled basis). Changes are made in the appropriate spreadsheets, and documented through inserted comments (which automatically record name and date):

- change base factors in <*1.Project Info*>
- add risks in <*2b.Risks by Category*>, and change risk factor assessments (including new assessments for added risks) in <*3b.Unmitigated Risk Assess*>
- change risk reduction factor assessments (e.g., if risk factors have changed in <*3b.Unmitigated Risk Assess*>*)*, and add management actions and their assessments (especially for new risks), in <*5a.Risk Reduction Evaluation*>
- change selections of risk management actions in <*5a.Risk Reduction Evaluation*>, and add new actions and their implementation plans, as well as update status of existing implementation plans (including end of some actions), to <*5a.Risk Reduction Plan*>.